**UNITED NATIONS**
**INDUSTRIAL DEVELOPMENT ORGANIZATION**

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# Technology Compendium for

# Energy Efficiency and Renewable Energy Technologies in

# Eastern Zone Metal Industries

## Volume III: Steel Re-rolling Mill Sector

### September 2020

# Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India

*A GEF funded Project being jointly implemented by*

**UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION**

Technology Compendium for

## Energy Efficiency and Renewable Energy Technologies in Eastern Zone Metal Industries

[Volume III: Steel Re-rolling Mill Sector]

September 2020

Developed under the assignment

## Scaling up and expanding of project activities in MSME clusters
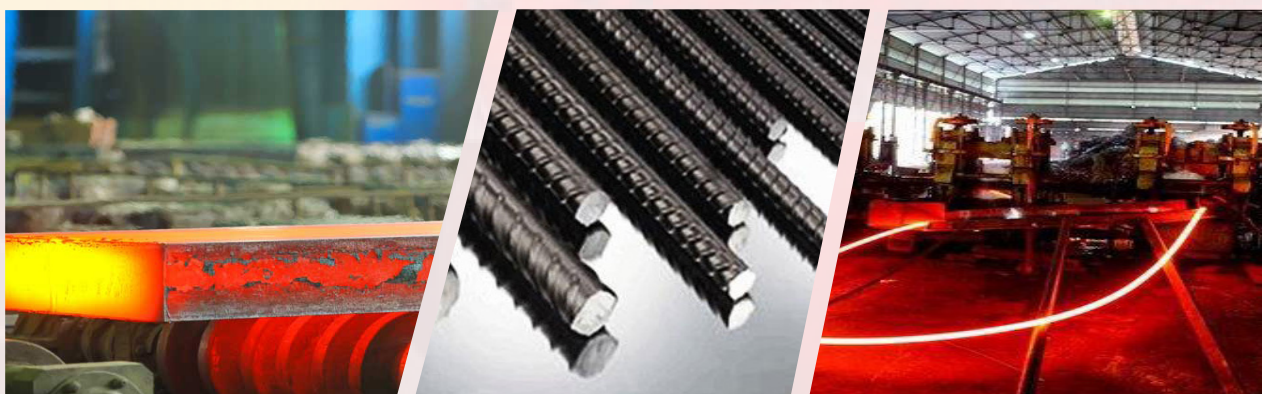
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# Acknowledgement

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# List of Abbreviations

| | |
|---|---|
| AISRRA | All India Steel Re-rollers Association |
| BEE | Bureau of Energy Efficiency |
| CBG | Coal Bed Gas |
| CBM | Coal Bed Methane |
| CMM | Coal Mine Methane |
| CSG | Coal Seam Gas |
| DESL | Development Environergy Services Limited, New Delhi, India |
| EE | Energy Efficiency |
| EET | Energy Efficient Technologies |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gases |
| MNRE | Ministry of New and Renewable Energy |
| MoMSME | Ministry of Micro, Small and Medium Enterprises |
| MS | Mild Steel |
| MSME | Micro Small and Medium Enterprises |
| PMC | Project Management Cell |
| PNG | Piped Natural Gas |
| PV | Photovoltaic |
| RE | Renewable energy |
| SPM | Suspended Particulate Matter |
| SRRM | Steel Re-Rolling Mill |
| SRRMA | Steel Re-rolling Mill Association |
| TMT | Thermo Mechanically Treated |
| UNIDO | United Nations Industrial Development Organization |
| VFD | Variable Frequency Drive |

# Unit of Measurement

| Parameters | UOM | Parameters | UOM |
|---|---|---|---|
| Ampere | A | Liter(s) | l |
| Approximate | ~ | Mega Joule | MJ |
| Centimeter | cm | Mega Watt Hour per Day | MWh/d |
| Centimeter Square | cm$^2$ | Meter | m |
| Cubic Centimeter | cm$^3$ | Meter cube | m$^3$ |
| Cubic Feet per Minute | CFM | Meter Cube per hour | m$^3$/h |
| Cubic meter | m$^3$ | Meter cube per second | m$^3$/s |
| Day(s) | d | Metric Ton | mt |
| Decibel | dB | Milligram | mg |
| Degree Centigrade | $^0$C | Milligram per liter | mg/l |
| Degree Fahrenheit | $^0$F | Millimeter | mm |
| Dry Bulb Temperature | DBT | Million | Mn |
| Giga Watt | GW | Million Tons of Oil Equivalent | MTOE |
| Giga Watt Hour | GWh | Minute(s) | min |
| Giga Watt Hour per Day | GWh/d | Normal Meter Cube | Nm$^3$ |
| Giga Watt Hour per year | GWh/y | Normal Meter Cube per Hour | Nm$^3$/h |
| Gross Calorific value | GCV | Parts Per Million | ppm |
| Hertz | Hz | Per Annum | p.a. |
| Horse power | hp | Percentage | % |
| Hour(s) | h | Power Factor | PF |
| Hours per year | h/y | Revolution per Minute | rpm |
| Indian Rupee | INR / Rs | Rupees | Rs |
| Kilo Ampere | kA | Rupees per kilo Watt Hour | Rs/kWh |
| Kilo Calorie | kCal | Rupees per Metric Ton | Rs/MT |
| Kilo gram | kg | Second | s |
| Kilo Joule | kJ | Square Meter | m$^2$ |
| Kilo ton | Kt | Standard meter cube | Sm$^3$ |
| Kilo volt | kV | Tesla | T |
| Kilo volt ampere | kVA | Ton | t |
| Kilo Volt Root Mean Square | kV rms | Ton of CO$_2$ | tCO$_2$ |
| Kilo watt | kW | Ton per Day | t/d |
| Kilo watt hour | kWh | Ton per Hour | t/h |
| Kilocalorie per kilogram | kCal/kg | Ton per Year | t/y |
| Kilogram | kg | Voltage | V |
| Kilogram per ton | kg/t | Watt | W |
| Kilogram per day | kg/d | Wet Bulb Temperature | WBT |
| Kilo volt | kV | Year(s) | y |
| Kilo volt root mean square | kV-rms | Year on Year | YOY |

# About the Project

The United Nations Industrial Development Organization (UNIDO), in collaboration with the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, is executing a Global Environment Facility (GEF) funded national project titled 'Promoting energy efficiency and renewable energy in selected MSME clusters in India'. The project aims to develop and promote a market environment for introducing energy efficiency (EE) and enhanced use of renewable energy (RE) technologies in process applications in selected energy intensive industrial clusters, comprising micro, small and medium enterprises (MSMEs). The project is supported by the Ministry of Micro, Small and Medium Enterprises (MoMSME) and Ministry of New and Renewable Energy (MNRE). The project was operational in 12 MSME clusters across India in five sectors namely Brass (Jamnagar); Ceramics (Khurja, Thangadh and Morbi); Dairy (Gujarat, Sikkim and Kerala); Foundry (Belgaum, Coimbatore and Indore); Hand Tools (Jalandhar and Nagaur) in its first phase. The Project has now scaled-up and expanded its activities to additional 11 new clusters, namely in Dairy (Tamil Nadu, Odisha, Madhya Pradesh, Andhra Pradesh & Telangana, Haryana, Maharashtra & Punjab), Foundry (Ahmedabad & Howrah), Ceramic (Himmatnagar), Mixed Cluster (Indore & Sikkim) to reach out to MSME's at national level.

This project so far has supported 303 MSME units in implementing 603 Energy conservation Measures and thus resulted in reduction of about 10,850 TOE energy consumption and avoided 62,868 metric tons of $CO_2$ emissions as on date. The key components of the project include:

- Increasing capacity of suppliers of EE/RE product suppliers / service providers / finance providers
- Increasing the level of end user demand and implementation of EE and RE technologies and practices by MSMEs.
- Scaling up of the project to more clusters across India.
- Strengthening policy, institutional and decision-making frameworks.

Jalandhar: Handtools Cluster
Punjab: Dairy Cluster
Nagaur: Handtools Cluster
Himmatnagar: Ceramic Cluster
Morbi: Ceramic Cluster
Jamnagar: Brass Cluster
Gujarat: Dairy Cluster
Thangad: Ceramic Cluster
Ahmedabad: Foundry Cluster
Maharashtra: Dairy Cluster
Belgaum: Foundry Cluster
Kerala: Dairy Cluster
Tamil Nadu: Dairy Cluster

Haryana: Dairy Cluster
Khurja: Ceramic Cluster
Indore: Foundry, Mixed Cluster
Madhya Pradesh: Dairy Cluster
Sikkim: Dairy Cluster, Mixed Cluster
Howrah: Foundry Cluster
Odisha: Dairy Cluster
Telangana: Dairy Cluster
Andhra Pradesh: Dairy Cluster
Coimbatore: Foundry Cluster

**Clusters intervened by the project**

# About the Technology Compendium

The Micro, Small and Medium Enterprises (MSME) sector in India are an important contributor to the country's economy. However, the sector faces challenges resulting from rising energy costs, environmental concerns and competitiveness. Most of the industries from the MSME sector use old and obsolete technologies leading to significant energy consumption. Studies show a significant potential in these units through adoption of energy efficient and renewable energy technologies.

The technology compendium has been prepared with the objective of accelerating the adoption of energy efficient and renewable energy technologies and practices applicable in the identified energy-intensive MSME sectors. The sector-wise technologies listed in the document consists of details about the baseline scenario, energy efficient alternatives available, advantages, limitations and cost benefit analysis for the same. The technology wise information is also supported by relevant case studies wherein benefits related to actual implementation of these technologies has been captured. Some notable points pertaining to the document are listed below:

- The compendium will act as a ready reckoner to the MSME units for continuously improving their energy performance leading to a cost-effective and sustainable production process.

- In the wide spectrum of technologies and equipment applicable for the sectors for energy efficiency, it is difficult to include all the energy conservation aspects in this manual. However, an attempt has been made to include more common implementable technologies across each of these sectors.

- The user of the compendium has to fine-tune the energy efficiency measures suggested in the compendium to their specific plant requirements, to achieve maximum benefits.

- The compendium also consists of a list of technology suppliers where the listed technologies can be sourced. However, in addition to the list provided in the compendium, there may be many more suppliers / consultants from where the technologies can be sourced.

- The technology compendium consists of list of energy efficient and renewable energy technologies under the broad categories of 'low investment', 'medium investment' and 'high investment measures'. Also due care has been taken to include technologies related to 'fuel switch', 'retrofit measures' as well as 'technology upgradation' options.

- The technologies collated in the compendium may not necessarily be the ultimate solution as the energy efficiency through technology upgradation is a continuous process and will eventually move towards better efficiency with advancement in technology.

- The document provides overview of the various available energy efficient and renewable energy technologies applicable in the targeted sectors. This provides an opportunity to the MSME units to implement the best operating practices and energy saving ideas during design and operations and to facilitate achieving world class energy efficiency standards.

# Executive Summary

The steel re-rolling mill sector in India forms an important link to the overall steel production in the country, manufacturing close to 65% of the total long steel finished products in the country. The steel re-rolling mill unit can be a standalone unit which procures raw material in the form of ingots, billets or scraps from the market and produces finished products comprising bars and rounds, sectional products or industrial products.

The other section comprises composite units having both melting and rolling facilities under the same premises. The steel re-rolling mill units are scattered across the country and exist in clusters in and around key industrial hubs.

The eastern zone of the country includes some of the significant rolling mill clusters in the country which include Howrah and Durgapur in West Bengal; Jamshedpur and Ranchi in Jharkhand, Rourkela in Odisha and Patna and Danapur in the state of Bihar. Besides these bigger clusters, a few units also operate from clusters such as Bokaro, Hooghly, Siliguri, Burdwan, Bankura, etc.

The steel re-rolling mill sector is a highly energy intensive cluster using both thermal and electrical energy. Most of the units in the sector use old and obsolete technologies leading to significant energy bills. Significant potential for savings exists in the cluster through adoption of energy efficient and renewable energy technologies. The adoption of these technologies can make the units more cost competitive and sustainable.

The United Nations Industrial Development Organization (UNIDO) is playing a pivotal role jointly with the Bureau of Energy Efficiency (BEE), Ministry of Power, and Government of India towards scaling up the penetration of low-cost Energy Efficient Technologies (EETs) in the foundry, forging and steel re-rolling mill units located in the eastern zone of the unit. A total of 80 MSME units in the cluster comprising foundry, forging and steel re-rolling mill units in the cluster are envisaged to be supported technically to become energy efficient and cost-competitive.

This document is an outcome of the enormous research carried out in the sector, energy audits conducted in representation units and stakeholders' consultation. The extensive research and ground level deployment of various teams have made it possible to consolidate the list of energy efficient and renewable energy technologies applicable for the steel re-rolling mill sector. While most of these technologies have proven implementation record, some of the technologies are still in the developmental stage and will require efforts for implementation.

The compendium for energy efficient and renewable energy technologies has been compiled and consolidated, keeping in mind different types and capacities of the units.

This compendium can be used as a single point information booklet for various economically viable energy efficient and renewable energy technologies applicable in the cluster. Each technology has been complemented by a techno-commercial analysis report; in order to provide the readers with in-depth understanding of the technology. Each technology comes up with information on tentative investment, energy saving potential, cost savings and simple pay-back.

A vendor list has also been compiled at the end for easy reference of the units.

The technology compendium will act as a ready reckoner to the MSME unit owners and help them select relevant technologies for their units. The technology compendium also consists of case studies on actual implementation of the technologies and benefits realized thereof. Although the compendium consists of some general information on the technologies, the same will require customization based on individual unit's requirement.

The Howrah foundry cluster has significant potential in terms of energy saving. The BEE-UNIDO project thus plays a pivotal role in making a transformational change in the sector which will lead to the units becoming cost competitive; thereby resulting in a sustainable future.

The technologies identified for the sector have been categorized into three groups and comprise both energy efficient and renewable energy technologies applicable for the sector.
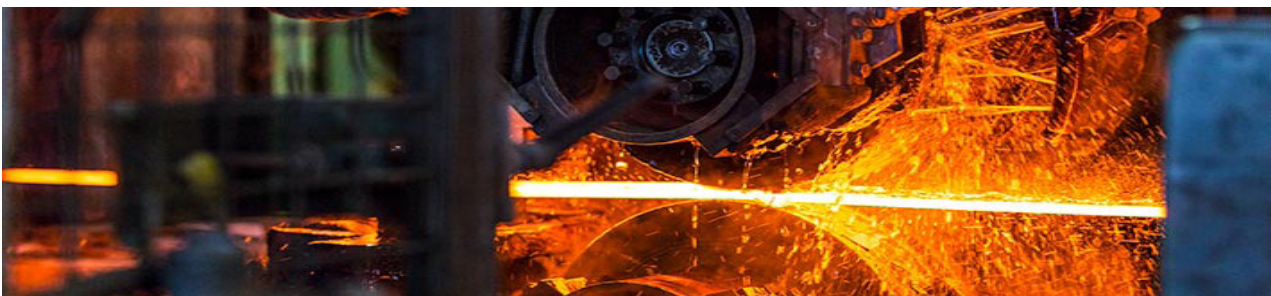
**Table 1: Energy efficient and renewable energy technologies for steel re-rolling mill sector**

| Category | Description | Technology | Investment (Rs in Lakhs) | Saving Potential (Rs in Lakhs) | Simple Pay-back (Rs in Lakhs) |
|---|---|---|---|---|---|
| A | Low Investment Technologies (up to Rs 2 lakhs) | Swirl burners for pulverized coal firing | 1.25 – 10 | 4 – 17.5 | < 1 year |
| | | Energy Efficient Motors | 10959 | 0.03-0.55 | < 1 year |
| | | Installation of VFD in blower | 1.5 – 5 | 4 – 20 | < 1 year |
| B | Medium Investment Technologies (up to Rs 10 lakhs) | High Efficiency Metallic Recuperator | 8.5 - 45 | 25- 135 | < 1 years |
| | | Re-heating Furnace Automation & Control System | 10 – 26 | 15- 85 | < 1 years |
| | | Energy Efficient Pulverizer | 6 – 25 | May-25 | < 1.5 years |
| | | Modified pulverized coal feeding system | 10 – 30 | 15 - 40 | < 1 year |
| | | Coal drying system | 10 – 25 | Dec-50 | < 1 year |
| | | Energy Efficient Lighting | 10 – 50 | 3 – 15 | < 3 years |
| | | Automatic Material Handling System | 10 – 60 | 10 – 35 | < 2 years |
| C | High Investment Technologies (more than Rs 10 lakhs) | New Energy Efficient Furnace | 15-250 | 55- 275 | < 1.5 years |
| | | Coal Bed Methane based re-heating furnace | 100 – 150 | 100 – 200 | < 1 year |
| | | Optimum Refractory & Insulation | 20 – 50 | 27668 | < 2 years |
| | | Biomass based producer gas as fuel | 70 – 120 | 250 – 500 | < 1 year |
| | | Natural gas firing for reheating furnace | 20 – 60 | 30 – 80 | < 1 year |
| | | Antifriction Roller Bearing | 20 – 60 | 75 – 190 | < 1 year |
| | | Universal Coupling and Spindles | 20 – 60 | 75 – 190 | < 1 year |
| | | Revamping of rolling mills | 60 – 150 | 100 – 250 | < 1 year |
| | | Adoption of direct rolling in TMT mills | 40-150 | 150 – 700 | < 1 year |
| | | Adoption of direct rolling in structural mills | 100 -200 | 150 – 600 | < 1 year |

*The figures on investment and savings are tentative and are based on budgetary quotations and technical calculations; the actual figure may vary.*

# 1 About the Cluster

## 1.1 Sector overview

The first steel re-rolling mill was established in the year 1928 at Kanpur long before Independence of India. Gradually, steel re-rolling mills came up in the limelight when concept of large scale steel plants was absent in the mind of the Government. The only large steel plant at that time started to function at TATA, Jamshedpur in the year 1907. Since 1928 till today, around 1,800 re-rolling mills are functioning all over India. This is because of the fact that many of the re-rollers from West Pakistan re-established their re-rolling mills in and around Punjab within India. Re-rolling mills serve the purpose as Secondary Steel Sector and as a complement to the main steel lines.

In 1984, the first manufacturing re-rolling mill unit was established with all key functional infrastructural operations in Liluah, Howrah. Manufacturing only Mild Steel (MS) Round bars and high strength deformed steel reinforcement bars (MS TMT); these products are manufactured till date due to the ever-growing demand from the construction industry.



**Figure 1: A typical steel re-rolling mill unit**

The growth in construction activity and infrastructure projects in India has buoyed the demand for steel industry. There is a demand for steel products such has Thermo Mechanically Treated (TMT) bars, structural steel viz., angles, plates, channels, rounds, etc.

The steel re-rolling mill (SRRM) sector in India is one of the most important segments of the steel industry and is a key link in the supply chain of iron and steel production in the country. The sector covers long product mills with re-heating furnace and rolling mills, and a few units have completed backward integration by installing induction furnaces to melt scrap and DRI cast by ingot or continuous casting.

Steel re-rolling is an energy-intensive process. It takes nearly 35-45 litres of furnace oil (or 100-200 kg of coal) and 80-150 Kilowatt-hour (kWh) of electricity to produce one ton of long steel finished product. Among India's small and medium enterprises (SMEs), there are more than 1,800 steel re-rolling mills, majority (75 percent) of which are small-scale units. The SMEs engaged in steel re-rolling constitute an important link in the overall supply chain of steel, contributing to more than 65 percent of steel produced in the country. However, these mills have grown haphazardly, utilizing outdated technologies, and are characterized by high production costs and low investment in upgrading technologies or research and development. The direct energy use in this sector includes fossil fuels (furnace oil, natural gas and coal) and electrical energy is estimated to account for 25-30 percent of the overall production costs.

## 1.2 Steel Re-rolling Mill Sector in the Eastern Region

The eastern zone of the country comprising the states of West Bengal, Jharkhand, Odisha and Bihar houses close to 20% of the total steel re-rolling mills in the country. Some of the key clusters located in the eastern zone of the country that house steel re-rolling mill standalone as well as composite units are Howrah, Hooghly, Burdwan, Bankura and Durgapur in West Bengal; Jamshedpur in Jharkhand; Patna in Bihar; Rourkela in Odisha and Guwahati in Assam. While most of the units in Howrah are small units re-rolling scraps consisting of miss-rolls from bigger plants; ship breaking scraps, etc., the clusters of Durgapur house relatively bigger units comprising mostly composite units. The clusters of Rourkela and Jamshedpur house both bigger as well as smaller units. The state-wise distributions of number of units in the eastern zone are summarized in the table below:

The following associations are active in the zone, apart from the state level associations:

● Steel Re-rolling Mill Association

● All India Steel Re-rollers Association

**Table 2: Tentative number of Steel Re-rolling units in Eastern region**

| State | West Bengal | Jharkhand | Bihar | Odisha |
|---|---|---|---|---|
| No. of units | 265 | 75 | 46 | 113 |

*Source: Survey carried out under UNDP-GEF project 2017*

## 1.3 The Process

The Steel Re-rolling mill sector can be broadly categorized into two segments:

● The standalone units where ingots/billets/scraps are re-heated to the re-crystallization temperature of steel and rolled to the desired product shape and size.

● The composite units comprising both melting and rolling facilities under the same premises.

In a standalone steel re-rolling mill unit, the process starts with raw material preparation. This includes cutting the ingots/

billets or scraps to the required size. These ingots/billets are then charged into a re-heating furnace which is fired either by coal, furnace oil, or natural gas. In a re-heating furnace, the charge is heated to the re-crystallization temperature which is around $1,170^0$C for mild steel. Steel attains the properties of ductility and malleability at this elevated temperature. The red hot charge is taken out of the re-heating furnace and rolled to desired shape and size. For rolling, two or three sets of rolls are used with grooves cut into the surface of the rolls. The rolls are placed in a vertical stand and rotated in opposite direction using a motor. The roll grooves are scientifically designed for gradual reduction of cross-sectional area of the charge. For production of an 8 mm bar from a 100 mm billet, normally 21 passes are used. The rolled product once rolled to the desired shape and size is subjected to quenching operation based on requirement. The rolled product is then cooled to atmospheric temperature in a cooling bed. The product is then packed and is ready for dispatch.

For composite units, scrap or sponge iron is purchased from the market. The raw material is fed into a melting furnace, mostly electric induction furnace. Steel is melted at an elevated temperature of around $1,600^0$C. The molten metal is casted into mould to form ingots or continuously casted to form billets. The ingots/billets are transferred to the rolling mill bay and the process of rolling repeats. In some units, the hot casted billets are directly fed into the rolling mill, bypassing the re-heating furnace, thus saving significant amount of energy.

## 1.4 Technology status and energy use

The re-heating furnace is the major energy guzzler in a typical standalone rolling mill. The re-heating furnace is fired using different types of fuels such as pulverized coal, coal based producer gas, natural gas, furnace oil and biomass based producer gas. A significant amount of fuel is burnt to heat the charge from ambient to the re-crystallization temperature of steel. It takes 35-45 liters of furnace oil or 90-120 kg of pulverized coal, 120-150 kg of coal (producer gas); 40-50 $Nm^3$ of Natural Gas to heat one ton of steel in the re-heating furnace. The electrical energy also forms a significant portion of the total energy consumption of the steel re-rolling mills. A typical unit manufacturing re-bars requires 100-130 units of electricity to roll one ton of steel.

The key equipment in a typical rolling mill includes the re-heating furnace, the rolling mill strands, compressors, blowers, roller tables, over head cranes, etc. The figure below shows the energy share of different critical equipment in a typical rolling mill unit:



*(Source: Energy audit carried out by DESL)*
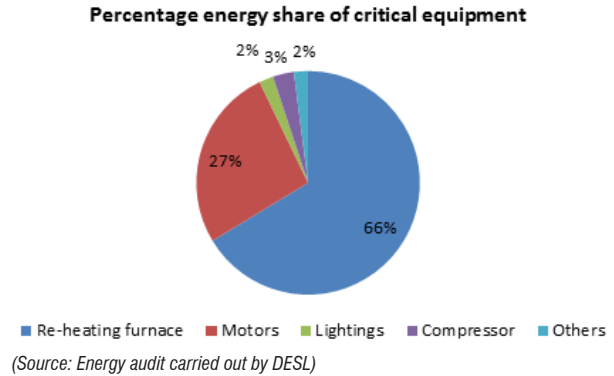
**Figure 3: Energy share of critical equipment**

The total energy share in steel re-rolling mill can be categorized into thermal and electrical energy. While the thermal energy share is mainly related to the fuel fired in the re-heating furnace, the electrical energy is consumed by the motors, compressors, pumps, blowers, cranes, etc. The energy share of a typical unit are shown below:
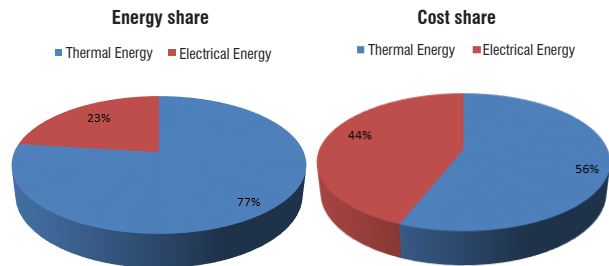


| **Figure 4: Energy share of typical rolling mill** | **Figure 5: Cost share of energy** |

Most of the rolling mills in the country use old and obsolete technologies which lead to significant energy consumption. A significant opportunity exists for cost saving by adoption of energy efficient and renewable energy technologies.

In case of composite unit, the recent times have seen adoption of a path-breaking technology in the form of 'Direct rolling. In 'Direct rolling' based units, continuously casted billets are directly fed in the rolling mill at elevated temperature, thereby eliminating the re-heating furnace completely.



**Figure 2: Typical process for standalone rolling mill**

# Technology 1: Energy Efficient Re-heating Furnace    2

## 2.1    Baseline Scenario

A re-heating furnace is considered the heart of a rolling mill. Typically, top fired pusher type re-heating furnaces are used in steel re-rolling mill units to heat the raw materials, i.e. ingots, billets or scraps to the re-crystallization temperature, i.e. around $1,170^{0}C$ for mild steel. The furnace is fired with a variety of fuels like lump coal, pulverized coal, furnace oil, natural gas, coal based producer gas etc. An optimum design of the furnace is important for higher productivity at least cost. A conventional furnace is not based on engineering design. Usually such furnaces are used as more heating chambers. The furnace walls are at excessive high temperature with flames gushing out of the openings. The furnace does not have any waste heat recovery system; so large quantity of heat is wasted into the atmosphere.



**Figure 6: Conventional re-heating furnace**

The furnaces are equipped with long pre-heating zone and heating zone is almost not present. Heavy firing is done through furnace front burners which often lead to high scale formation and energy consumption. Refractory in these types of furnaces are regularly replaced. Overall, the furnace performs at an efficiency level below 25%.

The details of re-heating furnace operating in conventional rolling mills are as follows:

**Table 3: Operating parameters for conventional re-heating furnace**

| Furnace Capacity (tph) | Thermal Efficiency (%) | Flue gas exit temperature ($^{0}C$) | Specific fuel consumption |
|---|---|---|---|
| 2-25 | 25-30 | 600-650 | 100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas |

## 2.2    Energy Efficient Technology

An energy efficient design of the re-heating furnace primarily aims at highest possible productivity and least possible fuel consumption and burning loss. The characteristics of an energy efficient furnace are:

- Complete combustion with minimum excess air
- Proper heat distribution
- Operation at optimum furnace temperature
- Reducing heat losses through furnace openings
- Maintaining correct amount of furnace draught
- Optimum hearth area utilization
- Maximum waste heat recovery from the flue gas
- Minimum heat loss through refractory
- Control & Instrumentation of the furnace

An energy efficient furnace is based on engineering design considering a variety of parameters. Although the capital cost for such type of furnace may be almost 1.5 times that of conventional furnace, the simple pay-back is less than a year. Designing an energy efficient furnace primarily depends on the type of fuel, raw material, productivity and discharge temperature.



**Figure 7: Energy efficient pusher furnace**

## 2.3    Benefits of the Technology

Implementation of energy efficient furnace has multi-fold benefits in a unit. Some of the key benefits include the following:

- Reduced energy consumption
- Reduced cost of production
- Reduced burning loss
- Low maintenance and breakdown

## 2.4    Technology Limitations

The cost of energy efficient furnace is 1.5 times more than conventional furnaces. Fuel switch over will require additional modifications.

## 2.5 Energy Saving; GHG Emission Reduction & Cost Benefit Analysis

In order to determine the energy saving, GHG emission reduction and cost-benefit analysis; one needs to carry out the life cycle analysis of an energy efficient furnace vis-à-vis conventional furnace.

The following table summarizes energy saving, estimated investment, cost saving and GHG emission reduction for a 15 t/h furnace fired by pulverized coal.

The investment and energy savings for new energy efficient furnace will vary based on the capacity of the furnace. The table below provides an estimate for different ranges of the furnace:

**Table 4: Cost benefit analysis for a 15 t/h furnace**

| Sl. No. | Particulars | UoM | As is | To be |
|---|---|---|---|---|
| 1 | Rated capacity of furnace | t/h | 15 | 15 |
| 2 | Productivity | t/h | 12 | 12 |
| 3 | Operating hours | h/d | 16 | 16 |
| 4 | Operating days | d/y | 330 | 330 |
| 5 | Annual production | t/y | 63,360 | 63,360 |
| 6 | Type of fuel | | Pulverized coal | Pulverized coal |
| 7 | Specific fuel consumption | kg/t | 120 | 96 |
| 8 | Gross calorific value | kcal/kg | 5,600 | 5600 |
| 9 | Annual fuel consumption | t/y | 7,603 | 6,083 |
| 10 | Saving in fuel consumption | t/y | | 1521 |
| 12 | Cost of fuel | Rs/kg | 7.5 | 7.5 |
| 13 | Monetary savings in terms of fuel | Rs in Lakhs/y | | 114 |
| 14 | Burning loss in furnace | % | 0.8 | 0.76 |
| 15 | Burning loss in furnace | kg/t | 10 | 7.6 |
| 16 | Saving in burning loss | kg/t | | 2.4 |
| 18 | Annual material saving due to burning loss saving | t/y | | 152, |
| 19 | Material cost | Rs/t | 33,000 | 33,000 |
| 20 | Monetary savings in terms of material | Rs in Lakhs/y | | 50 |
| 23 | Total Monetary savings | Rs in Lakhs/y | | 164 |
| 24 | Estimated cost of furnace | Rs in Lakhs | | 150 |
| 25 | Simple pay back | months | | 11 |
| 26 | Annual energy savings | toe/y | | 852 |
| 27 | Annual GHG emission reduction | $tCO_2$/y | | 94.6 |

*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

**Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

**Table 5: Investment and energy saving potential for different furnace capacities**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-25 | 15-250 | 55- 275 | < 1.5 years |

* based on estimated figures

## 2.6    Energy efficient furnace drawings
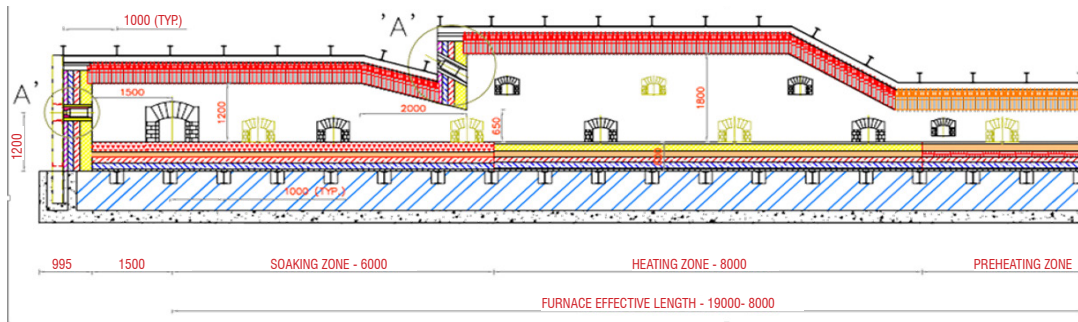


**Figure 8: Sectional view of a 15 t/h pulverized coal fired top fired pusher type energy efficient furnace**
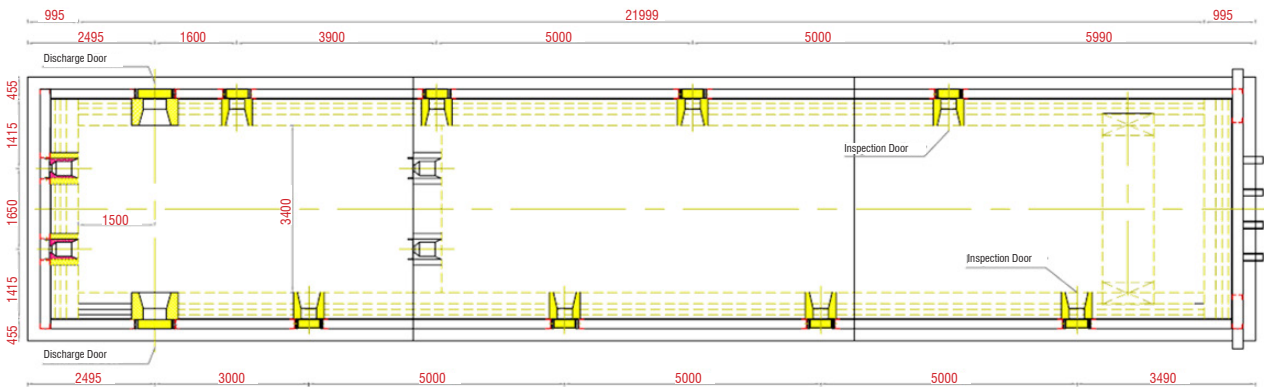


**Figure 9: Plan view of a 15 t/h pulverized coal fired top fired pusher type energy efficient furnace**

## Case Study 1: Installation of new EE furnace

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located in Ludhiana in Punjab. The plant was established in the year 1995. In 2015, the plant decided to implement a new energy efficient furnace under the guidance of the on-going UNDP-GEF project. A 10 t/h top fired pusher type re-heating furnace with furnace oil firing was installed and commissioned in the unit with expert support of the project. The plant achieved an astonishing 20% reduction in the specific fuel consumption and 5% reduction in the burning. The new furnace required an investment close to Rs 1 crore which was recovered in less than a year. The furnace is still in operation and performing extremely well.

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---------|-------------|-----|----------|---------------------|
| 1 | Furnace productivity | t/h | 10 | 10 |
| 2 | Type of fuel | | Pulverized coal | Pulverized coal |
| 3 | Specific fuel consumption | kg/t | 100 | 70 |
| 4 | Saving in fuel consumption | kg/t | 30 | |
| 5 | Annual fuel saving | t/y | 1,584 | |
| 6 | Cost of fuel | Rs/t | 8,000 | |
| 7 | Annual monetary savings | Rs in Lakhs/y | 126 | |
| 8 | Investment | Rs in Lakhs | 100 | |
| 9 | Simple pay back | months | 10 | |
| 10 | Annual energy savings | toe/y | 887 | |
| 11 | Annual GHG emission reduction | $tCO_2/y$ | 3,510 | |

*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
**Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2/TJ$ for sub-bituminous coal*

# 3 Technology 2: Installation of high efficiency metallic recuperator in re-heating furnace

## 3.1 Baseline Scenario

Most of the Steel re-rolling units use top-fired pusher type re-heating furnaces with solid, liquid or gaseous fuel. In a typical furnace only 30-40% of the total heat input is converted to useful heat. Rest of the energy is lost through different areas and forms.

The waste flue gas loss forms the major loss in a re-heating furnace which accounts for 30-35% of the total heat input. Exhaust flue gas from the



**Figure 10: Sankey diagram for pusher furnace**

furnace at a temperature of 500-700 °C has a potential to be re-used in the furnace. Traditionally, flue gases from the re-heating furnace were let out into the atmosphere through the chimney. Thus significant heat of flue gas was wasted.

## 3.2 Energy Efficient Technology

As an alternative to the conventional practice, a recuperator, i.e. a heat exchanger is installed in the flue duct and used to recover the waste heat from the flue gases. In a recuperator, heat exchange takes place between the flue gases and the inlet combustion air through metallic or ceramic walls. Ducts or tubes carry the combustion air to be pre-heated; the other side consists of the waste heat stream. The system works based on the basic principle of Physics which says energy moves from a hot body to a cold. Thus, in the process inlet combustion air from atmosphere is pre-heated using the waste gas. The pre-heated combustion air is fed directly into the burner. The result is saving in terms of fuels, increase in flame temperature and improvement in furnace efficiency.

The efficiency of the recuperator depends upon two important parameters - Surface area and time available for heat exchange and recuperator material.



**Figure 11: High efficiency metallic recuperator**

**Table 6: Effectiveness of different types of recuperator**

| Sl. No. | Parameter | Symbol | Unit | Radiative cum convective recuperator | High efficiency cross-flow type recuperator | Metallic radiation recuperator |
|---|---|---|---|---|---|---|
| 1 | Current specific fuel consumption | | kg/t | 100 | 100 | 100 |
| 2 | Annual production | | t/y | 30,000 | 30,000 | 30,000 |
| 3 | Flue gas temperature at recuperator inlet | $T_1$ | °C | 692 | 692 | 692 |
| 4 | Ambient air temperature | $t_1$ | °C | 35 | 35 | 35 |
| 5 | Flue gas temperature at recuperator outlet | $T_0$ | °C | 295 | 245 | 350 |
| 6 | Combustion air preheat temperature after recuperator | $t_0$ | °C | 283 | 395 | 190 |
| 7 | Gain in combustion air temperature | $t_0 - t_1$ | °C | 248 | 360 | 155 |
| 8 | Drop in flue gas temperature | $T_1 - T_0$ | °C | 397 | 447 | 342 |
| 9 | Recuperator effectiveness | % | °C | 62.47 | 80.54 | 45.32 |
| 10 | Annual fuel savings | | t/y | 33.81 | 49.09 | 21.13 |
| 11 | Cost of fuel per tone | | Rs/t | 8,000 | 8,000 | 8,000 |
| 12 | Annual monetary cost savings | | Rs in Lakhs /y | 2.70 | 3.93 | 1.69 |

*with every 220 C rise in combustion air pre-heat temperature there is a saving of 1% of fuel.
**calorific value of coal taken as 5600 kCal/kg; cost of coal taken as Rs 8 /kg
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal

It can be observed from the above table that the ideal effectiveness of a recuperator is 80%, wherein almost 60-70% of the waste heat can be recovered. The best effectiveness can be achieved by a high efficiency U-tube type cross-flow metallic recuperator. An effectiveness of around 60% can be achieved by a radiative cum convective recuperator where a combustion pre-heat temperature of around 250-285$^0$C can be achieved, which is around 50% of the waste heat. The worst performing recuperator is a metallic radiation recuperator, which has an effectiveness of around 40-45%, wherein the combustion preheating temperature remains below 200$^0$C. In the above table, the respective recuperator effectiveness has been compared with ideal effectiveness of 80% to determine the further scope of fuel saving by upgrading the recuperator.

At this point, it may be noted that the flue gas temperature at the chimney input should be maintained above 200$^0$C to avoid oxidation of the Sulphur particles in the flue gas which can lead to corrosion and rusting of the chimney.

**Inference:** While selecting a recuperator, the recuperator with highest effectiveness should be selected for optimum performance of the furnace. Although, such recuperator requires high initial investment, the same can be compensated by the relatively low pay-back.

## 3.3    Benefits of the technology

Installation of high efficiency metallic recuperator in steel re-heating furnace has the following benefits:

- Utilization of waste heat from flue gas to preheat combustion air
- Reduced energy consumption
- Increased productivity
- Improved furnace efficiency
- Reduced cost of production

## 3.4    Limitations

Installation of metallic recuperator especially in case of pulverized coal fired furnace requires special care and design modification. This is because of the possibility of the recuperator choke up due to presence of un-burnt coal particles in the flue gas. Required design modification needs to be done to avoid deposit of suspended particles in the recuperator.

## 3.5    Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The table below provides energy saving, GHG emission reduction and cost benefit analysis for a high efficiency metallic recuperator for a 15 tph furnace capacity.

The investment and energy savings for energy efficient recuperator will vary based on the capacity of the furnace. The table below provides an estimate for recuperator for different ranges of the furnace:



**Figure 13: Radiative cum convective recuperator**



**Figure 14: Cross-flow U-tube type metallic recuperator**
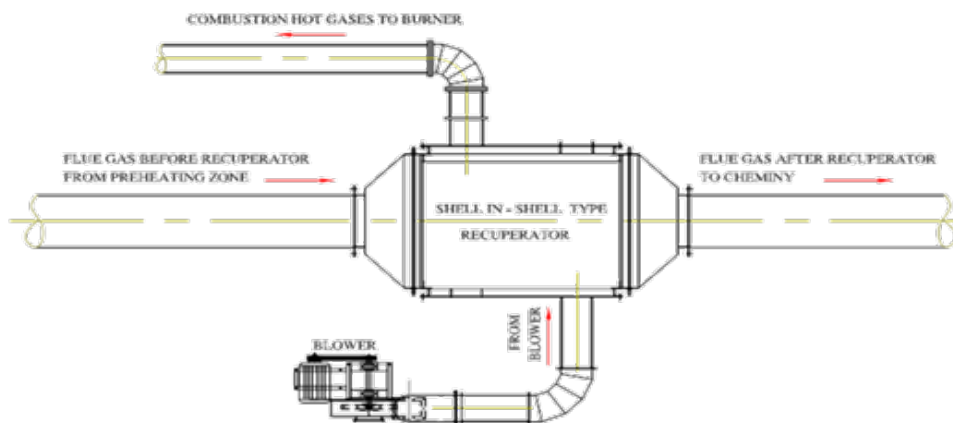


**Figure 12: Flow of exhaust flue gas**

**Table 7: Energy & GHG saving and cost benefit analysis for a high efficiency metallic recuperator**

| Sl. No. | Parameter | UoM | Without recuperator | With high efficiency metallic recuperator |
|---|---|---|---|---|
| 1 | Productivity | t/ h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Combustion air temperature | $^0C$ | 35 | 350 |
| 5 | Gain in combustion air pre-heat temperature | $^0C$ | | 315 |
| 6 | Specific fuel consumption* | kg/t | 90 | 77 |
| 7 | Annual fuel consumption | t/y | 7,128 | 6,107 |
| 8 | Annual saving in coal consumption | t/y | | 1,021 |
| 9 | Cost of fuel | Rs/kg | 8 | 8 |
| 9 | Monetary saving due to saving in coal consumption | Rs in lakhs | | 81.65 |
| 10 | Investment required for a high efficiency metallic recuperator | Rs in lakhs | | 26.25 |
| 11 | Simple pay-back | months | | 4 |
| 12 | Annual energy savings | toe/y | | 572 |
| 13 | Annual GHG emission saving | $tCO_2/y$ | | 2,262 |

*with every 220C rise in combustion air pre-heat temperature there is a saving of 1% of fuel
**calorific value of coal taken as 5,600 kCal/kg; cost of coal taken as Rs 8 /kg
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2/TJ$ for sub-bituminous coal

**Table 8: Investment and saving potential for different recuperator capacities**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-25 | 8.5 - 45 | 25- 135 | < 1 years |

* based on estimated figures

## Case Study 2: Installation of high efficiency metallic recuperator

Located in Bhiwadi, Rajasthan, Petropol India Limited is a leading manufacturer of TMT bars. In 2017, the plant decided to implement a new high efficiency metallic recuperator in their existing pulverized coal re-heating furnace of 15 tph capacity. The plant achieved an astonishing 15% reduction in the specific fuel consumption. The recuperator required an investment closed to Rs 25 Lakhs which was recovered in less than a year.

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Furnace productivity | t/h | 15 | 15 |
| 2 | Type of fuel | | Pulverized coal | Pulverized coal |
| 3 | Specific fuel consumption | kg/t | 100 | 85 |
| 4 | Saving in fuel consumption | kg/t | 15 | |
| 5 | Annual fuel saving | t/y | 1080 | |
| 6 | Cost of fuel | Rs/t | 8000 | |
| 7 | Annual monetary savings | Rs in Lakhs/y | 86.4 | |
| 8 | Investment | Rs in Lakhs | 25 | |
| 9 | Simple pay back | months | 3.5 | |
| 10 | Annual energy savings | toe/y | 604 | |
| 11 | Annual GHG emission reduction | $tCO_2/y$ | 2394 | |

*calorific value of coal taken as 5600 kCal/kg ; cost of coal taken as Rs 8 /kg
**Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2/TJ$ for sub-bituminous coal

# Technology No. 3: Installation of automation & control system in re-heating furnace

**4**

## 4.1    Baseline Scenario

A re-heating furnace is considered the heart of a rolling mill. Typically, top fired pusher type re-heating furnaces are used in steel re-rolling mill units to heat the raw material, i.e. ingots, billets or scraps to the re-crystallization temperature, i.e. around $1,200^0C$. The furnace is fired with a variety of fuels like lump coal, pulverized coal, furnace oil, natural gas, coal based producer gas, etc.

Optimum efficiency of the furnace can be ensured by maintaining correct temperature regime; ensuring optimum air-fuel ration including correct amount of excess air and maintaining optimum furnace pressure. Optimum efficiency of the furnace can lead to optimum specific fuel consumption and burning loss. Even today, most of the re-heating furnaces in the country are manually operated. Such conventional furnaces are not equipped even with basic monitoring equipment system like thermocouples. Manually operated furnaces do not have any control on maintaining the correct temperature regime as well as the correct air-fuel ratio required for combustion. Such furnaces are often over-fired leading to high energy consumption and burning loss.

## 4.2    Energy Efficient Technology

Optimum furnace efficiency can be achieved through complete automation and control system in the furnace. To start with; all furnaces should be equipped with basic monitoring instruments like thermocouples. Automation & Control system for re-heating furnace exists in three levels:

**Level 1:** On-off Control

**Level 2:** A proportional–integral–derivative controller (PID controller) based system

**Level 3:** A programmable logic controller (PLC) based system

Automation & control system in re-heating furnace ensures the following:

- Maintains proper temperature regime across the length of the furnace.

- Maintains air-fuel ratio including correct amount of excess air.

- Maintains correct furnace pressure and draught.

Re-heating furnace automation & control system consists of monitoring instruments like thermocouples of measuring temperature, zirconium based online oxygen analyzer to measure the oxygen percentage in flue gas; pressure transducers to measure the furnace pressure; control instruments like Variable Frequency Drives in FD and ID fan, solenoid valves in air and fuel line, DC motor driven screw feeder and a control circuit. All instruments and control setting are installed in a closed loop.

During the running of the furnace; feedback from the monitoring instruments like thermocouple; oxygen analyzer and pressure transducers are received by the control circuit; which in turn controls the DC motor driven screw feeder to control the coal flow and VFD to control air flow. The FD and ID fan speed is synchronized to maintain proper draught and furnace pressure. The control circuit can be either PID or PLC based. The air–fuel flow is accordingly controlled based on different running conditions of the furnace. The controlling of temperature, oxygen and pressure in a furnace is known as "Tops" control. The figure below shows the process and instrumentation diagram for a typical re-heating furnace:
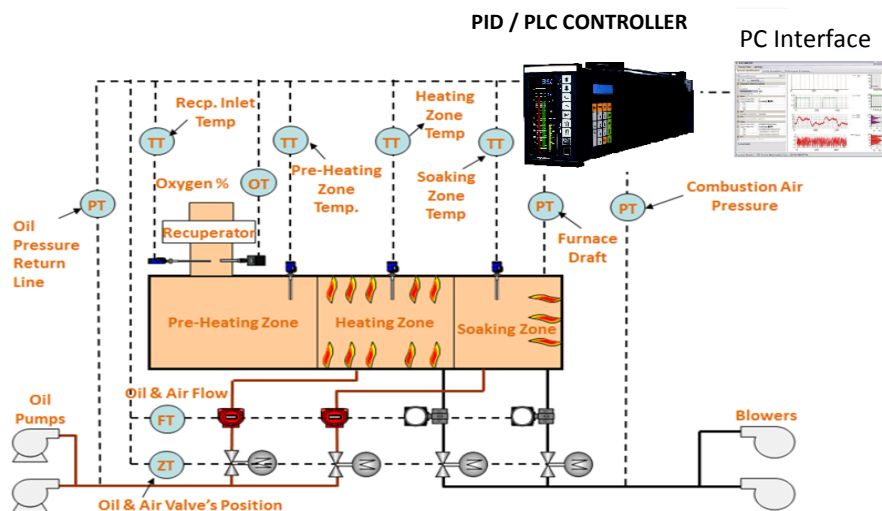


**Figure 15: P&I diagram of re-heating furnace automation (Courtesy: Masibus.com)**

## 4.3    Benefits of the technology

Installation of automation & control system in steel re-heating furnace has the following benefits:

- Complete monitoring and automatic control of furnace
- Proper air-fuel ratio control
- Furnace temperature monitoring and control
- Furnace pressure monitoring & control
- Reduced energy consumption
- Improved productivity

## 4.4    Limitations

The performance of the system is heavily dependent on the proper functioning of the sensors. The sensors need to be regularly maintained and calibrated. Also, the entire control loop should be checked properly. The system requires additional skilled manpower.

## 4.5    Energy Savings, GHG Emission Reduction and Cost Benefit Analysis

The energy savings, GHG emission reduction and cost-benefit analysis for installation of PID based automation and control system in a 15 t/h furnace is summarized below:

The investment and energy savings for furnace automation and control system will vary based on the capacity of the furnace. The table below provides an estimate for automation and control system for different ranges of the furnace:

**Table 9: Cost benefit analysis for reheating furnace automation**

| Sl. No. | Parameters | UoM | As Is | To Be |
|---|---|---|---|---|
| 1 | Furnace rated capacity | t/h | 15 | 15 |
| 2 | Productivity | t/h | 12 | 12 |
| 3 | Operating hours | h/d | 16 | 16 |
| 4 | Operating days | d/y | 330 | 330 |
| 5 | Annual Operating hrs | h/y | 5,280 | 5,280 |
| 6 | Annual Production | t/y | 63,360 | 63,360 |
| 7 | Type of fuel | | Pulverized Coal | Pulverized Coal |
| 8 | Oxygen Level in exit flue gas | % | 9.00 | 7.00 |
| 9 | Excess Air | % | 75.00 | 50.00 |
| 10 | Total air supplied | kg/kg of fuel | 12.43 | 10.65 |
| 11 | Ambient temperature | $^0$C | 35 | 35 |
| 12 | Flue gas exit temperature | $^0$C | 650 | 650 |
| 13 | Sensible heat loss | kCal/kg of fuel | 1982 | 1720 |
| 14 | Dry Flue Gas loss | % | 35.38 | 30.71 |
| 15 | Sensible heat loss | kCal/t | 158,522 | 137,563 |
| 16 | Reduction in Fuel Consumption | kg/t | 3.7 | |
| 17 | Annual fuel saving | t/y | 237 | |
| 18 | Unit Cost of Fuel | Rs/kg | 8 | |
| 19 | Savings (Fuel saving) | Rs in Lakh/y | 19 | |
| 20 | Material saving due to reduced burning loss | kg/h | 18 | |
| 21 | Unit Cost of Material | Rs/t | 33,000 | |
| 22 | Savings due to material savongs | Rs in Lakh/y | 31 | |
| 23 | Total savings | Rs in Lakh/y | 50 | |
| 24 | Estimated Investment | Rs in Lakh | 22 | |
| 25 | Simple Payback | months | 5 | |
| 26 | Annual Energy Savings | toe/y | 133 | |
| 27 | Annual GHG Emission Savings | $tCO_2$/y | 526 | |

*calorific value of coal taken as 5,600 kCal/kg; cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

**Table 10: Investment and saving for automation for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-25 | 10-26 | 15-85 | < 1 years |

*  based on estimated figures

## Case Study 3: Installation of furnace automation and control system

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located in Ludhiana in Punjab. The plant was established in the year 1995. In 2018, the plant decided to implement Level 3 automation and control system in the re-heating furnace under the guidance of the on-going UNDP-GEF project. The automation and control system was installed in their 10 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption and 5% reduction in the burning loss. The furnace automation and control system required an investment closed to Rs 20 lakhs which was recovered in less than a year.

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Furnace productivity | t/h | 10 | 10 |
| 2 | Type of fuel | | Pulverized coal | Pulverized coal |
| 3 | Specific fuel consumption | kg/t | 70 | 63 |
| 4 | Saving in fuel consumption | kg/t | 7 | |
| 5 | Annual fuel saving | t/y | 370 | |
| 6 | Cost of fuel | Rs/t | 8,000 | |
| 7 | Annual monetary savings | Rs in Lakhs/y | 30 | |
| 8 | Investment | Rs in Lakhs | 20 | |
| 9 | Simple pay back | months | 8 | |
| 10 | Annual energy savings | toe/y | 207 | |
| 11 | Annual GHG emission reduction | $tCO_2$/y | 820 | |

*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg
**Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal

## 5 Technology No. 4: Installation of optimum refractories and insulation in re-heating furnace

### 5.1 Baseline Scenario

A re-heating furnace can typically be defined as a chamber comprising four walls, hearth and roof, built with refractory bricks and insulation material enclosed



**Figure 16: Furnace sankey diagram**

within a steel structure. All the six faces of the chamber are exposed to high temperature ranging from 800 to 1,200⁰C. So, material of the wall, hearth and roof should be carefully selected so as to withstand the high temperature. Since the inside temperatures of the furnace are high, considerable amount of heat energy is lost by heat conduction through the walls, roof and hearth. Therefore, it is imperative to use material of as low thermal conductivity as possible for minimizing heat loss.

Moreover, small scale re-rolling mills do not run for 24 hours on continuous basis. Every day the furnaces are cooled after stopping the rolling and then again they are lighted up on the next day. During this process, heat energy is accumulated and then dissipated during idling period of the furnace. For minimizing this loss, the wall material should be of lower thermal mass so that heat accumulation can be minimized. Also, the refractory material should be able to withstand thermal shock due to cyclic operation. Thermal shocks lead to spalling and therefore the refractory material should have good spalling resistance.

Thus, selection of correct refractory and insulation is of significance. In conventional furnaces, due care is not given towards selection of correct refractory and insulation linings. This often leads to:

- Higher heat losses through the furnace walls
- Lower life of refractory and insulation
- Higher energy consumption

Almost 10-12% of the total heat input is lost as radiation and conduction losses through the furnace walls. Higher furnace skin temperatures are common symptoms of inadequate refractory and insulation material. In addition, a large amount of radiation heat losses happen through openings in the furnace, such as inspection doors, ejector space, etc. The radiation losses increase considerably as temperature increases.
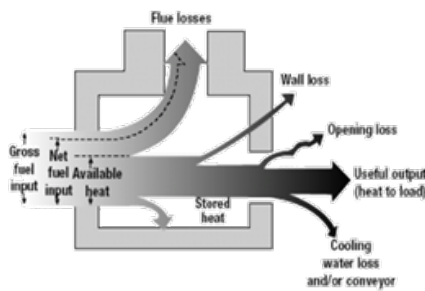
### 5.2 Energy Efficient Technology

Design of optimum refractory and insulation lining need to meet the following requirements:

- Selection of suitable material to meet the service requirements.
- Design of optimum lining thickness considering minimum heat loss and payback period.
- Selection of material considering cost, service life and fuel economy.

The furnace is divided into soaking, heating and preheating zones. The pattern of the refractory lining varies with these zones at the furnace roof, side walls and end walls. Constituents of lining at different locations of furnace are selected based on the temperature profile.

The suggested refractory and insulation pattern for different zones of the re-heating furnace has been tabulated in Table 10.

For effective insulation of the furnaces, it is recommended to install ceramic fibre insulation in the inspection doors. All openings in the burner blocks should be closed using ceramic fibre blankets. A significant amount of energy can be saved by adoption of optimum refractory and insulation and sealing of furnace openings. The suggestive refractory and insulation of pusher type furnace is shown in figure below:

### 5.3 Benefits of the technology

Installation of optimum refractory and insulation in steel re-heating furnace has the following benefits:

- Enhanced life of refractory leading to lesser background
- Improved efficiency of the furnace
- Reduced energy consumption

### 5.4 Limitations

It is important to quality test the refractory / insulation from each lot before installation. Even for reputed brand items, the bricks may not meet the quality standards. Installation of optimum refractory and installation requires significantly higher capital investment.

### 5.5 Energy Savings, GHG Emission Reduction and Cost Benefit Analysis

For the purpose of determining the energy & GHG emissions saving potential and cost benefit analysis, let us take a case

**Table 11: Indicative refractory and insulation lining for re-heating furnace**

| Furnace surface | Furnace zone | Suggested refractory & insulation lining pattern |
|---|---|---|
| Roof | Soaking zone | 250 mm thick special shaped bricks (hanger bricks) made of 60% Alumina refractories backed by 25 mm thick Insulating castable backed by 75 mm thick ceramic fibre blanket / mineral wool blanket. |
| | Heating zone | 250 mm thick special shaped bricks (hanger bricks) made of 60% Alumina refractories backed by 25 mm thick insulating castable backed by 75 mm thick ceramic fibre blanket / mineral wool blanket |
| | Pre-Heating zone | 250 mm thick special shaped bricks (hanger bricks) made of 40% Alumina refractories backed by 50 mm thick insulating castable/ ceramic fibre. |
| Side walls and end walls | Discharge end wall | 230 mm thick 60% Alumina quality refractories backed by 115 mm hot face insulation bricks, 115 mm thick Cold (Mica) Insulation bricks (IS-2042) and 75 mm thick Hysil blocks insulation and 5 mm thick asbestos sheet backed by steel sheets. |
| | Side walls (Heating & Soaking zones) | 230 mm thick 60% Alumina quality refractory bricks backed by 115 mm thick hot face insulation bricks, 115 mm thick Mica Insulation bricks / Cold face insulation bricks, 75 mm thick Hysil block insulation and 5mm thick asbestos sheet backed by steel sheets. |
| | Side walls (Pre-heating zone) | 230 mm thick 40% Alumina quality (IS-8) refractory bricks backed by 115 mm thick Hot face insulation bricks, 115 mm thick Mica Insulation bricks, 75 mm thick Hysil block insulation and 5 mm thick asbestos sheet backed by steel sheets. |
| | End wall (Charging side) | 230 mm thick 40% Alumina quality( IS-8) refractory bricks backed by 115 mm thick Hot face insulation bricks, 115 mm thick Mica Insulation bricks,75 mm thick Hysil block insulation and 5 mm thick asbestos sheet backed by steel sheets. |
| | Flue off take/down corners | 150 mm thick ceramic fibre blanket (RT128) to be held imposition by heat resisting (Stainless steel) studs and washers in case of flue port at the roof. If the flue line is below the hearth, lining pattern will be same as that of charging side end wall. |
| Hearth | Soaking zone | 200mm thick High Alumina fire bricks (LC-90 / TRL-88 / High Chromium Castables) backed by 115mm thick Hot Face Insulation backed by 115 mm Cold Face Insulations backed by 50 mm Insulating Castables and 5 mm thick asbestos sheet. |
| | Heating zone | 150 mm thick High Alumina quality fire bricks (60%Alumina) backed by 115 mm 40% Alumina (IS-8) backed by115 mm Hot Face Insulations, 115 mm Cold Face Insulation, backed by 65 mm Insulating Castables and 5 mm thick asbestos sheet. |
| | Pre-Heating zone | 190 mm thick High Alumina fire bricks (40%Alumina) backed by 115 mm Hot face insulation bricks, 115 mm thick cold face insulation bricks, 115 mm 36% (IS-6) quality fire bricks, 30 mm Insulating Castables and 5 mm thick asbestos sheet. |
| Others | Charging end doors | 175 mm thick RT128 grade ceramic fibre module backed by 25mm thick mineral wool insulation blanket. |
| | Discharge end doors | 225 mm thick RT128 grade ceramic fibre module backed by 25mm thick mineral wool insulation blanket. |
| | Recuperator area | 115 mm thick IS-8 quality firebricks backed by 15 mm thick Mica insulating bricks and 50 mm thick calcium silicate block insulation. |
| | Flue duct from Recuperator up to chimney | 115 mm thick IS-6 quality fire bricks backed by 115 mm thick Mica insulating bricks. |

of revamping of a 24 t/h capacity re-heating furnace with optimum refractory and insulation.

To determine the radiation loss from the surface of the furnace, the following formulae is used:

| Radiation heat loss from the surface of furnace (Q) = | a x $(t_1-t_2)$ ^ (5/4) + 4.88 E $[((t_1+273)/100)$ ^ 4 - $((t_2+273)/100)$ ^ 4] |
|---|---|
| Where, | |
| Q = | Quantity of heat released in kCal/W/m$^2$ |
| A = | factor regarding direction of the surface of natural convection ceiling 2.8m, side walls=2.2m, hearth =1.5m |
| $t_1$ = | temperature of external wall surface of the furnace ($^0$C) |
| $t_2$ = | ambient temperature ($^0$C) |

The table below shows a comparative of the wall losses from a re-heating furnace with and without optimum refractory and insulation. The table also establishes the energy and GHG emissions reduction and cost benefit analysis by adoption of optimum refractory and insulation:

The investment and energy savings for refractory and insulation will vary based on the capacity of the furnace. The table 13 further provides an estimate for refractory and insulation for different ranges of the furnace:

**Table 12: Cost benefit analysis for optimum refractory and insulation**

| Sl. No. | Parameters | Units | As Is | To Be |
|---|---|---|---|---|
| 1 | Furnace rated capacity | t/h | 15 | 15 |
| 2 | Productivity | t/h | 12 | 12 |
| 3 | Operating hours | h/d | 16 | 16 |
| 4 | Operating days | d/y | 330 | 330 |
| 5 | Annual Operating hrs | h/y | 5,280 | 5,280 |
| 6 | Annual Production | t/y | 63,360 | 63,360 |
| 7 | Temperature of the Walls | $^0$C | 125 | 60 |
| 8 | Ambient Temperature | $^0$C | 35 | 35 |
| 9 | Total Wall Area | m$^2$ | 296 | 296 |
| 10 | Heat Loss from Surface | kCal/h | 296,744 | 60,217 |
| 11 | Hourly fuel consumption | kg/h | 52.99 | 10.75 |
| 12 | Reduction in Fuel Consumption | kg/h | 42 | |
| 13 | Annual fuel saving | t/y | 223 | |
| 14 | Cost of fuel | Rs/t | 8,000 | |
| 15 | Annual monetary savings | Rs in Lakhs/y | 17.84 | |
| 16 | Estimated Investment | Rs in Lakhs | 40.00 | |
| 17 | Simple Payback | months | 27 | |

* Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg
  **Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO$_2$/TJ for sub-bituminous coal

**Table 13: Investment and saving for optimum refractory and insulation for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-25 | 20 – 50 | 10- 75 | < 2 years |

* based on estimated figures

# Technology No. 5: Installation of Energy Efficient Pulverizer   **6**

## 6.1   Baseline Scenario

In recent times, pulverized coal has emerged as the most widely used fuel in the steel re-rolling mill sector. Easy availability of coal, cost-economics of its use and lower capital investment required for switch-over has made pulverized coal popular in the industry. However, in order to get optimum output, it is important that supply chain of coal is properly maintained. Right from procurement till feeding of coal into the furnace; each step needs to be carefully monitored and controlled for better outputs.

Most of the operators of pulverized coal lack understanding of best operating practices related to its use. The coal typically used in SRRM sector is characterized by high ash and low calorific content. Using high ash content coal leaves ash deposits on the refractory bricks that react with the iron content of the bricks. This leads to premature cracks and failure of the refractory lining. Ash deposits require more heat to be added to the charge for attaining desired temperature, thus increasing burning losses. Also, high ash content leads to choking of recuperator tubes. This necessitates frequent cleaning, thus leading to high maintenance cost and reduced performance of heat exchangers. The ideal size of pulverized coal should be at least 75-80% of 75 microns. In conventional system, fine coal ranges from only 10% to 30%. Non uniform coal particles undergo partial combustion and result in deposition on the furnace walls. These coarse particles escape from furnace with flue gas in the form of unburnt carbon or ash.

## 6.2   Energy Efficient Technology

The energy efficient alternative to use pulverized coal as fuel starts with the procurement of good quality coal. Coal with high calorific value and low ash content, e.g. Assam coal is most ideally suited for the use as pulverized coal. Coal quality should be regularly examined in-house in order to keep a check on the sourcing of coal. For in-house testing of coal, laboratory size bomb calorimeter should be used.

Once good quality coal is sourced, the next step is to process or pulverize the coal into the desired fineness consistently. To do so, certain modifications in pulverizer are required. The critical components of a pulveriser are:

- a hammer,
- a mild steel liner,
- a classifier,
- an inbuilt blower

In order to achieve pulverized coal to the desired fineness in a consistent manner, the following modifications to existing pulverizer are suggested:

**Hammer:** Improve metallurgy with the addition of manganese (13%), carbon (1.13%), silicon (0.4%), sulphur (0.003%), and phosphorus (less than 0.2%) to increase its resistance to wear and tear.

**Liner:** Use grooved EN-31 hardened steel plates or casted high manganese.

**Classifier:** Ensure proper dimensions and thickness (gap between the classifier tip and casing to be less than 1 mm) to classify the pulverized coal to achieve 65%–80% of desired (–) 200 mesh size. The classifier should be high chrome, high nickel alloy.

The performance of a coal pulverizer can be gauged from the size and uniformity of the coal output. Thus, it becomes imperative to measure and maintain the fineness of coal coming out of the pulverizer. A metal sieve of minus 200 mesh size or 75 microns can be used for the purpose.

## 6.3   Benefits of the technology
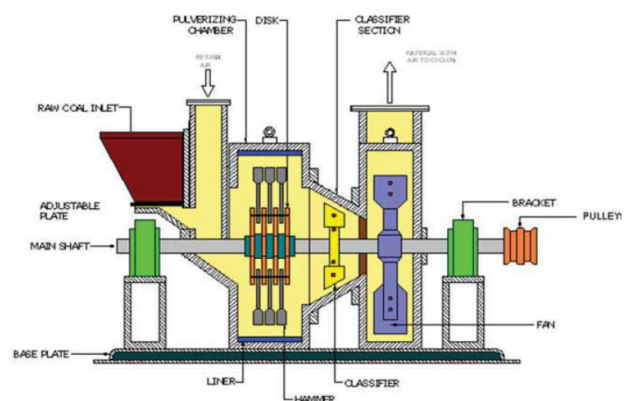


**Figure 17: Sectional view of a pulverizer**

Installation of energy efficient pulverizer has the following benefits:

- Enhanced combustion efficiency of furnace
- Increased flame temperature
- Reduced energy consumption

## 6.4   Limitations

There are no limitations for this technology.

## 6.5   Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of use of energy efficient pulverizer in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h SRRM plant.

Table 14: Cost benefit analysis for energy efficient pulverizer

| Sl. No. | Parameter | UoM | As Is | To Be |
|---|---|---|---|---|
| 1 | Productivity | t/h | 10 | 10 |
| 2 | No. of operating hours | h/d | 12 | 12 |
| 3 | No. of working days | d/y | 300 | 300 |
| 4 | Specific fuel consumption (Baseline) | kg/t | 90 | - |
| 5 | Percentage saving in specific fuel consumption after installation of energy efficient pulverizer | % | 5 | |
| 6 | Specific fuel consumption (post implementation) | kg/t | - | 85.5 |
| 7 | Annual production | t/y | 36,000 | 36,000 |
| 8 | Annual fuel consumption | t/y | 3,240 | 3,078 |
| 9 | Annual saving of coal | t/y | 162 | |
| 10 | Cost of coal | Rs/t | 8,000 | |
| 11 | Annual monetary savings | Rs in lakh/y | 12.96 | |
| 12 | Estimated investment (including recurring cost of critical components for a period of 6 months) | Rs in lakh | 8 | |
| 13 | Simple pay-back period | months | 7 | |
| 14 | Annual energy savings | toe/y | 91 | |
| 14 | Annual GHG emission reduction | $tCO_2/y$ | 359 | |

\* *Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

\*\**Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 $tCO_2/TJ$ for sub-bituminous coal*

Table 15: Investment and saving for energy efficient pulverizer for different ranges of furnace

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-20 | 6 – 25 | 5 - 25 | < 1.5 years |

\* *based on estimated figures*

## Case Study 4: Installation of Energy Efficient Pulverizer

Laxmi Steel Rolling Mill is a leading manufacturer of industrial products, located in Mandi Gobindgarh in Punjab. In 2018, the plant decided to implement an energy efficient pulverizer in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient pulverizer was installed in their 7 t/h furnace. The plant achieved an astonishing 6% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 7 lakhs which was recovered in less than a year.



Energy efficient pulverizeer

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Furnace productivity | t/h | 7 | 7 |
| 2 | Type of fuel | | Pulverized coal | Pulverized coal |
| 3 | Specific fuel consumption | kg/t | 70 | 65 |
| 4 | Saving in fuel consumption | kg/t | 5 | |
| 5 | Annual fuel saving | t/y | 126 | |
| 6 | Cost of fuel | Rs/t | 8,000 | |
| 7 | Annual monetary savings | Rs in Lakhs/y | 10.8 | |
| 8 | Investment | Rs in Lakhs | 7 | |
| 9 | Simple pay back | months | 8 | |
| 10 | Annual energy savings | toe/y | 70 | |
| 11 | Annual GHG emission reduction | $tCO_2/y$ | 729 | |

*\*Calorific value of coal taken as 5,600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2/TJ$ for sub-bituminous coal*

# Technology No. 6: Installation of Modified Pulverized Coal Handling and Feeding System

## 7.1    Baseline Scenario

Conventionally, the pulverized coal is conveyed with cold combustion air, without the provision of recuperator, and fired by a four-inch pipe. As there is no proper control on the fuel and air, the process results into improper combustion resulting in unburnt coals. Also, pulverizer in most cases is inefficient.

## 7.2    Energy Efficient Technology

In the energy efficient process, high quality lump coal is first fed into a pre-crusher, wherein coal is crushed to tea leaf size. The pre-crushed coal is passed through the dryer where the surface moisture of coal is removed using hot air from the recuperator. The coal is then fed into the pulverizer, where it is powdered to 75 micron size. Finer coal means more surface area available for combustion, and hence more heat output. Pulverized coal is transferred to the overhead furnace hopper which allows storing of coal of required quantity at the furnace head. DC motor run screw feeder controls the coal flow to the burner, based on the furnace temperature.
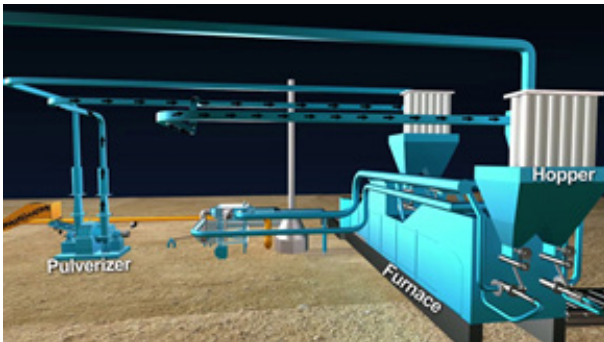


**Figure 18: Modified pulverized coal feeding system**

A swirl type burner with annual arrangement for separate entry of coal and hot air and equipped with circumferential vanes is used in the system to ensure proper turbulence and mixing of air and fuel.
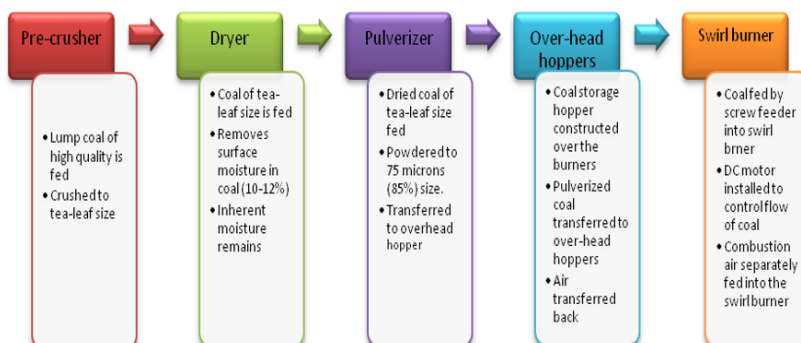
The process is completed by feeding pre-heated combustion air from the recuperator to the burner tip which along with the swirling motion improves the combustion significantly leading to lower specific fuel consumption and burning loss.

The process flow of the modified coal handling and feeding system is shown in the figure below:

A typical specification of the pulverized coal handling and feeding system for a 15 t/h furnace is tabulated below:

## 7.3    Benefits of the technology

Installation of modified pulverized coal handling and feeding system has the following benefits:

- Separate feeding lines for coal and hot air
- Removal of surface moisture from coal increasing combustion efficiency
- Swirl burner provide optimum time, temperature and turbulence required for combustion
- Enhanced combustion efficiency of furnace
- Monitoring and control of air fuel ratio
- Reduced energy consumption

## 7.4    Limitations

The installation of the hopper close to the furnace increases the danger of burning of coal at elevated temperature. Due care should be taken to avoid over-heating of coal. Also, the possibility of sticking can occur due to moisture in the coal. The hopper can be internally insulated with a stainless steel plate to avoid sticking of coal. The construction of the over head hopper needs to be carefully done to avoid over-heating.

## 7.5    Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of the modified pulverized coal handling and feeding system in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h SRRM plant.

The investment and energy savings for modified pulverized coal feeding system will vary based on the capacity of the furnace. The table below provides an estimate for modified pulverized coal feeding system for different ranges of the furnace:



**Figure 19: Process flow of pulverized coal handling and feeding system**

**Table 16: Technical specification of pulverized coal handling and feeding system**

| Sl. No. | Parts | Standard Specification |
|---|---|---|
| 1 | Pre-crusher | Type: Primary Crusher<br>Processing capacity: Up to 1.5 t/h<br>Feeding size : 10 – 30 mm<br>Output size : 2-5 mm<br>Motor: 10 hp/ 1440 RPM |
| 2 | Coal dryer | Type: Cyclone type<br>Drying capacity: Up to 12% surface moisture<br>Hot air input: from recuperator<br>No. of conveyors for transferring dried coal : 2<br>Additional feature: ID fan to throw away moisture laden air; air lock to restrict the entry of air into the conveyors.<br>Conveyor Motor: 5 hp / 1440 RPM – 3 no's.<br>ID Fan motor: 7.5 hp / 1440 RPM – 1 no.<br>Air lock motor: 2 hp / 1440 RPM – 2 no's. |
| 3 | Pulverizer | Type: Hammer Type<br>Hammer Material: High Chrome Manganese<br>Liner Material : EN-31 hardened steel plates<br>Classifier: Minimum gap maintained with casing<br>Feeding input: 2-5 mm crushed coal<br>Output: 75 microns pulverized coal<br>No. of pulverizing units : 2<br>Size of pulverizing unit: 38"<br>Motor: 75 hp / 1440 RPM – 2 no's. |
| 4 | Burner | Type: Swirl burner<br>Numbers: 4<br>Control: Screw feeder (DC motor driven)<br>Inputs: Separate entry for coal, primary and secondary air |

**Table 17: Cost benefit analysis for modified pulverized coal feeding system**

| Sl. No. | Parameter | UoM | As Is | To Be |
|---|---|---|---|---|
| 1 | Productivity | t/h | 10 | 10 |
| 2 | No. of operating hours | h/d | 12 | 12 |
| 3 | No. of working days | d/y | 300 | 300 |
| 4 | Specific fuel consumption (Baseline) | kg/t | 90 | - |
| 5 | Percentage saving in specific fuel consumption after installation of modified pulverized coal feeding system | % | 10 | |
| 6 | Specific fuel consumption (post implementation) | kg/t | - | 81 |
| 7 | Annual production | t/y | 36,000 | 36,000 |
| 8 | Annual fuel consumption | t/y | 3,240 | 2,916 |
| 9 | Annual saving of coal | t/y | 324 | |
| 10 | Cost of coal | Rs/t | 8,000 | |
| 11 | Annual monetary savings | Rs in lakh/y | 25.92 | |
| 12 | Estimated investment | Rs in lakh | 20 | |
| 13 | Simple pay-back period | months | 9 | |
| 14 | Annual energy savings | toe/y | 181 | |
| 14 | Annual GHG emission reduction | $tCO_2$/y | 718 | |

*\* Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

**Table 18: Investment and saving for modified pulverized coal feeding system for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-25 | 10 – 30 | 15 - 40 | < 1 year |

*\* based on estimated figures*

## Case Study 5: Installation of Modified Pulverized Coal Feeding System

T.K. Steel Re-rolling Mills is a leading manufacturer of alloy steel industrial products, located at Ludhiana in Punjab. In 2018, the plant decided to implement the modified pulverized coal feeding system in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient system was installed in their 7 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 15 lakhs which was recovered in close to a year.



**Modified pulverized coal feeding system at TK Steel**

| Sl. No. | Parameter | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Productivity | t/h | 7 | 7 |
| 2 | No. of operating hours | h/d | 12 | 12 |
| 3 | No. of working days | d/y | 300 | 300 |
| 5 | Specific fuel consumption | kg/t | 70 | 63- |
| 6 | Annual production | t/y | 25,200 | 25,200 |
| 7 | Annual fuel consumption | t/y | 1764 | 1587.6 |
| 8 | Annual saving of coal | t/y | 176.4 | |
| 9 | Cost of coal | Rs/t | 8,000 | |
| 10 | Annual monetary savings | Rs in lakh/y | 14.11 | |
| 11 | Estimated investment | Rs in lakh | 15 | |
| 12 | Simple pay-back period | months | 13 | |
| 13 | Annual energy savings | toe/y | 99 | |
| 14 | Annual GHG emission reduction | $tCO_2$/y | 391 | |

*\*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

# 8 Technology No. 7: Installation of Coal Drying System

## 8.1 Baseline Scenario

Coal is the predominantly used fuel in re-heating furnaces. Coal will normally have an inherent moisture of 8% and surface moisture of 10%. Such moisture content takes away substantial heat during combustion process as latent heat of vapour. Such high moisture also leads to chocking of coal storage hoppers leading to frequent breakdowns. Although many industries have attempted drying coal using crude methods (spreading coal on top of re-heating furnace, in open area etc.), they have not been able to get the desired results.

## 8.2 Energy Efficient Technology

Flue gas comes out of re-heating furnace at temperature of 600 to 700°C. Partial heat recovery is achieved in a recuperator for pre-heating combustion air. A bypass line from the pre-heated combustion air is fed into the cyclone dryer wherein it is mixed with the moisture laden air. Dried coal is dropped into two conveyors. An ID Fan throws out the moisture laden air. An air lock system is provided to block the entry of air into the conveyors. The two conveyors are used to carry dried coal to the pulverizer. In this process, the cyclone dryer is used to remove the surface moisture of the coal, which is around 10-12%. The inherent moisture in coal however remains intact. The entire coal drying system works on a principle of removing the moisture content by using the waste heat available in flue gas.

## 8.3 Benefits of the technology

Installation of coal dryer has the following benefits:

- Feeding of moisture free dry coal for combustion
- Avoiding formation of vapour during combustion
- Enhanced combustion efficiency of furnace
- Reduced energy consumption

## 8.4 Limitations

The dryer should be placed close as possible to the pulverizing. Over heating should be avoided.

## 8.5 Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of coal drying technology in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM plant:

**Table 19: Cost benefit analysis for coal dryer**

| Sl. No. | Parameter | UoM | Value |
|---------|-----------|-----|-------|
| 1 | Latent heat of evaporation of water vapour | kCal/kg | 542 |
| 2 | Amount of coal used in 15 t re-heating furnace operating for 16 hours per day (considering specific coal consumption of 75 kg/t) | kg/d | 18,000 |
| 3 | Mass of 1% of moisture present in coal | kg/d | 180 |
| 4 | Heat taken away by this 1% of moisture through latent heat of evaporation | kCal/d | 97,560 |
| 5 | Reduction in moisture by installing coal drying system | % | 6 |
| 6 | Total heat saved due to reduction in moisture content by installing coal drying system (Sl. No. 5 x Sl.No.4) | kCal/d | 5854 |
| 7 | Calorific value of coal used in re-heating furnace | kCal/kg | 5,600 |
| 8 | Saving in coal consumption due to installation of coal drying system | kg/d | 1.05 |
| 9 | Increase in calorific value of coal due to reduction in moisture (assuming 10% increase) | kCal/kg | 560 |
| 10 | Coal consumption due to increased calorific value | kg/d | 16,364 |
| 11 | Total reduction in coal consumption | kg/d | 1637 |
| 12 | Saving in fuel consumption | % | 9.10 |
| 13 | Annual coal saving | t/y | 540 |
| 14 | Cost of fuel | Rs/t | 8,000 |
| 15 | Monetary saving | Rs in Lakhs /y | 43 |
| 16 | Estimated Investment | Rs in Lakhs | 17 |
| 17 | Simple pay back | Months | 5 |
| 18 | Annual energy savings | toe/y | 303 |
| 19 | Annual $CO_2$ emission reduction | $tCO_2$/y | 1,198 |

*\* Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

The investment and energy savings for coal dryer will vary based on the capacity of the furnace. The table below provides an estimate for coal dryer for different ranges of the furnace:

**Table 20: Investment and saving for coal dryer for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-20 | 10 – 25 | 12 - 50 | < 1 year |

*\* based on estimated figures*

## Case Study 6: Installation of Coal Dryer System

Located in Jaipur, Rajasthan, Premier Bars Limited is a leading manufacturer of TMT bars. In 2018, the plant decided to implement a coal dryer system in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient system was installed in their 20 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 15 lakhs which was recovered in close to a year.

| Sl. No. | Parameter | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Productivity | t/h | 20 | 20 |
| 2 | No. of operating hours | h/d | 16 | 16 |
| 3 | No. of working days | d/y | 330 | 330 |
| 5 | Specific fuel consumption | kg/t | 70 | 63 |
| 6 | Annual production | t/y | 105,600 | 105,600 |
| 7 | Annual fuel consumption | t/y | 7,392 | 6,653 |
| 8 | Annual saving of coal | t/y | 739 | |
| 9 | Cost of coal | Rs/t | 8,000 | |
| 10 | Annual monetary savings | Rs in lakh/y | 59.13 | |
| 11 | Estimated investment | Rs in lakh | 15 | |
| 12 | Simple pay-back period | months | 3 | |
| 13 | Annual energy savings | toe/y | 414 | |
| 14 | Annual GHG emission reduction | $tCO_2$/y | 1,638 | |

*\*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

# 9 Technology No. 8: Swirl Burner Used for Pulverized Coal Firing

## 9.1 Baseline Scenario

Pulverized coal is the most preferred fuel used in a re-heating furnace, because of its easy availability, low cost and ease of operation. Combustion depends on three "T's" namely "Time, Temperature & Turbulence". Efficient burning of coal depends on proper air-fuel mixture. In most of the SRRM units, a 4-inch pipe is used as a burner for pulverized coal. This 4-inch pipe is inserted into the front and side walls of the re-heating furnace. Only primary air in ambient temperature is used for combustion in such conventional burners and the air-fuel ratio is neither monitored nor controlled. This crude practice of using 4-inch pipe as a burner leads to incomplete combustion, inefficient heat transfer to ingot/billet/scrap, and higher fuel consumption.

## 9.2 Energy Efficient Technology

In order to have proper control of the air-fuel mixture in a re-heating furnace and also to ensure optimum combustion of coal, swirl burners for pulverized coal-fired re-heating furnaces can be used. The purpose of using a swirl burner is to achieve a stable flame and to ensure proper mixing of air and fuel. In a swirl burner, secondary air is supplied along with primary air in annular arrangement. Both primary air and secondary air are hot air drawn from the recuperator. The swirl burner typically has three inputs; the closest input towards the furnace is for primary air, which is directly fed from the recuperator; coal is fed from the next input on a controlled manner from the screw feeder attached to the over-head hopper. The third input is for the secondary air which pushes the coal into the burner. The hot secondary air is also utilized for complete combustion of powder coal. This burner works on the basis of three T's of combustion:

- Time: Sufficient time for burning
- Temperature: Lgnition temperature must be achieved
- Turbulence: Proper mixing of fuel and air, which is achieved by swirlers

Vanes are fabricated in between the annular pipes. The turbulence caused due to the rotation of air-fuel mixture being generated by the vane swirl generator results in proper air-fuel mixing and better combustion of fuel.

## 9.3 Benefits of the technology

Installation of swirl burners in pulverized coal fired furnace has the following benefits:

- Provides sufficient time for burning
- Increased flame temperature
- Ensures proper air fuel mixture.
- Enhanced combustion efficiency of furnace
- Reduced energy consumption

## 9.4 Limitations

There are no limitations for this technology.

## 9.5 Energy Savings, GHG Emission reduction & Cost Benefit Analysis

The following section provides the details of the pulverized coal swirl burners in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM plant.

The investment and energy savings for swirl burners will vary based on the capacity of the furnace. The table below provides an estimate for swirl burners for different ranges of the furnace:

**Table 21: Cost benefit analysis for swirl burners for pulveirized coal firing**

| Sl. No. | Parameter | Unit | Furnace with pipe burner | Furnace with swirl burner |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Specific fuel consumption | kg/t | 75 | 72.75 |
| 5 | Annual fuel consumption | t/y | 5,940 | 5,762 |
| 6 | Saving in fuel consumption | t/y | 178 | |
| | Cost of fuel | Rs/t | 8,000 | |
| 7 | Annual monetary saving due to fuel savings | Rs in Lakhs/y | 14.3 | |
| 8 | Investment for say 6 nos. of swirl burners with required accessories | Rs in Lakhs | 7.5 | |
| 9 | Simple pay back | months | 6 | |
| 10 | Annual energy savings | toe/y | 100 | |
| 11 | Annual GHG emission reduction | $tCO_2$/y | 395 | |

*\* Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg*
  *\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

**Table 22: Investment and saving for pulverized coal swirl burners for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5-20 | 1.25 – 10 | 4 – 17.5 | < 1 year |

*\* based on estimated figures*

## Case Study 7: Installation of Swirl Burner in Pulverized Coal Fired Furnace

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located at Ludhiana in Punjab. The plant was established in the year 1995. In 2017, the plant decided to implement swirl burners in their existing re-heating furnace. The plant achieved a 3% reduction in the specific fuel consumption. The investment was recouped in less than a year.



**Pulverized coal swirl burner**

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Furnace productivity | t/h | 10 | 10 |
| 2 | Type of fuel | | Pulverized coal | Pulverized coal |
| 3 | Specific fuel consumption | kg/t | 70 | 67.9 |
| 4 | Saving in fuel consumption | kg/t | 2.1 | |
| 5 | Annual fuel saving | t/y | 166 | |
| 6 | Cost of fuel | Rs/t | 8,000 | |
| 7 | Annual monetary savings | Rs in Lakhs/y | 13.3 | |
| 8 | Investment | Rs in Lakhs | 5 | |
| 9 | Simple pay back | months | 5 | |
| 10 | Annual energy savings | toe/y | 83 | |
| 11 | Annual GHG emission reduction | $tCO_2$/y | 369 | |

*\*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

# 10 Technology No. 9: Replacement of Fossil Fuel Firing to Coal Bed Methane (CBM) Firing in Re-heating Furnace

## 10.1 Baseline Scenario

Traditionally, fossil fuels in the form of lump coal, pulverized coal, furnace oil, natural gas or producer gas have been the commonly used fuels to fire a re-heating furnace. The use of fossils fuels not only adds to the country's worries but also emits green-house gases which are proven threat to the universe. Under such scenario, there is a quest for alternate source of energy worldwide, to combat the harmful threats of global warming.



**Figure 20: Extraction of coal bed methane**

The details of re-heating furnace operating in conventional rolling mills are as follows:

**Table 23: Operating parameters for conventional re-heating furnace**

| Furnace Capacity (tph) | Thermal Efficiency (%) | Flue gas exit temperature (°C) | Specific fuel consumption |
|---|---|---|---|
| 2-25 | 25-30 | 600-650 | 100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas |

## 10.2 Energy Efficient Technology

Coal bed methane (CBM or coal-bed methane), coal bed gas, coal seam gas (CSG), or coal-mine methane (CMM) is a form of natural gas extracted from coal beds. Methane adsorbed into a solid coal matrix (coal macerals) is released if the coal seam is de-pressurized. Methane is extracted by drilling wells into the coal seam.

The goal is to decrease the water pressure by pumping water from the well. The decrease in pressure allows methane to desorb from the coal and flow as a gas up the well to the surface. Methane is then compressed and piped to market.

The objective is to avoid putting methane into the water line, but allow it to flow up the backside of the well (casing) to the compressor station. If the water level is pumped too low during dewatering, methane may travel up the tubing into the water line causing the well to become "gassy".

Although methane may be recovered in a water-gas separator at the surface, pumping water and gas is inefficient and can cause pump wear and breakdown. Extraction of coal bed methane in large quantity is being currently done in areas of West Bengal in and around Raniganj-Panagarh, etc.

Coal bed methane (CBM) can be used in rolling mill as a piped gas and has features similar to that of natural gas. Use of coal bed methane is considered as a carbon neutral fuel as the main component of the gas is methane ($CH_4$) which is a green-house gas, which is burnt in the combustion process.

## 10.3 Benefits of the technology

Switching over to coal bed methane as fuel has the following benefits:

- Utilization of methane which is a green-house gas
- Better combustion efficiency compared to solid fuel firing

## 10.4 Limitations

The technology is applicable only in areas where piped CBM gas is available. Also, the piped gas needs to be supplied in constant pressure. Cost of fuel will decide the economic feasibility of the technology.

## 10.5 Investment Required, Energy & GHG Saving Potential & Cost Benefit Analysis

The following section provides the details of energy & GHG saving potential, investment required and cost benefit analysis for implementation of CBM based unit as a replacement to furnace oil for a 15 t/h furnace.

The investment and energy savings for switching over from furnace oil to CBM as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to CBM as fuel for different ranges of the furnace:

**Table 24: Cost benefit analysis for switch over from furnace oil to CBM based reheating furnace**

| Sl. No. | Parameter | Unit | Furnace oil fired re-heating furnace | CBM fired re-heating furnace |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 20 | 20 |
| 3 | Operating days per year | d/y | 300 | 300 |
| 4 | Specific fuel consumption | l/t ; Nm³/t | 35 | 32 |
| 5 | Cost of fuel | Rs/l ; Rs/ Nm³ | 35 | 30 |
| 6 | Annual fuel consumption | kl/y ; Nm³/y | 3,150 | 2,880,000 |
| 7 | Annual cost of fuel | Rs in Lakhs/y | 1,102.5 | 864 |
| 8 | Annual monetary savings | Rs in Lakhs /y | 239 | |
| 9 | Investment towards modification of furnace and piped gasoline | Rs in Lakhs | 150 | |
| 10 | Simple pay-back | Months | 8 | |
| 11 | Annual energy savings | toe/y | 635 | |
| 12 | Annual GHG emission savings | $tCO_2$/y | 9,365 | |

*Calorific value of furnace taken as 9,600 kCal/kg; calorific value of CBM taken as 10,500 kCal/kg

**Density of furnace oil is 0.96 kg/l; Density of CBM is 0.7 kg/Nm³

**Cost of furnace oil taken as Rs 35 /l and cost of CBM taken as Rs 30/Nm3

*** Emission factor for furnace oil as per IPCC Guideline 2006 (C1; V1 & V2) taken as 77.2 $tCO_2$/TJ; GHG emission from CBM considered as 'zero'

**Table 25: Investment and saving for CBM as fuel for different ranges of furnace**

| Furnace Capacity (t/h) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -20 | 100 – 150 | 100 – 200 | < 1 year |

* based on estimated figures

# 11 Technology No. 10: Replacement of Fossil Fuel Firing to Biomass Based Producer Gas in Re-heating Furnace

## 11.1 Baseline Scenario

Traditionally, fossil fuels in the form of lump coal, pulverized coal, furnace oil, natural gas or producer gas are the commonly used fuels to fire a re-heating furnace. The use of fossil fuels not only adds to the country's worries but also emits green-house gases which are proven threat to the universe. Under such scenario, there is a quest for alternate source of energy worldwide, to combat the harmful threats of global warming.
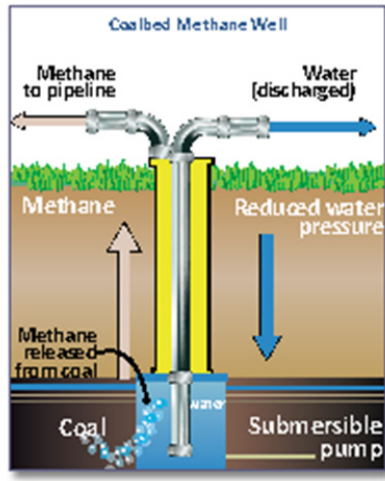
The details of re-heating furnace operating in conventional rolling mills are as follows:

**Table 26: Operating parameters for conventional re-heating furnace**

| Furnace Capacity (tph) | Thermal Efficiency (%) | Flue gas exit temperature ($^0$C) | Specific fuel consumption |
|---|---|---|---|
| 2-25 | 25-30 | 600-650 | 100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas |

## 11.2 Energy Efficient Technology

Biomass generated from agricultural waste such as groundnut shell, coconut shell, bagasse, etc. formed into briquettes by a suitable binding medium can be used as input to a biomass based producer gas plant; the producer gas in-turn can be used as a fuel for the re-heating furnace. Gasification is a thermos-chemical process where biomass is converted into a combustible producer gas. The main components in producer gas are $N_2$; $H_2$; CO; $CO_2$ and $CH_4$. Producer gas from biomass gasification is available in two forms, viz., (i) hot raw gas and (ii) cleaned cold gas.

Typical Schematic arrangement of biomass gasification for furnace is shown below:
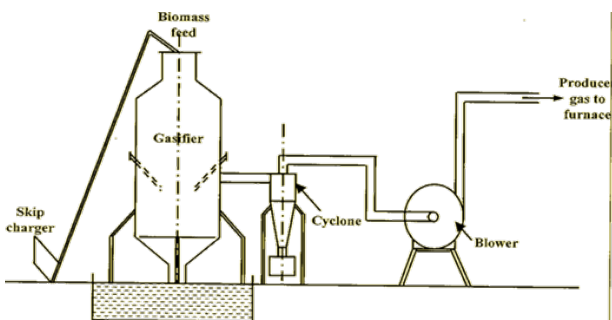


**Figure 21: Schematic diagram showing biomass gasification for re-heating**

The hot raw gas is obtained by tapping from an appropriate point of the reactor, where the gas is at a temperature of about 500$^0$C. In this gas, all tar and naptha will be in vapour form. Therefore, the CV is high about 1,350 to 1,400 kCal/Nm$^2$. Also, since this gas is at high temperature, adiabatic flame temperature by combustion of this gas with air at 350$^0$C will be above 1800$^0$C, which is adequate for re-heating furnaces. However, the raw gas will be available at low pressures, about 50 mm WC, which is just sufficient level for typical burners. This means it is not possible to introduce any measurement and auto control system with hot raw gas, since the pressure is not adequate. With lack of flow measurement and flow control furnace temperature control cannot be maintained at optimum levels. Boosting the hot raw gas with tar, to the required pressure level by a booster is not practical. Biomass based producer gas can be effectively used in a rolling mill using suitable producer gas burners. Cold gas is tapped from top of the reactor after the heat content of the gas is recovered for drying and preheating of the coal charge. The gas further processed for removal of tar and naphtha in scrubbers, and ultimately the gas will be free from tar. Since the gas is free from tar, this can be boosted to the desired pressure. However, since tar has been removed, CV of the gas will be in the range of 1,050 to 1,100 kCal/Nm$^2$. Adiabatic flame temperature of cold gas with this CV and with combustion air temperature of 350$^0$C will be about 1,600$^0$C. With this adiabatic flame, temperature furnace cannot be heated to 1,280$^0$C, which is required in the re-heating furnaces. Therefore, when this gas is used, support of high CV fuel like furnace oil is required.

GHG ($CO_2$) emissions from the biomass are high as compared to other fuels in the reheating furnace but it cannot be considered as GHG emission because $CO_2$ emission from biomass is considered as a part of natural carbon cycle. Thus, use of biomass based producer gas in the re-heating furnace is a carbon neutral process.

## 11.3 Benefits of the technology

Adoption of biomass based producer gas plant as fuel has the following benefits:

- Utilization of renewable source of energy
- Better combustion efficiency compared to solid fuel firing
- Reduced cost of production

## 11.4 Limitations

Continuous availability of biomass is a limiting factor for the technology. Also, cost of biomass briquettes will determine the feasibility of the technology.

## 11.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of furnace oil with biomass based producer gas in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for switching over from furnace oil to biomass based producer gas as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to biomass based producer gas as fuel for different ranges of the furnace:

**Table 27: Cost benefit analysis for biomass based reheating furnace**

| Sl. No. | Parameter | Unit | Furnace oil fired re-heating furnace | Biomass based re-heating furnace |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 20 | 20 |
| 3 | Operating days per year | d/y | 300 | 300 |
| 4 | Specific fuel consumption | l/t ; kg/t | 45 | 100 |
| 5 | Cost of fuel | Rs/l ; Rs/ kg | 35 | 6 |
| 6 | Annual fuel consumption | kl/y ; t/y | 4,050 | 9,000 |
| 7 | Annual cost of fuel | Rs in Lakhs/y | 1,418 | 540 |
| 8 | Annual monetary savings | Rs in Lakhs/y | 878 | |
| 9 | Investment for gasifier & furnace modification | Rs in Lakhs | 120 | |
| 10 | Simple pay-back | Months | 2 | |
| 11 | Annual energy savings | toe/y | 454 | |
| 12 | Annual GHG emission savings | $tCO_2$/y | 11,915 | |

*Emission factor of furnace oil as per IPCC guideline 2006 (V2; C1& C2) is 77.2 $tCO_2$/y; calorific value of furnace oil taken as 9,600 kCal/kg; calorific value of biomass taken as 3600 kCal/kg. GHG emission from biomass is taken as zero.*

**Table 28: Investment and saving for biomass based producer gas as fuel for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -20 | 70 – 120 | 250 – 500 | < 1 year |

*\* based on estimated figures*

## Case Study 8: Installation of Biomass Based Producer Gas Plant

Located in Pondicherry, Pulkit Steel Rolling Pvt. Ltd. is a leading manufacturer of TMT bars. In 2016, the plant decided to implement a biomass based producer gas plant under the guidance of the on-going UNDP-GEF project. The biomass gasifier fed to the 20 tph top fired pusher type re-heating furnace. The plant achieved significant savings in terms of energy cost reduction.

**Biomass based producer gas plant**

| Sl. No. | Particulars | UoM | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Furnace productivity | t/h | 20 | 20 |
| 2 | Type of fuel | | Furnace Oil | Biomass based producer gas |
| 3 | Specific fuel consumption | kg/t | 40 | 110 |
| 4 | Cost of fuel | Rs/kg | 30 | 6 |
| 7 | Annual monetary savings | Rs in Lakhs/y | 518 | |
| 8 | Investment | Rs in Lakhs | 90 | |
| 9 | Simple pay back | months | 2 | |
| 10 | Annual energy savings | toe/y | (-)300 | |
| 11 | Annual GHG emission reduction | $tCO_2$/y | 11297 | |

*\*Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
*\*\*Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 $tCO_2$/TJ for sub-bituminous coal*

# 12 Technology No. 11: Replacement of Coal Firing to Natural Gas Firing in Re-heating Furnace

## 12.1 Baseline Scenario

Coal has been traditionally used as the most common form of energy used in re-heating furnace. However, firing coal into the re-heating furnace is a dirty process and also causes threat to health of the workers due to the local level pollution. Coal also increases the suspended particulate matter (SPM) level of the factory's environment thus causing threat to the nearby locality. Also, burning of coal leads to formation of accretion in the furnace walls; primarily due to un-burnt coal and formation of soot.

The details of re-heating furnace operating in conventional rolling mills are as follows:

**Table 29: Operating parameters for conventional re-heating furnace**

| Furnace Capacity (tph) | Thermal Efficiency (%) | Flue gas exit temperature ($^0$C) | Specific fuel consumption |
|---|---|---|---|
| 2-25 | 25-30 | 600-650 | 100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas |

## 12.2 Energy Efficient Technology

Use of natural gas as fuel as replacement of coal leads to cleaner and healthier production. Piped gas line is available in some parts of the country which can be used as fuel for the re-heating furnace. Natural gas as fuel not only allows a better environment for the unit; but also provides significant improvement in the furnace internal environment. Natural gas firing, if controlled in a proper fashion, can lead to optimum specific fuel consumption and burning loss. Also, the efficiency of the furnace improves significantly leading to a longer furnace life.

## 12.3 Benefits of the Technology

Replacement of coal fired furnace with natural gas fired furnace has the following benefits:

- Utilization of a clean fuel
- Better combustion efficiency compared to solid fuel firing
- Reduced burning loss
- Better life of furnace

## 12.4 Limitations

The technology is applicable only in areas where piped natural gas is available. Also, the piped gas needs to be supplied at constant pressure. Cost of fuel will decide the economic feasibility of the technology.

## 12.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of coal firing with natural gas firing in re-heating furnace in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h furnace.

The investment and energy savings for switching over from furnace oil to natural gas as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to natural gas as fuel for different ranges of the furnace:

**Table 30: Cost benefit analysis for switching over from coal fired furnace to NG fired furnace**

| Sl. No. | Parameter | Unit | Coal fired re-heating furnace | Natural Gas fired re-heating furnace |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 300 | 300 |
| 4 | Specific fuel consumption | kg/t ; Nm³/t | 120 | 30 |
| 5 | Cost of fuel | Rs/kg ; Rs/ Nm³ | 8 | 30 |
| 6 | Annual fuel consumption | t/y; Nm³/y | 8,640 | 2,160,000 |
| 7 | Annual cost of fuel | Rs in Lakhs/y | 691.2 | 648 |
| 8 | Annual monetary savings | Rs in Lakhs/y | 43.2 ||
| 9 | Estimated Investment for furnace modification | Rs in Lakhs | 40 ||
| 10 | Simple pay-back | Months | 11 ||
| 11 | Annual energy savings | toe/y | 3,137 ||
| 12 | Annual GHG emission savings | $tCO_2$/y | 14,800 ||

*Calorific value of coal taken as 5,600 kCal/kg; calorific value of NG taken as 10,500 kCal/kg

**Density of NG is 0.7 kg/Nm³

**Cost of coal taken as Rs 8000/t and cost of NG taken as Rs 30/Nm³

*** Emission factor for coal as per IPCC Guideline 2006 (C1; V1 & V2) taken as 94.6 $tCO_2$/TJ; GHG emission from NG considered as 65.5 $tCO_2$/TJ

**Table 31: Investment and saving for natural gas as fuel for different ranges of furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -20 | 20 – 60 | 30 – 80 | < 1 year |

* based on estimated figures

# 13  Technology No. 12: Installation of Anti-friction Roller Bearing in Rolling Mill Strands

## 13.1  Baseline Scenario

Bearings are one of the most critical equipment in a rolling mill and they perform three basic functions:

- Carrying a load
- Reducing friction
- Positioning moving machine parts

Rolling mill bearings are required to withstand extremely severe operating conditions, including heavy shock loads, varying
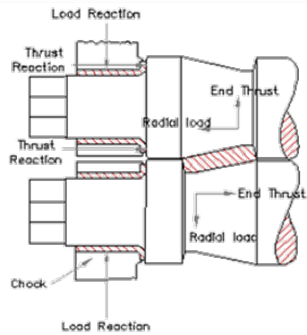


**Figure 22: Various Loads in bearing**

speeds and extreme temperature variations. In most of the cases, the bearing has to withstand both the radial roll separating force and the roll end thrust as illustrated in figure.
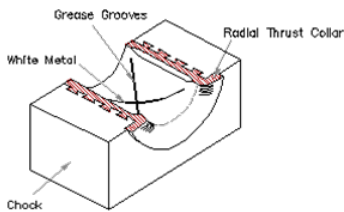


**Figure 23: Plain metal bearing**

The proposition of end thrust varies considerably being quiet low in flat rolling but high in section rolling. Traditionally, many types of bearings are used in a rolling mill. The plain metal bearings (e.g. bronze and white metal) were
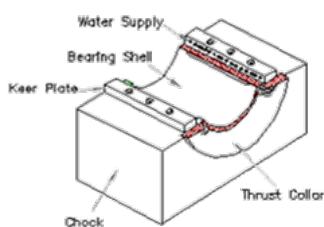


**Figure 24: Fabric bearing**

used extensively in the past, but is now being superseded by the other bearings; although examples can still be found today which are giving very satisfactory performance.



**Figure 25: Fiber bearing in rolling mill**

Fabric bearing have in many cases replaced the plain metal bearing and often represent the most economical bearing for particular equipment. They are composed of a fabric such as cotton impregnated with a resin, and are manufactured by moulding or wrapping accordingly to the type of resin used.

A fabric bearing is subjected to a linear contact with the rotating rolls. Thus, these bearings lead to more



**Figure 26: Fiber bearing key**

friction, thereby leading to significant mechanical losses and lead to comparatively higher power consumption.

## 13.2  Energy Efficient Technology

As an alternative to the conventional metal & fabric bearing, is an anti-friction roller bearing.

A typical roller bearing consists of rolling elements or rollers, an inner ring, an outer ring, and a retainer. In a typical installation, the outer ring is fixed and doesn't move and the inner ring is fitted to the shaft. As the shaft rotates, the inner ring also rotates. The rollers are held into position by the retainer which positions the rollers equally around the rings and ensures that the load is distributed equally on each roller when the shaft is rotating.

Ball and roller bearings are finding wide use in all types of mills due to their close tolerance and low power loss. Parallel, taper and spherical taper races are available and even



**Figure 27: Roller bearing**

ball races vary considerably in form – angular contact and deep-seated types being used for thrust races. Taper rollers can take thrust as well as radial loads but parallel rollers require a separate thrust race. Two typical arrangements are shown in Fig 29 and 30. The method of mounting the inner races varies with the duty – for slow-speed applications, a loose fit on the roll neck might suffice whereas in high-speed application



**Figure 28: Roller bearing based mill stand**

a shrink fit on a parallel or taper neck may be required. Lubrication may be by grease pack or automatic feed of grease, oil or oil mist.

## 13.3  Benefits of the technology

Adoption of roller bearings has the following benefits:

- Less friction compared to metal or fabric bearing
- Improved transmission efficiency
- Improved life of rolls
- Reduced energy consumption
- Improved mill utilization
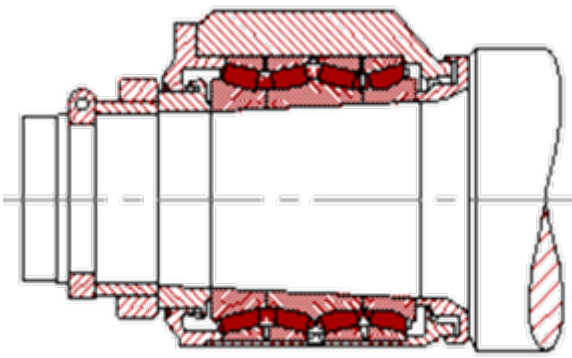
**Figure 29: Taper roller bearing for radial load and thrust**
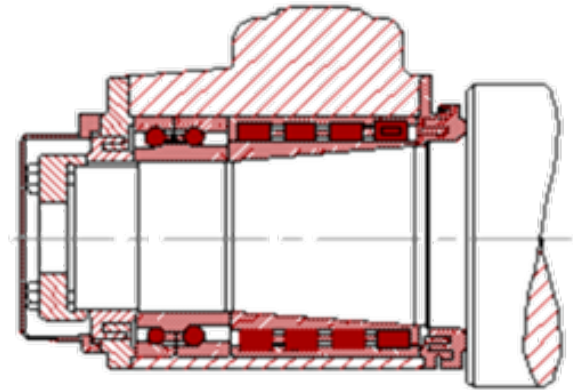


**Figure 30: Parallel roller for radial load and angular contact ball bearing for thrust**

## 13.4 Limitations

The bearings must be lubricated properly to avoid failure. The roll alignment may be checked properly before installation. Conversion from fabric to roller bearing depends on the roll strand.

## 13.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional bearing with roller bearing in terms of energy &

GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h plant.

The investment and energy savings for installation of roller bearing will vary based on the capacity of the rolling mill and number of stands to be changed.

The table below provides an estimate for installation of roller bearing for different ranges of rolling mills:

**Table 32: Cost benefit analysis for roller bearing**

| Sl. No. | Parameter | UoM | With conventional bearings | With roller bearings |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Annual operational hours | h/y | 5,280 | 5,280 |
| 3 | Mill Utilization | % | 85 | 89 |
| 4 | Annual production | t/a | 67,320 | 70,686 |
| 5 | Specific power consumption (average) | kWh/t | 120 | 108 |
| 6 | Saving in specific power consumption | kWh/t | 12 | |
| 7 | Annual power savings | kWh/y | 848,232 | |
| 8 | Power Tariff | Rs/kWh | 7.5 | |
| 9 | Annual monetary saving due to power saving | Rs in Lakh/y | 64 | |
| 10 | Annual monetary profit due to increase in productivity** | Rs in Lakh/y | 50 | |
| 11 | Total annual saving | Rs in Lakh | 114 | |
| 12 | Investment for replacement of conventional bearing with roller bearing*** | Rs in Lakh | 50 | |
| 14 | Payback Period | months | 5 | |
| 15 | Annual energy saving | toe/y | 73 | |
| 16 | Annual saving in $CO_2$ emission due to reduction in coal saving* | $tCO_2$/y | 763 | |

*Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 &C2) is 0.90 $tCO_2$/MWh
**Profit margin of Rs 1,500 per ton of production has been considered
*** The cost includes replacement of bearings in roughing mill and intermediate mill strand only. It is assumed finishing mill is already equipped with finishing stands. Also, cost of change of stand has not been considered.

**Table 33: Investment and saving for installation of roller bearing for different ranges of rolling mills**

| Rolling Mill Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -25 | 20 – 60 | 75 – 190 | < 1 year |

* based on estimated figures

## Case Study 9: Replacement of Fibre Bearing with Roller Bearing

Located in Jaipur, Rajathan, Premier Bars Limited is a leading manufacturer of TMT bars. In 2017, the plant replaced their roughing and intermediate mill stand from fibre bearing to roller bearing. The plant achieved significant savings in terms of energy cost reduction.

| Sl. No. | Parameter | Unit | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Productivity | t/h | 20 | 20 |
| 2 | Annual operational hours | h/y | 5,280 | 5,280 |
| 3 | Mill Utilization | % | 85 | 89 |
| 4 | Annual production | t/a | 89,760 | 94,248 |
| 5 | Specific power consumption (average) | kWh/t | 120 | 108 |
| 6 | Saving in specific power consumption | kWh/t | 12 | |
| 7 | Annual power savings | kWh/y | 1,130,976 | |
| 8 | Power Tariff | Rs/kWh | 7.5 | |
| 9 | Annual monetary saving due to power saving | Rs in Lakh/y | 85 | |
| 10 | Annual monetary profit due to increase in productivity** | Rs in Lakh/y | 67 | |
| 11 | Total annual saving | Rs in Lakh | 152 | |
| 12 | Investment for replacement of conventional bearing with roller bearing*** | Rs in Lakh | 50 | |
| 14 | Payback Period | Months | 4 | |
| 15 | Annual energy saving | toe/y | 97 | |
| 16 | Annual saving in $CO_2$ emission due to reduction in coal saving* | $tCO_2$/y | 1,018 | |

*Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 $tCO_2$/MWh

# Technology No. 13: Installation of Universal Couplings/ Spindles in Rolling Mill **14**

## 14.1  Baseline Scenario

Couplings are devices used to connect two pieces of rotating equipment or shafts together. Couplings are used for transmitting power. Spindles are used for transmitting rotation to the rolls from pinion stands or from electric motors. Careful selection, installation and maintenance of couplings and spindles will ensure substantial savings. The savings will be in terms of reduced power consumption, reduced maintenance costs and downtime.



**Figure 31: Wobbler Couplings**

Traditionally, wobblers are the most commonly used couplings in steel re-rolling mill units. These wobbler couplings are made of cast iron, either three fluted or four fluted, and are used in un-machined condition. These couplings are usually used with nylon or wooden packing's. The roughness or improper pairing gives rise to low metal to metal contact. Further, the wobbler connections do not allow flexibility towards inclination from the roll axis beyond 1-20C. The disadvantages of using wobbler couplings are:

● Jerking loads on drive motor due to wear out of Nylon/ Wooden pads owing to repeated biting of rolling stocks in various parts

● Higher load on drives due to limited flexibility of inclination of the Spindles owing to differential wear diameter of the rolls

Higher mill downtime and lower mill utilization

## 14.2  Energy Efficient Technology

As an alternative to the wobbler couplings and spindles, the energy efficient way is to use universal couplings and spindles.

Universal spindles allow rotation to be translated to the rolls at considerable angles, up to 8-100 between the axis of the spindle and the axes of the rolls or pinion of a pinion stand.

The horizontal projection of the spindle's length alters in accordance with the angle of inclination. For this reason, one of the hinges of a spindle is usually fixed at the end of the driving shaft and the other, at the roll end; in not fixed, i.e. it floats in an axial direction.

An improvised form for a universal coupling is the cardon shaft coupling and spindles. In case of cardon shaft, the flexibility of inclination is even more. The advantages of Universal couplings over wobbler couplings are:

● They have high torque transmission capacity.

● Their simplicity of design results in easy maintenance; this reduces the down time.

● They have negligible backlash and radial clearance.

● They have high operational life and low operational costs.

● They lead to uniform loading on drive motors.

● They lead to increased roll life due to the higher flexibility of the spindle inclination.

● Reduces power: increased mill utilization.

## 14.3  Benefits of the technology

Adoption of universal coupling and spindles has the following benefits:

● Increased margin for roll usage

● Improved transmission efficiency

● Reduced energy consumption

● Improved mill utilization

## 14.4  Limitations

The roll alignment may be checked properly before installation. Conversion from wobbler coupling to universal coupling and spindle will depend on the roll strand. For optimum performance, universal coupling and spindle should be clubbed together with roller bearing



**Figure 32: Univeral coupling and spindles in rolling mill**

## 14.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional couplings/spindles with energy efficient universal couplings / spindles in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for installation of universal spindle/couplings will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for installation of universal spindle/couplings for different ranges of rolling mills:

**Table 34: Cost benefit analysis for universal couplings and spindles**

| Sl. No. | Parameter | UoM | With Wobbler couplings / spindles | With Universal couplings / spindles |
|---------|-----------|-----|-----------------------------------|-------------------------------------|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Annual operational hours | h/y | 5,280 | 5,280 |
| 3 | Mill Utilization | % | 85 | 86.7 |
| 4 | Annual production | t/y | 67,320 | 68,666 |
| 5 | Specific power consumption (average) | kWh/t | 120 | 114 |
| 6 | Saving in specific power consumption | kWh/t | 6 | |
| 7 | Annual power savings | kWh/y | 411,998 | |
| 8 | Power Tariff | Rs/kWh | 7.5 | |
| 9 | Annual monetary saving due to power saving | Rs in Lakh/y | 31 | |
| 10 | Annual monetary profit due to increase in productivity** | Rs in Lakh/y | 20 | |
| 11 | Total annual saving | Rs in Lakh/y | 51 | |
| 12 | Investment for replacement of wobbler coupling / spindles with universal coupling/ spindle*** | Rs in Lakh | 50 | |
| 14 | Payback Period | Months | 12 | |
| 15 | Annual energy saving | toe/y | 35 | |
| 16 | Annual saving in $CO_2$ emission due to reduction in coal saving* | $tCO_2$/y | 371 | |

*Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.90 $tCO_2$/MWh
**Profit margin of Rs 1,500 per ton of production has been considered
*** The cost includes replacement of coupling in roughing mill and intermediate mill strand only. It is assumed finishing mill is already equipped with universal couplings & spindles. Also, cost of change of stand has not been considered.

**Table 35: Investment and saving for installation of universal spindles/couplings for different ranges of rolling mills**

| Rolling Mill Capacity (t/h) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|-----------------------------|--------------------------|---------------------------------|-------------------------|
| 10 -25 | 20 – 60 | 75 – 190 | < 1 year |

* based on estimated figures

# Technology No. 14: Installation of Y-table / Tilting Table / Repeaters in Rolling Mill

**15**

## 15.1 Baseline Scenario

To improve upon the efficiency of operation of a rolling mill, one has to improve upon the mill utilization factor which can be done through combating mill delays. A large portion of mill delays can be avoided by minimizing manual intervention and adoption of automatic material handling machines3 Hi Roughing Mill stand forms the major bottleneck towards increased mill speed of a rolling mill.

The roughing mill is generally used for heavy reduction of charge. The hot charge is alternatively processed between middle-bottom and top-middle rolls.

Conventionally, after a pass rolling, the charge is transferred to the next pass using a guide through manual intervention. The manual handling is done by a tongues man; who usually holds the rear end of the hot charge and enters it into the next pass. Delays in the process of charging also sometimes lead to cooling of the charge, which in turn reduces the life of the machine.

Traditionally, manual intervention can also be seen in cross-country mill, wherein unskilled workers use tongues to hold a hot charge and put it into the next pass. Manual handling of charge is a unsafe process which can lead to threats on one's life.

## 15.2 Energy Efficient Technology

Automatic material handling system is the energy efficient alternative for manual handling systems. For automatic handling of hot charge in the 3 Hi Roughing Mill stand, a Y-table or Tilting Table are used. Y-tables are usually used for material weight of less than 150 kg. A Y-table is a steel fabricated structure in the shape of a Y.

The structure is made of roller conveyors. A metal lid is used in the Y-joint, which allows only one-way travel of the charge. The charge after rolling from the bottom-middle rolls passes through the rear end of the table; the metal lid falls once the charge has completely passed through. During return, the metal charge passes through the top end; thus transfer of billet to next pass is facilitated. A Y-table is common in TMT mills, wherein in one side of the stand Y-tables are installed and on the opposite side drop tilters are present.

Tilting machine is quite similar to Y-table and used for higher cross-sections especially in structure mills. Here the steel structure, fitted with roller conveyor, is mounted to a motor. The structure is operated by an operator; and on his instruction the entire steel structure moves up and down as per requirement.

Repeaters are steel fabricated pathways connected between two consequent rolling stands. The repeaters are fitted to guides and allow free movement of hot charge between two rolling mill stands. Twisting of charge, if required, can also be facilitated by the design of a repeater.

## 15.3 Benefits of the technology

Adoption of Y-table/ tilting table/repeaters has the following benefits:

- Automatic handling of material
- Reduced temperature loss during material handling
- Reduced energy consumption
- Improved productivity
- Improved mill utilization

## 15.4 Limitations

Installation of Y-Roller Table / tilting table can be done only in 3 high mills. Installation of Y-roller table / tilting table / repeaters depends on the mill layout.
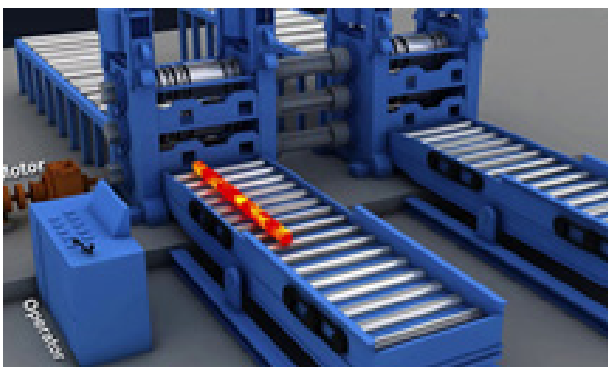


**Figure 33: Tilting Table**



**Figure 34: Repeater in steel rolling mill**

## 15.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of manual handling with automatic handling in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit:

The investment and energy savings for installation of automatic material handling system will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for installation of automatic material handling system for different ranges of rolling mills:

**Table 36: Cost benefit analysis for automatic material handling system**

| Sl. No. | Parameter | Unit | Rolling mill with manual handling | Rolling mill with automatic handling |
|---|---|---|---|---|
| 1 | Design Capacity of rolling mill | t/h | 15 | 15 |
| 2 | Mill Utilization | % | 75 | 82.5 |
| 3 | Operating hours per day | h/d | 16 | 16 |
| 4 | Operating days per year | d/y | 330 | 330 |
| 5 | Annual production | t/y | 59,400 | 65,340 |
| 6 | Additional production due to increased mill utilization | t/y | 5,940 | |
| 7 | Annual monetary benefit due to increased production | Rs in lakh/y | 89 | |
| 8 | Specific fuel consumption | kg/t | 90 | 85.5 |
| 9 | Annual saving in coal consumption | t/y | 356 | |
| 10 | Monetary saving due to fuel saving | Rs in lakh/y | 29 | |
| 11 | Specific power consumption | kWh/t | 110 | 106.7 |
| 12 | Annual saving in power consumption | MWh/y | 261 | |
| 13 | Monetary saving due to power saving | Rs in Lakhs/y | 20 | |
| 14 | Total monetary saving | Rs in Lakhs/y | 137 | |
| 15 | Investment | Rs in Lakhs | 50 | |
| 16 | Simple pay back | months | 4 | |
| 17 | Annual energy savings | toe/y | 222 | |
| 18 | Annual GHG emission savings | $tCO_2$/y | 1,025 | |

*Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 $tCO_2$/MWh; emission factor of coal as per IPCC guidelines in 94.6 $tCO_2$/TJ for sub-bituminous coal; cost of coal is Rs 8/kg, cost of electricity taken as Rs 7.5/kWh; profit margin taken as Rs 1500/t*

**Table 37: Investment and saving for installation of automatic material handling system for different ranges of rolling mills**

| Rolling Mill Capacity (t/h) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -25 | 10 – 60 | 10 – 35 | < 2 years |

* based on estimated figures

# Technology No. 15: Revamping of Rolling Mill  **16**

## 16.1  Baseline Scenario

Layout of a rolling mill is significant while determining the mill's productivity, energy consumption and efficiency. In earlier days, rolling mill was haphazardly built without proper layout design. Also, most of the units were driven by manual material handling and equipped old outdated machines. These, in turn, led to increase in mill downtime, cobble formation and high energy consumption. Also, productivity of such mills was low. As and when a rolling mill unit decided to enhance the production, required numbers of stands were added haphazardly, without giving due consideration to the overall layout. Thus, these units usually have very high energy consumption. Conventional bar mills consumes 120 – 140 units of electricity per tonne of production.

## 16.2  Energy Efficient Technology

Energy efficient design of a rolling mill consists of design of proper layout, selection of proper size of equipment and considering the correct roll pass design including temperature profile across stands. Following are some of the general considerations for revamping a rolling mill into an energy efficient one:

- Maintaining correct temperature profile in the furnace.
- Reducing the distance between furnace discharges and roughing mill stand; in case of long distance, use automatic roller conveyor.
- Uniform feeding of raw material, i.e. installation of ingot turning table.
- Proper distribution of draft across roughing, intermediate and finishing mill.
- Maintaining angle of bite to the optimum level (around 210).
- Conversion of cross-country mill configuration to continuous configuration.
- Adoption of automatic material handling.
- Increasing speed of rolling.
- Addition of roughing mill continuous side.
- Reduction of mill downtime by adoption of cantilever stands and housing less stands.

## 16.3  Benefits of the technology

Adoption of better rolling mill layout has the following benefits:

- Improved utilization
- Increased mill efficiency
- Reduced energy consumption

## 16.4  Limitations

Energy efficient design of mill should be executed properly under the supervision and guidance of technical expertise. Energy efficient mill layout depends on space availability

## 16.5  Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

Revamping of rolling mills do not have any fixed investment and the same is dependent on the layout of the existing mill, scope for improvement and space available for the same. The following section provides the details of revamping carried out worth Rs 1 crore in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for revamping of rolling mill will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for revamping of rolling mill for different ranges of rolling mills:

**Table 38: Cost benefit analysis for energy efficient rolling mill design**

| Sl. No. | Parameter | UoM | Conventional Rolling Mill Design | Energy Efficient Rolling Mill Design |
|---------|-----------|-----|----------------------------------|--------------------------------------|
| 1 | Design capacity of rolling mill | t/h | 15 | 15 |
| 2 | Mill Utilization | % | 75 | 86.25 |
| 3 | Operating hours per day | h/d | 16 | 16 |
| 4 | Operating days per year | d/y | 330 | 330 |
| 5 | Annual production | t/y | 59,400 | 68,310 |
| 6 | Additional production due to increased mill utilization | t/y | 8,910 | |
| 7 | Annual monetary benefit due to increased production | Rs in lakh/y | 134 | |
| 8 | Specific fuel consumption | kg/t | 90 | 81 |
| 9 | Annual saving in coal consumption | t/y | 713 | |
| 10 | Monetary saving due to fuel saving | Rs in lakh/y | 57 | |
| 11 | Specific power consumption | kWh/t | 110 | 104.5 |
| 12 | Annual saving in power consumption | MWh/y | 436 | |
| 13 | Monetary saving due to power saving | Rs in Lakhs/y | 33 | |
| 14 | Total monetary saving | Rs in Lakhs/y | 223 | |
| 15 | Investment | Rs in Lakhs | 100 | |
| 16 | Simple pay back | months | 5 | |
| 17 | Annual energy savings | toe/y | 437 | |
| 18 | Annual GHG emission savings | $tCO_2$/y | 1,972 | |

*Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 $tCO_2$/MWh; emission factor of coal is 94.6 $tCO_2$/TJ for sub-bituminous coal; cost of coal is Rs 8/kg, cost of electricity taken as Rs 7.5/kWh; profit margin taken as Rs 1500/t*

**Table 39: Investment and saving for revamping of rolling mill for different ranges of rolling mills**

| Rolling Mill Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|-----------------------------|--------------------------|---------------------------------|-------------------------|
| 10 -25 | 60– 150 | 100 – 250 | < 1 years |

* based on estimated figures

# Technology No. 16: Replacement of Existing Motors with IE3 Class Efficiency Energy Efficient Motors

**17**

## 17.1 Baseline Scenario

Three-phase induction motors are most commonly used to run various applications in a steel re-rolling mill unit. Apart from the heavy capacity motors driving the rolling mill strands, numerous smaller capacity motors ranging from 1 hp to 30 hp are used in numerous applications like blower, pump, roller tables, overhead cranes etc.

The 3-phase induction motors have 2 main parts: the stator or the stationary part and the rotor or the rotating part. Stator is made by staking thin slotted highly permeable steel lamination inside a steel cast or cast iron frame. Windings pass through slots of stator. When a 3-phase AC current is passed through it, it produces a rotating magnetic field. The speed of rotation of the magnetic field is called as the synchronous speed.

The rotor similar to a squirrel cage is placed inside the magnetic field; current is induced in bars of squirrel cage which is shortened by end ring. In effect, the rotor starts rotating. To aid such electromagnetic induction, insulated iron core laminas are packed inside the rotor; such small slices of iron ensure that the eddy current losses are minimal. The rotor always rotates at a speed slightly less than the synchronous speed; the difference is referred to as slip. Rotational mechanical power is transferred through a power shaft. Energy loss during motor operation is dissipated as heat; so a fan at the other end helps to cool down the motor.

Motor efficiency is defined as the ratio of mechanical power output to electrical power input. In most of the applications in a hand-tool unit, conventional motors (of IE 1 rating) are used with an efficiency range from 75 to 88% depending on the size. At times, motor fail and work of a unit may come to complete stand still. Motor failures can attribute to mechanical and electrical failures. Causes such as improper voltage, voltage fluctuations, improper lubrication and damaged bearings lead to rise in motor winding temperature ultimately leading to failure. These electrical failures lead to the next obvious step, i.e. motor re-winding.

The motor efficiency further decreases with each re-winding campaign; as it is mostly carried out by unskilled workers. Normally, a unit carries out 7-8 times motor rewinding within its life span of 10 years. Considering 1% efficiency drop in each rewinding campaign; it may lead to a loss of approximately Rs 40,000 per kWh.

## 17.2 Energy Efficient Technology

Compared to conventional motors, the efficiency of energy efficient motors (Premium Efficiency class-IE3), available in the market ranges from 80-95% depending on the size. Energy efficient motors operate at higher efficiencies compared to conventional motors, due to the following design improvements:

- Stator and rotor copper losses constitute for 55-60% of the total losses. Copper losses are reduced by using more copper conductors in stator and by using large rotor conductor bars

- Iron loss accounts for 20-25% of the total losses. Using a thinner gauge, low loss core steel and materials with minimum flux density reduces iron losses. Longer rotor and stator core length, precise air gap between stator and rotor also reduce iron losses

- Friction and Windage losses constitute about 8-10% of the total losses. Friction loss is reduced by using improved lubricating system and high quality bearings. Windage loss is reduced by using energy efficient fans

- Stray load loss accounts for 4-5% of the total losses. Use of optimum slot geometry and minimum overhang of stator conductors reduces stray load loss

- Conventional motors operate in a lower efficiency zone when they are loaded less than 60%. The efficiency of energy efficient motors drop when they are loaded less than 50%. However, efficiency of energy efficient motors is always higher than conventional motors, irrespective of the loading

When old motors are rewound more than 5 times, energy efficient motors can be considered as an ideal replacement. The Technical Specification of 7.5 hp energy efficient motor presented in Table 41:
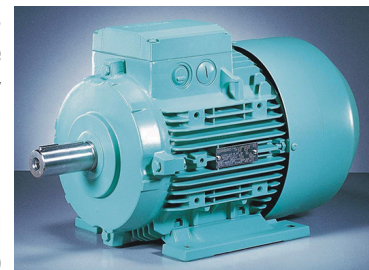
**Figure 35: Energy efficient motor**

Motor efficiency as per IEC 60034-30 for 2-pole, 4-pole and 6-pole at 50 Hz frequency is tabulated in Table 42.

The efficiency graph for 4-pole IE 1 to IE 4 class efficiency motors at 50 Hz frequency is shown in Figure 36.

## 17.3 Benefits of technology

The implementation of IE 3 class efficiency motors in place of conventional motors leads to following benefits:

Reduced specific energy consumption

- Lower breakdown
- Improved process efficiency
- Improved productivity
- Less operation and maintenance cost

**Table 40: Specification of 7.5 hp energy efficient motor**

| Sl. No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Capacity of Motor | hp | 7.5 |
| 2 | Duty type | | Continuous duty |
| 3 | Performance | | Premium IE 3 class efficiency conforming to IEC: 60034-30. |
| 4 | Type of Motor | | AC Induction |
| 5 | Motor Power | kW | 5.5 |
| 6 | Rated Current | A | 10 |
| 7 | Rated Voltage | V | 415 |
| 8 | PF | | 0.8 |
| 9 | Frequency | Hz | 50 |
| 10 | Efficiency at full load | % | 89.63 |

**Table 41: Motor efficiency values as per IEC 60034-30**

| kW | 2-Pole Frame Size | 2-Pole Efficiency % IE2 | 2-Pole Efficiency % IE3 | 4 Pole Frame Size | 4 Pole Efficiency % IE2 | 4 Pole Efficiency % IE3 | 6 Pole Frame Size | 6 Pole Efficiency % IE2 | 6 Pole Efficiency % IE3 |
|---|---|---|---|---|---|---|---|---|---|
| 0.37 | 71 | 72.2 | 75.5 | 71 | 70.1 | 73 | 80 | 69 | 71.9 |
| 0.55 | 71 | 74.8 | 78.1 | 80 | 75.1 | 78 | 80 | 72.9 | 75.9 |
| 0.75 | 80 | 77.4 | 80.7 | 80 | 79.6 | 82.5 | 90S | 75.9 | 78.9 |
| 1.1 | 80 | 79.6 | 82.7 | 90S | 81.4 | 84.1 | 90L | 78.1 | 81 |
| 1.5 | 90S | 81.3 | 84.2 | 90L | 82.8 | 85.3 | 100L | 79.8 | 82.5 |
| 2.2 | 90L | 83.2 | 85.9 | 100L | 84.3 | 86.7 | 112M | 81.8 | 84.3 |
| 3.7 | 100L | 85.5 | 87.8 | 112M | 86.3 | 88.4 | 132S | 84.3 | 86.5 |
| 5.5 | 132S | 87 | 89.2 | 132S | 87.7 | 89.6 | 132M | 86 | 88 |
| 7.5 | 132S | 88.1 | 90.1 | 132M | 88.7 | 90.4 | 160M | 87.2 | 89.1 |
| 11 | 160M | 89.4 | 91.2 | 160M | 89.8 | 91.4 | 160L | 88.7 | 90.3 |
| 15 | 160M | 90.3 | 91.9 | 160L | 90.6 | 92.1 | 180L | 89.7 | 91.2 |
| 18.5 | 160L | 90.9 | 92.4 | 180M | 91.2 | 92.6 | 200L | 90.4 | 91.7 |
| 22 | 180M | 91.3 | 92.7 | 180L | 91.6 | 93 | 200L | 90.9 | 92.2 |
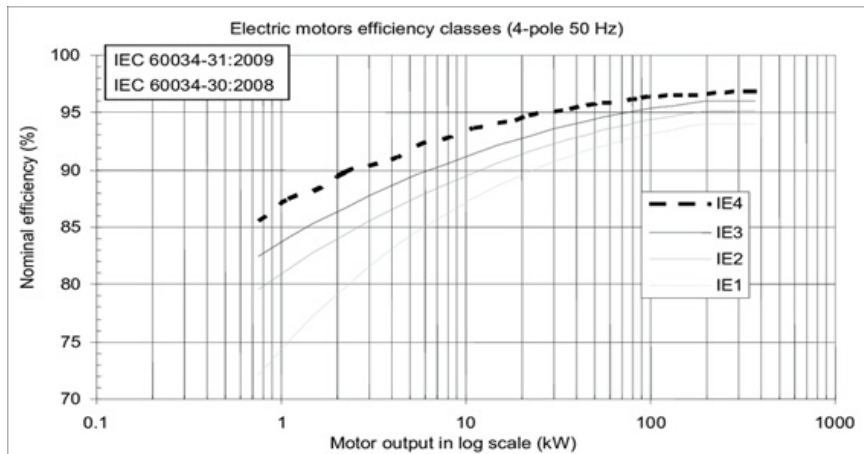


**Figure 36: IE efficiency classes for 4 pole motors at 50 Hz**

## 17.4   Limitation of technology

An energy efficient motor requires a higher initial capital investment compared to conventional motors.

## 17.5  Energy & GHG emission saving potential, Investment Required & Cost Benefit Analysis

To understand the cost-benefit analysis, let us consider a 20 hp motor. The cost-benefit analysis for adoption of the technology is tabulated below:

The investment required, energy savings and simple payback for different ratings of IE class efficiency energy efficient motor (4 pole motors) are tabulated below:

**Table 42: Cost benefit analysis for 20 hp IE 3 class efficiency motor**

| Sl. No. | Parameter | Unit | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Rated Power of motor | hp | 20 | 20 |
| 2 | Rated Power of motor | kW | 14.9 | 14.9 |
| 3 | Motor Efficiency | % | 83 | 92.1 |
| 4 | Motor Loading | % | 90 | 90 |
| 7 | Annual operating hours | h/y | 5,280 | 5,280 |
| 9 | Annual energy consumption | kWh/y | 85,421 | 76,981 |
| 10 | Annual energy saving | KWh/y | | 8,440 |
| 11 | Average power tariff | Rs/KWh | | 7.5 |
| 12 | Annual monetary saving | Rs in lakhs /y | | 0.63 |
| 13 | Investment | Rs in lakhs | | 0.44 |
| 14 | Simple Payback | months | | 8 |
| 15 | Annual energy saving | toe/y | | 0.73 |
| 16 | Annual GHG emission reduction | tCO$_2$/y | | 7.60 |

*Motor efficiency as per IEA
***Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO2/MWh

**Table 43: Investment, savings and simple pay back for IE 3 motors**

| Parameters | Motor Rating | Investment | Annual monetary savings | Simple payback |
|---|---|---|---|---|
| Units | hp | Rs in Lakhs | Rs in Lakhs | Years |
| | 1-30 | 0.03-0.55 | 0.06-0.34 | < 2 years |

## Case Study 10: Installation of EE Motors

Established in 1973, Sterling Cast & Forge is one of the leading manufacturer, supplier & exporter of hand tools & garden tools, tower pincers, water pump pliers, lock grip pliers, end cutting, nippers, long- nose, side cutter & carpenter pincer. Machining is one of the most energy intensive processes in the industry, which has a large numbers of motors of varied rated capacity. The company took a significant step towards conserving energy by replacing their old motors in energy efficient IE-3 class motors. The unit installed one number of 4 kW, two 2 kW and three numbers of 1.5 kW IE-3 class efficiency motors in place of the existing 7.5 kW, 4 kW and 2 kW motors in the shank grinder, stone grinder and furnace blower respectively. The plant was able to make a reduction of 9 kW in the rated capacity, thus saving significantly in the production cost.

| Parameters | UoM | Baseline | Post Implementation |
|---|---|---|---|
| Rated Capacity of Motors | kW | 21.5 | 12.5 |
| Annual operating hours | h/y | 3,600 | 3,600 |
| Reduction in rated capacity | kW | 9 | |
| Annual energy consumption | kWh/y | 61,920 | 36,000 |
| Annual energy saving | kWh/y | 25,290 | |
| Power Tariff | Rs/kWh | 7.5 | |
| Annual Monetary Saving | Rs in Lakh/y | 1.94 | |
| Investment | Rs in Lakh | 2.00 | |
| Simple Pay-back | Months | 12 | |
| Annual Energy Savings | toe/y | 2.22 | |
| Annual GHG Emission Reduction | tCO$_2$/y | 23.33 | |

*Emission factor of Electricity as per IPCC Guideline 2006 (V2) is 0.9 tCO$_2$/MWh
**Source: Implemented under GEF-UNIDO-BEE project

# 18 Technology No. 17: Energy Efficient Lightings

## 18.1 Baseline scenario

Lighting accounts on average for about 15% of total electricity used in industry. Most of the conventional units use a variety of lighting fixtures like fluorescent tubes, incandescent & mercury vapour lamps, metal halide (MH), etc. in their offices and factory sheds. These conventional lighting fixtures consume lot of energy. Also, lives of such fixtures are limited. Most of the rolling mills operate for whole day long and consume a significant portion of energy on account of lightings and fixtures. Also, due care is not given towards the lux level of different areas. Most of the units have sheds covered with asbestos sheet with negligible or no provisions for natural lightings.

## 18.2 Energy Efficient Technology

Recent developments in lighting technology combined with planned lighting control strategies can result in very significant cost savings, typically in the range of a third to a half of the electricity traditionally used for lighting. In new installations, energy efficient lighting costs little more to provide than the older less efficient kind. In retrofit situations, pay-back periods generally of between 1 and 5 years can be anticipated. Some of the important areas of energy conservation in a typical rolling mill are:

- Replacement of conventional lighting with energy efficient LED lighting

- Maximize the use of daylight to reduce the need for electric lighting. Roof lights are particularly efficient as they disperse light evenly over the whole floor area. Provision of natural lighting in the rolling mill bay using translucent sheets in the shed is suggested.

- Painting of surfaces (including the ceiling) with matt colours of high reflectance to maximize the effectiveness

of the light output. Light/bright colours can reflect up to 80% of incident light; dark/deep colours can reflect less than 10% of incident light.

For the purpose of establishing benefits from energy efficient lighting, let us consider a case study of a rolling mill unit of 25 t/h capacity.

## 18.3 Benefits of technology

The implementation of energy efficient lighting in place of incandescent lighting leads to following benefits:

- Reduced energy consumption
- Longer life of lighting
- Less operation and maintenance cost

## 18.4 Limitation of technology

The lux level needs to be properly checked before deciding of lighting loads.

## 18.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional lighting with energy efficient lightings in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for energy efficient lighting will vary based on the rolling mill layout and total lighting load. The table below provides an estimate for energy efficient lighting for different ranges of rolling mills:

**Table 44: Cost benefit analysis for energy efficient lighting**

| Sl. No. | Parameter | Unit | With conventional lighting | With energy efficient lighting |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Total Connected Load | kW | 1,800 | 1,760 |
| 5 | Total lighting load (considering 15% of total connected load as lighting load) | kW | 270 | 230 |
| 7 | Annual energy consumption due to lighting (Considering 5% energy savings on the lighting load by switching over to energy efficient lighting, total power saved) | kWh/y | 1,425,600 | 1,354,320 |
|  | Annual energy saving | kWh/y | 71,280 | |
| 8 | Power Tariff | Rs/kWh | 7.5 | |
|  | Annual monetary savings | Rs in Lakhs/y | 5 | |
| 9 | Investment | Rs in Lakhs | 26 | |
| 10 | Simple Pay-back | Month | 58 | |
| 11 | Annual energy saving | toe/y | 6 | |
| 12 | Annual saving in $CO_2$ emission due to saving in power | $tCO_2$/y | 64 | |

*Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO2/MWh*

**Table 45: Investment and saving for revamping of rolling mill for different ranges of rolling mills**

| Rolling Mill Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10 -25 | 10 – 50 | 3 – 15 | < 3 years |

* based on estimated figures

# 19 Technology No. 18: Combustion air flow regulation using variable voltage variable frequency drives

## 19.1 Baseline scenario

In the SRRM sector, centrifugal fans are used as forced draft (FD) fans in re-heating furnaces with the main aim of supplying ambient air for the combustion of fuel. Performance of centrifugal fans depends on various factors like type of fan, proper sizing of the fan, and the specification and design of ducting for the fan.

Generally, air flow to a re-heating furnace is kept constant irrespective of temperature, draft and excess air in the re-heating furnace. It has been observed that due to inadequate draft and supply of excess air, the flame continuously gushes out of various openings of the re- heating furnace, which poses a threat to the safety of the men and machines working near the re-heating furnace.

The most general practices of the flow regulation mechanisms in FD fans currently employed in the SRRM sector include damper control, suction control or change of pulley. All of the above methods for controlling the air flow require manual interventions. Thus, most of the time combustion air flow is not monitored and controlled under the conventional system leading to higher energy consumption and high burning loss.

## 19.2 Energy Efficient Technology

As an energy efficient alternative, it is recommended to regulate the air flow of the combustion air blower by variable frequency drives (VFDs). VFDs reduce the speed of the fan for reduced air flow demand, and this speed reduction is achieved by altering the frequency of input power. Hence, power consumption of FD fans will be proportional to the air flow being delivered to the re-heating furnace. The feedback for VFDs can be taken from an oxygen analyzer installed in the flue gas line. This analyzer will measure the excess air content in the flue gas. Along with stoichiometric air required for combustion, a certain amount of excess air needs to be supplied and this excess air varies based on the type of fuel used in the re-heating furnace.



**Figure 37: Circuit of a typical VFD unit**

VFD is a device introduced in 1980's to effectively run a 3 phase AC motor at variable speed. AVFD consists of 3 diodes which allow flow of current only in the direction of the arrows. So, we have a convertor which converts the 3 phase AC power into DC. The DC which comes out of this is not very smooth; so a capacitor is used in order to clean that DC up. The capacitor works as a reservoir in the plumping circuit which smoothens everything out and gives a nice clean DC. Then going to the right, there are six switches. These switches compose of the DC to AC invertor, By switching these switches on and off, we can create any frequency that we like and that frequency would regulate the speed of the motor.

The Technical Specification of VVVF drive for a 40 hp blower is presented below:

## 19.3 Benefits of technology

The implementation of VFD in blower leads to following benefits:

- Helps in controlling flow in blower as per air requirement
- Helps in maintaining correct air fuel ratio
- Helps in improving combustion efficiency
- Reduced fuel consumption in furnace

**Table 46: Specification of VFD**

| Sl. No. | Parameter | Unit | Value |
|---------|-----------|------|-------|
| 1 | Power rating | kW | 0.18 to 4 |
| 2 | Voltage supply | V | 120 (single phase) 240 (single phase or three phase) |
| 3 | Fan management | - | Required above 0.75 kW |
| 4 | Noise level | dba | < 50 |
| 5 | Commissioning | Type | Plug & Play |
| 6 | PF | | 0.8 |
| 7 | Frequency | Hz | 50 |
| 8 | Operating ambient temperature | ⁰C | -10 to +40 (without derating) Upto 60 with a derating |

- Reduced power consumption
- Can be integrated with furnace automation

## 19.4   Limitation of technology

The VFD in blower needs to be integrated with a close loop monitoring and control system of furnace for optimum performance.

## 19.5   Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of optimum air flow regulation using VFD and online oxygen analyzer with in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h rolling mill.

The investment and energy savings for installation of VFD in blower will vary based on the capacity of the furnace. The table below provides an estimate for VFD in blower for different ranges of reheating furnace:

**Table 47: Cost benefit analysis for VFD in blower**

| Sl. No. | Parameter | UoM | Blower with damper control | Blower with VFD |
|---|---|---|---|---|
| 1 | Productivity | t/h | 10 | 10 |
| 2 | No. of operating hours | h/d | 12 | 12 |
| 3 | No. of working days | d/y | 300 | 300 |
| 4 | Specific fuel consumption | kg/t | 90 | 88.2 |
| 5 | Annual production | t/y | 36,000 | 36,000 |
| 6 | Annual fuel consumption (considering 2% energy saving due to better air fuel ratio) | t/y | 3,240 | 3,175.2 |
| 7 | Annual fuel savings due to air-fuel ratio control using VFD | t/y | 64.8 | |
| 8 | Cost of fuel | Rs/t | 8000 | |
| 9 | Annual monetary saving due to fuel saving | Rs in Lakh/y | 5 | |
| 10 | Electrical energy consumption in blower (considering 20% reduction in energy due switch over from damper control to VFD) | kWh/h | 149.2 | 119.36 |
| 11 | Annual energy saving due to VFD | kWh/y | 107,424 | |
| 12 | Power Tariff (average) | Rs/kWh | 7.5 | |
| 13 | Total monetary saving due to energy saving | Rs in Lakh/y | 8 | |
| 14 | Total monetary saving | Rs in Lakh/y | 13 | |
| 15 | Estimated investment | Rs in Lakh | 2.5 | |
| 16 | Simple payback | months | 2 | |
| 17 | Annual energy saving | toe/y | 46 | |
| 18 | Annual saving in $CO_2$ emission due to reduction in coal saving | $tCO_2$/y | 240 | |

*Emission factor of coal as per IPCC guidelines 2006 (V2; C1 & C2) is 94.6 tCO2/TJ for sub-bituminous coal and for electricity is 0.9 $tCO_2$/MWh.*
 **Calorific value of coal taken as 5,600 kCal/kg*

**Table 48: Investment and saving for installation of VFD for different ranges of reheating furnace**

| Furnace Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 5 -25 | 1.5 – 5 | 4 – 20 | < 1 year |

*\* based on estimated figures*

# 20 Technology No. 19: Adoption of Direct Rolling in TMT Mills

## 20.1 Baseline scenario

A composite unit consists of a rolling mill and an induction furnace in the same premises. Sponge iron or scrap sourced from the market is fed into an induction furnace; wherein electricity is used for melting of steel at 1,600$^0$C. The molten steel is casted into moulds to form ingots or through a continuous casting machine to form billets or blooms. The casted ingot / billet or bloom is cooled to ambient temperature and stored in the billet yard. For the rolling process, the ingot, billets or blooms are used as raw material. They are charged into the pusher type re-heating furnace. The raw materials are re-heated to the re-crystallization temperature of steel which is around 1,200$^0$C. The red hot charge is then processed in a rolling mill to the desired shape and cross-section. A large number of composite units in the country followed the above process till the introduction of direct rolling. In this conventional process; a significant portion of energy was lost in the process of cooling the billets in the CCM cooling bed and then again re-heating the same in the re-heating furnace.

## 20.2 Energy Efficient Technology

The energy efficient way of rolling in case on composite units has been dictated by a revolutionary technology in the last few years. Hot charging or direct rolling of hot billets from continuous casting machine (CCM) to rolling mill; eliminating the re-heating furnace in the process, has transformed the entire sector to a new dimension of energy saving. The process of direct rolling / hot charging of billets is shown in the process flow below:

The process flow for direct rolling starts with tapping of molten metal from induction furnace at a slightly higher temperature (around 1,650$^0$C) compared to conventional system. Due care is taken for minimum heat loss during ladle transfer. Hot metal at 1,600$^0$C is poured into the tundish of the continuous casting machine. Secondary cooling at CCM is controlled with a PLC system to maintain billet temperature at CCM outlet at 1,100$^0$C. Subsequently, there is a slight temperature loss during the shearing process.
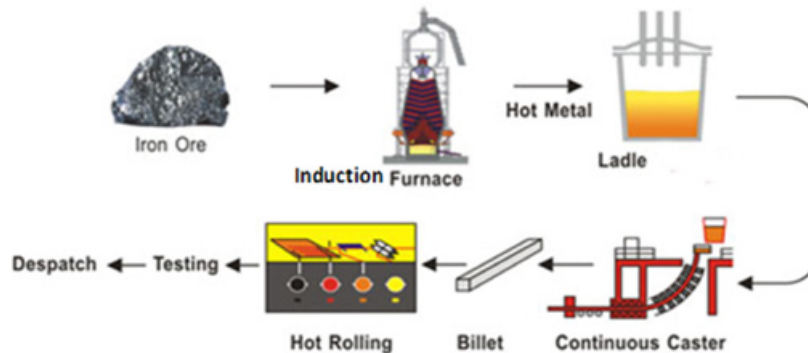
Preferably, hot billet shearing should be used in place of gas cutting for minimum temperature loss. Once, the hot billet is cut to piece, the next step involves transferring of billet in a high speed conveyor to the rolling mill first stand. It should be ensured that minimum heat loss occurs during the process. For this, refractory made canopy covers should be used in the conveyors. Also, high rpm motors to be used for the conveyors for minimum time travel of the billets. Bends should be avoided in the conveyor to the extent possible. Billet reaching the first pass will be processed at a temperature of 1,045$^0$C. In the direct rolling process, the core of the billet is at higher temperature than the surface. During 2 to 3 passes of the rolling, the charge attains a uniform temperature at the core is exposed in such case. The roll pass design needs to be revamped in case of switch over to direct rolling. Also, if the temperature drop is high, it should be ensured that the gear box for the first stand should be of heavier capacity. The temperature maintained at different processes of a direct rolling unit is shown in the figure below:



| | Tapping in Induction Furnace | Ladle Pouring | Ladle Transfer | Nitrogen Purging | Pouring Starts at CCM | Pouring Ends at CCM | CCM Outlet | Hot shearing | Rolling mill first pass |
|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1683 | 1620 | 1610 | 1605 | 1600 | 1546 | 1100 | 1050 | 1045 |
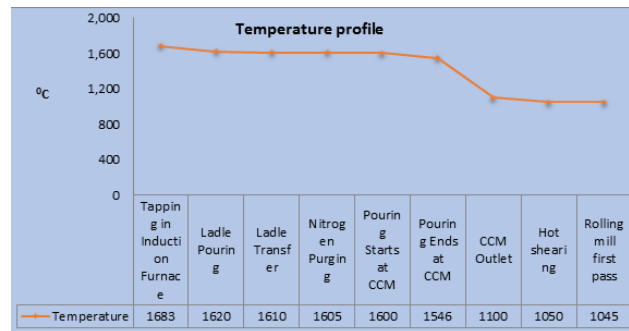
**Figure 39: Temperature profile for different processes of direct rolling**

Conventional process of melting and casting differs with the direct rolling process mainly on the temperature profile. Since the metal coming out of the cooling bed should be solidified, the temperature profile needs to be very precisely maintained. A PLC based control system is suggested for the purpose. The temperature difference in the various processes for conventional melting and casting with direct rolling is shown in the figure below:



**Figure 38: Process flow diagram of direct rolling mill**
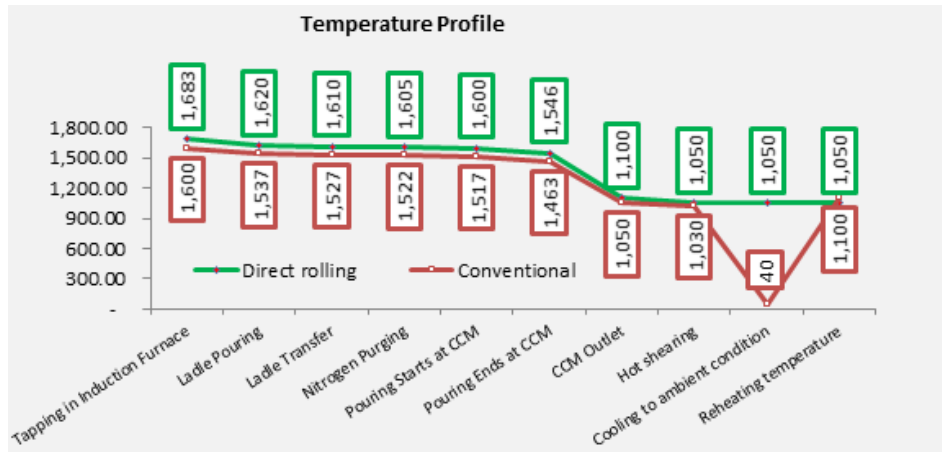
**Figure 40: Conventional Vs Direct Rolling**

## 20.3   Benefits of technology

The adoption of direct rolling leads to following benefits:

- Complete elimination of re-heating furnace
- Avoids burning loss due to re-heating
- Avoids operation and maintenance cost related to re-heating furnace
- Significant reduction in energy cost
- Significant reduction in cost of production

## 20.4   Limitation of technology

Direct rolling technology is applicable only for composite units. The feasibility of the technology is hugely dependent on the layout. Also, it is important to ensure correct temperature

required for rolling. The rate of melting and casting should match the rolling mill rate to avoid lower utilization of the plant.

## 20.5   Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional rolling with direct rolling in terms of energy & GHG saving potential, investment required and cost-benefit analysis. The calculations have been provided considering a 15 t/h rolling mill.

The investment and energy savings for adoption of direct rolling will vary based on the capacity of the melting furnace, layout and rolling mill capacity. The table below provides an estimate for adoption of direct rolling for different ranges of rolling mills:

**Table 49: Cost benefit analysis for direct rolling for TMT units**

| Sl. No. | Parameter | Unit | Conventional mill | Direct Rolling |
|---------|-----------|------|-------------------|----------------|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace) | kg/t | 90 | - |
| 5 | Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables) | kWh/t | 110 | 121 |
| 6 | Annual savings in terms of coal | t/y | 7,128 | |
| 7 | Annual increase in power consumption | kWh/t | 871,200 | |
| 8 | Net monetary savings | Rs in Lakhs | 504.9 | |
| 9 | Investment required | Rs in Lakhs | 100 | |
| 10 | Simple pay back | months | 2.38 | |
| 11 | Annual net energy saving (Thermal – Electrical) | toe/y | 3,917 | |
| 12 | Annual net saving in $CO_2$ emission due to reduction in coal saving and increase in power consumption | $tCO_2$/y | 15,015 | |

*Emission factor of electricity as per IPCC guidelines is 0.9 $tCO_2$/MWh; emission factor of coal as per IPCC guidelines is 94.6 $tCO_2$/TJ; cost of coal has been taken as Rs 8/kg; cost of coal has been taken as Rs 7.5/kWh.*

**Only rolling mill has been taken as boundry for calculations. Increase in energy consumption due to increase in melting temperature has not been considered for calculations.*

***It has been assumed that the plant already has requisite melting facility. Investment cost includes cost towards facilities for transferring of hot billets and required modification in rolling mills.*

**Table 50: Investment and saving for adoption of direct rolling for different ranges of rolling mills**

| Rolling Mill Capacity (tph) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 10-25 | 40-150 | 150 – 700 | < 1 year |

* based on estimated figures

## Case Study 11: Adoption of Direct Rolling

Located in Chennai, Tamil Nadu ARS Metals Limited is a leading manufacturer of TMT bars. In 2017, the plant implemented direct rolling thereby completely eliminating the re-heating furnace. The plant achieved significant cost saving. The investment made was recouped in less than 6 months' time.

| Sl. No. | Parameter | Unit | Baseline | Post Implementation |
|---|---|---|---|---|
| 1 | Productivity | t/h | 20 | 20 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace) | kg/t | 80 | - |
| 5 | Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables) | kWh/t | 115 | 126.5 |
| 6 | Annual savings in terms of coal | t/y | 8,448 | |
| 7 | Annual increase in power consumption | kWh/t | 1,214,400 | |
| 8 | Net monetary savings | Rs in Lakhs | 584.76 | |
| 9 | Investment required | Rs in Lakhs | 100 | |
| 10 | Simple pay back | months | 2.05 | |
| 11 | Annual net energy saving (Thermal – Electrical) | toe/y | 4626 | |
| 12 | Annual net saving in $CO_2$ emission due to reduction in coal saving and increase in power consumption | $tCO_2$/y | 17,632 | |

*Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 $tCO_2$/MWh

# Technology No. 20: Adoption of Direct Rolling in Structural Mills

## 21.1 Baseline scenario

In composite units, billets / blooms, suitable for rolling of structures are casted in a continuous casting machine. The billets/blooms are cut into required sizes using gas cutting and cooled to ambient temperature. The cold billet/bloom is transferred to the rolling mill bay, wherein the same is re-heated using a fuel fired re-heating furnace. Rolling of structures requires heating to 1,200°C or more.

The heated billets are then rolled to desired shape and size. Due to the requirement of higher rolling temperature, direct rolling or hot charging of billets / blooms directly from the continuous casting machine to the rolling mill has not been preferred.

While the concept of direct rolling was touching new heights in TMT rolling during the last few years; the same remained unattended in structural rolling especially in case of medium and heavy structures.

## 21.2 Energy Efficient Technology

The technological innovation of direct rolling can be made successful even in the case of structural rolling by introducing induction heating in between. This means, billets or blooms at around 1,050-1,100°C are received from the continuous casting machine.

The temperature of the hot billets or blooms at this stage is not sufficient for rolling. So, to heat the material to the desired temperature, intermittent heating is done through induction heating.

A series of induction heaters are installed and the hot billets or blooms are passed through it at a relatively slow speed. This raises the temperature of the billet by 100°C, thus making it suitable for structure rolling.

The process flow diagram of direct rolling in case of rolling of structures is shown in the figure below:

The technical specification of induction heater required for intermittent heating is tabulated below:
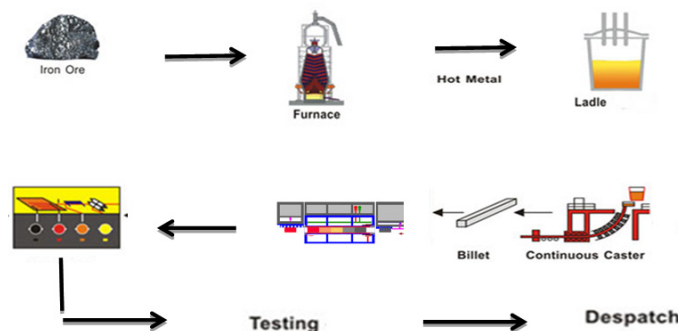


**Figure 41: Process flow of direct rolling in structural mill**

**Table 51: Specification of in-line induction heater**

| Sl. No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Equipment Type | | In-line induction heating for hot rolling |
| 2 | Frequency | Hz | 50 Hz to 6000 Hz |
| 3 | Power | kW | 500 kW to 10000 KW |
| 4 | Heating time | | Instantaneous |
| 5 | Rated Voltage | V | 415 |
| 6 | PF | | 0.8 |
| 7 | Efficiency | % | 60-65% |

## 21.3 Benefits of technology

The adoption of direct rolling leads to following benefits:

- Complete elimination of re-heating furnace
- Avoids burning loss due to re-heating
- Avoids operation and maintenance cost related to re-heating furnace
- Significant reduction in energy cost
- Significant reduction in cost of production

## 21.4 Limitation of Technology

Direct rolling technology is applicable only for composite units. The feasibility of the technology is hugely dependent on the layout. Also, it is important ensure correct temperature required for rolling. The rate of melting and casting should match the rolling mill rate to avoid lower utilization of the plant. Rolling temperature is key for structural steel production.

## 21.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of adoption of direct rolling in structural units in terms of energy & GHG saving potential, investment required and cost-benefit analysis. The calculations have been provided considering a 15 t/h unit.

The investment and energy savings for adoption of direct rolling will vary based on the capacity of the melting furnace, layout and rolling mill capacity. The table below provides an estimate for adoption of direct rolling for different ranges of rolling mills:

**Table 52: Cost benefit analysis for direct rolling for structural units**

| Sl. No. | Parameter | Unit | Conventional mill | Direct Rolling |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace) | kg/t | 90 | - |
| 5 | Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables & induction heater) | kWh/t | 110 | 137.5 |
| 6 | Annual savings in terms of coal | t/y | 7128 | |
| 7 | Annual increase in power consumption | kWh/t | 2,178,000 | |
| 8 | Net monetary savings | Rs in Lakhs | 406.89 | |
| 9 | Investment required | Rs in Lakhs | 100 | |
| 10 | Simple pay back | months | 3 | |
| 11 | Annual net energy saving (Thermal – Electrical) | toe/y | 3,804 | |
| 12 | Annual net saving in $CO_2$ emission due to reduction in coal saving and increase in power consumption | $tCO_2$/y | 13,839 | |

*Emission factor of electricity as per IPCC guidelines is 0.9 $tCO_2$/MWh; emission factor of coal as per IPCC guidelines is 94.6 $tCO_2$/TJ; cost of coal has been taken as Rs 8/kg; cost of coal has been taken as Rs 7.5/kWh.

**Only rolling mill has been taken as boundry for calculations. Increase in energy consumption due to increase in melting temperature has not been considered for calculations.

***It has been assumed that the plant already has requisite melting facility. Investment cost includes cost towards facilities for transferring of hot billets and required modification in rolling mills including installation of billet induction heater.

**Table 53: Investment and saving for adoption of direct rolling for different ranges of rolling mills**

| Rolling Mill Capacity (t/h) | Investment (Rs in Lakhs) | Savings Potential (Rs in Lakhs) | Simple pay back (years) |
|---|---|---|---|
| 15-25 | 100 -200 | 150 – 600 | < 1 year |

* based on estimated figures

## Case Study 12: Adoption of Direct Rolling in structural mill

Located Located in Raipur, Chhattisgarh, Nandan Steel & Power Limited is a leading manufacturer of medium sectional products. In 2017, the plant implemented direct rolling thereby completely eliminating the re-heating furnace. The plant achieved significant cost saving. The investment made was recouped in less than 6 months' time.

| Sl. No. | Parameter | Unit | Conventional mill | Direct Rolling |
|---|---|---|---|---|
| 1 | Productivity | t/h | 15 | 15 |
| 2 | Operating hours per day | h/d | 16 | 16 |
| 3 | Operating days per year | d/y | 330 | 330 |
| 4 | Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace) | kg/t | 90 | - |
| 5 | Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables & induction heater) | kWh/t | 80 | 100 |
| 6 | Annual savings in terms of coal | t/y | 7128 | |
| 7 | Annual increase in power consumption | kWh/t | 1,584,000 | |
| 8 | Net monetary savings | Rs in Lakhs | 451 | |
| 9 | Investment required | Rs in Lakhs | 100 | |
| 10 | Simple pay back | months | 3 | |
| 11 | Annual net energy saving (Thermal – Electrical) | toe/y | 3,855 | |
| 12 | Annual net saving in $CO_2$ emission due to reduction in coal saving and increase in power consumption | $tCO_2$/y | 14,374 | |

*Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 $tCO_2$/MWh

# Conclusion

The compendium consists of a list of energy efficient and renewable energy technologies applicable for the micro, small and medium enterprises (MSME) units in the targeted sectors. The listed technologies have been grouped into three broad categories of 'low investment', 'medium investment' and 'high investment' technologies. In most cases, MSME units use old and obsolete technologies leading to higher energy consumption. There is a significant potential for cost savings through the adoption of these energy efficient and renewable energy technologies. The compendium consists of a list of commonly applicable energy efficient and renewable energy technologies in the cluster. These technologies need to be customized based on individual unit's requirements. The techno-commercial feasibility depends on the process, operational conditions and other variable parameters in a particular unit. Also, all technologies may not be applicable in every unit.

In order to achieve maximum benefits of a particular technology, the same should be supported by good operating practices. Continuous capacity enhancement of the operators is important to achieve maximum benefits from technology up-gradation.

Micro, small and medium enterprises (MSMEs) are the growth accelerators of the Indian economy, contributing about 30% of the country's gross domestic product (GDP). Under such scenario, it becomes important for these industries to adapt to efficient technologies and practices. Accelerated adoption of energy efficient and renewable energy technologies can ensure a cost effective and energy efficient production process. With an overarching objective of bringing in a transformational change in the sector, the technology compendium provides information on options available to do so.

The eastern zone of the country comprising the states of West Bengal, Jharkhand, Odisha and Bihar houses close to 20% of the total steel re-rolling mills in the country. Some of the key clusters located in the eastern zone of the country that house steel re-rolling mill standalone as well as composite units are Howrah, Hooghly, Burdwan, Bankura and Durgapur in West Bengal; Jamshedpur in Jharkhand; Patna in Bihar; Rourkela in Odisha and Guwahati in Assam. While most of the units in Howrah are small units re-rolling scraps consisting of miss-rolls from bigger plants; ship breaking scraps, etc., the clusters of Durgapur house relatively bigger units comprising mostly composite units. The clusters of Rourkela and Jamshedpur house both bigger as well as smaller units. The technologies listed in the compendium cater to various sections of the industry.

The implementation of the technologies listed in the compendium will lead to multi-fold benefits including improvement in the factory environment, productivity, energy performance as well as the environmental sustainability. The technologies listed in the compendium have saving potentials in the range of 5% to 35%. The technologies discussed in the document include:

Low Investment Technologies (less than Rs 2 lakhs):

- Swirl burners for pulverized coal firing
- Energy efficient motors
- Installation of VFD in blower

Medium Investment Technologies (up to Rs 10 lakhs):

- High efficiency metallic recuperator
- Re-heating furnace automation & control system
- Energy efficient pulverizer
- Modified pulverized coal feeding system
- Coal drying system
- Energy efficient lighting
- Automatic material handling system

High Investment Technologies (more than Rs 10 Lakhs):

- New energy efficient furnace
- Coal bed methane based re-heating furnace
- Optimum refractory & Insulation
- Biomass based producer gas as fuel
- Natural gas firing for re-heating furnace
- Antifriction roller bearing
- Universal coupling & spindle
- Revamping of rolling mills
- Adoption of direct rolling in TMT mills
- Adoption of direct rolling in structural mills

Through this technology compendium the project hopes to maximize the environment benefits that would lead to Energy savings and GHG emission reduction. The project titled "Promoting energy efficiency and renewable energy in selected MSME clusters in India" provides a unique opportunity to the MSME units to progress towards a sustainable future.

# List of Vendors

### 1.    List of Suppliers- Rolling Mills Equipment

| SN | Name of Company | Address | Phone No. | E-mail / Website |
|---|---|---|---|---|
| 1 | A.R Engineering Works | 22, Okhla Industrial Estate, Phase-Iii, New Delhi 110020 India | 011-41612339 | info@argroup.net |
| 2 | P.P Rolling Mill Mfg. Pvt. Ltd. | D-820, New Friends Colony, New Delhi 110065 ,India | 011-26848885 | ppeng@vsnl.com |
| 3 | SMT Machines Limited | Post Box 71, G.T. Road, Sirhind Side, MandiGobindgarh 147301 Punjab ,India | 01765-255199 | smtindia@sancharnet.com, info@ smtmachinesindia.org |
| 4 | Kathuria Rollmill Pvt. Ltd. | A-7/56-58, S.S.G.T. Road Industrial Area, Gaziabad-201009, UP | 011-22934986 / 22931475 | kathuriarollmill@gmail.com, info@ kathuriarollmill.com web: www.kathuriarollmill.com |
| 5 | Rana Udyog (P) Ltd. | 18-D, Everest House 46-C, Jawaharlal Nehru Road | 033-3052-1116 033-2288-9247 | ranaudyog@hotmail.com |
| 6 | Jatindra Engineering Corporation | A-10/11, Jhilmil Industrial Estate G.T. Road, Shahdra New Delhi-110095 | 91-011-22110211 91-011-22592321 | jec@ndf.vsnl.net.in |
| 7 | Nav Bharat Engg. Works | C-233, Site First Ghaziabad-201120 (U.P) | 0120-2866715 0120-2867252 | bkmakkad@del3.vsnl.net.in |

### 2.    List of Suppliers- Energy Efficient Motors

| Sl. No. | Name of Company | Address | Phone No | E-mail /Website |
|---|---|---|---|---|
| 1 | Kirloskar Electric Company Ltd. | P.B. No. 5555, Malleswaram West, Bangalore -560055 | +91-80-23572111 +91-80-23371771 | enq@vrkec.com www.kirloskar-electric.com |
| 2 | Crompton Greaves Limited. | CG House, 6th Floor, Dr. Annie Besant Road. Worli, Mumbai - 400 030 | +91-22-24237777 | www.cglonline.com |
| 3 | ABB | 49 Race Course Road KhanijaBhavan, 2nd floor, Eastern Wing, Bangalore 560001 Karnataka | +91-80-22949150 | www.abb.com |
| 4 | Siemens India Limited | Electric Mansion, 134/ A, Dr. A. B. Road Worli Mumbai, Maharashtra 400018 | +91-22-4938786 +91-22-4937403 | www.siemens.co.in |
| 5 | Alstom India Ltd. | 1, Taratola Road, Kolkata – 700024 | +91-33-24695036 +91-33-24693751 | www.alstom.co.in |

### 3.    List of Supplier – Variable Voltage Variable Frequency Drives (VVFDs)

| SN | Name of Company | Address | Phone No.. | E-mail |
|---|---|---|---|---|
| 1 | ABB India | 49, Race Course Road, Bangalore, India | 91-9845193809 / 91-80-22949355 Mr. N. Venu | nvenu@in.abb.com |
| 2 | Siemens Ltd. | 384,Phase-II, UdyogVihar, Gurgaon, Haryana, India | 0124-4578100 Contact Person : Mr. L. Maheswari | |
| 3 | Simatech Automation Contact Person: Sushil Kumar Dubey | Gala No. 3, Saraswati Building Tungareshwar Industrial Complex, Sativali, Vasai (East), Thane - 401208, Maharashtra | Phone:  250 2481692 Fax: 250 2481692 | |
| 4 | Power Tech System Contact Person: Jitendra Patel, Proprietor | No. 22, Shukan Mall, Science City Road, Sola Ahmedabad - 380060, Gujarat | Mob:8447565164 | powertechsystem@ yahoo.com |

4. **List of Supplier- Thermo-mechanical Treatment Plants**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----------------|---------|-----------|--------|
| 1 | P.P Rolling Mill Mfg. Pvt. Ltd. | D-820, New Friends Colony, New Delhi 110065 India | 011-26848885 | ppeng@vsnl.com |
| 2 | SSS Engineering Co. Ltd. | 114, MG Road, 3rd Floor, Banglore-560001 | | srikantjois@hotmail.com |
| 4 | Jet Therm Technologies | 61/C, Laxmi Market, Supela BHILAI-490023 (C.G) | 09329235363 Mr. Sanjay Choudhary, Director | jettherm@hotmail.com , jettherm@rediffmail.com |
| 5 | H&K Rolling Mill Engineers Pvt. Ltd., | 401, Balarama, BandraKurla Complex, Bandra East, Mumbai 400051. | +91-22-30622004 (8 lines) | handk.india@gmail.com |
| 6 | Evotech Pvt. Ltd., Bhilai INDIA. | 17, 18 Commercial Complex, IT Tower, Nehru Nagar (East), Bhilai-490020 (CG) | +91-0788-4075901 4075999, 4075900, 4040539. | |

5. **List of Supplier- Re-Heating Furnace**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----------------|---------|-----------|--------|
| 1 | Fuel Save Systems & Devices Contact Person: S.B.Sharma | Plot No-65, Crossing Road, 3&6, Vill- Saroorpur Industrial Area, Near Sohna Road, Faridabad (Haryana) | Phone: 0129-2470298/0129-3955434 Fax: 0129-2503075/4047266 | moonlightmail@yahoo.com |
| 2 | Zooks International Contact Person: Mr. U. Nandy, Director | EC-277, Sector-I, Salt Lake, Kolkata-700064 (WB) | Phone: 033-23341839 Fax: 033-23349731 | thermal@cal12.vsnl.net.in |
| 3 | K N Engineering Works Contact Person: Mr. A. Nandi, Managing Director | Plot No. 2, New DLF Industrial Area, Faridabad-121003 (Haryana) | Phone: 129-2278868/ 129-2273932 Fax:129-2273055 | nandi_a@hotmail.com kn_engineeringindia@yahoo.com Web: www.knengg.tradeindia.com |
| 4 | ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD | 297, Sector-21 B Faridabad – 121001 Haryana | Phone: 0129-4041185 Fax: 0129-4044355 | sales@encon.co.in Web: www.encon.co.in |
| 5 | Allied Consulting Engineers (P) Ltd. Contact Person: Mr. V.N. Nasta, Director | Allied House, First Road, Opp. B.M.C Office, Chembur-400071(Maharashtra) Factory Plot No- A-373, Road No-27, Wagle Industrial Estate, Thane-400604 | Phone: 022-2528-4028-32/ 022-6797-3018-20 Fax: 022-2528-3805 | ace@bom3.vsnl.net.in Web: www.alliedfurnaces.com |
| 6 | The Wesman Engineering Co. (P) Ltd. | Wesman Center, 8-Mayfair Road, Kolkata-700019 (WB) | Phone: 033-40020300 Fax:033-22908050, 033-22816402 | mailbox@wesman.com furnace@wesman.com Web: www.wesman.com |
| 7 | Centro Combustion Furnaces Pvt. Ltd. | Giga Space, Alpha 2, 101 A Viman Nagar Pune 411014 Maharashtra – India | Mobile : 9370546015 (AbhijitParanjape) | a.paranjape@india.danieli.com |
| 8 | R.K.Industrial Enterprises* | Plot No. 82, Parvatiya Colony, Sohna Road, Near Peer Baba N.I.T. Faridabad – 121005 | Mobile: 9350543850 ShriNaresh Gupta | rkindenterprises@yahoo.co.in Web: www.rkindenterprises.com |
| 9 | Refined Structures & Heat Control Unit* | A-227. Nehru Nagar, Jaipur – 302016 (Raj.) | Mobile : 09829060615 ShriV.K.Sharma Chief executive | refinefurance@gmail.com |

*specialized in pulverized coal fired furnaces*

**6.    List of Supplier- Furnace Instrumentation**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----|----|----|----|
| 1 | S.S. Engineering Industries (dealers of Kent Oil Flow Meters) | C-15, Sector - 7 Noida, U.P. - 201301 (INDIA) | Tel : +91-120-2423191/ 207/ 523/ 382 Fax : +91-120-2423654 Contact Person : Mr. Mahesh Gupta | sales@ssengg.com |
| 2 | Fuji Electric India (P) Ltd. | 409-410, Meadows, Sahar Plaza, AndheriKurla Road, J.B. Nsagar, Andheri (E) Mumbai 400 059 | Phone: 022-4010 4870/71 Fax:022-4010 4872 | info@fein.fujielectric.com www.fujielectric.co.in |

**7.    List of Supplier – Pulverizer**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----|----|----|----|
| 1 | Pinesap Machine Tools (Regd.) | G.T Road Hanna Side, Opp.Power House, MandiGobindgarh, Punjab 147301 | 91-1765-241304 | panesarmachinetools@hotmail.com |
| 2 | Prithvi Steel Re-Rolling Machine Contact Person: Sudesh Sharma, Director | B-230, Road No. 9 Vishwakarma Industrial Area, Jaipur-302013 | Phone: 0141-2330478 Mob: 9314466666 | E-mail: info@prithvisteel.com |

**8.    List of Supplier – Automation & Control System**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----|----|----|----|
| 1 | Masibus Automation And Instrumentation Pvt. Ltd. | B-30, G.I.D.C Electronic Estate, Sector - 25, Gandhinagar - 382044. Gujarat - India. | +91 79 23287275-79 Fax +91 79 23287281-82 | sales@masibus.com |
| 2 | Pyramid Automation | 214/215, Gauri Commercial Complex, Navghar, Vasai Road (E), Dist. Thane – 401 210. INDIA. | Contact Person : Mr. RakeshPatil Cell No. : +91- (0) 99677 55779    / 93266 92106 | info@pyramidautomation.co.in www.pyramidautomation.co.in |
| 3 | Ragtron India | 1449/116, Street No. 3, Durgapuri, Shahdara, Delhi - 110093, India | | www.ragtron.com |
| 4 | Yokogawa India Limited | Plot No. 36, Electronics City Complex, Hosur Road, BANAGLURU – 560 100 | Phone: 080-41586000 | |
| 5 | Tata Honeywell Limited | ESTATE HADAPSAR, PUNE - 411013, MAHARASHTR | Tel: 56039909 | |
| 6 | SIEMENS Limited Industry Sector Metal technologies | 130, PandurangaBudhakarMarg Worli, MUMBAI – 400 018 | Phone: 022-3967 2068 | |
| 7 | ABB India | BU Measurement & Analytics 14, Mathura Road, Faridabad, INDIA - 121003 | Phone: 0129-2279627, 2275592 | tejbir.singh@in.abb.com |

**9.    List of Supplier – Furnace Oil / Producer Gas Burners**

| SN | Name of Company | Address | Phone No. | E-mail |
|----|----|----|----|----|
| 1 | The Wesman Engineering Co. (P) Ltd. | Wesman Center, 8-Mayfair Road, Kolkata-700019 (WB) | Phone: 033-40020300 Fax:033-22908050, 033-22816402 | mailbox@wesman.com furnace@wesman.com Web: www.wesman.com |
| 2 | ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD | 297, Sector-21 B Faridabad – 121001 Haryana | Phone: 0129-4041185 Fax: 0129-4044355 | sales@encon.co.in Web: www.encon.co.in |
| 3 | Continental Engineers | 477, SIDCO Industrial Estate, Ambattur, Chennai - 600 098. | Phone : +91-44-26254266, 26259988, 26257239, 26257303 | info@contitherm.com http://www.contitherm.com |

**9.      List of Supplier – Metallic Recuperator**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Eastern Equipment & Engineers P Ltd | 7B, Kiran Shankar Roy Road, 3rd Floor, Kolkata 700 001 | + 91 33 2243 0468 / 0469 Fax + 91 33 2248 7130 | vka@recuperators.in |
| 2 | Refined Structures & Heat Control Unit* | A-227. Nehru Nagar, Jaipur – 302016 (Raj.) | Mobile : 09829060615 Shri V.K. Sharma Chief executive | refinefurance@gmail.com |
| 3 | R.K. Industrial Enterprises* | Plot No. 82, Parvatiya Colony, Sohna Road, Near Peer Baba N.I.T. Faridabad – 121005 (Haryana) | Mobile: 9350543850 ShriNaresh Gupta | rkindenterprises@yahoo.co.in rkindustrialenterprises@yahoo.co.in |
| 4 | ENCON Thermal Engineers (P) Ltd Contact Person: Mr.  V B Mahendra, MD | 297, Sector-21 B Faridabad – 121001 Haryana | Phone: 0129-4041185 Fax: 0129-4044355 | sals@encon.co.in Web: www.encon.co.in |

*specialized in pulverized coal recuperator

**10.      List of Supplier –Refractories & Insulation**

| SN | Name of Company | Address | Fax No. | E-mail |
|---|---|---|---|---|
| 1 | Nilachal Refractory | Plot No. 4, Bapujinagar, Bhubaneswar-751009, Orissa | Phone: 033-22496507 Fax: 033-22499511 | info@nilachal.in |
| 2 | SAIL Refractory Unit, | Indira Gandhi Marg, Sector-IV, Bokaro Steel City– 827004 Jharkhand | Ph:     (06542) 233179, 233673 Fax: (06542) 233672 | edsrubokaro@gmail.com |
| 3 | SKG Refractories Ltd. | B 193 MIDC, Butibori, Nagpur 441108 | +91-9423105484 | Psengupta@skgrl.com |
| 4 | TRL Krosaki Refractories Limited (formerly Tata Refractories Limited) | Belpahar Jharsuguda, Odisha, India Pin : 768218 | 06645 258486 Fax : 06645 250243 | pkjana@trlkrosaki.com |
| 5 | HIL Limited | Sanatnagar, Hyderabad-500018, A.P, India. | +91 40 30999000 Fax : +91 40 23701227 / 23702400 | contactus@hil.in |
| 6 | ACC Limited | Cement House 121, MaharshiKarve Road, Mumbai - 400 020 | Tel: 91-22-33024321; Fax: 91-22-66317440 | |
| 7 | New Bharat Refractories | 1-B, Trikut, 181, Block 'G' New Alipore, Kolkata - 700 053 | Phone : +91 33 2445 7566 | |

**11.      List of Supplier – Ceramic Fibre**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Murugappa Morgan Thermal Ceramics Limited | Post Box No 1570, DARE House Complex, Old No. 234, New No. 2 NSC Bose Road, Chennai 600 001 India | Tel +91 (44) 2530 6876, 2534 5986 Fax: +91 (44) 2534 5985 | mmtcl.india@morganplc.com http://www.murugappamorgan.com |
| 2 | Lloyds Insulations (India) Limited Mr. K. K. Mitra (Vice President) | Punj Star Premises, Kalkaji Industries Area, New Delhi - 110019. | +91-11-30882874 / 75 Fax: +91-11-44-30882894 /95 | kk.mitra@lloydinsulation.com |
| 3 | Unifrax India Ltd. | C - 102, Business Square, Andheri-Kurla Road, Nr.Chakala, Andheri (East), Mumbai - 400 093 | Cell No.+91 98694 24830 | |

### 12.  List of Supplier – Oxygen Analyser

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | ABB India | BU Measurement & Analytics 14, Mathura Road, Faridabad, INDIA - 121003 | Phone: 0129-2279627, 2275592 | tejbir.singh@in.abb.com |
| 2 | Ecolibrium  Energy (P) Ltd | 1-4, CIIE, IIM New Campus, Vastrapur , Ahmedabad-380015, Gujarat | Phone :079-663241919 Mobile: 9871582246 | himanshu.nagpal@ ecolibriumenergy.com |
| 3 | Jupiter Integrated Senser System Pvt. Ltd. Contact Person: Mr. BipinGhelani, Director | Kailash Industrial Complex A-401, Behind Godrej Colony, Park Site Vikhroli, Mumbai-400079, India | Phone :  022-25186470 Fax: 022-25186471 Mob: 9819575467 | bipin@jupiterelectronics.co.in |
| 4 | Swan Environmental Private Ltd. | House no. 1 – 5017, 3rd floor, SMR Chamber Opposite St annes College Medinaguda, Seringapally, Hyderabad, (AP) | Tel: 040-23043328, Fax: 040-23041905 | |
| 5 | Testo India Pvt. Ltd. | Plot-23, Sind Colony, Boner Road, Aundh, Pune Maharastra – 411007, India | Tel :  020-65600203, Fax: 020-25850080 Mob :  9370319654 | |

### 13.  List of Supplier – Coal / Gas Analysis

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | N.D. International | 107B, Block-F, New Alipur Kolkata – 700 053 | Mr. Debasis De, Managing Partner Mob :  9830238048 Off :  4021-6600-17 (18 lines)  4021-6600 (Direct) | |
| 2 | Bharat Foundation | 25/11A, K. P. Ray Lane, Kolkata – 700 031 | Tel :  2415-2145 / 2405-5015, Mob: 9831857775 Mr. S.Niyogi, Partner | bharatfoundation@gmail.com |
| 3 | Envirocheck | 180/190, Rastraguru Avenue, Kolkata – 700 028 | 2579-2889/2579-2891 Dr. SumitChowdhury Mob : 9830067043 | envcheck@cal2.vsnl.net.in |
| 4 | Indian Institute of Chemical Technology Contact Person: Dr. Ahmed Kamal, FNASc | Hyderabad-500004 | Phone: 040-27193030 Fax: 040-27160387 | ahmedkamal@iict.res.in |
| 5 | Central Institute of Mining & Fuel Research | Digwadih Campus PO: FRI, Dhanbad-828 108, Jharkhand, India | Tel. :+91-326-2381111 2388202 Fax :  +91-326-2381113 | dnb_dcfri@sancharnet.in |
| 6 | Sigma Test & Research Centre | BA-15, Mangolpuri Industrial Area Phase-II Delhi-110034(India) | Ph:  +91-11-49491440 49491444, +91- 987327 2900 (M) Fax: +91-11-4385 2040 | info@sigmatest.org |
| 7 | SGS India | 226, UdyogVihar, Phase 1, Gurgaon 122 016, India | t  +91 9871701549 f   +91 (0) 124 239 9762 | http://www.sgsgroup.in |

### 14.  List of Supplier – Continuous Casting Machine

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Concast (India) Limited | CONCAST HOUSE, 1/5 Marol Co-op Industrial Estate, Andheri (E), Mumbai - 400 05 | Telephone +91 22 2850 1789 Fax:+91 22 2851 5145 | concasti@bom4.vsnl.net.in http://www.concastindia.com |
| 2 | Inductotherm (India) Pvt. Ltd. | Building Ambli-Bopal Road, Bopal, Ahmedabad 380058 | Phone :  +91-2717- 306196 Cell :  +91-9374578586 ShriKishorebhai D. Vyas | sales@inductothermindia.com |

**15.    List of Supplier – Coal / Biomass Based Producer Gas Plant**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Ankur Scientific Energy Technologies (P) Ltd. Contact Person: Mr. Ankur Jain, Director | "Ankur"Near Old SamaJakat Naka, Sama Road Vadodara-390008 | Phone: - 0265-2793098/2794021, Fax: - 0265-279404 | ascent@ankurscientific.com Mob: - 94-265-10863 |
| 2 | Radhe Renewable Energy Development (P) Ltd. Contact Person: Shri Sunil Mittal, Marketing Mgr | Plot No-2621/2622, Gate No. 1, Road D/2, Lodhika G.I.D.C, Kalawad Road PO-Metoda  Tal- Lodhika, Dist-Rajkot-360021 (Gujarat) | Phone:-2827-287888/287889 Fax: 2827-287887 Mob:98980 92843 | info@radhegroup.com Web:  www.radhegroup.com |
| 3 | MPR Refractories Ltd. | 1-10-114, Ashok Nagar, Hyderabad-500020 | Phone: 040-27644381/27637420 Mobile: 8870460191 | ceo@afetechpl.com |
| 4 | Ashutosh Engg. Consulting Contact Person: P. Trivedi | 749/2 A-2, 1st Floor, GIDC, Makarpura, Vadodara – 10 (Gujarat) | Phone: 0265-6590225 Fax: 0265-3047088 Mobile: 9825955157 | ashutoshengg1969@yahoo.co.in |
| 5 | COSMO Power Tech Pvt. Ltd. | Near Jain Public School, Devpuri, Dhamtari Road, Raipur - 492 015, Chhattisgarh | Phone : 0771-4011262 Fax : 0771-4013016 Mob 9893030085 | cosmo_powertech@yahoo.co.in www.cosmogasifiers.com |
| 6 | CASE | 117, Charmwood Plaza, Charmwood Village,  Surajkund, Faridabad, Haryana - 121009, India | Telefax : +91-129-4266699 Ph: +91-129-4266666 | info@casepl.com , case@casepl.com http://www.casepl.com |
| 7 | Dev Knitfab Ltd. Contact Person: Mr. Varun Kumar, Director | 23, Motiakhan, Rani Jhansi Road, New Delhi-110055 | Phone: 011-23551758 Fax: 011-23647528 Mob: 9810085165 | varun@devknitfab.com |

**16.    List of Supplier – Blowers**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | KAY International Ltd. | Registered & Head Office 205-206 Lusa Tower, Azadpur Commercial Complex, Delhi - 110 033 | +91-11-27674703 | kayintl@vsnl.com / kayintl@eth.net |
| 2 | Everest Pressure &Vaccum Systems | 435, Modern Industrial Estate, Phase-1, Bahadurgarh-124507, Haryana, India. | 91-1276-267029, 267030 | info@everestblowers.com |
| 3 | AMETEK Precision Motion Control | 1st Floor, Prestige Featherlite Tech park, Plot 148, EPIP Phase II Whitefield, Bangalore 560 066 Karnataka,India | Dir No - 080 67823237 Mob no – 9686679509 | |
| 4 | Ventilair India Pvt. Ltd. | 201 Guru ArjunDevBhawan Ranjeet Nagar Comercial Complex New Delhi | 011 - 25701825 011 – 25708240 | |
| 5 | Maxtech Engineers | Plot No. 22, Tribhuvan Industrial Estate, Opp. Road No. 8, Kathwada G.I.D.C., Ahmedabad - 382430. | Tele Fax : 079 - 22901299 Phone : +91-9427609165 +91-79 - 22871576, 22900657 | maxtechengineers@yahoo.com info@maxtechengineers.com Web : www.maxtechengineers.com |

**17.** **List of Supplier – Oxy Fuel Burners / Regenerative Burners**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Qingdao Olympia Heat Energy Equipment Co. Ltd | East Of Seven Road, Second Zone, Jiaozhou Bay Industrial Park, Jiaozhou City, Qingdao, China - 266300 | Tel: 86-0532-82279618 Fax: 86-0532-82279617 | qdolpy@olpy.net http://www.olpy.net |
| 2 | ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD | 297, Sector-21 B Faridabad – 121001 Haryana | Phone: 0129-4041185 Fax: 0129-4044355 | sales@encon.co.in Web: www.encon.co.in |
| 3 | Bloom Combustion India | City Centre Apartments, Office No. 405 AErand Centre Apartments, Office No. 405 A, Erandawane, Karve Road, Pune - 411004, Maharashtra, India | Mobile +919881001342 Contact Person Mr. Rahul Pathak (Manager Sales ) | |
| 4 | Wesman Center | 8 Mayfair Road Kolkata 700 019, India | Tel:+91 (33) 40020300 Fax: +91 (33) 22908050, | mailbox@wesman.com, furnace@wesman.com Web: www.wesman.com |
| 5 | Precimax Engineers Limited | Shahani House, Raj Palace Society, Plot 16, Sector 2, opar Khairane Navi Mumbai – 400709 | +(91)-(22)-64568712 +(91)-(22)-64568714 | lalitshahani@precimaxonline.com varshahotchandani@precimaxonline.com |
| 6 | Maxon (A Honeywell Company) | 53, 54, 56, 57 Hadapsar Industrial Estate, Environmental & Combustion Controls, Sapphire Building, A-Wing, 2nd Floor Pune 411013 | 91-98-50907894 91-20-66008330 91-20-66008509 91-20-66039979 | https://www.maxoncorp.com |

**18.** **List of Supplier – Roller Bearings**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | TIMKEN India Limited | 2nd Floor, Ramnath Building, 18, Community Centre Yusuf Sarai, New Delhi 110 016, India | Phone: 91-1-4604 3444 | http://www.timken.com/india |
| 2 | SKF India | Mahatma Gandhi Memorial Building NetajiSubash Road, Charni Road, Mumbai - 400 002 | Tel: +91 22 6633 7777 Fax: +91 22 2281 9074 | http://www.skfindia.com |
| 3 | FAG Bearings India Ltd. | B-1504, Statesman House 148, Barakhamba Road New Dehli 110 001, India | Tel. +91 11 237382-77/-78, 415214-76/-77 Fax +91 11 51521478 | info.fag.delhi@schaeffler.com http://www.schaeffler.co.in |

**19.** **List of Supplier – Antifriction Roller Entry / Exit Guides**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Morgards hammer India Ltd., New Delhi | 1400 Modi Tower, 98 Nehru Place New Delhi - 110019 | Tel: +91-11-26286641/ 66504555 | http://www.morgardshammar.in |
| 2 | SMT Machines Limited | Post Box 71, G.T. Road, Sirhind Side, MandiGobindgarh 147301 Punjab ,India | 01765-255199 | smtindia@sancharnet.com, info@smtmachinesindia.org |

**20.** **List of Consultant- Hot Charging / Direct Rolling**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | SEVAT | Walden- Charis, C/o. Greenhome Landscape (P) Ltd..Dheenampalayam. P.O, Coimbatore-641109 PrateekshaMadona, Thittamel, Chengannur, Kerala - 689121 | Mobile: +9387676039 Mr. Philip George Ittyerah, | philip.ittyerah@gmail.com, sevati@yahoo.co.in |
| 2 | SOMA Consultancy Services | 625 Sundar Nagar Raipur. CG. | Mobile: +91-9303278071 | |

**21.    List of Supplier – Universal / Cardon Shaft Couplings / Spindles**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Voith Turbo Private Limited - Contact Person Mr. K. Chakraborti | AB-06, Sector-1, Salt Lake City, Kolkata, West Bengal - 700064, India | 91-33-23592356 /23587641 Fax No :   91-33-913323592356 | |
| 2 | Cardan India | G. T. Road Panagarh Bazar Durgapur - 713 148 WB, India | Mobile : +91 98000 46890 / +91 94343 33326 / +91 98322 88664 Fax : +91 343 2527065 | sales@cardanindia.com / cardanindia@gmail.com Website : www.cardanindia.com |
| 3 | Dullabh Commercials | 386, Ahmmed chambers, Opp. Swastik Cinema, Lamington Rd, Near Opera House, Mumbai - 400 004, Maharashtra (India) | Mobile No +91- 9820967337 Contact Person Mr. Raj Mistry | raj@dullabhcommercials.com |
| 4 | Cardan Shaft India | Plot No. 308, Sector -3, Block - C Loha Bazar, MandiGobindgarh– 147301, Punjab, INDIA | Tel : +91 - 81466-22027, 09357755555 | info@cardanshaftsindia.com rsingh@cardanshaftsindia. www. cardanshaftsindia.com com \| |
| 5 | A.R Engineering Works | 22, Okhla Industrial Estate, Phase-Iii, New Delhi 110020 ,India | 011-41612339 | info@argroup.net |
| 6 | P.P Rolling Mill Mfg. Pvt. Ltd. | D-820, New Friends Colony, New Delhi 110065 ,India | 011-26848885 | ppeng@vsnl.com |
| 7 | Kathuria Roll mill Pvt. Ltd. | A-7/56-58, S.S.G.T. Road Industrial Area, Gaziabad-201009, UP | 011-22934986 /22931475 | kathuriarollmill@gmail.com, info@kathuriarollmill.com web: www.kathuriarollmill.com |
| 8 | RanaUdyog (P) Ltd. | 18-D, Everest House 46-C, Jawaharlal Nehru Road | 033-3052-1116 033-2288-9247 | ranaudyog@hotmail.com |

**22.    List of Supplier – FRP blades**

| SN | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Poly Fans | S-4,Amita Apartments,118,New Baradwari, Sakchi,Jamshedpur, Jharkhand | Mobile :+91-9470351780;0812340691 | bksinha@gmail.com |
| 2 | Parag ' Fans  & Cooling systens Ltd | Plot no. 1/2B & 1B/3A, Industrial  Area no.1 AB Road, Dewas-455001, Madhya Pradesh | 07272-425100/01/02/03/04 Mobile:09993027026 | info@impactgroupindia.com |
| 3 | Dew –pond Engineering Pvt. Ltd | Plot no.A-478, Road 26, wagle Ind. Estate, Thane-400604, Maharashtra | 022-25829208 | dewpond@gmail.com;sunil@ dewpondcoolingtowers.com |
| 4 | Paharpur Cooling Towers Ltd | Paharpur House, 8/1/B Diamond Harbour Road, Kolkata-700027, West Bengal. | 033-40133000 | pctccu@paharpur.com |

For more details, please contact



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