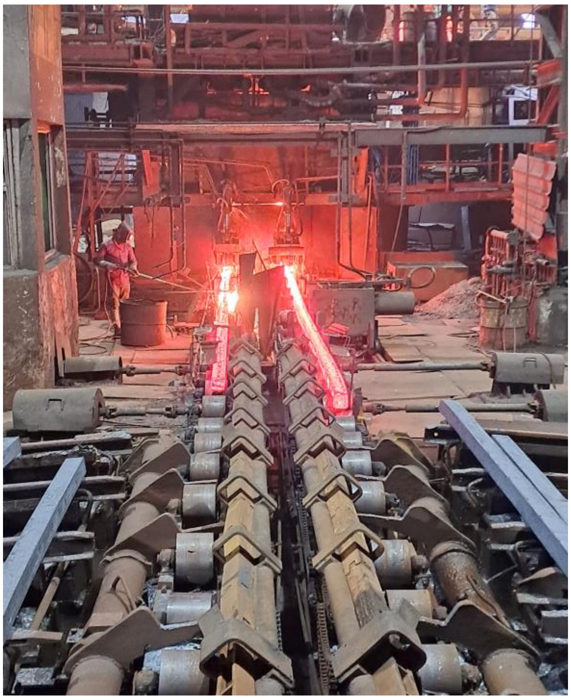
Energy Profile

Bankura Secondary Steel Cluster



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Promoting Energy Efficiency in SMEs
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Contents

Abbreviations

CCM	Continuous Casting Machine
CFM	Cubic feet per minute
CO_2	Carbon Dioxide
DIC	District Industries Centre
DRI	Direct Reduced Iron
DVC	Damodar Valley Corporation
EIF	Electric Induction Furnace
GHG	Greenhouse Gas
IGBT	Insulated Gate Bipolar Transistor
MSME	Micro Small and Medium Enterprise
MW	Mega Watt
PMSM	Permanent Magnet Synchronous Motor
SAF	Submerged Arc Furnace
SCR	Silicon-Controlled Rectifier
SEC	Specific Energy Consumption
SMS	Steel Melting Shop
SRRM	Steel Re-Rolling Mill
TERI	The Energy and Resources Institute
TMT	Thermo-Mechanically Treated
Toe	Tons of Oil Equivalent
TPA	Tonnes per Annum
TPD	Tonne per day
VFD	Variable Frequency Drive
WBSEDCL	West Bengal State Electricity Development Corporation Limited
WBSIMA	West Bengal Sponge Iron Manufacturers Association
WHR	Waste Heat Recovery

Bankura Cluster

1.0 Overview of the cluster

The Bankura district in West Bengal is surrounded by Purulia district in the west and Bardhaman district in the east (Figure 1). The trditional industry clusters in the district are roofing tiles and brass and bell metal.

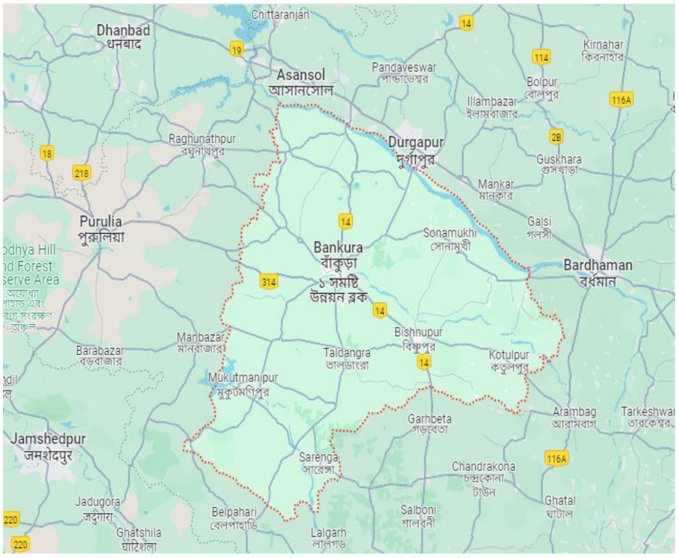

Figure 1: Bankura District Map

Source: Google Map

The district is rich in natural resources, including coal, which has led to the growth of secondary steel industries there. The cluster has a number of steel industries, including sponge iron/DRI, ferro-alloys, electric induction furnaces (EIFs) based steel melting shops (SMS) and steel re-rolling mills (SRMM).

2.0 Product, market and production capacities

The secondary steel cluster in the Bankura district comprises around 37 units. The major type of steel industries are shown in Figure 2. These industries form a vital backbone for a wide array of markets, spanning local, domestic, and international sectors, depending on the products they manufacture. Their products cater to industries, construction, railways, and infrastructural needs. The major products manufactured within the cluster include TMT bars, rods, angles, alloys, ingots and billets. These products play crucial role in meeting the demand of various industries and fulfilling the infrastructural requirements.

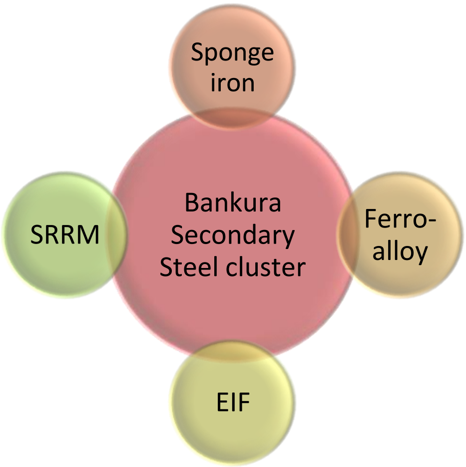

Figure 2: Type of steel industries in the cluster

Table 1 outlines the different types of technology, raw materials, and energy sources utilized by the secondary steel industries in Bankura.

Table 1: Technology, energy and raw material use in Bankura secondary steel industries

Technology	User industry	Raw material	Process step	Energy used	Product
Rotary kiln	DRI	Iron ore	Heating and reduction	Coal, electricity	Sponge iron
Submerged Arc Furnace	Ferro alloy	Mineral ore	Heating and reduction	Coal, electricity	Alloys
Electric induction Furnace	SMS	Sponge iron, scrap	Steel melting	Electricity	Ingots and billets
Continuous casting machine	SRRM	Liquid metal	Casting	Electricity	Hot billets for rolling
Rolling mill	SRRM	Hot ingots and billets	Rolling	Electricity	TMT bars

Bankura cluster has has a significant presence of ferro-alloys, sponge iron and steel melting industries. The production profile of the cluster is outlined in Table 2.

Table 2: Production from steel industries

Type	Nos	Production (TPA)
DRI	10	13,96,500
Ferro Alloy	11	3,06,740
EIF	11	12,63,600
SRRM	5	6,32,966
Total		35,99,806

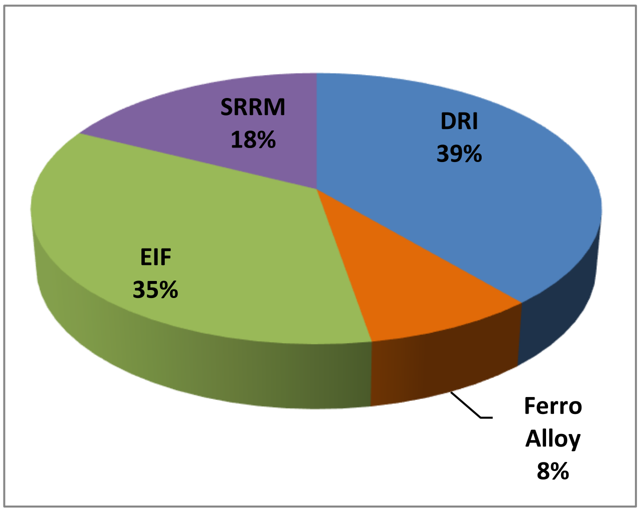

Figure 3: Production share of steel industries

Total production of from steel industries in the cluster is estimated to about 3.6 million tonnes. The major share of production comes from DRI follows by electric induction furnaces industries. Share of DRI is 39% while that of the electric induction furnaces is 35% (Figure 3).

3.0 Production Process

3.1 DRI

Direct Reduced Iron (DRI) also known as sponge iron, is produced with the use of coal in a rotary kiln. In this method, oxygen is extracted from iron ore under controlled parameters within a rotary kiln. Chemical reactions take place and the iron ore which is in oxides form is reduced to iron. The reactions take place in the kiln and the temperature is maintained round 900 - 1100°C throughout the kiln length and reduction zone. Carbon monoxide gas exhibits an affinity for oxygen, leading it to react with oxygen from iron oxide to form carbon dioxide, which is then released. Subsequently, the carbon dioxide reacts with carbon from coal to produce carbon monoxide, perpetuating the reaction cycle. Once the metallization process is complete, resulting in sponge iron and residual charge, the mixture is conveyed to a rotary cooler. The solid discharge undergoes separation from the impurities through an electromagnetic separator. The separated sponge iron is then screened in series to different size fractions, facilitating separation of lumps and fines. The typical process flow of DRI production is illustrated in Figure 4.

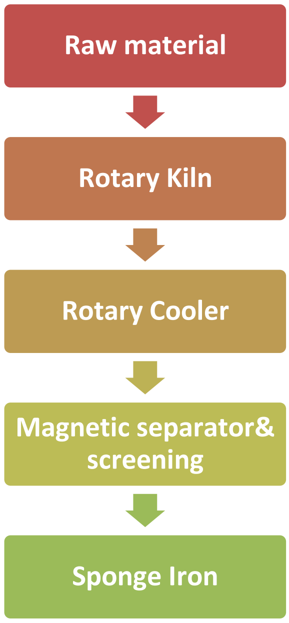

Figure 4: Process flow of DRI production

3.2 Ferro alloy

The production of ferro alloys starts with the reduction of quartz and alloy-bearing ores at elevated temperatures using a reductant. These raw materials are then blended and conveyed via a bucket elevator to a circulating feed hopper located at top the furnace. From there, they are distributed onto the stroking floor to ensure even distribution and prevent lump formation. The process flow is depicted in Figure 5.

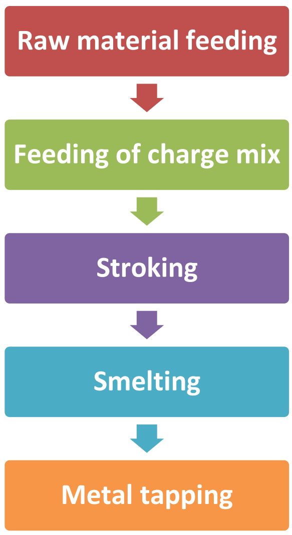

Figure 5: Ferroalloy production process

Following this, the smelting process occurs, characterized by the high-temperature arcing of oxide minerals in the presence of carbon. This results in the formation of liquid alloy elements, which subsequently react with iron to produce the desired ferroalloy. The electric arc furnace is equipped with three carbon electrodes which supplies high-voltage electricity to induce high-temperature arcing within the furnace core. Finally, the molten ferroalloy is extracted from tapping holes at the bottom of the furnace, with the temperature around 1500-1600°C.

3.3 Steel melting shop

Induction furnace melting, commonly known as a steel melting shop, is an important process in the stage of steel production. This process involves melting raw materials such as pig iron, metal scrap and sponge iron in the induction furnace to manufacture billets or castings tailored to specific requirements.

The raw materials are loaded into the electric induction furnace where an electromagnetic field using a coil carrying alternating electric current is generated. This electromagnetic field melts the metal at temperatures ranging from 1400-1500°C. Once the metal is molten in liquid form it is then transferred to cast. Typically, the molten metal is poured into a continuous casting machine to produce billets, which are subsequently processed in re-rolling mills. This streamlined process ensures the efficient and consistent production of high-quality steel products. The process flow in the steel melting shop floor is illustrated in Figure 6.

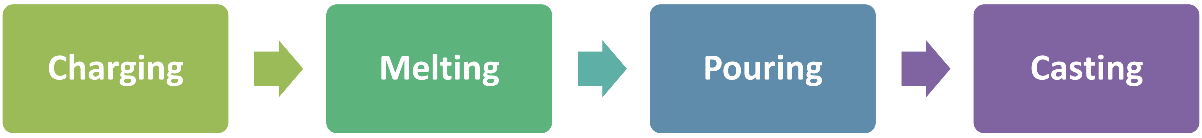

Figure 6: Steel melting process flow

3.4 Re-rolling

In rerolling units, the initial step involves charging the raw material, billet, into the reheating furnace for heating or the casted billets from continuous casting machine are directly rolled in the rolling mill. The billets are heated to temperatures ranging from 1100-1200°C to facilitate further shaping in the rolling mills.

Subsequently, the hot billet is passed through rollers multiple times to achieve the desired shape. The final product can take various forms such as round bars, flats or angles, depending on the specific production unit. TMT (thermos-mechanically treated) bars are the most produced items in these rerolling units. This process ensures the efficient transformation of billets into finished steel products suitable for various construction applications. The typical process flow of rerolling units is illustrated in Figure 7.

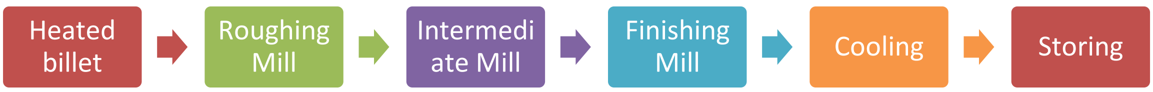

Figure 7: Process flow of re-rolling units in the cluster

4.0 Energy consumption in cluster

Coal is the primary source of energy utilized in the iron and steel industries. Both domestic and imported coal is used. Electricity is sourced from utilities such as Damodar Valley Corporation (DVC) or West Bengal State Electricity Distribution Corporation Limited (WBSEDCL). The energy consumption of the different steel industries in the cluster is shown in Table 3.

Table 3: Energy consumption in cluster

Type	Thermal		Electrical		Total Energy	GHG emission
	Coal consumption (Mt/year)	(toe/year)	Million units	(toe/year)	(toe/year)	($MtCO_2$/year)
DRI	1.53	6,91,268	111.7	9607.9	7,00,875	2.87
Ferro Alloy	0.073	33,128	2883.3	247968.6	2,81,097	2.2
EIF	0	0	1200.4	103236.1	1,03,236	0.86
SRRM	0	0	50.6	4354.8	4,355	0.036
Total	1.61	7,24,395	4246.1	365167.5	10,89,563	5.96

The total coal consumption in the cluster is calculated to 1.61 million tonnes and the electricity consumption is calculated to 4246.1 million units (MU) and hence the total energy consumption is calculated to 1.089 million tonnes of oil equivalent. GHG emissions from these industries are calculated to be 5.96 million tonnes of carbon dioxide.

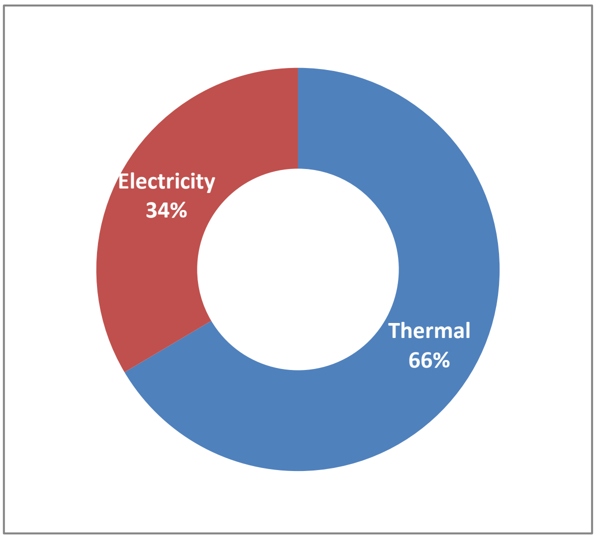

Figure 9: Type of energy share in the cluster

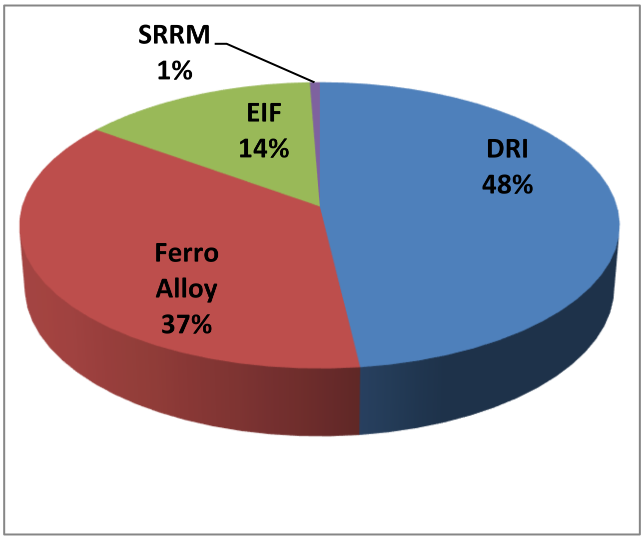

Figure 8: Industry wise share of energy consumption in cluster

The share of thermal energy is 66% and electrical energy is 34% in the cluster (Figure 8). The major consumers of energy are DRI (48%), ferro alloy (37%) and EIF (14%).

5.0 Technologies employed

Some of the major equipment used in the production of steel are described below.

5.1 Rotary kiln

The horizontal rotary kiln is the main equipment in the production of coal-based sponge iron. Its dimensions are customized to suit production capacity requirements. Lined with high alumina castable refractories, it is inclined at an angle of 2.5 degree and supported by 2-4 stations. Material flow is regulated by adjustments in the slope and rotation speed.

Figure 10: Rotary kiln

Inlet and outlet ends are cooled individually by fans, while sampling ports aid in monitoring for combustion temperature inside the kiln. Coal and iron ore are introduced at the kiln's inject end along with dolomite to react inside the kiln. A pictorial view of rotary kiln is shown in Figure 10.

5.2 Submerged arc furnace

Figure 11: Submerged Arc Furnace

The submerged arc furnace is at the heart of ferroalloy production. The furnace employs electric arcs between three electrodes and the metallic charge to generate the required heat. These furnaces comprise of an outer cylindrical steel shell lined with multiple layers of refractory materials and feature a motorized tilting mechanism for operational ease. Electrodes, positioned at a 120° angle from the roof, are managed by a thyristor-based system to ensure precise vertical movement. The refractory brick roof, often high alumina, serves as insulation. Both the crucible and electrodes are water-cooled, enhancing temperature control and extending longevity of the furnace operation. The furnaces typically incorporate rear door for alloying, oxygen lancing, and de-slagging processes.

5.3 Electric induction furnace

The electric induction furnaces (EIF) is the main melting unit used to produce steel by the steel melting shops. They utilize a non-conductive crucible surrounded by a copper wire coil supplied with strong alternating current. The flow of electricity through the coil heats

Figure 12: Electric induction furnace

the metal bulk through the Joule heating effect. EIFs employ either silicon-controlled rectifiers (SCRs) or insulated gate bipolar transistors (IGBTs) to regulate the power circuit, with the IGBT variant recognized for its superior efficiency. A view of an electric induction furnace under relining is shown in the Figure 12.

5.4 Continuous casting machine

Continuous casting is a crucial process in the steel industry, allowing for the efficient production of high-quality steel products like billets, blooms, slabs, and bars. This modern method ensures the continuous casting of molten metal, eliminating interruptions and ensuring the consistent production of defect-free materials. At the heart of continuous casting is the continuous caster machine, a key element in the re-rolling process. The molten metal, drawn from the induction furnace, is introduced into the continuous caster, where it undergoes shaping and solidification, resulting in uniform metal products.

Figure 13: Continuous casting machine

5.5 Rolling mill

A rolling mill operates with multiple strands, including roughing and finishing stages, where the feedstock is shaped into the desired form. Its main function is to transform hot ingots into thinner and longer products through successive passes across different rolling stands. The process begins with the heated slab passing through the roughing stand, where its thickness is reduced over several alternating passes. Typically, this stage involves about three passes. Next, the intermediate stand processes the material with additional passes, tailored to meet specific product requirements. Finally, the material reaches the finishing stand, where precise shaping occurs through further passes to ensure the final product meets the required quality and dimensions.

6.0 Potential energy efficient measures

The present technology and energy consumption across various secondary steel industries within the cluster indicate significant potential for energy conservation and reduction of greenhouse gas (GHG) emissions. Identifying various energy losses during the operational phase signifies a substantial opportunity to decrease Specific Energy Consumption (SEC) levels and improve overall energy efficiency. Some of the measures are as follows:

6.1 DRI industry

(i) Waste heat recovery (WHR) system for power generation

In coal-based DRI production using a rotary kiln, the off-gases exit the kiln at temperature ranging between 950 to 1000°C, carrying a substantial amount of sensible heat. This heat can be harnessed by employing a Waste Heat Recovery (WHR) boiler to produce high-pressure steam for power generation. A typical 2 x 100 TPD plant has potential to generate 5 MW of power which can be utilized in the plant for captive consumption and excess can be exported to the grid. The capital investment for a WHR power plant of 5 MW is about Rs 500 million. The energy saving with use of WHR-based power generation system in a DRI plant of 2 x 100 TPD kiln capacity is about 23.5 million kWh of electricity per year. The equivalent emission reduction potential is 16,685 tonne CO_2 per year.

(ii) Replacement of iron ore lumps with pellets

Coal-based DRI plants commonly utilize iron ore lumps sized between 5 to 20 mm. The naturally mined iron ore supplied to DRI plants typically contains low iron content. Processing these lumps often leads to the generation of fines, necessitating agglomeration processes to maintain yield levels. An alternative approach involves using iron ore pellets instead of lumps, which can notably enhance the yield of the DRI process and reduce coal consumption.

(iii) Improved kiln lining to reduce surface heat losses

In conventional rotary kiln, high-alumina low-cement castable refractories are used as inner lining. The temperature of external surfaces of the kiln are about 180–250°C. The radiation heat loss of the rotary kiln typically accounts for 5% of the total heat input, which can be reduced with application of low-thermal conductivity material such as mullite-based kiln lining. The energy saving potential for 100 TPD kiln with improved lining is 580 tonne of coal per year equivalent to emission reduction potential of 1050 tonne of CO_2 per year.

6.2 Ferro alloy industry

(i) Use of efficient transformers

The submerged arc furnace uses a specialized arc transformer. The inefficient transformers can be replaced with efficient transformers. The major benefit of efficient transformers include increase in productivity, reduction in electrode consumption and energy saving.

(ii) WHR for power generation

The waste heat available in off gases in ferro alloys plant can be utilized to generate captive power. The reduction in electrical load with adoption of WHR based power generation system in ferro alloys industry would help in bringing down energy cost to a significant extent. The capital investment in waste heat recovery-based boiler and power plant system would have a payback between 3-4 years.

(iii) Feed material drying and preheating

The off-gases from the furnace leave at about 900–1200°C, carrying about 20% of input energy. This waste heat available in off-gases can be effectively recovered and reused. Waste heat recovery from off-gases can be used in preheating of input scrap material. A ferro alloys plant can also utilize the waste heat for drying and preheating of feed material. Apart from having an attractive payback on investment, the dryer will help in reducing the GHG emissions as well.

6.3 Steel melting industry

(i) Efficient charge preparation and charging

The raw material must be weighed and arranged on the melt floor near to furnace initiating the melting activity. Charge must be free from sand, dirt and oil/grease. Rusty scraps not only take more time to melt but also contain less metal per charge. Efficient scrap charging system in the furnace will lead to less electricity consumption. It will save on the heat cycle time consuming less electricity. The potential energy saving is estimated to range between 5-10 percent of the present electricity consumption.

(ii) Efficient furnace operation

The units do not follow standards operating procedures and are operated crudely. There are many tips to ensure efficient furnace operation such as:

- Always run the furnace with full power. This not only reduces batch duration but also improves energy efficiency.
- Use lid mechanism for furnace crucible, radiation heat loss accounts for 4–6 percent input energy.
- Reduce interruptions by locating spectro-testing lab near to melt shop to avoid waiting time for chemical analysis.
- Avoid unnecessary super-heating of molten metal. Superheating by 50°C can increase furnace specific energy consumption by 25 kWh per tonne.

(iii) Replacement by IGBT type induction furnace

Many of the steel melting industries use SCR type furnaces. Replacing SCR-based induction furnace with IGBT type induction furnace would help in reducing SEC level. The potential energy saving could range between 15–20 percent. The investment for IGBT furnace is expected to pay back within one year on account of energy saving alone.

(iv) Retrofit of lid mechanism for furnace crucible

All induction furnaces use crucible for melting. The mouth of crucible is kept open during operation, resulting in substantial radiation losses (6-8 percent of total energy input). Retrofitting induction furnace crucible with lid mechanism will lead to an energy saving of up to 3 percent. The saving would depend on the size of crucible and operating practices. The investment in the lid mechanism is expected to be paid back within a few months.

6.4 Steel Re-rolling Mills

(i) Replacement of rewound motors

Motor burn-out is not a rare phenomenon in foundries, this is a result of number of factors including power quality, overloading, etc. Rewinding of motors is the cheapest solution followed, but it results in a drop in efficiency of motors between 5-7 percent. It is better to replace old motors which have undergone rewinding two or more times. The old rewound motors may be replaced with energy efficient motors (IE3/IE4 efficiency class). This would result in significant energy savings with payback period of 2 to 3 years.

(ii) Replacing inefficient pumps with energy efficient pumps

The pumps installed colling water in the rolling mill for continuous casting machine as well as to cool the roughing, intermediate and finishing mill rollers are inefficient, old and not able to pump the desired flow. It is better to replace the old inefficient pumps with new energy efficient pumps which consume less power and deliver a better flowrate of water. Energy savings in replacing the old with new pumps are about 15-25 percent and the investment yields a payback with a year or two.

(iii) Replacing old inefficient compressors with energy efficient compressors

Plants use old inefficient compressors (more than 15 years old) which consume high power delivering low compressed air i.e. the specific power consumption (kW/cfm) of these compressors is high. Replacing the old compressors with new energy efficient permanent magnet synchronous motor (PMSM) compressors will lead to lower specific power consumption.