# Hot-charging sequence critical analysis for steel bar plant for Pollution control and Energy Optimization -A case study

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**Abstract- Temperature is the main process variable needed for every operation in hot rolling process for all value addition activity and can be considered as main variable also to control pollution.. It is a tool for the steel hot rolling plant to improve profitability, environment and productivity by controlling the process energy balance by its sequences optimization. In the steel rolling plant the importance of thermal or temperature energy is very high and as the main constitute, which consume energy and destroy the environment also. The Hot-charging system is a new development and its critical analysis for process energy optimization and energy cost also improve the rolling plant energy efficiency, save the working atmosphere of the plant and environment both.**

**Keywords – Hot-charging system, Rolling processes energy optimization, Pollution control, Energy balance.**

## I. INTRODUCTION

Industry contributes directly and indirectly (through consumed electricity) about 37% of the global greenhouse gas emissions, of which over 80% is from energy use. Historically, industrial energy-efficiency improvement rates have typically been around 1%/ year [11]. Global steel industry with production of 1,129 Mt in 2005 emits 2,200 to 2,500 $MtCO_2$ or about 6% to 7% of global anthropogenic emissions. Total energy-related industrial emissions have grown by65% since 1971[7]. China and India have high primary energy intensity compared to the other countries [5].

The different types of rolling mill such as rolling-forging mill, plate mill and wire rod plant are developed to produce different finished products easily and to capture the market with fast production and productivity [13]. In a wire rod and bar rolling plant processes, the aim of energy conservation and saving can be achieved by reduced resource consumption of process energy and by efficient use of plant installation and utility [12]. The wastages or losses may be reduced by proper and efficient machinery and tooling and by the advanced manufacturing techniques [3]. The different shaped raw materials for rolling mill like net shape slab for plate, compact beam blank production for beam etc. is also developed, so reduce the energy, cost and length of manufacturing process [9].

The hot rolled material unlike cold-rolled sheets, heavy plates, pipes, sections and other steel products are seldom used as hot rolled, for final products, but they are manufactured into machine parts after undergoing one or more stages of so-called post-processing such as heat treatment, forging and wire drawing. The steelmaker takes care, regarding these products for good processes and fulfillment of required properties after the processing [12].

The costs of the post-processing is sometimes several times the price of the hot-rolled steel material, so it is increasingly important to reduce the total energy cost from the steel material to final product. The hot charging is a best way to reduce the energy cost and improve the product quality at the same time.

## II. LITERATURE REVIEW

In the hot charge technique for round rolling, the billets are delivered for hot rolling in the wire rod or bar mill after they exit the casting unit but before they lose all their heat [1]. The main feature and advantages of hot charging technique are:

- Energy savings,
- Decreasing billet inventory / yard space
- Reducing production cycle time
- Billet surface quality defects prevention during the cooling process.

The different work has been done to take advantage of hot charging in the rolling, like buffer soaking pit, hot tunnel, hot charging in the rolling plant from mini steel plant, etc. done [3]. To obtain an optimum condition, the mini steel plant scheduled is a way to get maximum hot charge and alloy steel production is planned in a manner that it cast during time when mill is not working and in case of rolling mill failure the reheating furnace is also provided as buffer. The hot charging system should plan in a manner to reduce life cycle costing of manufacturing costs [6].

In manufacturing processes design a major portion of cost are developed due to losses, these losses are due to variations in various functions of organization like manufacturing, personnel, finance, purchasing, etc. The plant operation with minimum break-down delays and miss-roll helps to obtained maximum hot charging and at a maximum billet temperature, so optimum product quality may developed at minimum energy costs [2]. The amount of energy needed for the hot-rolling can be reduced by lowering the working temperature and optimizing the rolling speed and pass design, which might involve a reduction in the total number of passes used in the rolling operation [11]. Such changes would require optimization of the characteristics of the production process during the design of the technology, and that in turn would entail a large volume of preliminary evaluation and calculation [7].

## III. MANUFACTURING COSTS AND LIFE CYCLE COSTING

The product design and then manufacturing cannot limit only to the development of a functional product, but include consideration of parts, manufacturing, assembly, life cycle cost of manufacturing and other functions [6]. In a good product design manufacturability and life cycle costing are important considerations on which the success of product depend. Delivering a high-quality product at low cost involve engineering, economics, statistics and management [1]. The production cost can easily control and planned from design phase of product and manufacturing processes [5]. The hot charging system is a way to obtain optimum quality by optimum rolling temperature, optimum speed and tension and finally by optimum reduction [9]. The **Fig.1** represents a common hot charging system for a steel rolling plant [8].

Fig.1 Hot charging system for steel plant [8]

## IV. ENERGY CONSERVATION AND ENERGY OPTIMIZATION IN STEEL ROLLING PLANTS

Energy conservation implies reducing the physical consumption of energy resources per unit output [8]. The main options for energy conservation are more efficient energy use in production processes and reduction in the losses during energy distribution [11]. The energy efficiency of steel rolling plant can be further improved by mathematically modeling the heating and rolling of the metal and using the results to create algorithms and systems for controlling the energy-saving technologies that are introduced [6].From the viewpoint of instrumentation and process control, however, it is felt that there are certain limitations to the cost reduction and quality enhancement by optimizing the conditions (equipment and operation conditions) of individual production processes[10]. In this situation, efforts should be oriented toward optimization of process conditions encompassing plural sequential processes, or multi-processes [12].

## V. IMPORTANCE OF POLLUTION CONTROL FOR HOT CHARGING

The **Table-1** represents the intensity of pollution emission by 5 developing country of steel production and **Table-2** represents the saving potential by best and optimum practices. The accelerating environmental consciousness of individuals, companies, and government serve as a driver for manufacturers to focus attention on the environmental performance of their operations. The CO2 emission-intensity indicators are derived by applying emission factors to the energy components of the energy-intensity indicators [7]. Hence, the CO2 emission-intensity indicator will depend not only on the process energy efficiency, but also on the energy resource consumed.

Table-1 Energy use and carbon dioxide emissions from the steel industry of five developing countries [7].

| Country | Primary energy use (PJ) | Primary energy intensity (GJ/t) | Carbon dioxide emissions (MtC) | Share of total country carbon dioxide emissions (%) |
|---|---|---|---|---|
| Brazil | 578 | 23.1 | 9.1 | 13 |
| China | 3576 | 36.7 | 104.0 | 12 |
| India | 775 | 37.3 | 20.4 | 8 |
| Mexico | 274 | 22.6 | 5.1 | 6 |
| South Africa | 387 | 44.4 | 9.6 | 12 |

Table-2 Potential energy savings and carbon dioxide emissions reductions using optimum and best practice technologies.

| | | | |
|---|---|---|---|
| Primary energy intensity | 36.7 GJ/t | Carbon dioxide intensity | 0.87 tC/t |
| Best practice energy intensity | 20.2 GJ/t | Best practice $CO_2$ intensity | 0.43 tC/t |
| Actual energy consumption | 3502 PJ | Actual $CO_2$ emissions | 82.7 MtC |
| Best practice energy consumption | 1927 PJ | Best practice $CO_2$ emissions | 45.8 MtC |
| Potential savings | 1575 PJ (45%) | Potential savings | 36.9 MtC (45%) |

The CO2 emission-intensity indicator consists of three components: direct, utilities and external [7]. The direct emission intensity considers emissions from sources. The utilities emission-intensity component takes into account emissions from facilities that supply utilities (steam, water, etc.) that are located outside of the process itself but are within the boundary of the plant. This ensures the CO2 emission-intensity indicators for the processes depend only on the technologies and practices within the process area boundary. When comparing plants, the actual emission factors for the production of the utilities at the plant being considered must be used because the facilities providing the utilities are within the plant boundary [4]. The emission factors for fuel (coal, carbon, coke, natural gas, oil, coke oven gas, blast furnace gas, BOF gas) are derived from the carbon content of the fuel [7].

## VI. ENERGY EFFICIENCY AND ENERGY BALANCE

Energy is present in numerous forms such as thermal, chemical, mechanical, magnetic and nuclear. The energy is applied in a controlled way by means of machinery and tooling. The human energy is used for controlling the machine, to check the work piece or to load and unload parts [3]. The conversion efficiency of less than 100% indicate that conversion of energy is less than perfect and some losses may be occurred during conversion process. The 100% efficiency indicates a perfect conversion with no friction or other irreversibility [4]. The law of energy conservation state that the net energy transfers during a process is equal to the change in the energy content of the system. The way to obtain ideal efficiency is to obtain energy balance of all main equipment of processes [10]. In some organization like steel plant, a huge energy loss is developed due to large energy imbalance.

The energy balance is carried out in the operation and the process design stage. It is carried out from design stage to operation stage in complete process. It helps to understand the patterns of energy consumption and suggest means for the conservation of energy [5]. An energy balance is required in steel plant to obtained optimum conditions. The energy balance principle is based on losses recovering equipment, employed during process operations like heat exchanger or cooler or recuperator etc. [2]. These losses are mainly reduced due to maintaining of ideal parts size during operations, by maintaining the temperature during process or energy recover from flue gases of furnaces. The hot charging system can be used to maintain energy balance of a steel rolling plant, if follows the best energy techniques as in Table-3.

Fig. 2 Rolled finished products.

Table-3Best Steel techniques-Energy consumption

| S.N. | Process | Energy consumption |
|---|---|---|
| 1 | Iron making | 12.7-18.6 GJ/Ton |
| 2 | Steel making | 3.9-5.0 GJ/Ton |
| 3 | Casting | 1.2-3.2GJ/Ton |
| 4 | Hot rolling | 2.3-5.4 GJ/Ton |
| 5 | Cold rolling | 1.6-2.8 GJ/Ton |
| | Total | 20.7-37.8 GJ/Ton |

## VII. CASE STUDY OF HOT CHARGED WIRE ROD/BAR PLANT

The following case study demonstrates the importance of temperature control during rolling with hot charging system. In a wire rod plant due to high fuel and energy cost the importance of energy optimization is very high. The steel wire rod/bar plant are suitable for hot charging to save energy resource, environment pollution and life cycle costing by proper temperature control only. Although the plant layout is optimum, the plant quality, economic and environment results are not satisfactory due to temperature and performance variation. The heat-cascading systems, where waste heat from one industry is used by another, are a promising and suitable cross-industry option for saving of energy [2]. The **Fig.** 2 represents the finished products of a wire rod and bar mill.

The main problem in steel rolling plant of reducing reheating energy for rolled steel, which account about 1.1 MBtu/ton or 60% of total energy input of the plant [12]. The hot charging system can save about 75% of this heat input. Also, the steel industry emits about tons of carbon emission annually, which includes energy losses also. The temperature optimization during rolling process by hot charging to the rolling plant can reduce these energy and environment losses also. The temperature to which the billets are heated can be lowered by shortening the heating time, which reduces oxidation losses of the metal in the furnace and makes it possible to also reduce fuel consumption. The main problem in steel rolling plant of reducing reheating energy for rolled steel, which account about 1.1 MBtu/ton or 60% of total energy input of the plant [11]. The hot charging system can save about 75% of this heat input. Also, the steel industry emits about tons of carbon emission annually, which includes energy losses also. The temperature optimization during rolling process by hot charging to the rolling plant can reduce these energy and environment losses also. The temperature to which the billets are heated can be lowered by shortening the heating time, which reduces oxidation losses of the metal in the furnace and makes it possible to also reduce fuel consumption.

The unit consumption of electric power for the rolling operation can be decreased by increasing the temperature of the metal being rolled, but this conflict with the above-stated requirement of lowering the temperature to which the billet is heated in order to decrease fuel consumption. Taking all of the above into account, it is necessary to minimize the unit consumption of the different types of energy carriers that are used while simultaneously taking into account their effects on one another [13].

## VIII. METHODOLOGY

The **Fig. 3** showed the complete methodology of the case study to optimize the hot charging system by temperature control rolling from furnace to material dispatch. The methodology is considered the importance of hot charging system success and its contribution in steer rolling plant energy cost control.

The main criteria and object of the hot-charging system can be obtained by following objectives-

- Improve efficiency and reduce the total cost of producing and using energy sources through the use of energy-saving technologies and equipment and optimizing the structure of the fuel-energy balance
- Minimize the techno genic effects of the energy sector on the environment
- Develop a system for government regulation of energy-conservation efforts based on evaluation of the energy efficiency of energy users.

The **Table-4** data shows the energy consumption data for hot rolling process for different energy forms

Table-4 Total hot rolling Energy consumption

| S.N. | Rolling Process Functional area | Standard Energy consumption |
|---|---|---|
| 1 | Reheating | 1.2.-1.8 GJ/Ton |
| 2 | Electrical | 0.35-1.9GJ/Ton |
| 3 | Hydraulic /Pneumatic | 0.05-0,1GJ/Ton |
| | Total hot rolling Energy consumption | 1.6-3.8 GJ/Ton |

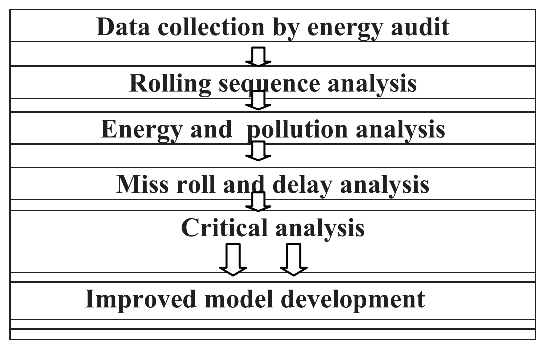


Fig. 3 Methodology

## IX. DATA COLLECTION:

The data are collected as in the detailed energy audit so the rolling process energy cost may reduce by optimum hot charging and to carry out rolling process at optimum temperature. The hot charging system data are collected for analyzing the hot charging % in the rolling mill. The increasing trend of hot charging % in 5 year data represents a hope to maximize it and save the valuable energy input and so the environment. The energy data of fuel energy and electricity consumption, miss-roll and delays are also summarized for the 5 years. The environmental factors such as lighting, noise control and air conditioning support for consistent performance in rolling environment which is affected by high temperature, dust and noise. The **Table-5** represents the mill production data for various grades and the responsible causes of delays and miss rolls.

Table-5 Plant 5 year data collection with responsible causes

| Month of Year-2006-2011 | Total Miss Roll | | | Reasons | | | |
|---|---|---|---|---|---|---|---|
| | Alloy Steel | Mild Steel | Stainless steel | Operational | Mechanical | Electrical and Electronics | Others |
| January/year | 3.6 | 1.7 | 2.2 | 36% | 17% | 12% | 35% |
| February/year | 3.6 | 1.7 | 2.3 | 39.11% | 18.31 | 13.40% | 29.18% |
| March/year | 3.7 | 1.8 | 2.1 | 39.80% | 20.03 | 12.63% | 27.54% |
| April/year | 3.5 | 1.7 | 2.5 | 39.45% | 12.21 | 12.50% | 35.39% |
| May/year | 3.5 | 1.6 | 2.6 | 39.90% | 18.34 | 11.79% | 29.97% |
| June/year | 3.7 | 1.8 | 2.7 | 39.09% | 16.22% | 5.47% | 39.22% |
| July/year | 3.7 | 1.8 | 2.8 | 39.80% | 16.34% | 8.63% | 35.23% |
| August/year | 3.6 | 1.8 | 2.4 | 38.38% | 18.44% | 12.13% | 30.66% |
| September/year | 3.8 | 1.9 | 2.3 | 38.77% | 17.31% | 12.24% | 31.64% |
| October/year | 3.7 | 1.7 | 2.1 | 39.80% | 14.22% | 9.10% | 36.88% |
| November/year | 3.7 | 1.7 | 2.2 | 17% | 15.23% | 25% | 42.77% |
| December/year | 3.8 | 1.8 | 2.5 | 18.5% | 15.22% | 25.16% | 41.12% |
| Average/year | 3.658333 | 1.75 | 2.4 | 36% | 17% | 13% | 34% |

## X. ROLLING SEQUENCE ANALYSIS:

The plant various operation sequences are depends on plant layout and equipment like mill, shears etc. The plant analysis indicates that there are too many stands causes high energy consumption and low productivity also. It is very difficult to control tolerances with too many stands. The energy analysis start with the energy consumption data collected for one year as shown in **Fig.4.**

## XI. ENERGY AND POLLUTION ANALYSIS:

The steel rolling process is an energy intensive process. It is also known the production of 1 ton of steel under domestic conditions requires an energy input from 30 to 40 GJ [15]. This is definitely too much, given that the heat consumption in a well prospering steel mill only slightly exceeds 20 GJ [1]. The power and pollution emission are also analyzed as shown in **Fig.5**.

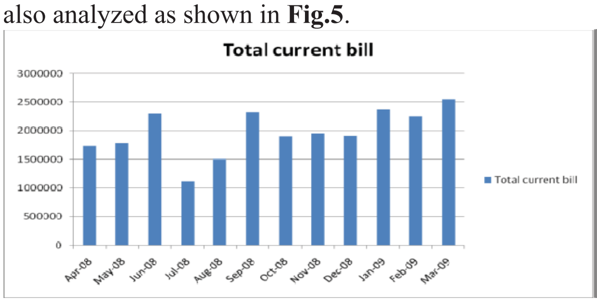


Fig.4. Monthly Electricity consumption for plant

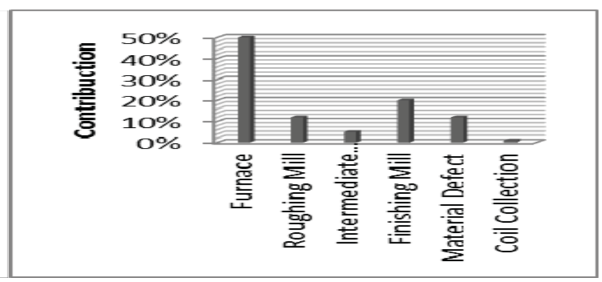


Fig.5 Diagram for 5 year emission losses.

## XII. DELAY AND MISS-ROLL ANALYSIS:

The hot charging system in a steel rolling plant faced many difficulties due to billet handing problem and not proper scheduling with the mini steel plant. The production data analysis of plant's 5 years, delay indicate the critical area, where maximum losses were developed. The Pareto principles state that a few contributors or causes are responsible or account for major cost of failure, defects or delay. These few contributors are needed to be identifying so that improvement can be concentrated on those vital areas. The **Fig.6** analyses the delays and **Fig.7** analyses the miss-roll due to various functions.

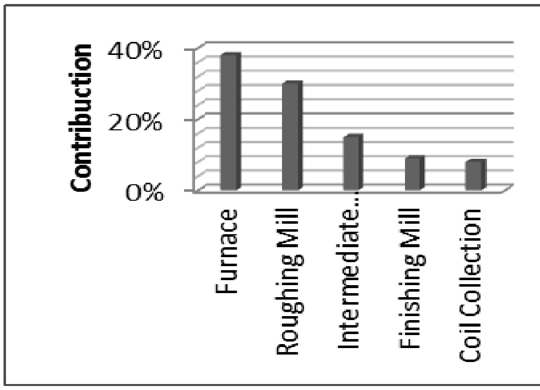


Fig.6 Diagram for 5 Years Delay

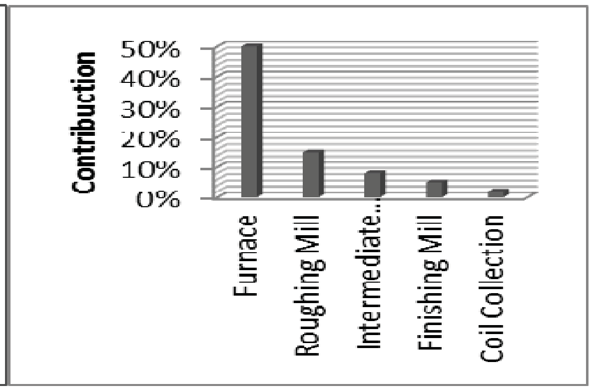


Fig.7 Diagram for 5 Years Miss Rolls

## XIII. CRITICAL ANALYSIS OF WIRE ROD FUNCTIONAL AREAS:

The fuel is main source of carbon emission in the steel plant. The critical analysis object is to use hot charging as a tool to control the rod temperature from roughing mill to finishing section to optimise the temperature as required to develop quality with optimum energy consumption. The optimum energy consumption and efficiency, automatically optimizes the pollution emission. To increase plant yields and productivity in a bar plant needed close tolerance and optimum set-up is required for energy conservation by hot charging system. The fuel saving is depend on the percentage of hot charging and cold charging billet temperature. The hot charging of billet with cold charging also helps to improve reheating furnace efficiency and burner efficiency. The furnace soaking zone can be used without any firing and burner's flame length also increased due to increased furnace inlet temperature. The hot charged billet also increased soaking zone efficiency with partial hot charging or along with cold charging. An optimized thermal handling system is needed to obtain 100% hot charging. The hot billet charging in the reheat furnace results in shorter reheating and soaking time, better heating efficiency. The critical analysis indicates temperature as main factor or variable which causes the delay, miss-roll and emission**.**

## XIV. IMPROVED MODEL DEVELOPMENT

The improved model of rolling process with hot charging can be obtained with temperature control of the rolled stock. The**Table-6** represents the **improved model** of reduction in furnace fuel Consumption of rolling reheat furnace by hot-charging. The temperature optimization of rolled material, control the whole manufacturing or rolling process, it is the temperature which governs the rolling load, quality, maintenance and other losses. In rolling mill the inline temperature monitor and control at finishing, optimized the energy efficiency by speed control.

## XV. RESULTS

The improved model of hot charging of billet system work in a manner so maximum inlet billet temperature at furnace obtained and at roughing mill rolled at minimum possible hot rolling temperature, by high speed controlled rolling at intermediate and finishing mill with controlled cooling system a desired and equalizing temperature can be obtained at the laying head by speed-temperature control system. The hot charging of billet can be used with structural steels, valve steel, tools steels and high speed grades etc.

## XVI. HOT CHARGING TEMPERATURE OPTIMIZATION

The higher hot charging temperature is controlled by rolling process batch optimization and scheduling. The higher hot charging temperature is only obtained by delay and miss-roll free rolling and good rolling practices help to optimize the hot charging.

## XVII. CONCLUSION

The **Fig.8** shows the increasing trend of hot charging in the plant. The metallurgical transformation in the crystal structure takes place as the material cools, which, depending on the specific chemistry of the material, typically is in between 750° and 860°C. Additionally, the mechanical properties of the final product depend to some degree to the temperature of the final rolling pass. To avoid the heat loss in case of rolling plant breakdown or failure, a system of soaking pit can be used. These socking pit are actually roller tables with in suitable covers and when rolling plant breakdown will be over than billet from soaking pit can be transferred in the reheating furnace.

Table-6 improved model of % reduction in furnace fuel

| S. N. | Charging temp. at furnace inlet | Reduction in furnace oil consumption | Reduction in emission |
|---|---|---|---|
| | 650°C | 50% | 30% |
| 2 | 700°C | 55% | 33% |
| 3 | 750°C | 60% | 38% |
| 4 | 800°C | 65% | 43% |
| 5 | 850°C | 70% | 48% |
| 6 | 900°C | 75% | 54% |
| 7 | 950°C | 80% | 60% |
| 8 | 1000°C | 85% | 67% |
| 9 | 1050°C | 90% | 75% |

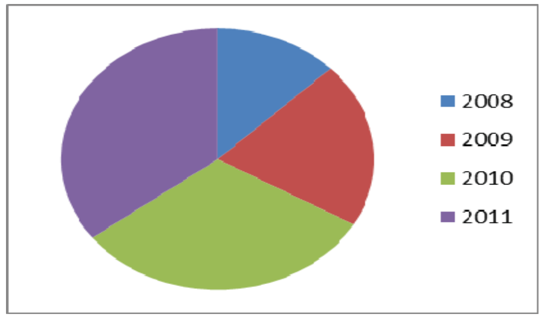


Fig.8 Diagram showing increase % of hot charge

A different socking pit system can be used to store the hot charging billet during rolling plant shut down also. Despite operational problems remarkable improvements in yield, energy consumption and operating and energy cost will be developed. A well-insulated heat retention tunnel near troche cutting at cold charging can also be developed to store 40/50Tons of billets. These heat tunnels can also use as preheating chamber of reheat furnace by providing burner in the tunnel to maintained or increase the billet temperature. These tunnels have recuperated to save the exhaust gas heat. The tunnel is act as pre-soaking, equalizing and preheating zone. By hot charging a significant improvement in yield and quality of rolling mill is obtained and processing energy optimization will be developed and remarkable increase in the production capacity.

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