Critical analysis of a steel wire rod plant Processes for Energy Optimization -A case study

Modi A.
Department I. P Engineering
SGSITS, Indore, M.P., India

Hindolia D.A.
Principal, JNCT, Bhopal M.P. India

Abstract- Energy is needed in the wire rod plant processes for any value addition activity to develop the finished product. The increased energy costs and an uncertain steel markets have created the demand for a system in the steel plant, to utilizes the rolling process waste heat, or improve rolling process so that next further processing may be avoided for rolled product.. The process energy optimization is a tool to improve profitability, environment and productivity of an organization. In a wire rod plant processes, the aim of energy saving can be achieved by reduced resource consumption and by efficient use of plant installation like reheating furnace, mills and utility. A case study is used to illustrate the rolling processes energy optimization and to demonstrate its applicability.

Keywords – Energy optimization, Steel wire rod plant, Critical analysis.

I. INTRODUCTION

The steel plant is considered as backbone in the industrial growth of any nation. The steel plant are included in five energy-intensive industrial subsectors life chemical, petroleum, paper and cement industry, which accounts for the bulk of industrial energy consumption and related carbon dioxide emission[7]. India is fifth in world's steel production [9]. Industrial sector is the largest user of energy in India and many parts of the world. In India the steel plant energy cost is high about 30% of total manufacturing cost in compared to abroad be around 20% [14]. Energy-intensive industries in developing economies, offer significant energy-saving potential owing to the technology gap as well as lower operating efficiency [1].

The steel rolling plant throughout the world uses conventional or manual and modern or automatic system or technology and equipments and follows the same approach for plant improvement. The success of any manufacturing organization depends on its energy consumption, its cost and its total environment losses [16]. The rolling is sequence of various operations [12]. The energy is essential in one or other form, for obtaining the maximum customer satisfaction and for value addition in the product and process, [10]. Efforts are made for improvements in steel plants by introducing modern equipment and its operating systems [2]. For designing energy optimized process to maximize the production and to reduce the losses, the knowledge with experience of that area is essential [9].

The wastages or losses may be reduced by proper and efficient machinery and tooling and by human skill efficient management [15]. The volatile energy cost and limited resources also force for rolling plant optimization [1]. While there is general consensus on the purpose of energy optimization i.e., improvement of energy efficiency and reduction of energy cost, different points of view exist about the way to achieve the goal [3]. The energy optimization techniques not only help to develop new economic source of energy source but control the losses [15]. The critical analysis of rolling process helps to identify the losses areas and their causes [8]. The cost of energy conservation is always less than the cost of energy production [2]. By this paper a methodology will be developed for steel wire rod rolling mill for process energy optimization and to develop a robust steel rolling plant with energy considerations.

II. PROBLEM FORMULATION

The steel rolling plants consumes high energy and create pollution also [9]. In rolling different types of internal and surface defects are developed and defect free rolling is not an easy task in present environment and varying condition of parameters. The steel rolling mills are the most economical and high productive metal forming process to obtained the different shapes and sizes [14]. The steel plant involves many complex and integrated system and

processes [8]. In a steel plant, many improvements were done which aims finally for reduction in plant energy consumption, by help of change in manufacturing process and its design and modification of equipment or rolling heat utilization to improve its mechanical properties etc. [6]. For a country like India who depends mainly on oil import, the wastage on energy result into heavy loss of foreign exchange [5]. In rolling mills, wastage of energy found in the form of miss-roll, scrap, scale-losses, rework and changed design or improvements [7]. The problem of interrupted power supply and high raw material and energy cost also increased the problem criticality [15].
In this competitive world cost competitiveness is very essential and increasing energy cost is alarming [9]. The most important in obtaining finished products are increasing the productivity of the mills, improving the quality indices of the rolled products, increasing usable output, and making more efficient use of the existing equipment [13].

III. ENERGY OPTIMIZATION IN STEEL ROLLINGPLANT

Rolling is most widely used metal working process because of its high productivity and uniform finished product quality. To obtain finished product different steps and operation are needed. More than half of the total energy is used in industries to operate various energy using machineries [4]. In a process industry like steel rolling plants energy optimization applies, wise use of energy to get more output for money spends. A system approach is preferred than the component approach [3]. The conventional rolling plants and high failure rate both on quantity and quality basis open a path for improvements. Furthermore, the cost of post-processing after hot rolling is several times than the cost of rolled materials [11]. The energy optimization is a means to determine wastefulness or losses of the manufacturing system [1]. The energy optimization of rolling plant is an economic way of plant improvement by reducing energy losses of processes [13].
The optimization in steel rolling plant can actually base on economic, energy and environment criteria or considerations [1]. The product energy cost reduction is also a way for energy and environment optimization [9]. The scope of improvements and energy conservation, energy mix, availability and reliability of the energy source are other aims of energy optimization and can be obtain with suitable equipment, trained personnel and team work only [13]. Energy conservation is a cost-effective approach for any energy optimization program that can be implemented in industrial activities [7].

IV. CRITICAL ANALYSIS

The target values of parameters to develop the desired performance of the product in field condition are very important. The critical analysis helps to identify and remove adverse effect or risk on product or process. The variability in performance and associated loss areas and product manufacturability aspect with plant safety and pollution are the other aim of critical analysis. The steel rolling plant critical analysis required knowledge of different branches of engineering to identify the responsible factors and failure mode.

V. METHODOLOGY

To optimize the rolling processes for energy consumption, the complete sequence of operations are to be optimized in the order of severity, delay and miss roll analysis. The energy audit helps in data collection. In steel hot rolling plant the main failure analysis or delay analysis helps to identify the critical area or area of maximum influence. The critical analysis is essential to provide the optimum performance of output. The Pareto diagram is a diagnostic tool commonly used for separating the vital few causes that account for a dominant share of loss. To apply Pareto principle the symptoms of defects, delay and cost are analyzed and frequency and intensity are formulated. The data critical analysis by Fish bone diagram identifies the critical area from where the improvement will start in the plant and causes of failures. The Taguchi goal-post method is then used for process optimization.

VI. CASE STUDY OF A WIRE ROD PLAT

The wire rod plant is designed to produce quality steel product. The wire rods coil in diameters 5.5 to 14mm is produced at high speed in no-twist block mill with minimum quality deviations. A steel wire rod plant is considered as optimum production system due to heavy coil weight say up to 2/4 tons and uniform finished products quality and microstructure [16]. In a wire rod plant due to high fuel and energy consumption and cost the importance of energy optimization is also very high in comparison to conventional plant or modern bar mill [9].

VII. DATA COLLECTION

The steel wire rod plant energy consumption information and data of 5 year energy consumption, production, miss roll and furnace oil consumption etc. are collected. The data give a trend of energy consumption per unit of finished products or specific energy consumption. The data collected are represented by the Pareto diagram in **Fig.1 & 2**.

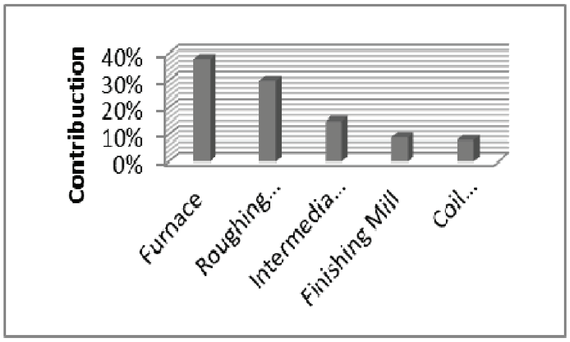

Fig.1 Pareto Diagram for 5 Years Miss rolls

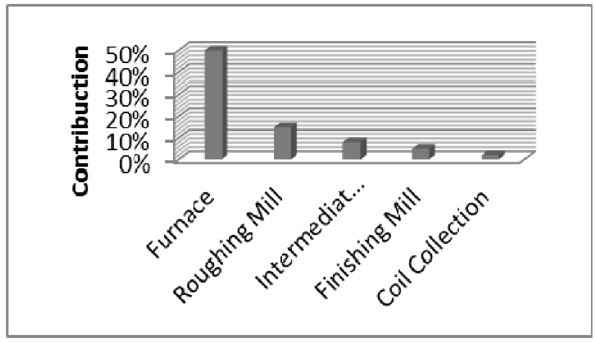

Fig.2 Pareto Diagram for 5 Years Delays

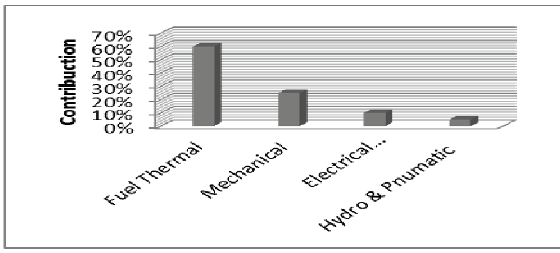

Fig.3 Pareto Diagram for Energy Consumption

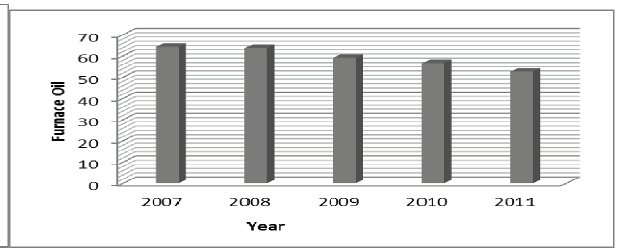

Fig.4 Pareto Diagram for 5 Years F.oil consumption

VIII. IDENTIFICATION OF CRITICAL AREA

The data collected indicate that in a steel wire rod plant the furnace consumed more than 50% energy as thermal energy and 5 year furnace oil consumption data are also collected to determine the performance trend as in Fig.3 & 4. The **table-1** indicates the five year ranking of rolling plant's main areas and furnace is the major culprit.

Table: 1. Steel wire rod plant yearly ranking for Delays (Mech. Elect. Gen. & Prod.) and miss roll

Year	Furnace	Roughing	Intermediate	Finishing	Coil collection
2007	I	III	IV	II	V
2008	I	II	IV	III	V
2009	I	II	IV	III	V
2010	I	III	IV	II	V
2011	I	II	IV	III	V

To determine furnace condition the reading of furnace temperature at various positions is also taken in **table-2.** The furnace delays and contribution of furnace in total quality rejection and miss-roll data of 5 years are also collected and analyzed.

Table: 2. Steel wire rod plant Reheating Furnace Data

Oxygen%	**12%**	**Ex. Gas Temp.**	**500 º C**	**Temp. Variation in Billet Length.**	**10º C**
Oil preheat Temperature	**75 º C**	**Recuperator Inlet Temp.**	**Ambient**	**Temp. Varied. from Billet to Billet**	**15º C**
Oil in Water (S. Tank)	**2%**	**Recuperator Outlet Temp.**	**300 º C**	**Average Temp. of F. Wall Outer**	**120º C**

IX. DATA CRITICAL ANALYSIS

The steel wire rod rolling plant 5 years data analysis indicate that furnace is critical area to control energy losses and energy efficiency of plant's equipment as started with steel plant manufacturing system energy audit analysis. The **Fig. 5** represents the fishbone diagram of furnace problem. The cause and effect diagram or Fish Bone Diagram of Steel Rolling Plant Furnace problems determines the failure areas due to man, machine, material and process and their possible reasons. If a Pareto diagram is used in conjunction with a Fishbone diagram it reveals defects in terms of criticality in a more effective way and contribution of both tools is highest effective for Furnace and rolling plant's other problems.

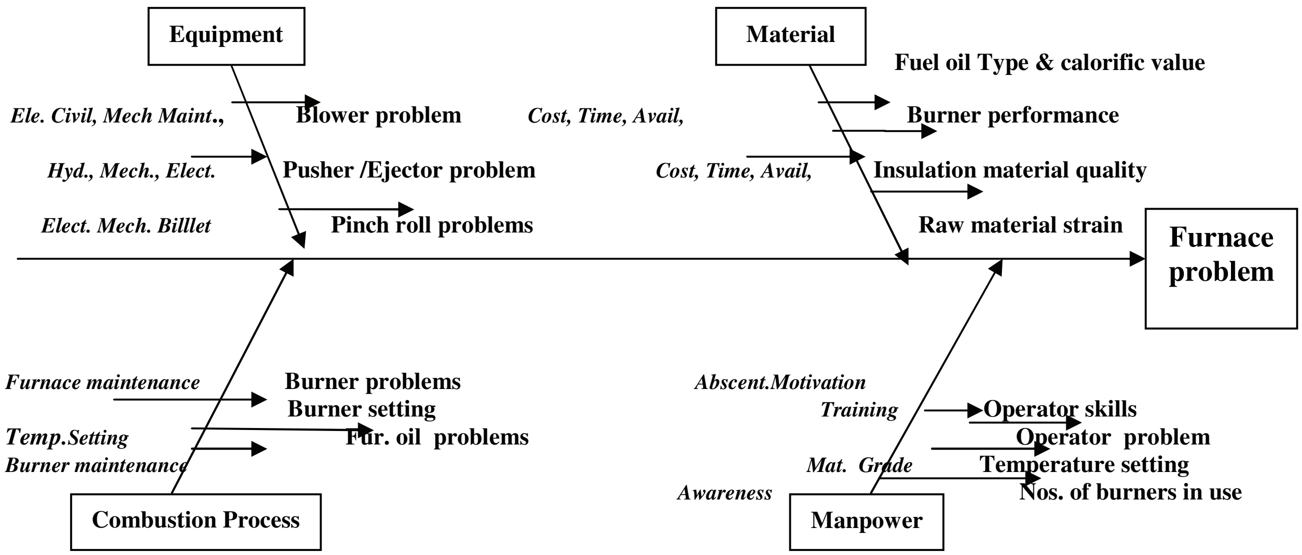

Fig.5 Fish Bone Diagram of Steel Rolling Plant Furnace problems.

X. ENERGY OPTIMIZED IMPROVED MODEL FOR STEEL PLANT REHEAT FURNACE

To implement energy optimized processes for furnace the Taguchi concept is applied to developed the P diagram or product/process diagram as in Fig.6. In the p diagram the control factors are design specifications and noise factors are difficult or impossible to control factors. The control factors are set in a manner that minimizes the noise effect.

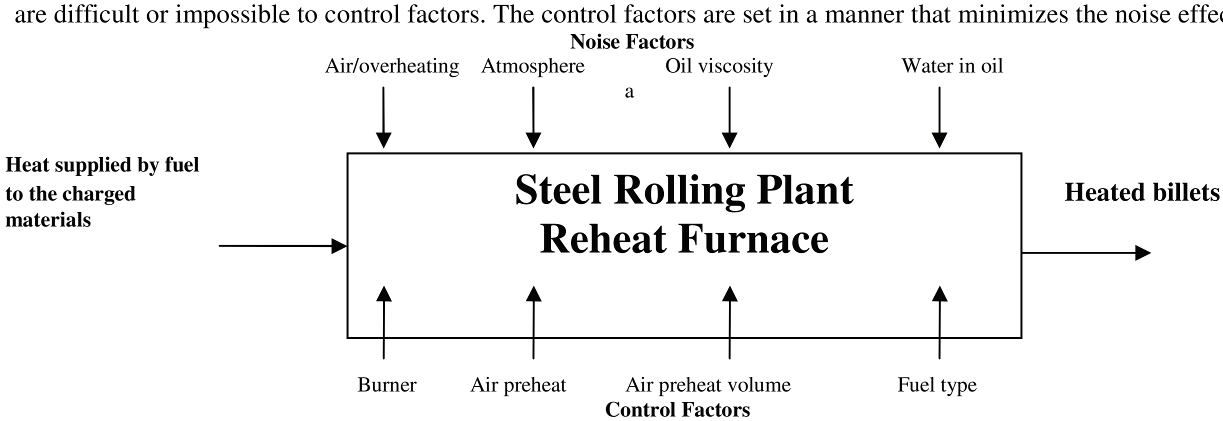

FIG.6.TAGUCHI MODEL FOR IMPROVEMENT OF REHEATING FURNACE.

Table-3: Proposals for Improved model | Table-4 Furnace combustion energy optimization

S.N.	Furnace combustion energy optimization	S.N.	LOSSES AREA	EXPECTED SAVING
1	Combustion with minimum excess air.	I	Dry flue gas loss	
2	Proper heat distribution.	I-A	By excess air control	09%
3	Operating at the desired temperature	I-B	By stack loss	08%
4	Reducing heat losses of furnace openings	II	Latent heat loss	
5	Minimizing wall losses.		By control water in air/fuel	02%
6	Control of furnace draught.	III	Incomplete combustion	
7	Optimum capacity utilization.	III-A	Low oil temperature at burner	02.5%
8	Waste heat recovery of flue gases.	III-B	Recuperator problems	10%
		IV	Furnace insulation problems	02.5%
		V	By Automatic control	08%

			Total	**42%**

XI. PROPOSALS FOR ENERGY OPTIMIZATION

The various technical factors which affect fuel economy in industrial furnaces to develop the improved model are considered in **table-4.**The proposals are also financially analyzed for payback of investment and the rate of return. The proposals are only for current furnace problems.

XII. RESULTS

The final outcome of the improved model is shown in **Fig.7**. The expected change in furnace fuel consumption indicates the importance of the study and act as motivational factor. The saving results also indicate the potential of energy optimization and approaches used and similar results can be obtained in other types of energy like electrical, hydraulic and pneumatic energy of the manufacturing system.

The **table-5**. indicate the expected performance improvements as -

Table-5 Results:Furnace process energy optimization

Energy consumption	**Old** 189 Units/Ton-	**New** 159 Units/Ton-
Miss Roll%	4.1	2.0
Delay%	11	04
Pollution(**o** %)	20	10
Maintenance%	5	2

XIII. NEXT IMPROVED MODEL DEVELOPMENT

The improved model developed a potential of 42% saving for reheat furnace fuel. This is a substantial saving and indicates the importance of energy optimization in the steel rolling plant, which consumes high energy. The existence of steel rolling plant is now governed by energy optimized process, as this the way to survive them. The scope of optimization in the wire rod plant, similar to any steel rolling plant are very vast and start from design stage to finished product supply and optimum output or results.

In a country like India the importance of energy optimized process is very essential due to high energy consumption and wastages in comparison to other countries for same product. The furnace is very critical area for rolling plant and need many proposals for improvements and optimization. Once the reheating furnace losses are controlled the next step will be, determination of the next critical area where maximum energy consumed and which contributes for maximum losses of energy, quality, miss-roll and delays.

XIV. ROBUST FEEDBACK SYSTEM

The post-processing cost is best measure or feedback system of the improved model of the steel rolling plant. The success of improved model depends on feedback from the next users or customers. A Robust feedback system can be developed by both types of corrective actions, e.g. first make a corrective change and if it is not sufficient than change the system, so process of continuous improvement may not stop to reduce process energy consumption.

XV. CONCLUSION

At the time when Indian and world’s steel rolling plant are suffering from capital shortage the increased energy losses and wastage are alarming. The improved model opens a door to reduced energy consumption in the Indian working environment, which is an essential need of time. The steel rolling plant’s processes energy optimization is the up gradation of outdated technology and an essential step to stay in the market and to meet competiveness. The aim of energy cost reduction, along with maximum yields can be obtained by improved model.

The Taguchi methods are one of the best approaches for optimization but has drawback to guess or clues the real problems or week area. Pareto and Fishbone diagram are used to determine the area where urgent action is required, so limitation of Taguchi method is eliminated. The reheating furnace processes optimization reduces plant’s specific energy consumption and a major step towards plant’s rolling processes energy optimization. The other losses of furnace like scale loss and process control loss are automatically minimized. The energy optimization of rolling process also causes to reduce miss-roll, delays and quality rejection. The above work is a step towards plant’s losses control and then optimization. It is developed for realistic and competitive manufacturing system, to meet demands of continuous improvement.

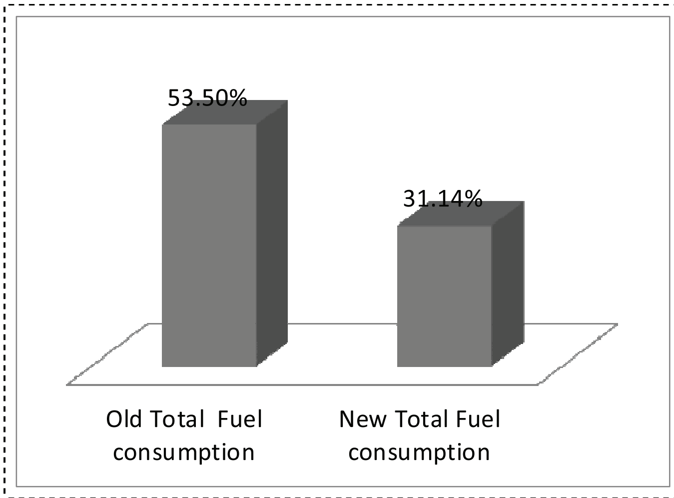

Fig.7. Proposed Improved model Fuel saving

REFERENCES

[1] Cao Jian-guoa,, Liu Si-jia , Zhang Jie , Song Ping, Yan Tan-li , Zhou Yi-zhong,. "ASR work roll shifting strategy for schedule-free rolling in hot wide strip mills." Journal of Materials Processing Technology 211 (2011) 1768– 1775

[2] D.D. Wang, A.K. Tieu, F.G. de Boer, B. Ma, W.Y.D. Yuen., "Toward a heuristic optimum design of rolling schedules for tandem cold rolling mills" Engineering Applications of Artificial Intelligence 13 (2000) 397±406 www.elsevier.com/locate/engappai

[3] Deshpande V.S., Modak J.P. "Maintenance strategy for tilting table of rolling mill based on reliability considerations?" International Journal of Reliability Engineering and System Safety 80 (2003) 1–18

[4] Greis P., "Radical changes in the steel industry-some technical trends," Metallurgical Plant and Technology, D-4000 Düsseldorf Germany, 17(1), 5/94, 26-42.

[5] Graus W., Blomen E., "Global Energy efficiency improvement in long term; a demand-and supply-side perspective," International Journal of Energy Efficiency, Paper No. DOI:10.1007/s.12053-010-9097-z.

[6] Hauck A., "Modernization of existing wire rod mill," Metallurgical Plant and Technology, D-4000 Düsseldorf Germany, 10(1), 5/87, 56-66.

[7] Kejun J., " Energy efficiency improvement in China: a significant progress for 11'Th five year plan," International Journal of Energy Efficiency, Paper No. DOI:10.1007/s.12053-009-9054-7.

[8] Kumar S.,Chandra U., "Production engineering design,"Chapter13,Satya Prakashan, New Delhi-110005

[9] PCRA,"Fuel economy in furnaces and waste recovery," Petroleum conservation research association, New Delhi,

[10] P. van Hullen and W. U. Amerling, "Plan for modernization of a section mill," *Chern. Metally,* No. 4, 40–45.

[11] P al S.K., Linkens D.A., "Temperature distribution in steel during hot rolling: pseudo-bond graph view," Simulation Modelling Practice and Theory 10 (2002) 69–85 www.elsevier.com/locate/simpat

[12] Raju R., Akshyalingam K., "Energy audit: A case study in a railway workshop," Industrial Engineering Journal XXXIV (6), 30-32.

[13] Singhal K.K., "Energy efficiency in steel industry and clean development mechanism (CDM)," International convention on clean, green and sustainable technologies in iron and steel making at Bhubaneswar.

[14] Shirizly A., John G. Zhang L. Cui Z.S., "C The effect of lubrication on mill loads during hot rolling of low carbon steel strips", Journal of Materials Processing Technology 97 (2000) 61±68

[15] Tang a L, Liu j,, Rong A, Yang Z., "C A multiple traveling salesman problem model for hot rolling scheduling in Shanghai Baoshan Iron & Steel Complex,", European Journal of Operational Research 124 (2000) 267±282 www.elsevier.com/locate/dsw

[16] Zhuchkov S.M., Palamar D.G., Leshchenko A.L., "New technical and technological innovations being used in reconstruction of continuous section and rod mills," Metallurgist vol. 50, nos 9-10, UDC 621.771.25:06.004.68