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Steel Industries and Six Sigma

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Abstract: *This paper aims to address the problems that are facing a large steel company in a Developing country like India regarding defects in the end product. Initially in this paper the attention is drawn towards the proportion of the energy consumed by Indian steel industries and thereby their importance of improving energy efficiency in this sector. It is mentioned that the efforts for improving the process for energy efficient performance are already being done as a primary focus. The focus of this paper is on defect reduction which can be a small but very impactful measure when considered in a long term. By applying Six Sigma principles, the firm can identify the current situation that operations are in. Six Sigma DMAIC methodologies can be used in the project to determine the project's CTQ characteristics. It defines the possible causes as a first step of implementation and then identifying the probable causes goes to the sources of variation. Paper can be useful for any company that needs to find the most cost efficient way to improve and utilize its resources through the reduction of defects.*
Keywords-Six sigma, DMAIC, steel Industries

1. INTRODUCTION

Indian industrial sectors such as Iron & Steel and Cement manufacture products for equitable growth but at the same time consume huge amounts of energy. India's total final energy consumption was estimated at 449.27Mtoe of which the industrial sectors consumed about 30%. The Iron & Steel sector is one of the most energy intensive manufacturing industries, consuming about 25% of the total industrial energy consumption. The total GHG emissions in India were assessed at 1904.73 MtCO2, and 38% (719.31 MtCO2) and 22% (412.55 MtCO2) were from electricity generation and industry sectors respectively. The Indian Iron and Steel sector contributed to about 117.32 MtCO2 or 6.2%.

Figure 1 shows the sectoral share of total industrial energy consumption in India and the world. Among the major industries the Iron and Steel sector is among the most energy intensive. Globally, the sector consumes almost 21% of total industrial energy consumption.

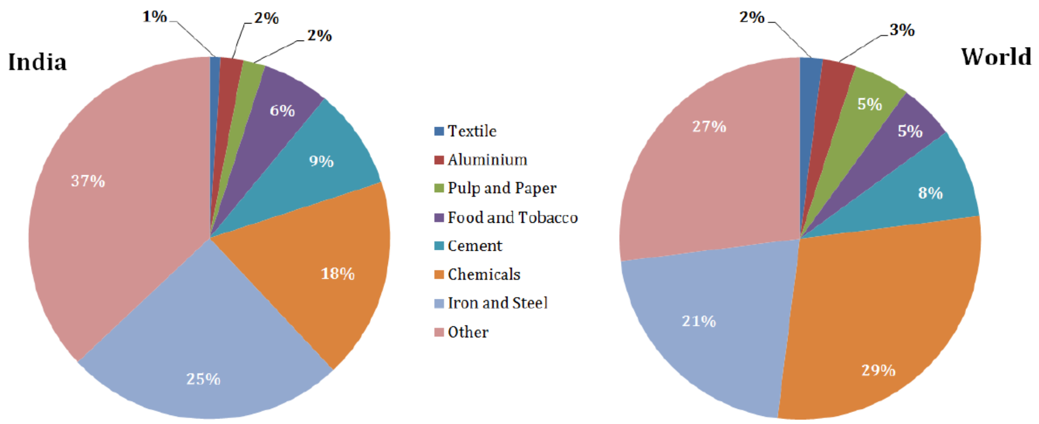

Fig.1 Sectoral energy consumption (2009), India (150Mtoe) and World (3019 Mtoe)

The Indian Iron and Steel industry is vital to the nation's development efforts and to support the required rapid economic growth. Steel finds its application in a wide range of sectors such as automobile, power, machine goods, and infrastructure. Energy efficiency and low carbon growth have emerged as key pathways to reduce the nation's energy intensity and emissions intensity. The industry has taken several initiatives to conserve energy at each sub process by adopting best technologies and innovative process operations or the usage of alternate materials.

The Bureau of Energy Efficiency (BEE) under the Ministry of Power (MoP) has been entrusted with the responsibility of implementing various strategic policy mechanisms specifically to enhance the energy efficiency. The National Steel Policy has been framed by the Ministry of Steel, Government of India for long-term objectives of improving production, consumption, quality and techno-economic efficiency, environmental and social sustainability. The Central Pollution Control Board (CPCB) has set norms for permissible emissions and other hazardous pollutants from several industrial sectors.

The Indian industrial sectors have worked hard amidst several challenges in the development of the Indian economy. The industry needs to be supported with rigorous research and development studies focusing on technology, economics and policy aspects. The research findings will be disseminated among industries, policy making bodies, financial institutions and related stakeholders to enable them to contribute to the development of a globally competitive industry by enhancing energy efficiency while increasing environmental sustainability.

Designated Consumers (DCs) in the Iron and Steel industry are plants that consume more than 30,000 tonnes of oil equivalent of energy per annum. The estimated list has 67 DCs in the Iron and Steel Sector.

Table 1: Minimum annual energy consumption and estimated number of DCs

SECTOR	Minimum annual energy consumption for the DC (tonnes of oil equivalent - toe)	No. of DCs
Cement	30,000	85
Iron and Steel	30,000	67
Aluminium	7,500	10
Fertiliser	30,000	29
Pulp and Paper	30,000	31
Textiles	3,000	90
Chlor-Alkali	12,000	22
Thermal Power Plants	30,000	144

2. NATIONAL STEEL POLICY

From the report on energy efficiency in Indian steel industry (1), the steel sector is one of the important sectors which drive the country's economic growth. Countries have strongly relied on domestic steel production during their journey towards economic development. The National Steel Policy 2012 aims to attract investment in Indian steel sector from both domestic and foreign sources to reach the ambitious goal of crude steel production capacity of 300 Mt with a production level of 275 Mt by 2025-26. One more objective is to ensure easy availability of inputs and necessary infrastructure to achieve a projected ambitious production level. The key goals of NSP 2012 are depicted in Table 2 and Table 3.

Table 2: Raw Material Requirement at 7 and 8% GDP

Raw Material Requirement		
At 7% GDP	**2016-17**	**2025-26**
Iron Ore	203	392
Coking Coal	89	173
Non-coking coal	27.8	66.2
PCI	4.5	9
Met Coke(including captive)	67.4	89.2
At 8% GDP	**2016-17**	**2025-26**
Iron Ore	215.4	452
Coking Coal	94.2	200
Non-coking coal	30.4	78
PCI	4.8	10.4
Met Coke(Including Captive)	72.5	153.9

Table 3: Parametric goal towards 2025-26 from the existing level

Parameter/Area	Unit	Existing Level	Strategic Goal/Projection by 2025-26
Specific Energy Consumption	GCal/tcs	6.3	4.5
CO_2 emissions	T CO2/tcs	2.5	2.0
Material Efficiency	%	93.5	98.0
Specific Make up Water Consumption (Works excluding power plant)	T/tcs	3.3	2.0
Utilization of BOF slag	%	30	100
Share of continuous cast production	%	70.0	95.0
BF Productivity	T/m3/Day	1.9	2.8
BOF productivity	No. of Heats/ Converter/year	7800	12000
R&D expenditure/turnover	%	0.2	1.5

3. BACKGROUND

3.1. Status of Indian Iron and Steel Sector

Globally, the Indian Iron and steel sector is the fourth largest crude steel producer and expected to become second largest in near future. World crude steel production during 2012 was estimated to 1547.8 Million tonnes, China at the top with 716 Mt followed by Japan, USA and India (Figure 2). Figure 3 illustrates the historical crude steel production in comparison with annual capacity. The trend indicates that the sector has observed a steady performance with capacity utilisation between 85-90%.

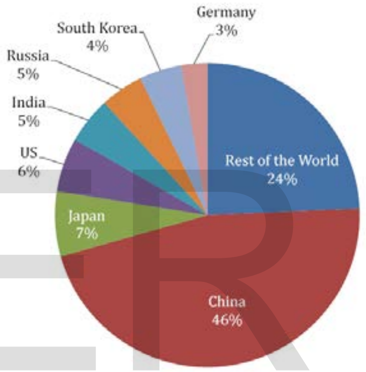

Figure 2: World Crude Steel Production in 2012

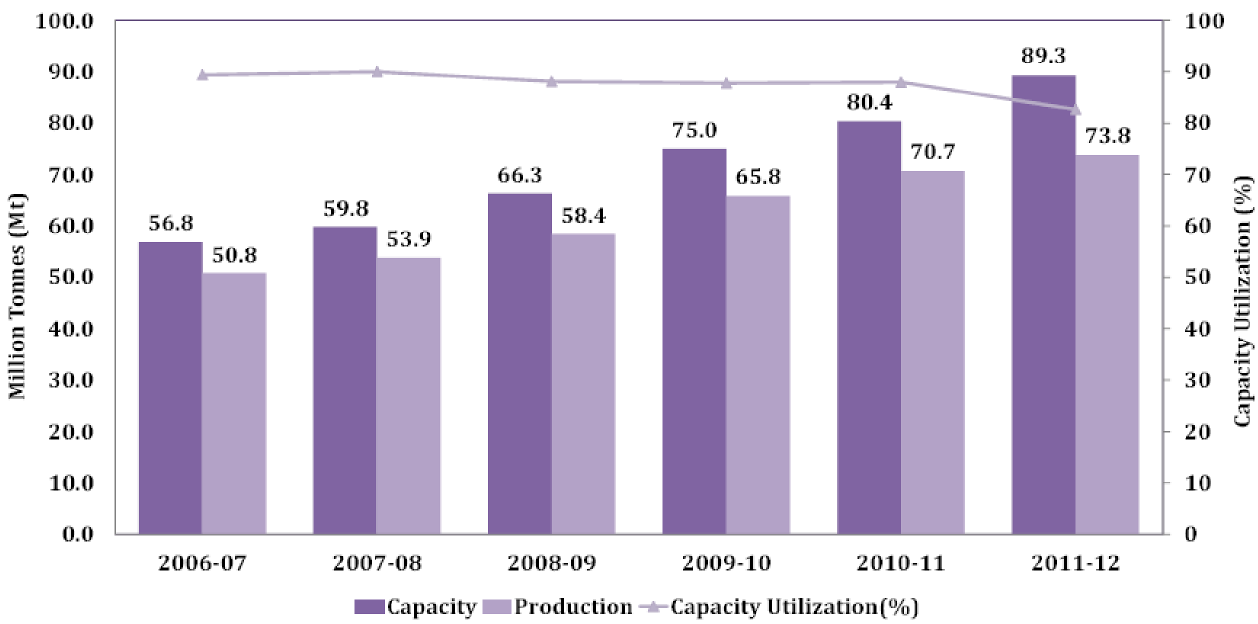

Figure 3: India's crude steel production, capacity and Capacity

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3.2. Energy Consumption

Review of Energy Efficiency in Iron and Steel Plants

Reduction of hematite and magnetite ores to iron and thereafter to steel involves highly energy intensive processes. Coal, electricity and natural gas are most widely used energy sources in this sector. The efficiency of steelmaking varies with the kind of production route, type of iron ore and coal used, the steel product mix, operation control technology, and material efficiency. The iron and steel sector follows three major process routes in steel making. About 45% steel is produced by Blast Furnace – Basic Oxygen Furnace route, 24% and 31% by electrical furnace such as Arc furnace and Induction furnace routes respectively. It is observed that the blast furnace process is an energy intensive process and 48% of the total energy input in the BF-BOF route is used in blast furnace operations. Typically, the larger plants utilize the BF-BOF route while smaller plants have DRI-EAF, mini blast furnace and induction furnace processes.
The sub process wise energy consumption associated with the best available techniques in steel production shows blast furnace has large share.. The Best Available Technology (BAT) indicates the SEC of 16.4 GJ/tcs through BF-BOF route, 19.3 GJ/tcs by the smelt reduction (COREX)-BOF route, 19.0 GJ/tcs through coal based DRI-EAF route and 15.9 GJ/tcs in the gas based DRI-EAF route in 2009 (Table 4). In India, the average SEC from selected major steel plants was 27.3 GJ/t of crude steel. When compared to the best available technology, the current technology has an energy saving potential of about 35% without adjusting for variations in major operating parameters.

Table 4: SEC by different process routes

Process		BF-BOF (GJ/tcs)	Smelt Reduction-BOF (GJ/tcs)	Coal based DRI-EAF (GJ/tcs)	Gas based DRI-EAF (GJ/tcs)
Material Processing	Sintering	2.1	-	-	-
	Pelletizing	-	0.8	0.8	0.8
	Coking	1.0	-	-	-
Iron Making	BF	11.8	-	-	-
	Smelt Reduction	-	17.0	-	-
	DRI	-	-	12.6	9.5
Steel Making	BOF	1.0	1.0	-	-
	EAF	-	-	5.6	5.6
	Refining	0.4	0.4	-	-
	Continuous Casting	0.1	0.1	0.1	0.1
Total		16.4	19.3	19.0	15.9

3.3. Rejection rate analysis in steel industries

The quantity of rejection can be analysed from the research paper (2) where the simulation model is designed for reducing defects in a foundry. In this research Primary data includes the rejection rate of castings for the past few years and its major problem and causes which are obtained from Quality control reports and Rejection reports of an Indian Foundry. Secondary data are obtained from journals, literature survey and websites. Fig:4 Shows the rejection analysis of an Indian foundry which is having an average rejection of around 19.5 percentages and the permissible customer rejection as per ISO standard is 3.

Fig.4: Rejection rate for past five years in Autokast.

Also from a research paper (3), rejection analysis in one of the Indian foundry was done in this paper. The objective of this paper was to investigate the various forging defects that occur in a forging industry that causes high rejection rates in the components and this paper describes the remedial measures that can reduce these defects in the hot forging. The investigation was done with the help of quality assurance department within the industry. The various defects that occur in the components during forging are identified. The result indicates that the rejection rate in the company was more than five percent of the total productions made each month. The defects in the forged components includes the lapping, mismatch, scales, quench cracks, under filling etc.

From above data it is apparent average rejection rates in steel industries are significant. Various methods are adopted to reduce this rate. Following is the proposed method which is widely used in the industries.

3.3.1 Inspection Report for month July 2012 In One of the Indian Foundry

Table 5: inspection report by the QA department for month July

SR NO	Item	Quantity received		Quantity rejected		Total
		No	M Tonnes	No	M Tonnes	
1	80 bevel pinion	119	16.07	118	15.93	1
2	786 crank shaft gear	155	17.83	155	17.83	0
3	254 saddle	101	11.11	62	6.82	39
4	833 coupling	42	3.23	39	3	3
5	819 pylon	20	0.59	18	0.53	2
6	621 saddle	10	1.55	10	1.55	0
7	807 internal axle arm	58	10.21	58	10.21	0
8	794 cam shaft	55	3.96	55	3.96	0
9	256 crank shaft	39	2.34	39	2.34	0
10	496 rod wheel arm	180	7.38	180	7.38	0
11	175 con rod	635	25.84	549	22.34	86
12	855 gear	25	11.25	20	9	5
13	55 valve body	200	21.4	200	21.4	0
14	263 cam shaft gear	81	11.34	81	11.34	0
15	837 gear	55	18.15	54	17.82	1
16	814 companion flange	63	4.28	63	4.28	0
17	779 gear	250	14.88	250	14.88	0
18	958 mf centre	37	4.51	37	4.51	0
19	959 mf centre	15	1.38	15	1.38	0
20	960 mf end	15	1.58	15	1.58	0
21	527 d cage	113	2.6	111	2.55	2
22	127 valve body	200	36.6	200	36.6	0
23	219 mb cap	285	19.38	281	19.38	4
24	272 gear	45	8.28	45	8.28	0
Total		**2798**	**255.74**	**2655**	**244.89**	**143**

4. METHODOLOGY

A method to implement six sigma is mainly bases on two techniques DMAIC & DMAVD.DMAIC is used to improve already existing process on the other hand the DMAVD technique is adopted for the products or processes which are under design stage. In our paper the main focus is on DMAIC technique as it is used for an existing process is tell industries. As per this technique following activities are undertaken-

Define the problem
Measure the variation and its sources
Analyse the sources of variation
Implement the solutions for variation reduction
Control the process so as to get desired results as per the implemented solution

4.1. Six sigma background

The background of six sigma can be best understood from the research paper (4). Six Sigma is recognized as a problem-solving method that uses quality and statistical tools for basic process improvements. Six Sigma is now widely accepted as a highly performing strategy for driving defects out of a company's quality system. Six Sigma is defined as a set of statistical tools adopted within the quality management to construct a framework for process improvement. Statistical tools identify the main quality indicator which is the parts per million (PPM) of non-conforming products. Achieving a Six Sigma level means to have a process that generates outputs with 3.4 defective PPM. Six Sigma is also defined as a multifaceted, customer-oriented, structured, systematic, proactive and quantitative philosophical approach for business improvement to increase quality, speed the deliveries up and reduce costs.
The literature suggests the DMAIC and DMAVD as the two most common methodologies to implement Six Sigma. In a recent paper, Talankar et al. (2011) et al. introduced the Six Sigma-based methodology for non-formal service sectors, the framework which explores the quality needs and maps them to define measure, analyze, improve and control (DMAIC) methodology. Eisenhower (2008) used DMAIC methodology to show that quality performance data expressed as the usual percentage defect rate can be converted into a wide range of vital, Six Sigma metrics and that these can be used to develop insight into a company's quality system. The literature further shows that there are several variations for DMAIC (even if it remains the most commonly adopted methodology) such as Project-DMAIC (P-DMAIC), Enterprise-DMAIC (E-DMAIC) and DMAIC Report (DMAICR). The selection of the methodology, in the end, depends on the specific requirements. In the present work, Project-DMAIC (P-DMAIC) has been used.

This project follows the five step methodology used in the Six Sigma process.

5. Application of six sigma define, measure, analyze, improve, control methodology

5.1. Define phase

The objective of this phase was to clearly understand and articulate the current reality and the desired situation. A clear definition of the problem is the first step of a six sigma roadmap.

5.1.1 Defining the problem After historical data analysis and assessing the present situation, the following problems are identified for the company

5.1.2 Voice of Customer

The next step was to determine CTQ (Critical to Quality Characteristics) for the project. The tool used for the purpose was VOC (Voice of Customer).

5.1.3. Process Mapping

This was done to understand the process in detail. This included the macro as well as micro level of process mapping. The macro level mapping was done using SIPOC (suppliers, Inputs, Process, Output, Customers) concept. SIPOC provides important inputs to monitor products and services provision for customer satisfaction

5.2. Measure

Under this phase of project, the aim was to identify the root cause of the problem, narrow down to few potential causes, set measurement for the Project CTQs and potential causes, establishing a measuring system that have less inbuilt variability so as it could capture the variation in the process. Thus step followed were:
1 Defining all possible causes
2 CTQ Matrix
3 Defining Performance Parameters
4 CTQs Identification for Measurement System Analysis (MSA)
5 MSA for Coil Buildup.

5.2.1. Defining possible causes

Cause and effect analysis technique can be used to identify all the causes. It is used to prioritize the potential causes. Failure Mode Effect Analysis can also be used in capturing potential causes. This can be the outcome from a brainstorming session of the concerned managers.

5.3. Analysis

In this phase of the project the aim is to establish the base line of the project, its performance criteria by finalizing its target. .

5.4. Improvement

In this phase of project the aim was to validate the causes identified through data analysis done in analyze phase.

5.5. Control

Under this phase findings are summarized in a manner that will reflect in process variables for the sustenance of improvements. The deliverables of this phase were Development & Implementation of Control Plans, Institutionalizing Improvement and Monitoring are conducted. The problem statement is closely verified with implemented solutions.

6. SIX SIGMA IMPLEMENTATION REQUIREMENTS AND HURDLES

However to be able to implement the six sigma approach in the industry following are some of the important points to be taken into account also have t overcome the below discussed barriers-

4.1 Six sigma prerequisite:

- Strong support from Top Management and its involvement
- people should accept changes and should be ready to learn
- adequate and proper planning
- for the people to be aware of quality, workshops have to be organized regularly
- open discussions and involvement of all people regarding quality matters
- Understand and implement cross business proper definition of internal and external customers and thus a thorough attention to them.

4.2. Challenges in implementing six sigma:

- no adequate support from Top Management
- Resistance of people in organization for a change
- Lac of Planning, inadequate planning or sometimes improper planning
- Lack of Training
- Lack of participation in the talk regarding quality matters or not involving people at all level in the discussions
- Insulating organization from Cross business
- No proper definition of internal and external customers and thus not a thorough attention to them

5 Discussion

This paper suggests a very impactful way of energy efficient practice which is, unlike other sophisticated methods of resource energy saving, indirect method of efficient utilization of energy. As we already know defect generation not only cause the loss of money in terms of material but also loss of useful company space, time spent on decision regarding disposal or rework. Not only has this but it also led to lowering the employee morale and company reputation in a long term. Through reduction of defects company can save the energy consumed in the processing of such defective components in steel industries. And the saving is higher as the proportion of energy consumption in steel sector is considerable. The methods implemented at one place can successfully be implemented at other with minor modifications.

Also this paper gives initial definition and theory of six sigma based on grounded theory approach. Although Six Sigma builds off prior quality management practices and principles, it offers a new structure for improvement. The structural differences simultaneously promote both more control and exploration in improvement efforts. Some organizations may find benefit from the Six Sigma approach because it fits heir organizational needs better. Academics need to better understand Six Sigma so that they do not overhype it or too quickly dismiss it as nothing new. It proposes a rigorous base definition of Six Sigma from the literature and field study that can be used for further research. We differentiate Six Sigma from TQM and other quality management approaches.

7. REFERENCES

1. *"A Study of Energy Efficiency in the Indian Iron and Steel Industry"* by S. S. Krishnan Venkatesh Vunnam ,P. Shyam Sunder,J V Sunil ,A. Murali Ramakrishnan Center for Study of Science, Technology and Policy Bangalore, India
2. *"Reducing rejection rate of castings using Simulation Model"* by Binu Bose V, K N Anilkuma at International Journal of Innovative Research in Science, Engineering and Technology
3. *"Controlling Measures to Reduce Rejection Rate due to Forging Defects"* Aju Pius Thottungal, Sijo.M.T,Mechanical department, S.C.M.S.School of Engineering and Technology
4. *"Improvement process for rolling mill through the dmaic six sigma approach"* by Kunal Ganguly from MT Ghaziabad, UP, India, presented at International Journal for Quality research