A REVIEW: SUSTAINABILITY IN MANUFACTURING INDUSTRIES - CASE STUDY OF STEEL RE-ROLLING MILLS

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Abstract - The traditional manufacturing processes resulted in depletion of natural resources as well as created environmental pollution issues which were directly affecting the society. Sustainable development in manufacturing industries leads the way towards clean and green manufacturing. Sustainable manufacturing is emerging out as one of the most important area for environmental, economic, societal and technological changes in an industry. It has become the centre of research for the academicians, government and industries. The present paper reviews different areas of manufacturing were sustainable manufacturing has been applied. A case study of sustainable manufacturing in steel re-rolling mills has also been provided. The aim of this paper is to give a thought of application of sustainability in manufacturing.

Keywords – Sustainability, Energy, Environmental, Manufacturing, Steel Re-rolling, Key Performance Indicators.

I. INTRODUCTION

"Sustainable Manufacturing", these words are now a days at the top most level of research and has become a benchmark to be achieved for the industries. The companies who have achieved this target are having positive results towards product quality, market share and social image. Sustainability has become a global concern in context of manufacturing.

II. SUSTAINABLE MANUFACTURING

Sustainable manufacturing can be defined as creation of finishes goods that minimize negative impact on environment conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound. The main principle of sustainable manufacturing is to decrease materials use, energy consumption, reduce environmental pollution, and the creation of unwanted by-products while maintaining, or improving, the value of products to society and to organizations. Thus sustainable manufacturing is integration of three indicators economic, social and environmental. These three indicators are the base of the whole process. [1]

U.S. Department of Commerce defines sustainable manufacturing as " the creation of manufactures products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers are economically sound." [2]

The final destination of applications of sustainable manufacturing concept is to reduce environmental impact while benefiting the society.

III. METRICS

Evaluation of sustainability performance of the manufacturing processes and system is necessary by qualitative as well as quantitative metrics. The metrics so developed aims for improving decision making while optimizing the process. [3]

Singh et al. listed 41 sustainability indicators which are accepted globally. They restated that though all pillars are important, mostly single pillar is more focused. [4]
Hard work has been done towards simultaneous consideration of all the three pillars of sustainability in context of manufacturing processes and systems. Wanigarathne et la. [5], Jawahir and Dillon [6] recommended six major elements that affect sustainability of manufacturing processes. Manufacturing cost, energy consumption, waste management, environmental impact, personnel health and operator safety, out of which the later three are very tough to quantify.

IV. MAJOR MANUFACTURING IMPACT AREAS

For sustainability in manufacturing, two main points which are to be considered about manufacturing is “where” and “which” manufacturing process is carried out. The “where” emphasis the economic view point of manufacturing and “which” gives the overview of the process and material carried out for generating products. [7]

V. METAL MANUFACTURING

5.1 Casting

Casting process has highest negative impact on environment due production of oxide fumes, chemicals and melting of metal with fuel. Large quantity of water is used to carry out casting. Heat recovery technologies have increased the efficiency of the casting process resulting in reduction of green house gases in the atmosphere. The improved quality of binders and molding sand has decreased the machining and finishing steps through the production. Process simulation and improved thermal management has given a way for environment friendly process.[8,9,10,11]

5.2 Forming

Tooling and machine effectiveness are the major domains of improvement in forming process. Different technologies have been developed to decrease the material and energy requirement. Remanufacturing of tools with additive manufacturing process to decrease the tooling cost and to increase the effectiveness lead to decrease in usage of conventional tooling, were high energy was used. In an automobile case study, the research shows nearly saving of $250,000, 30 weeks of lead time and prevents large amount of CO$_2$ to be emitted to environment. Reusable dies and dies with protective coating increases the life of dies resulting in high economical savings. [12,13]

5.3 Metal Removal Processes

Metal removal processes are the subtractive manufacturing in which high amount of metal waste are produced in form of chips.

Scrap so produced is reused and recycled but it is not beneficial from environment point of view. Effective part design and process layout results in reduction of waste leading to less intrusion with environment. The different approaches like near dry machining, minimum quantity lubrication and alternative fluids such as liquid nitrogen must be considered for total life cycle assessment. Cryogenic cooling has efficiently enhanced the process sustainability for machining hard materials like nickel, cobalt and titanium alloys. [14,15,16]

5.4 Consolidated Manufacturing

Consolidation of different material results into new material with combined property of the consolidated materials.

Subtractive manufacturing removes the material from the stock material while additive manufacturing adds the material to form final product. Powder metallurgy and 3d printing are the examples of additive or blend manufacturing. Additive manufacturing though highly precise but uses high rate of energy with low production rate.

Technology like direct metal deposition helped in increasing the strength and acquires required properties of the material. Still additive manufacturing are in great concerned with respect to environment as large amount of energy is used in this process. [17,18]
VI. SUSTAINABILITY: STEEL RE-ROLLING MILLS [SRRM]

6.1 Steel Re-Rolling

Steel Re-rolling is the process of converting raw/processed steel into finished steel products by rolling and re-rolling them in their hot state into desired shapes such as bars, TMT rods [thermo-mechanically treated], sectional products and wires. A bulk of these products is used in the construction industry.

The production process in a typical SRRM unit begins with hot charging of raw billets, ingots or blooms in an oil-, coal- or gas fired re-heating furnace. Once the raw material achieves the desired temperature, it is manually or automatically pushed out into the rolling floor, where iron rollers (also called drums) are used to squeeze and stretch them into finished steel products. In the entire process, the re-heating furnace is central to efficient production.

![Steel Re-Rolling Process](image)

6.2 Steel Re-Rolling Sector in India

Initiating from 1928 till today the Indian SRRM Industry have covered upto 68% of the total production of non-flat steel products in the country. 80% of the total exports of bars are sourced from this secondary steel sector. It has also been estimated that the sector employs, directly and indirectly, about 400,000 people. These employees are a mix of skilled engineers, semi-skilled foremen and technicians, and unskilled shop-floor workers. [19,20]

6.3 Competency of Steel Re-Rolling Mill

Energy efficiency is always a highest priority issue in SRRM; the reasons for less energy efficient SRRM where listed by UNDP reports are:

- Outdated technologies and practices
- Low information and awareness levels on the developments in the sector.
- Inappropriateness of generic energy-efficient technologies (EETs) developed.
- Lack of incentives to cater to small-scale energy efficiency projects.
- Lack of experience in accessing external funds
- High investment costs of EETs
- Low research and engineering base and other institutional linkages.

In sum, a combination of low awareness, lack of technical capacity, and absence of incentives is inhibiting the Indian SRRM sector from achieving its full potential, both as a globally competitive powerhouse of finished steel products as well as a sustainable environmentally conscious industry. [19,20,21]
6.4 Metrics in SRRM

The metrics or the KPI's [key performance indicators] are the stepping stones for acquiring sustainability in manufacturing. There are large number of KPI which always causes complication for categorizing due to their independencies and dependencies over other indicators. Some of the KPI’s are categorized are shown in fig.2. [22]

![Figure 2 Key Performance Indicators](image)

6.5 Energy Consumption in SRRM

SRRM are the most energy consuming industries. Nearly 70% of energy in form of heat is consumed by reheating furnace, 20% by rolling mill and 10% by auxiliary machines as shown in fig.3. [19,23]

![Figure 3 Energy Consumption](image)

The thermal energy has the maximum energy share reaching upto 70% and remaining 30% is electrical energy as shown in fig.4.

![Figure 4 Energy Share](image)

6.6 Losses in SRRM

Losses in SRRM can broadly be distinguished by direct losses and indirect losses. [24,25]

The direct losses are:
- Improper combustion of fuel leads to increase in usage of fuel.
• Inaccurate furnace heating profile leads to more or less efficient heating of steel.
• Inaccuracy in temperature leads increase of usage of fuel.
• Incomplete combustion of fuel leads to increase in environment pollution

The indirect losses are:
• Inaccurate heating in furnace leads to
  – Scale formation
  – Decarburization
  – Surface melting
  – Shape distortion
• This leads to material losses resulting in increase of production cost.

6.7 Opportunities for energy efficient technologies

The reheating furnace and the roll mills are the target area as they are the highest energy consumers in whole process. [26,27,28]

11 Technology advances are developed for reheat furnaces all configured to reduce the consumption of thermal energy in furnaces.

i. High efficiency recuperator with improved furnace design.
ii. Technology for the use of coal based producer gas as fuel.
iii. Technology for the use of pulverized coal as fuel
iv. Technology for the use of biomass gas fuel.
v. Technology for the use of coal bed methane as fuel.
vi. Regenerative burner system
vii. Hot charging of continuous cast billets
viii. Top and bottom firing system
ix. Oxy-fuel combustion system
x. Walking hearth/beam furnace
xi. Direct rolling of continuous cast billets.

The top five technologies are low end technologies requiring less investment and energy saving ranges from 20% to 25%. The remaining six are high end technologies requiring more investment but energy saving ranges from 30% - 40%. [29,30,31]

The above said advancements were supported by 19 technology options for the rolling mill process, which focused on reducing electricity consumption. [19]

i. Crop length optimization
ii. Roller guide
iii. Spindle and couplings
iv. Antifriction roller bearings
v. Installation of Y-roller table
vi. Installation of tilting table
vii. Quenching and self-tempering of re-bars.
viii. Oval repeater
ix. No-twist block
x. Slit rolling
xi. Computerized roll pass design
xii. Lubrication technology
xiii. Cast in carbide rolls in conventional stands
xiv. Pre-stressed housing less stands
xv. Endless welding roll
xvi. Reactive power compensation
xvii. Energy efficient drives
xviii. High voltage AC motor

The installation of above technologies resulted increase of electrical energy saving from 2% to 12%. 
VII. CONCLUSION

Since lately, the ideas of sustainability has continuously advanced and has started getting worldwide consideration, also, organizations are under weight to have natural well disposed manufacturing, consequently, this paper gives an effort to have a short review towards the supportability and related issues.

Manufacturing sustainability is considered as an operation methodology same as agile manufacturing, lean manufacturing and business process reengineering. This idea causes association to have positive financial changes friendly to environment and society. In alternate words, naturally agreeable item and absolutely manageable inventory network and assembling framework causes association to decrease utilization of material and improve the business intensity.

In spite of the fact that there is plenty of investigation done on sustainable manufacturing in steel re-rolling mills, there is lack of development in small and medium scale industries which are the back bone of Indian economy. Heat loss, material loss and reduction of GHG gases through adoption of energy efficient technologies are the issues, which require more examination in future research.

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