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Green Manufacturing Approaches for the Foundry Sector

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Abstract: Green manufacturing is a sustainable approach, designed to use energy, water and other resources more efficiently thereby reducing the overall impact on the environment. Improved quality of life, better health conditions and diminished costs are other benefits. This paper focuses mainly on the foundry industry, as being very energy intensive, it offers immense scope for the application of green concepts. A case study conducted in a foundry in Tamil Nadu, gives an over view as to how green manufacturing can be made possible in the foundry industry. Each process involved in the foundry was analyzed using green concepts and alternatives and suggestions were made. Additional green strategies have also been discussed.

Introduction

In the present era, with global climate change and threats of resource scarcity, the energy dilemma is here to stay. The world faces an energy challenge with the production capacity lagging far behind an ascending demand, leading to diminished supplies and price rise. In order to prevent this global energy crisis from heading to a state of utter chaos, every sector, especially the field of manufacturing with its high pollution and resource consumption rates, must make a drastic effort towards significantly lowering its carbon footprint. One of the newer technologies that can be implemented to contain the energy situation to a great extent is Green Manufacturing (GM). Green Manufacturing is generically defined as elimination of waste by redefining the existing production process or system. Ergonomics, process redundancy and cost implications arising from faulty methods of producing goods are addressed by Green Manufacturing [1].

The Indian foundry industry is the fifth largest in the world [2]. There are atleast around 6,000 foundries in India. Nearly 90 percent of all foundries in India fall under the small and medium scale category and are located in clusters (The institute of Indian foundry men, 2013). Being highly energy intensive, it offers vast energy saving potential. With contemporary green technology innovations aided by Cleaner Production (CP) tools involving energy management and life cycle analysis, huge energy savings are realised [3]. Suggestion and implementation of green manufacturing and construction techniques in the foundry sector is the primary focus of this paper.

Energy Auditing

The foundry sector being energy intensive, energy auditing has to be done to determine the energy consumption and the effectiveness of the energy management system. These auditing activities have to go through the following set of procedures to obtain the best possible data which have been shown in Fig.1.

Fig.1. Energy auditing process

Data collection: Key areas within the complete process where energy is consumed in a foundry are identified, accounted and enlisted. This requires a thorough examination of all contributing factors wherein a true account of all energy consuming devices and establishments is enlisted. All balances of both materials and energy are checked for such as that of coal, cast iron, oil, etc., [4]. Each step in the overall process in the foundry as shown below in Fig.2, must be accounted for.

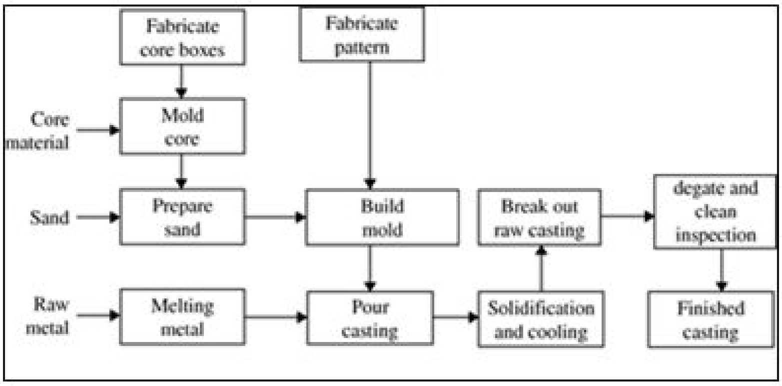

Fig.2. General Process layout for a Foundry (Source: Groover 1996 [5])

Measurement: This involves assigning numerical values to the amount of energy consumed in each process. This also includes the specific energy consumption of coal if with regard to a cupola furnace or the electricity consumed if with regard to an electrical inductor furnace.

Analysis: The data collected for each enlisted energy consuming source is compared to a theoretical analysis that would have been conceived during the setting up of the foundry.

Technical discussion: With better technology and guidelines being made for greener manufacturing, those principles are studied and compared to the current practices in foundries like the implementation of ISO 14000, ISO 14001, LEED, etc. The shortcomings of traditional foundry practices with modern technology and guidelines are attributed to the following reasons:

- Foundries being placed in remote locations
- Workforce being employed is unskilled
- The large expenses for setup and materials makes additional finance for upgrading unfeasible.
- Lack of awareness within foundries regarding better practices
- Lack of forums to educate on new, economical and greener technologies.

Conclusion and implementation: The processes that have been analyzed are enlisted with proper measures to reduce the carbon footprint while making them more economical and profitable for companies in the long run. Reuse of risers and gates cut off from the cast component or by preheating the crucible to decrease the loss of heat from the molten iron before being poured into the mold are possible innovations.

Implementing Green strategies in the Manufacturing Process

Data collected from the case study performed in a foundry in Tamil Nadu, was used in identifying areas for implementing green strategies. The findings have been discussed below.

Cupola Furnace: Cupola furnaces commonly used in most Indian foundries account for about 45% of the energy usage as depicted in Fig.3 making efficient cupola operation the key to saving energy.The shell of the furnace can be lined with refractory material, which increases its operating life. Radiation losses can be decreased by proper insulation, lid covers and exterior painting of the surface resulting in 5 -7% fuel savings [6]. This also prevents regular on-off operations which involve huge energy losses while compared to steady state operation. Coke usage should be minimized as its increases the amount of lime required for 'clean iron' and results in excess slag. Losses also occur due to impure charging materials as one pound of sand charged means two pounds of iron or steel not melted. Using a divided blast cupola decreases the energy consumption by 15% [7, 8].The furnace can be enriched with sufficient oxygen, which will aid better combustion and hence improve overall efficiency of the furnaces. A 4% oxygen enrichment improves the production rate by 25%. Introducing power monitoring devices to monitor overall energy consumption in foundries thus contributes to electricity savings upto10-15% [8]. Keeping the upper stack full is another viable method to utilize reheating options. Maximum charge levels increase preheating of metals and reduce coke usage. Varying stack levels also cause metallurgical variations; maintaining constant stack levels decreases metallurgical variations.

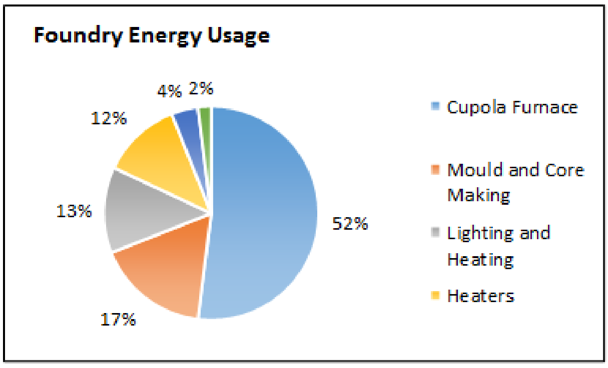

Fig.3. Energy distribution based on case study conducted in the foundry

Waste Heat Reduction: Significant area to ensure energy savings is reusing waste heat resulting from many foundry processes. Waste heat reuse has 15~20% energy saving potential. While new technology can prove costly in terms of expenditure and payback, simple approaches like directly recovering captured waste heat can be used. This can be performed by transporting heat between various combination conversions involving air and liquid mediums. Waste heat from melting operations can be utilised for core drying, shower water heating and for building heat. Waste heat can also be used for air-conditioning systems by serving as a heat engine. Lack of preheating charge increases energy required for melting by around 55-83 kWh per tonne.

Air Handling Systems: With emissions requirements being imposed on the metal-casting industry many foundries have been forced to put expensive air handling systems into place. However these systems being primitive consume up to 20% of the total energy needs of a foundry [8, 9]. Improving air handling systems by understanding the role of mass flows through ductwork, pressure drops across components, motor, fan and other machinery operating curves, and reusing existing fans, motors and other components to cut down on new installation costs, implementation of green principles with sufficient cost reduction can be ensured.

Mould and Core making: The developing of moulds and cores also utilises a large part of the overall energy. The efficiency of these processes can be improved by proper separation of impurities, water content moderation and replacing high firing capacity burners with numerous small firing capacity burners.

Melt Savings: Using the right kinds of scrap can help power savings in a huge way. Eliminating the non-metallic materials Melting savings can also be achieved by cleaning gates and risers of sand by either sand blasting or other methods. Proper cleaning is required otherwise large amount of sand from the moulds or dust when gates and risers are exposed to the environment will cause increase in slag formation causing some amount of heat used for melting the iron to be lost without purpose.
Through these changes and upgrades that have been proposed there is considerable improvement in the energy savings that could take place in a foundry and hence reduce the overall carbon footprint.

Other Green Strategies: Compressors are used to drive the machine tools and pneumatic equipment. But only 10-30% of the energy input is used as the balance 90-70% energy input is lost due to friction. Regular maintenance of the equipment can save 30% of the energy [10, 11]. Moreover optimum orientation, location, loading and pressure setting of the compressors are key factors to minimize the energy requirements.Also the longer dimensions of the storage houses should face east and west directions, to maximise collection of solar energy which will aid in pre-heating and thereby reduce dependence on fuels and other energy needs for the same. Replacing 40 W Light by T5 with 28 W Light and 100 W GLS bulb by 20 W CFL helps to conserve power by 40% [8].Other green strategies include the usage of vibratory feeder mechanisms and energy efficient motors into the furnace which will allow for controlled and even feed of raw materials helping for better melting efficiency and improving overall efficiency of the process. The benefits of the proposed green strategies are shown in Table 1.

Table1. Benefits with usage of proposed green modifications in foundries

Existing System	Blast Cupola Furnace	Bare Shell of Furnace	Unused Waste Heat	Compression Systems	40W T5, 100W GLS bulbs	Poor Oxygen Content in Furnace
Proposed Green Modification	Divided Blast Cupola Furnace	Refractory Linings and Paint Insulation	Reuse of waste Heat	Regular Maintenance	28W Light and 20W CFL bulbs	4% Oxygen enrichment
Benefits	15% energy consumption reduction	5-7 % fuel savings	15-20 % energy reduction	30% friction reduction	40 % energy consumption reduction	25% improvement in production rate

Sustainable Foundry Infrastructure

Apart from incorporating means to reduce the ecological footprint of the manufacturing processes, a major part of the expenses can reduced by implementing a sustainable infrastructure for foundries. This can be achieved by reducing the environmental impact of every factor in the life cycle of the buildings, namely, (1) the materials used, (2) the processes and construction approaches, (3) operation and, (4) demolition and recycling. This can be undertaken by using alternative building materials and construction techniques, modularization and energy efficient operation systems. Certain eco-friendly construction materials include:

- Pozzolana Blended cement consisting of fly ash substituted for cement (up to 35%) ensures a superior microstructure while saving energy by 20% with up to 35% less $C0_2$ emissions [12].
- Precast plank for flooring/roofing ensure 12% overall cost saving and 20% reduction in construction time [13].
- Calcium Silicate Bricks formed by compaction of siliceous waste sand, lime and fly ash has a higher strength and finish and using 30% less energy [14].
- Bamboo Mat Veneer Composite ensures 50% wood substitution with greater strength and durability [15].

All these construction improvements using modern green technology, can be assisted by selective waste management and industrial symbiosis in order to secure an even lower cost and energy requirement. Approaches like using aggregates from pulverised debris, sun drying of bricks, brick production from coal washery rejects and industrial mine waste, and salvaging of waste wood can be used. Aside from technological improvements, effective interfacing between people, processes, materials, equipment and information improves job-site efficiency and manageability. Also greater use of modularization, prefabrication, preassembly and off-site fabrication helps in improving resource efficiency and formulating designs for reuse and deconstruction.

Conclusion

The foundry industry in India can be described as one of the potentially largest industries present and has been established all over the country. Energy saving methods should be integrated with the foundries due to the rising costand dependence of energy in India. With processes such as melting and pouring being some of the main energy consuming processes, usage of experimentally proven approaches and technologically improved methods with the findings that have been provided in this paper, would help to make the practice greener with lesser use of resources and in the process the environmental impact would definitely reduce.The government, to encourage MSME (Micro, Small and Medium) foundries to shift to greener practices, can help with initial capital. Moreover due to lesser reach of technological advancements for these small scale industries, it would be very fruitful if they are made aware of better methods to produce castings which would not only prove better for the environment but also be economical and profitable in the long run.

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