SOME STUDIES ON ENERGY CONSUMPTIONS AND IDENTIFICATION OF SUITABLE ENERGY MANAGEMENT TECHNIQUES IN INDIAN FOUNDRY INDUSTRIES

Gajanan Patange (ME.)
Charotar University of Science and Technology, Changa, Gujarat, India
Mohan Khond (PhD)
College of Engineering, Pune, Maharashtra, India

Abstract

The Indian foundry industry is the second largest in the world. There are more than 6,000 foundries in India. Most foundries (nearly 90%) in India fall under the small and medium scale category and are located in clusters. The foundry industry is energy intensive and has an important role to play from an environmental point of view whilst seeking to develop and play an important role in the nation's continued economic development. In foundries energy accounting is necessary to determine where and how energy is being consumed and how efficient is the energy management system. There are many opportunities for improving energy efficiency in most foundries. Some of these, such as optimizing the efficiency of ancillary services can be achieved at minimal cost and make a valuable improvement to the bottom line. Reports from many foundries suggest that energy efficiency is one of the most significant cleaner production options still to be addressed in the industries. The study reveals that the two thirds of the energy consumed in a foundry is used for metal casting and holding operation. Considerable energy saving can be achieved by proper attention to this process with proper energy management. This paper presents a need of energy saving in Indian foundries. This gives an idea of the current energy consumption of the foundries, which can be compared with standard norms and can be used to implement in Indian foundries.

Keywords: (Foundry, environment, energy management, foundry energy audit)

1. Introduction

The Indian foundry industry is the second largest in the world. There are more than 6,000 foundries in India. Most foundries (nearly 90%) in India fall under the small and medium scale category and are located in clusters (The institute of Indian foundry men,2013).

The metal casting industry is naturally very energy intensive. Energy consumption in foundry mainly depends on electricity (Saha VJ,2010). The energy efficiency of any metal casting facility depends largely on the melting processes (Eppich R, Naranjo RD et al, 2007). Global warming is putting pressure on policy makers to formulate and adopt energy policies aimed at different sectors of the economy, industrial energy efficiency plays a central role in this regards (Patrik Thollander, Maria Danestig et al 2007).

Foundry consumes huge amount of energy, and yields tons of wastes. Foundry industry is one of major energy consumption industry and exerts significant effect on environment. Energy accounting is necessary to determine where and how energy is being consumed and how efficient is the energy management system (M.arasu, Rogers Jeffrey et al, 2007). Energy conservation and emission reduction is related tightly with the survival and development of the industry, and it is also a key point of sustainable development (Li yuanyuan, Chen weiping et al 2010).

In India The energy saving potentional varies from industry to industry,ranging from 10% to 0%.Arecent study carried out by Administrative Staff College(ASC) Hyderabad India indicates that only few companies maintained records of energy use (G. L. Datta,2001). Energy management is an ongoing concern in any foundry. In foundry the energy management may be define as the strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems , energy efficiency measures for on-site combustion systems (e.g., furnaces, boilers, cupolas, heat-treating ovens) reduce emissions in direct proportion to the amount of not consumed fuel. Reductions in consumption of electricity lead to reductions in demand for electricity and, consequently, reductions in emissions from thermal electric power generating station (Seweryn Jarza,2011).

Air compressors account for significant amount of electricity used in Indian industries. Air compressors are used in a variety of industries to supply process requirements, to operate pneumatic tools and equipment, and to meet instrumentation needs. Only 10 – 30% of energy reaches the point of end-use, and balance 70 – 90% of energy of the power of the prime mover being converted to unusable heat energy and to a lesser extent lost in form of friction, misuse and noise (energymanagertraining,2004).

There are a number of equipments in India where the flow is controlled by mechanical dampers for fans and valves for pumps. Further, majority of the doubling machines are operated at constant speed irrespective of the load on the machine. Hence, it is recommended to install Variable Frequency Drives (VFDs) for ID/FD(Induced draft/Forced draft) fans, oil circulation pumps and doubling machines. A minimum saving of 20% can be realized by installing Variable Frequency Drives (VFDs) (Winrock International India, 2010).

Success of Energy management depends on a team effort starting with a firm commitment from the top executive and management team. The first assignment in energy saving activity must be the initial energy audit. It is a key step that establishes the baseline from which the future energy efficiency improvements can be measured. One of the main results of energy audit is the possibility of determination of the energy consumption pattern. The energy pattern is the key in understanding the way energy is used in a foundry and helps to control energy cost by identifying areas where waste can occur and where scope for improvement may be possible. Safety is a critical part of any energy audit. The auditor and the audit team should have a basic knowledge of safety equipment and procedures. Before starting the facility tour, the auditor or audit team should be thoroughly briefed on any specialized safety equipment and procedures for the facility. They should never place themselves in a position where they could injure themselves or other people at the facility (Barney L. Cape Hart et al, 2003).

1.1 Major Energy Consumption Areas of Foundry

The main processes and consumption of energy of foundry are presented in table 1

Equipment / process	Consumption of total plant energy, (%)	Area savings potential, (%)	Overall plant saving (%)
Melting	59	15	9
Fans and pumps	6	35	2
Lighting	6	30	2
Motors	12	10	1
Air compressors	5	20	1
Miscellaneous	12	10	1

Table.1 Energy consumptions in different department of foundry and saving potential [7]

1.2 Power Distribution Tree of Foundry

In figure1 the main processes of foundry energy consumption is shown so that one can understand the whole system step by step with power consumptions in different departments and also the losses(Brakes India Limited Foundry Division, 2004).

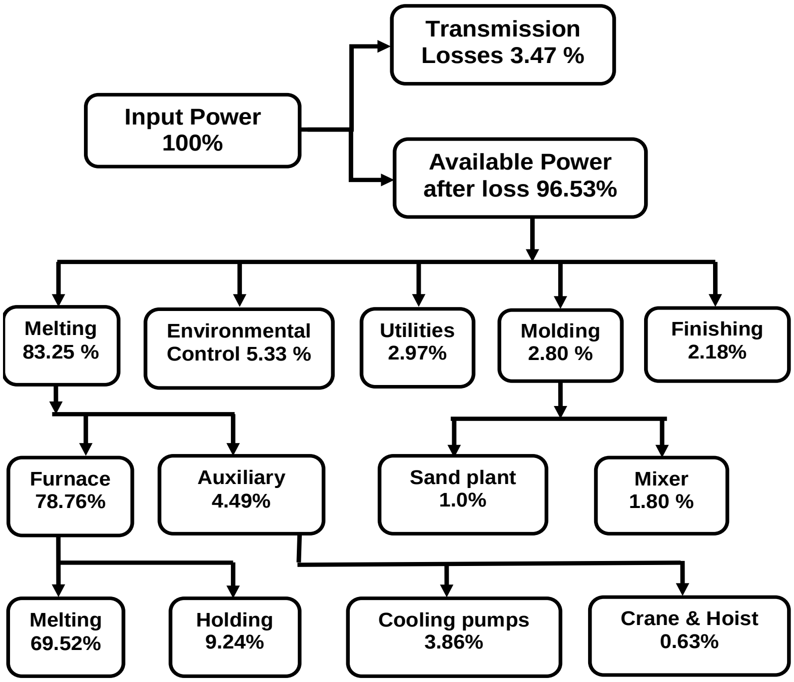

Figure1. Power distribution tree of Foundry

2. Energy management in foundry(a case study)

To know the trends in an Indian Small and Medium scale foundries we had chosen three foundries (Foundry A,B,C) from the cluster of vatva (Ahemedabad) Gujarat India. Collected energy consumption data from these foundries with respect to furnace, compression system and electrical distribution system are as below. Following are the energy consumption of the foundries.

2.1 Specific energy consumption for two different furnaces

In table2 energy consumption patterns of two foundries are presented

Types of Furnace	Types of Fuel Use	Running hr/Day	Production Capacity	Fuel Consumption/ Day	Specific Energy Consumption/ Ton molten material	Specific energy Consumption in rupees
Cupola (F-A)	Coal + Electricity For Blower Motor	8	15 Metric Tonnes	3.2 Metric Tonnes Coal + 110 kWh Electricity	0.2 Metric Ton Coal + 8 kWh electricity	Rs. 2800 + Rs 40.0 = Rs.2840
Inducti	Electrici	12	8 Metric	4800 kWh	900 kWh	Rs. 3500/

on Furnac e (F-B)	ty		Tonnes	Electricity	electricity	

Table 2: Specific energy consumption for two different furnaces
Assuming Coal Rate Rs.14, 000/ton
Assuming electricity Rs 5.0/kWh
Blower Motor Capacity 20 Hp

2.2 Energy consumption in Melting section: Foundry B

A foundry had two medium frequency induction furnaces. The unit had fair energy metering and reporting systems. Every melting furnace was connected to an individual energy meter (average type). Every day the consumption and production of each furnace was recorded and monitored. The furnace details are presented in table 3.

Furnace #	No of crucibles	Crucible Capacity, kg.	Rated kW	Rated frequency, Hz	Average specific consumption, kWh/Mt	Metals melted
# 1	2	1000 & 1000	1000	500	674	SG Iron
# 2	3	500, 500 & 1000	550	100	777	SG Iron
The Range of practically achievable optimum value of specific energy consumption(Manufacturers broacher)					625 – 650 kWh/Mt	SG Iron

Table 3: Furnace details with specific energy consumption

2.3 Energy consumption in Compressors: Foundry B

Air compressors were used in the machine shop for pneumatic equipment and machine tools. While visited the foundry compressor system had found some issues were presented below in table 4.

Present system of Air compressor system	Location of the compressor was near by the heat source that shown the reason of rise in inlet temperature may reduce power saving.
	Measured temperature of inlet air is about 45°C by contact thermometer.
	Regular checking of leak were not taken place that cause pressure drops that adversely affect the operation of air-using equipment and tools, reducing production efficiency.

Table 4: Present system of Air compressor system

2.3 Present system of electrical distribution in foundry: Foundry B

It was found during visit that present electrical distribution system was not proper with respect to timing and capacitor as presented in table 5.

Present system of electrical distribution in foundry.	No load is being shifted to Night timing when the electricity is at low cost.
	There are no any capacitors using in electrical system to maintain or improve the power factor.

Table 5: Present system of electrical distribution in foundry

3. Result and discussion

From the collected data it is found that the major energy consumption department is melting department and to save energy from that must carried to save energy from furnaces. As shown from power distribution tree that accordingly air compressors and electrical distribution systems are also found major energy consumption areas in foundry after furnaces. Savings in each department can be accomplished as per choosing best energy management procedure.

For proper energy management system it would be necessary to choose an efficient furnace that must be satisfy demand of foundry. Although high energy expenses are a significant concern for metal casters, many foundries are using melting technologies with poor energy efficiency. The amount of heat put into the furnace, the thermal efficiency refers to the percentage of that heat that actually melts the metal. The remaining heat is lost, through for example, inefficient combustion, the furnace's housing and flue.

3.1 Energy Savings in Induction Furnaces

The factors contributing for the high specific energy consumption from table 3 were analyzed and presented below.

- The heat cycle that is pouring to pouring, recorded about 25-40% of the specified standard time.
- The power to the furnace was varied very frequently due to empty space in the crucible, excess charge, and sample analysis delay.
- The recorded electrical parameters indicate that about 35-40% of the heat time the furnace was operated at 70-80% of rated power.
- About 80% metal is charged before taking the sample for the analysis. The remaining 20% of crucible volume is loaded after obtaining the sample analysis.
- The first batch sample analysis indicates the short fall of different elements, based on this the additional material is added to achieve the required composition and quantity.
- Details of techno-economics: Foundry B is as shown in table 6

Furnace	# 1 Furnace	# 2 Furnace	Total
Possible reduction in time (min)	6	8	-
Reduction in energy (kW)	24	23.4	47.4
Operating days per year	330	330	-
Operating hours per day	22	17	-
Energy savings (Lakh kWh/year)	1.95	1.33	3.88
Annual cost savings (Rs. Lakh)	6.30	4.06	10.36
Investment required (Rs. Lakh)	1	1	2
Payback period (Months)	2	3	2

Table 6: Details of techno-economics: Foundry B

Plant should take various steps and followed to reduce the specific energy consumption.

- Supply of the full power during the melting (most of the time) is being practiced.
- To lower the specific energy consumption, Reduction in time taken for sample analysis & communication was significantly reduced the heat time. Use of intercoms and alarms, pneumatic conveying and advanced logistical preparations helped to reduce the time for sample analysis.
- In addition to above, use of recently introduced energy optimizer for melting operation created a benchmark and enforced conscious practice to complete the job within the set goal. This energy optimizer senses the inverter output power and integrates into energy delivered to the furnace. It is possible to set a predetermined energy requirement value for melting the material to the desired temperature.
- For proper energy management, Setting of energy parameter was based on lowest achieved energy consumption figure during the past fortnight. Close monitoring of set goal and analysis of the reasons for not being able to comply with the benchmarking if any, shall ensure reaching the optimum level of energy consumption.

3.2 Energy Savings in the Compressed Air System

Energy savings of up to 30% can be realized in a compressed air system by regular simple maintenance measures. The following points should be taken into consideration while deciding the location of compressors or combined compressed air systems.

From table 7, the relation between inlet temperature and relative air delivery and due to that power consumption can be analyzed and it can be seen that lower inlet temperature can save more power.(Energymanagertraining2004)

Inlet Temperature (°C)	Relative Air Delivery (%)	Power Saved (%)
10.0	102.0	+ 1.4
15.5	100.0	Nil
21.1	98.1	– 1.3
26.6	96.3	– 2.5
32.2	94.1	– 4.0
37.7	92.8	– 5.0
43.3	91.2	– 5.8

Table 7: Effect of intake air temperature on power consumption (standard data comparison)

- Foundry had found inlet temperature about 45°C. So from table 5 it consumes more power. While extending the air intake from the outside of the building, minimize excess pressure drop in the suction line by selecting a duct of large diameter with the smallest number of bends that gave air at 32°C temperature.
- Locate the compressor away from heat sources such as kilns, dryers and other items of equipment that radiate heat.

3.3 Proposed energy Savings in the Electrical Distribution System

- Stagger the non-critical load according to the electricity tariff to reduce the energy bill. The benefits of load staggering are shown in Table 8.
- Maintain a high power factor, which will lead to reduced demand, better voltage, high system efficiency as well as rebates from the electricity supplying company. The power factor can be improved by installing capacitors in the electrical system. Table 7 shows the benefits of power factor improvements from the point of view of costs.
- Control the maximum demand by tripping non-critical loads through a demand controller. This will avoid the penalty levied when usage is greater than the sanctioned load.
- Balance the system voltage to reduce the distribution losses in the system. For every 1% increase in voltage imbalance, the efficiency of the motors decreases by 1%.

Load to be shifted to night shift (10 PM - 6 AM)	15 kW
Assumed working hours per shift	8 hours
Monthly power consumption (30 days/month)	3000 kWh
Electrical cost for night shift operations (assuming Rs 3.5/kWh during 10 PM - 6 AM)	Rs 1,0500
Electrical cost for general shift operations (assuming Rs. 5/kWh)	Rs 1,5000
Savings per month	Rs 4500
Annual savings	54,000 Rs

Table 8: Benefits of load staggering

Existing load of the unit (KW)	100
Existing power factor	0.9
Desired power factor	0.99
Existing demand (kVA)	111
Capacitor required (kVAr)	35(approx)
New demand (kVA)	101
Reduction in maximum demand (kVA)	10
Monthly savings in demand charges @ Rs 300/kVA	3000
Cost of capacitors @ Rs 250/kVAr	8750
Simple payback period	3 months

Table 9: Cost benefit analysis of power factor improvement

3.4 Justification for Selection of Technology in current situation

For energy efficiency following measures is suggested among three different foundries of the cluster and selection of that system will give beneficial and environmental improvement in the foundry. Energy Management proposals in foundry cluster is shown in table 10.

Foundry [A,B,C]	**Present System**	**Proposed System**	**Justification for Selection of Technology**
Foundry-A	Blast Copula for melting material	Replace Blast Copula with Divided Blast Copula	This technology is already implemented in a few units and savings have been Achieved. DBC are one of the best available low cost energy efficient technologies available for Foundry Industry.
Foundry-C	No APFC for maintaining higher power factor	Installation of APFC with some extra capacitor to maintain unity power factor	This is the simplest and widely accepted measure for energy cost reduction in all the industries. Installation of the capacitors and APFC panel however due to lack of technical understanding of PF, monitoring of PF is not adequate. The understanding on PF is improving however this measure has to be taken as a specific measure

			till the results are not achieved on sustained basis. Periodical checking of the de-rated capacitors and their replacement is must.
Foundry-A	No insulation over furnaces	Provide surface insulation by insulation paint coating of Copula/Rotary furnace to reduce heat losses	As a routine maintenance insulation levels must be regularly checked. If timely corrective measure is not taken then the losses will go up over a period of time. So it is not an option. This measure can be implemented during annual shut down. For Implementation of this measure, creating the awareness is required.
Foundry-B	No Damper Control For reducing excess air	Optimize Combustion Efficiency of Furnace By Reducing Excess Air	By controlling excess air quantity, coal consumption would be reduced. And extra unwanted air would be avoided; it will result in higher furnace temperature, hence high melting temperature.
Foundry-C	Conventional T/8 40 W Tube Light	Replace 40 W Light by T5, 28 W Light	It may be high efficient and very environment friendly. It also operates on high PF and it has instant start up also.
Foundry-B	100 W GSL Bulb	20 W CFL	It is very efficient and consumption of energy is less comparatively.
Foundry-A	Old re-winded for blower	Energy Efficient motors	Energy efficient motors are highly efficient and it has less power consumption. It also has less starting torque. There is good opportunity to replace old motors in Furnace blowers with Energy efficient motors.
Foundry-B	Open Lid	Lid cover & insulation for induction furnace	The basic requirement for thermal insulation is to provide a significant resistance path to the flow of heat through the insulation material. To accomplish this, the insulation material must reduce the rate of heat transfer by conduction, convection, radiation, or any combination of these mechanisms.

Table 10: Energy Management proposals in foundry cluster

4 Conclusion

There is a large scope of energy management in foundry industry sector in Indian small and medium scale foundry industries considering the fact that the large amount of power is being wasted by many ways. As majority of these foundries are not aware of these facts.

From above case study we conclude that the better energy management program may save not only in terms of energy but also it may save money. Savings of at least 10% and up to 40 % may be realized by implementing some useful energy management techniques. The key to achieving savings is to take a strategic approach to managing energy use and giving importance to energy management techniques. While energy efficient technologies have a significant role to play in reducing energy use in foundry industry.

Most of the small-scale foundry units are family owned and managed. The general level of awareness among them about energy conservation and new technologies is low. Although some of the entrepreneurs are interested in energy efficiency and technological improvements they are constrained by lack of technical know-how and finances. Looking into today's scenario, it becomes very essential for Foundry men to look for means which can bring down the energy consumption in melting operation significantly by efficient methods and techniques.

The Indian Metal Casting (Foundry Industry) is well established & producing estimated 9.99 Million MT of various grades of Castings as per International standards. However, Grey iron castings have the major share i.e. approx 68% of total castings produced.
There are approx 4500 units out of which 85% can be classified as Small Scale units & 10% as Medium Scale units (Foundry informatics centre,2013).

The Indian foundry industry currently generates revenue of $12.5 billion and exports worth $2 billion. In this context, the role of the foundry industry will be very crucial to support the manufacturing and engineering industry in the coming years, according to A.K. Anand, director, The Institute of Indian Foundrymen - FIC, New DelhiSpecific energy consumption should go down by 10 percent (The institute of Indian foundry men,2013).

The strengths of the Indian foundry industry lie in the fact that it has a large base which is spread all over the country. India has a traditional legacy of metal casting and manpower is available at a reasonable cost.ButThe ferrous foundry industry is highly energy intensive. Energy cost is almost 15-20 percent of the manufacturing cost and cost of energy in India is very high in comparison to other countries (The institute of Indian foundry men2013).

The best available energy management techniques needs to be used in order to optimise the production. It is expected that there will be ample scope for Indian foundry operators in energy mangement.

5 Acknowledgment:

The authors' wishes to thank research paper review committee, department of mechanical engineering. We thank to the Principal and dean faculty of Charotar University of science and technology, Changa for their suggestions, encouragement and support in undertaking the present work. Special thanks to the management for their moral support and continuous encouragement.

The authors would also like to thank the staff at the studied foundry for their positive response and support, especially Mr. Chetan champaneria for his valuable guidance and helpful discussions.

The authors would also like to thank editor "European Scientific Journal" for giving oppurtinity to publish a paper and reviewer giving valuable suggestions for improvement of quality of paper to obtain specific objectives for Indian foundry.

References:

Barney L. Cape Hart, Wayne C. Turner and William J. Kennedy, Guide to energy management, The Fairmont press Inc, Fourth Edition, 2003.

Compressed air system, available on www.energymanagertraining.com, 2004. http://www.em-ea.org/Guide%20Books/book

Energy conservation measures in the Foundry sector, Published by: Winrock International India, 2010.

Eppich R, Naranjo RD. Implementation of metal casting best practices. Report of US Department of Energy; 2007.

Foundry informatics centre. (http://www.foundryinfo-india.org)

G. L. Datta: energy management and audit in foundries, first edition, Calcutta, the Indian institute of foundrymen,5-40, 2001.

Latest trends in Energy Efficiency-Foundry industry by Brakes India Limited Foundry Division, 2004. http://www.energymanagertraining.com/Journal/latesttrend%20greenbusinesscentre.pdf

Li yuanyuan, Chen weiping, Huang dan, Luo jie, Liu zhe1, Chen yongcheng, Liu Qiping and Su shifang, Energy conservation and emissions reduction strategies in foundry industry, The 69th WFC paper, Vol-7(no-4)2010.

M.arasu, Rogers Jeffrey, Energy consumption studies in cast iron foundries, 57th Indian foundry congress Kolkata,331-336, 2009.

Patrik Thollander, Maria Danestig and Patrik Rohdin, Energy policies for increased industrial energy efficiency - Evaluation of a local energy programme for manufacturing SMEs, Energy Policy, (35), 11, 5774-5783, 2007.

Saha VJ. Energy efficiency improvement in melting furnaces, report. World Foundrymen Organization; 2010.

Seweryn Jarza, Importance of energy management in foundries, polish journal of management studies-2011.

The institute of Indian foundry men (http://www.indianfoundry.org.)

Thollander P, Palm J, Söderström M, editors. Energy efficiency research advances, industrial energy auditing – A key to competitive energy efficient Swedish SMEs. Hauppauge, New York, USA: NOVA Science Publisher; 2007.