ENERGY CONSUMPTION STUDIES IN CAST IRON FOUNDRIES

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ABSTRACT

Foundry being an energy intensive industry, energy accounting is necessary to determine where and how energy is being consumed and how efficient is the energy management system. An energy accounting method should define the areas of high energy use, energy waste and should point out areas in which energy saving can be accomplished. To arrive at the energy consumption pattern is the main part of the energy audit process. Energy pattern can be used to understand 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. Energy management is very important as it deals with adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements. This paper presents a case study of energy required to produce a ton of liquid metal in four 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 deviation control methods. This paper also explores the various avenues for energy savings and cost control.

INTRODUCTION

Foundry being an energy intensive industry, energy accounting is done to determine where and how energy is being consumed and how efficient is the energy management system. It defines the areas of high energy use, calls attention to energy waste and points out areas in which energy saving can be accomplished. The methodology of energy consumption studies carried out in foundries is shown in Fig.1. A detailed discussion on the methods is carried out in the following sections.

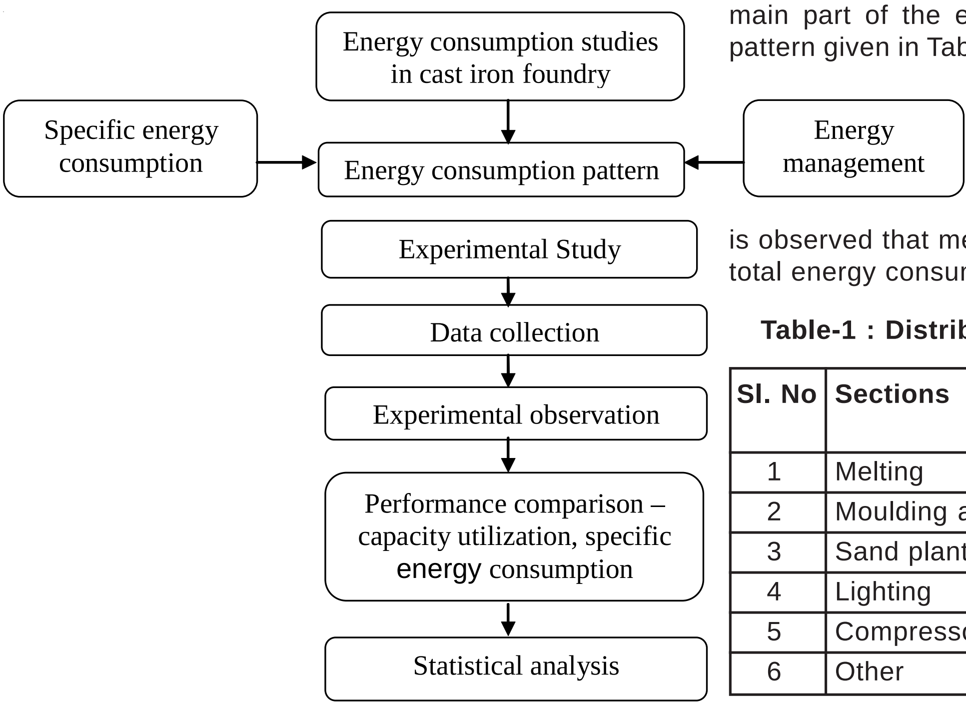

Fig.1 Methodology for energy consumption studies

ENERGY CONSUMPTION PATTERN

To arrive at the energy consumption pattern is the main part of the energy audit process. The energy pattern given in Table 1 is helpful 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. It is observed that melting consumes a major portion of total energy consumed.

Table-1 : Distribution of energy consumption

Sl. No	Sections	Energy Consumption
1	Melting	70%
2	Moulding and core making	10%
3	Sand plant	6%
4	Lighting	5%
5	Compressor	5%
6	Other	4%

Specific Energy Consumption

Specific energy consumption is the energy consumed per ton of liquid metal produced. Table 2 shows the specific energy consumption for induction furnace, rotary furnace and cupola, per ton of liquid metal for cast iron grade.

Energy management

Energy management is the strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output by keeping constant or reducing total costs of producing the output from these systems. The term energy management can be considered as consisting of three basic steps - planning, execution and control.

EXPERIMENTAL STUDY

In this paper a study on energy required to produce one ton of liquid metal for a selected four foundries is carried out. This will give an idea of the current energy consumption of the foundries, which can be compared with standard norms and can be used to implement deviation control methods. This also explores the various avenues for energy savings and control and involves data collection related to energy consumption, rejections and capacity utilization.

Data collection

Energy consumption and process details were collected through a questionnaire from four foundries for a period of two years. This study has been limited to fuel usage in the melting department and electrical energy consumption in various departments. The data when compared, gives a trend of energy consumption. Energy consumption in different forms should be expressed in a common unit to facilitate easy comparison.

The collection of data has made use of metering facilities for energy consumption in different sections/ equipments. In all the foundries considered the castings produced were of type Grey CI, SG Iron, also all the foundries use induction and rotary furnaces. Here SG Cast iron is taken up for detailed study. The consolidated energy consumption in all four foundries is shown in Table 3.

Table-2 : Specific energy consumption in melting furnaces

S. No.	Description	Energy Consumption
1	Specific Power Consumption norm in Induction furnace per ton of liquid metal	620 kWh/ton
2	Specific oil consumption norm in rotary furnace per ton of liquid metal	135 L/ton
3	Specific coke consumption norm in cupola per ton of liquid metal	135 Kg/ton

Table-3 : Energy consumption in cast iron foundries

Sl. No	Description	Foundry			
	A	B	C	D	
1	Installed Capacity (tonnes/annum)	10,800	7,200	5,150	8,400
2	Actual Production (tonnes/annum)	9,072	5,400	3,605	6,048
3	Capacity utilization (%)	84	75	70	72
4	Salable Castings (tonnes/annum)	5,900	3,350	2,160	3,630
5	Rejection (%)	8	9	8	10
6	Electrical energy consumption (kWh/ month)	5,28,320	1,01,000	55,000	1,29,000
7	Utilities (kW)	1016	183	319	122
8	Induction furnace (kWh/ton)	700	720	750	740
9	Furnace oil (L/ton)	200	220	200	210
10	Melt/day (tonnes)	30	18	12	20
11	Yield (%)	65	62	60	60

Among the four foundries studied, the parameters like installed capacity, actual production and electrical energy consumption are measured. The findings show that Foundry A has good capacity utilization of 84%. A further study provides an insight into the electrical consumption per month and its relevance to the capacity of the induction furnace. The electrical energy consumption per month is higher for Foundry A whose capacity of the induction furnace is the least among all the four studied, which is at 700 kWh/ton.

Experimental observation

Among the foundries studied, the electrical energy consumption pattern is shown in Table 4 and Table 5.

It is observed that the major consumption of electrical energy is occurring in the melting division of the foundry.

3.3 Capacity utilization - comparison between the foundries

Good manufacturing performance alone is not sufficient to guarantee the manufacturing cost competitiveness. Utilizing available capacity adequately is equally essential. Optimizing capacity utilization is largely dependent on factors such as production planning capabilities and increasing the number of equipment options available for production. According to the analysis it is observed that though foundry A has the melting capacity of 32 tonnes of castings per day, it is capable of producing only 24 tonnes to 30 tonnes daily. The study reveals that the melting capacity is limited by the moulding capacity. The statistical relationship for this analysis was observed to be in the logarithmic line. Further, it is observed that, there is a significant effect of increased cooling time in the pouring section. The furnace or ladles are to wait before the metal is poured, consequently only a few heats are possible, which results in low production. The fixed elements of energy requirements in the operations form the basis of high energy consumption per ton with low capacity utilization. Therefore, in the present study, performances have been done on melting furnace to establish a mathematical relationship between energy consumption and capacity utilization. The specific energy consumption and percentage capacity utilization were collected from electrical melting furnace in the selected foundries and the summary of the data is given in Table 6.

Table-4 : Electrical energy consumption

Sl.No	Sections	Average electrical power consumption/ month (kWh)			
		Foundry A	Foundry B	Foundry C	Foundry D
1	Sand plant	26,245	1,000	720	5,250
2	Moulding and core making	15,855	9,000	540	8,400
3	Melting	4,28,085	7,700	15,300	78,750
4	Compressor	15855	1,000	360	2,100
5	Lighting	21,140	9,000	720	5,250

Table-5 : Comparison of electrical energy distribution

Sl. No	Sections	Distribution (%)				
		CII Standard (*****)	Foundry			
		A	B	C	D	
1	Sand plant	6	5	1	4	5
2	Moulding and core making	10	3	9	3	8
3	Melting	70	81	77	85	75
4	Compressor	5	3	1	2	2
5	Lighting	5	4	9	4	5

(*Confederation of Indian Industry)

Capacity utilization is given by actual production to installed capacity based on a one-year average; the findings are given in Table 7.

Foundry A is operating with 84 % of capacity utilization. It can be observed that the specific power consumption and oil consumption is minimized when the foundries are running with more capacity utilization.

Comparison of specific energy consumption

Based on the survey conducted, the following specific energy consumption values have been obtained in various melting equipments of the foundries and the data are given in Table 8.

In Foundry A, the specific power consumption of induction furnace is 12.9% higher and the specific oil consumption of the rotary furnace is 48.15% higher than the CII specified standard norms. In Foundry B, the specific power consumption of induction furnace is 16.13 % higher and the specific oil consumption of rotary furnace is 62.96 % higher than the CII specified standard norms. In Foundry C, the specific power consumption in induction furnace is 20.97 % higher and the specific oil consumption of rotary furnace is 48.15 % higher than the CII specified standard norms. In Foundry D, the specific power consumption of induction furnace is 19.35% higher and the specific oil consumption of rotary furnace is 55.56% higher than the CII specified standard norms.

Based on the studies on energy consumption pattern on induction furnace, it is observed that, the specific energy consumption in the foundries is about 18% higher than the CII standard norms. It is also observed that the specific oil consumption on rotary furnace is about 54% higher than the standard norms.

STATISTICAL ANALYSIS

In order to arrive at a pattern of energy consumption it is recommended that a mathematical model would be helpful. In this context a model for regression analysis is developed. Regression analysis is a statistical tool that compares the relationship between two or more variables. It is the identification of a relationship between dependent variables and one or more independent variables. Regression analysis attempts to explain changes in the dependent variables as function of the independent variables through the quantification of a single equation. Based on the values from Table 9 the quantification of a single linear regression equation has been developed.

Table-7 : Comparison of capacity utilization

Foundry	% of Capacity Utilization
A	84
B	75
C	70
D	72

Table 6 Relationship between capacity utilization and specific energy consumption

Sl. No.	Capacity utilization (%)	Specific energy consumption (kWh/ton)
1	72	625
2	72	625
3	70	628
4	71	629
5	75	617
6	78	614
7	75	614

Table 8 Comparison of specific energy consumption

Sl. No.	Foundry	Specific oil consumption (Lt./ton)	Specific power consumption (kWh/ton)
1	A	200	700
2	B	220	720
3	C	200	750
4	D	210	740

Table-9 : Annual production Vs Energy consumption

Sl. No	Foundry	Energy Consumption (MJ)	Annual Production (ton)
1	A	4710	5900
2	B	4800	3350
3	C	3768	2160
4	D	5672	3630

$$Y = 0.183\ X + 4046 \quad \text{[Eq. No. 1]}$$

(X = Annual production, tonnes and Y = Energy consumption, MJ)

In Eq.1, the dependent variable is energy consumption, MJ and independent variable is annual production in terms of tonnes. Fig.2 shows the relationship between the production and energy consumption based on Eq.1.

The regression analysis provides a normal curve and a relationship is developed. It is observed that the above model gives the positive correlation between the annual production and energy consumption (Regression co-efficient is +0.68). This relationship is useful to forecast the energy consumption with respect to the production rate. Based on the above analysis, it is observed that, the energy specific consumption is optimized with increased capacity utilization.

CONCLUSION

The specific energy consumption studies show that the major consumption of electrical energy is occurring in the melting division of the foundry. Therefore from the study it is concluded that there is scope for reducing the energy consumption and increasing the productivity. Melting and pouring processes have been identified as key factors influencing energy consumption. It is also observed that the process variables studied have significant influence on the quality of casting.

The studies on energy consumption pattern on induction furnace revealed that the specific energy consumption is about 18% higher than the standard norms specified by CII. It is also observed that the specific oil consumption on rotary furnace is about 54% higher than the standard norms specified by CII. The study also revealed that foundries were operating on low capacity utilization resulting in less productivity. This results in increased energy cost for per ton production of castings.

Based on the statistical analysis, a generalized model based on linear regression has been developed to obtain the correlation between production of castings and energy consumption. Based on the regression analysis, it is observed that the specific energy consumption is reduced with increased capacity utilization.

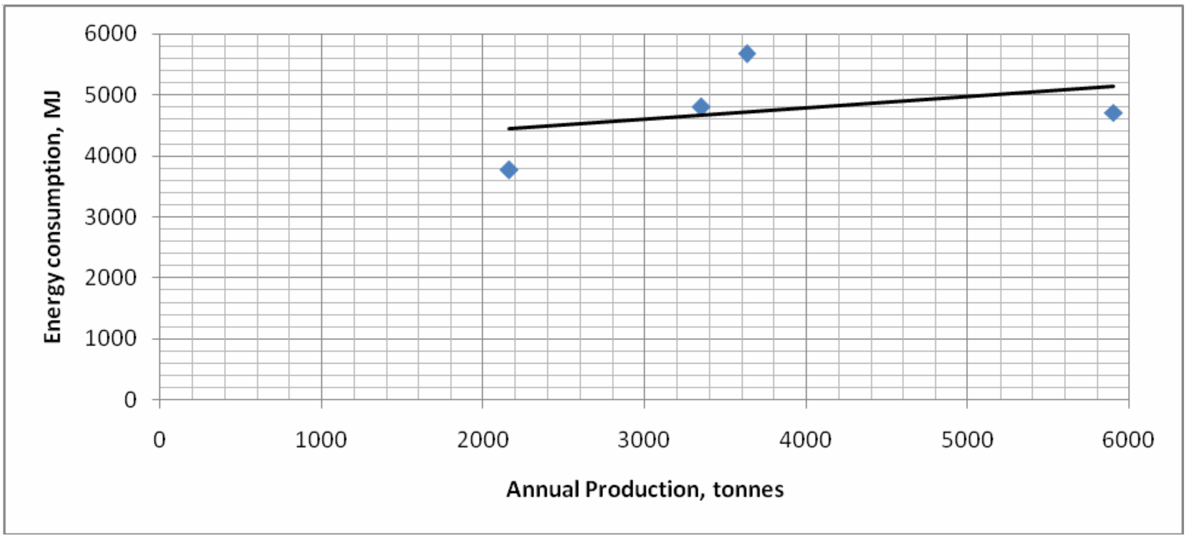

Fig. 2 : Linear regression model for energy consumption

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