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Application of Regression Analysis in Modeling and Optimization of Experimentally Investigated Effect of Process Parameters on Melting Rate of oil fired Rotary Furnace

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Abstract—*This paper deals with Experimental Investigations of effect of process parameters on melting rate of oil fired rotary furnace for optimal melting rate in view of enhancing the production leading to fuel conservation of oil fired rotary furnace.*

The data set as given in observations is based on actual experimental investigations carried out on a self designed and developed 200 kg rotary furnace installed in a foundry industry manufacturing cylinder heads and engine parts. the multi pass counter flow heat exchanger was used in conjunction with furnace for preheating the air required for combustion. The experimental investigations revealed that the input process parameters viz rpm, fuel consumption, flame temperatures have a significant effect on melting rate.

An attempt has been made to establish a correlation between melting rate considered as an output parameter and time of melting of charge (minutes), Melting Rate(kg/hr) and flame temperature considered as input parameters employing the regression analysis as tool for modeling and optimization . it was found that variations between modeled results and actual experimental results is % which is acceptable

Keywords:—*oil furnace, melting rate, regression analysis, rpm*

1. INTRODUCTION

The oil fired Rotary Furnace is a melting unit consisting of a cylindrical shaped drum in centre which is supported on a roller and surrounded by two conical shaped structures. one accommodates the burner while other the duct for heat exchanger for exit of hot flue gases.

The drum contains a rectangular opening at top for charging the material and emptying it, and can be rotated about its central axis, during melting, driving the rollers by small electric motor. the oil for combustion is supplied from an overhead tank using pump and valves, connected to burner through a suitable diameter pipe. figure 1 shows the layout of furnace.

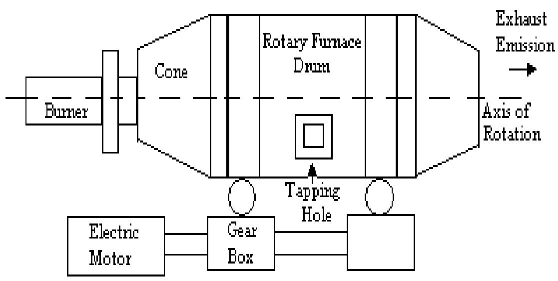

Figure 1: The layout of furnace

2. LITERATURE REVIEW

Jain R.K, Singh R [1] applied mathematical tool for modeling and optimizing basic input parameters of rotary furnace. The results correlated with experimental investigations

Pandey G.N., Singh Rajesh, Sinha A.K [2] are of the opinion that for significant reduction of emission levels and melting time in foundries the furnace should be supplied with oxygen at pressure of 8 kg/cm^2

W.W.Levi [3] successfully developed a model for cupola furnace for corelating the carbon content in the charge and its molten metal .

Pehlke[4] accurately predicted the performance of cupola furnace for melting cast iron, under different conditions of charge quantity, pressure and temperature.

Landefeld and Katz [5] carried out further works on model developed by Levi, resulting in a kinetic model which accurately predicted the pickup of carbon in a furnace operation

Stanik S., Katz C.F., Landefeld A, et al [6] has developed mathematical model of the behavior of metal drops in contact with coke in the cupola furnace

Sahajwala V and Pehlke R.D etal [7] developed a kinetic model for evaluating the rate influencing factors and inter-relations among carbon dissociation and mass transfer in the liquid iron

Karunakar and Datta[8] has successfully applied artificial neural networks in the control of cupola furnace

Alexiades V., and Solomon A. D. [9] applied numerical techniques for modeling of melting process including variation of phases and effect of core element on the process.

Jain R. K.[10] successfully applied Neural Networks for Modeling and Simulation of Fuel Consumption in furnace to conclude that variation in modeled and experimental results lies within permissible limits hence furnace modeling and parameters selection can be implemented using artificial neural networks.

Kumar Purshottam, Singh Ranjit [11] attempted to establish a relation between output parameters viz fuel consumption and melting time with basic process parameters like flame temperature, rpm etc using ANN

3. MELTING OPERATION

3.1 Experimentation Investigations of Effect of input parameters on melting rate-

The observations of actual experimental investigations, performed on an oil fired rotary furnace for determining effect of Time (min.) Fuel(liters), and Flame Temp°C on Melting Rate (kg/hr)are given in table 1

Table 1: Effect of time, fuel and flame temperature on melting rate

S. N	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melting Rate(kg/hr [E])
1	1510.0	41.0	72.0	293.0
2	1530.0	40.0	70.0	300.0
3	1540.0	39.0	69.0	307.6
4	1545.0	38.0	68.0	315.7
5	1550.0	37.0	66.0	324.3
6	1568.0	37.0	64.0	324.3
7	1570.0	36.0	63.0	333.3
8	1578.0	35.0	61.0	342.8
9	1580.0	34.0	60.0	352.9
10	1590.0	34.0	59.0	352.9
11	1620.0	33.0	58.0	363.6

The graphical presentation of above recorded observations as per table 1 of effect of time, fuel and flame temperature on melting rate is shown in figure 2.

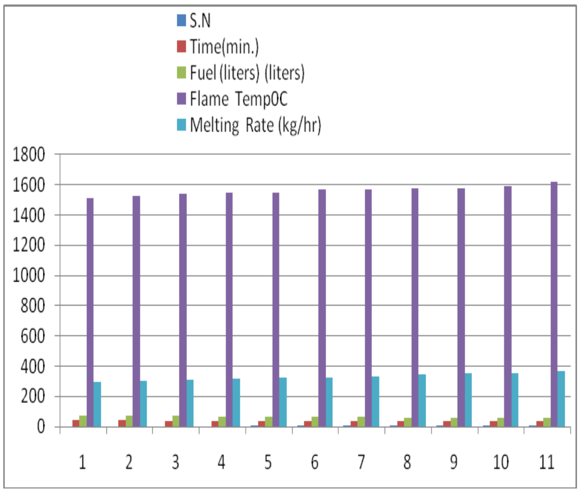

Figure 2 : Effect of time, fuel and flame temperature on melting rate

4.0 MODELING AND OPTIMIZATION

4.1 Input Parameters

For modeling and optimization the Time (min.), Fuel (liters) and Flame Temp°C are considered as input parameters

4.2 Output Parameters

The output parameters considered is Melting Rate(kg/hr)

4.2 Regression Model

The following relationship has been developed between above mentioned input parameters and output parameter using the regression analysis employing Microsoft axle programme. The programme run is shown below as table 2

A= FLAME TEMP, B= TIME, E= FUEL

EQUATION ---- OUTPUT IS MELTING RATE---

MELTING RATE = 581.4784+0.035982 (FLAME TEMPERATURE) --8.07734(TIME)- -0.19834(FUEL)

MELTING RATE[E] = 581.4784+0.035982[A]-- 8.07734 [B]-- -0.19834[C]

Table 2: The programme using regression analysis

Regression Statistics	
Multiple R	0.998038
R Square	0.99608
Adjusted R Square	0.9944
Standard Error	1.732112
Observations	11

ANOVA

	df	SS	MS	F	Significance F
Regression	3	5336.815	1778.938	592.9378	8.77E-09
Residual	7	21.00147	3.000211		
Total	10	5357.816			

	Coeffi-cients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	581.4784	142.8672	4.070061	0.004749	243.6511	919.3057	243.6511	919.3057
[B]	0.035982	0.072387	0.497075	0.634366	-0.13519	0.20715	-0.13519	0.20715
[C]	-8.07734	1.511648	-5.3434	0.001072	-11.6518	-4.50286	-11.6518	-4.50286
E	-0.19834	0.871795	-0.2275	0.826533	-2.25981	1.863131	-2.25981	1.863131

5. COMPARISON OF ACTUAL AND MODELED MELTING RATES

Based on above equation the output melting rate has been evaluated and compared with actual experimental melting rate as given in table 3

Table 3 – Comparison of Experimental and Modeled Values of melting rate

S.N	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	**Melting Rate(kg/hr [E] experimental**	**Melting Rate(kg/hr [E]modeled**	**Percentage variation**
1	1510.0	41.0	72.0	293.0	**290.35980**	**-0.901092%**
2	1530.0	40.0	70.0	300.0	**299.55346**	**-0.148846%**
3	1540.0	39.0	69.0	307.6	**308.18896**	**+0.191469%**
4	1545.0	38.0	68.0	315.7	**316.64455**	**+0.299192%**
5	1550.0	37.0	66.0	324.3	**325.29848**	**+0.307887%**
6	1568.0	37.0	64.0	324.3	**326.342836**	**+0.629921%**
7	1570.0	36.0	63.0	333.3	**334.69048**	**+0.417185%**
8	1578.0	35.0	61.0	342.8	**343.19672**	**+0.115729%**
9	1580.0	34.0	60.0	352.9	**351.80**	**-0.311703%**
10	1590.0	34.0	59.0	352.9	**352.35816**	**-0.153539%**
11	1620.0	33.0	58.0	363.6	**361.7133**	**-0.5146481%**

The graphical presentation is given in figure 3

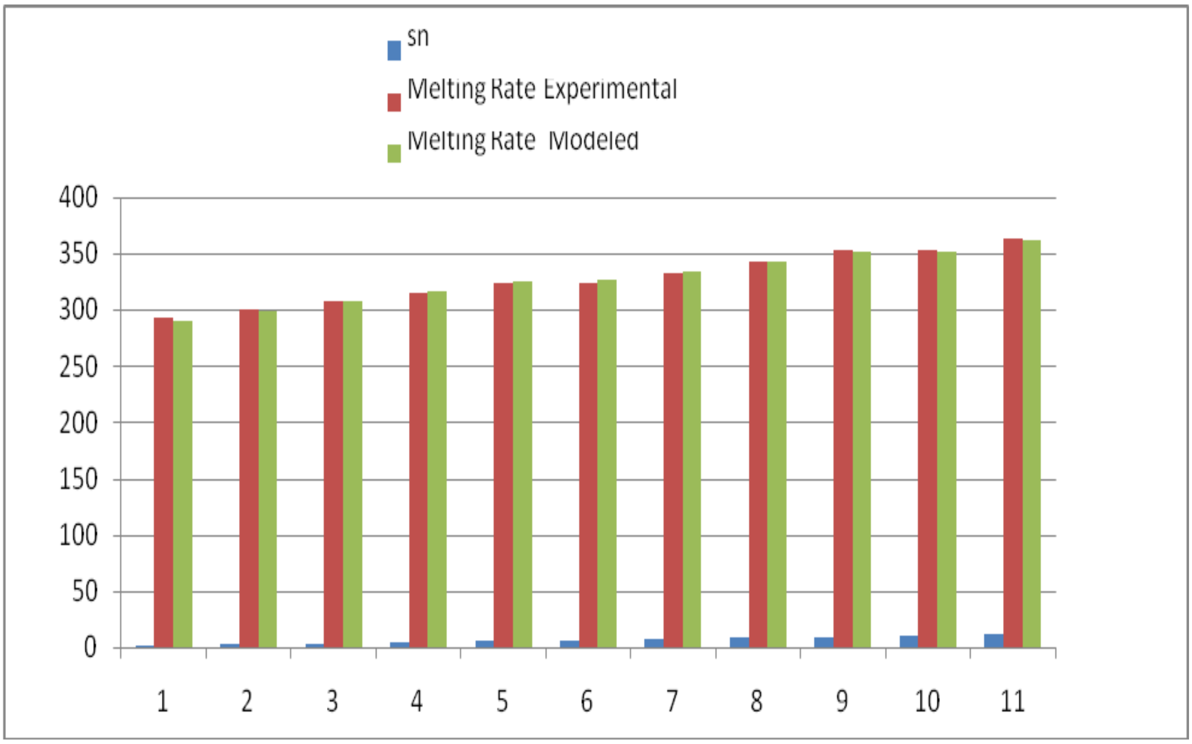

Figure 3: The graphical presentation of Experimental and Modeled melting rates

6. OPTIMIZATION OF MELTING RATE

For optimization of melting rate the regression technique is used initially for settings of input parameters. The status after successive iterations is given in table 4

Table 4: The status after successive iterations

SN	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melting Rate(kg/hr
1	1617.5	34.0	59.0	355.5
2	16 20.0	33.0	58.0	358.0
3	1624.5	32.5.	58	362.0

It is clear from table 4 that input parameters for optimal melting rate are as given in table 5:

Table 5 : Input parameters for optimal melting rate

SN	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melt-ing Rate (kg/hr
1	1624.5	32.5.	58	362.0

This value is taken as the optimal value giving the final solution

7. RESULTS AND DISCUSSION

The average percentage variation between experimentally investigated and modeled melting rate as per regression analysis is 0.01531318%. It is within the limits and acceptable

The values of input parameters based on successive iterations considered for optimal melting rate are given in table 6 .

Table 6 : Values of input parameters for optimal melting rate

Sn	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melt-ing Rate (kg/hr
1	1624.5	32.5.	58	362.0

The actual and optimized melting rate with %Error are given in table 7

8. CONCLUSIONS

It is very clear that under actual conditions of experimental investigations of Flame Temp=1620°C, Time=33 minutes, and Fuel =58.0 liters, the Melting Rate=363.6 kg/hr

Contrary to it as per optimization the optimized value of input parameters are Flame Temp=1624.5°C, Time=32.5 minutes, and Fuel =58.0 liters, which gives the optimal Melting Rate=362.0 kg/hr

The optimized value suggests that if experimental investigations are carried out at Flame Temp=1624.5°C, Time=32.5 minutes, and Fuel =58.0 liters the Melting Rate=362.0 kg/hr

The percentage error in actual experimental melting rate and optimized melting rate based on successive iterations, as per regression analysis is **0.44004%** .

The average percentage variation between experimentally investigated and modeled melting rate as per equation developed by regression analysis is **0.01531318%**

Both of these variations between

Table 7: The actual and optimized flame temperature with %Error

Actual				Optimized				%Error
Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melting Rate (kg/hr)	Flame Temp°C [A]	Time (min.) [B]	Fuel (liters) [C]	Melting Rate (kg/hr)	
1620.0	33.0	58.0	363.6	1624.5	32.5.	58	362.0	0.44004%

experimentally investigated and modeled melting rate are within the limits therefore acceptable

Hence it is concluded that regression analysis can very well be applied for modeling and optimization of process parameters of oil fired furnaces to suitably predict the output melting rate before actually operating the furnace. it is going to be very economical and beneficial for foundry industry.

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