Development of Probability Concept for Thermal Fatigue Life Cycle Prediction

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Abstract: ***Furnaces are most commonly used for melting of Ferrous Metals and its alloy materials. Induction furnaces use Electrical Power so that they are more advantageous as no fuel is required. It is a very critical problem to find life span of Induction Melting Furnace Wall under thermal load variation. The life cycle of induction furnace refractory wall is a variable as minor variation is always present due to effect of skill of workers and many other factors. The life cycle of furnace wall will vary minor with some miscellaneous factors and cannot be justified as a single value always. The probability concept is utilized here in the forecast of life cycle calculation to justify the miscellaneous factors effected for the damage of the induction furnace refractory wall. The probability concept initially defines a minimum life of induction furnace wall for a certain case then it is assumed to vary with different probability as given below. So, all the cases of induction furnace wall are having minimum life always but some cases of induction furnace wall are having much longer life. It is due to effect from many miscellaneous factors like skills of workers, efficiency of workers, raw material quality used for construction of wall, tools applied for ramming of it, row material employed for melting, etc.***

Keywords: -Induction Furnace, Heat Transfer, Probability Concept, Life Cycle Prediction

I. INTRODUCTION

The furnace is an equipment used for melting. It is combustion type and electric type. In combustion type furnace generally used as fuel is oil and coal. Then electric type furnace called as induction furnace. These are generally used in automobile and melting scrap industries.If we want to solving problem of simple heat transfer involving simple geometries with simple boundary condition. It is solved by analytical method but, when it wills complex boundary condition than we cannot solved analytically. There are several ways of obtains the numerical formulation of heat transfer problem such as finite difference method, finite element method, boundary element method.

II. LITERATURE SURVEY

The study on the distribution rule of temperature and thermal stress distribution and on the fatigue life comparison process for the refractory wall is not going to lay foundation for the improvement acquaintance of on the thermal fatigue of this form of elements underneath thermal shock circumstances of low cycle and excessive phase transition stresses but in addition presents amazing management for thermal fatigue failure.

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A whole literature assessment on computational investigation on one of a kind of variety of furnaces is completed to be trained study trends. An overview is done on applications of distinct numerical approaches in heat transfer with its applications. Thermal fatigue evaluation of induction melting furnace wall is done for silica ramming mass.

An evaluation is accomplished for study on induction heating. A evaluate is finished for metal forming analysis utilizing exceptional numerical approaches. Transient heat transfer analysis of induction furnace is done through utilizing finite detail evaluation. Thermal fatigue evaluation of induction furnace wall is finished for alumina ramming mass. Thermal evaluation of scorching wall condenser is done for home refrigerator using numerical process for temperature distribution. Optimization of wall thickness for minimal heat loss for induction furnace wall via finite detail evaluation. An assessment is finished on numerical evaluation of furnace. Thermal fatigue analysis of induction furnace refractory wall is finished for zirconia. Comparison of finite difference system and finite detail procedure is finished for 2 D transient heat switch predicament. Thermal fatigue analysis of induction furnace wall is completed for magnesia ramming mass.

III. EXPERIMENTAL INVESTIGATION

Initially, experimental work is done at Jyoti CNC Limited and rate of change of temperature with respect to time is measured. They are having temperature sensors in the form of thermo-couples by which we can measure the temperature after different time intervals. We had found temperature variation for different time periods like 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes, 60 minutes, 70 minutes, 80 minutes etc. The temperature readings for different time periods can be measured by temperature sensors shown in Figure 1. The computer program results for temperature distribution and experimental conditions are completely matching with minor variations. The average life of induction furnace refractory wall is 220-250 hours which is matching with our answer from computer program which utilize data of stresses and S-log N curves. The answer is 220-250 thermal fatigue stress cycles. So, our value of temperature distribution and maximum stress is correct.

The same kind of experimental work is carried out at Gujarat Casting Pvt. Ltd. Sapar for magnesia ramming mass and temperature distribution is validated from experimental work. The temperature sensor at Gujarat Casting is same as shown in Figure 1. The average life of refractory wall is 350-390 cycles which is matching with program stresses results and S-Log N curves predictions. The answer is also in the range of 350-390 thermal stress cycles.

The same kind of experimental work is carried out at Echajay Steel, Rajkot for alumina ramming mass and temperature distribution is validated from experimental work. The temperature sensor at Echajay Steel is same as shown in Figure 1. The average life of refractory wall is 340-370 hours which is matching with program stresses results and S-Log N curves predictions. The answer is in the range of 340-370 thermal stress cycles.

It can be observed that thermal stresses are created inside furnace refractory wall from Figure 2. Because of high temperature and temperature variation due to pouring, thermal stress variation is created and reduces life of refractory wall of induction melting furnace. Comparison between maximum temperature as per algorithm and as per experiment for silica ramming mass, alumina ramming mass and magnesia ramming mass are indicated in Table1. From experimental work, it is validated that the values of temperatures and stresses found out by developed algorithm and results found out from computer program using S-log N curves for all materials are predicting life approximately accurate. It is validated from experimental work that the methodology used in this research work for prediction of low cycle thermal fatigue life is correct. This experimental work is done in the industries with the help of skilled workers available for taking reading of maximum temperature after different time interval.

Fig. 1 Measurement of temperature using thermocouple (Source: Field Observation)

Fig. 2 Melting of scrap material in induction furnace (Source: Self Observation)

Table-II Comparison between Maximum Temperature as per Algorithm and as per Experiment

Sr. No.	1	2	3	4	5	6	7	8	9
Time (Minutes)	0	10	20	30	40	50	60	70	80
Maximum Temperature as per Experiment (Kelvin) for Magnesia Ramming Mass	307	1180	1517	1658	1712	1728	1724	1725	1640
Maximum Temperature as per Algorithm (Kelvin) for Magnesia Ramming Mass	300	1173.674316	1512.872559	1650.082642	1708.423828	1724.053101	1724.053101	1724.053101	1643.532593
Maximum Temperature as per Experiment (Kelvin) for Alumina Ramming Mass	305	1192	1565	1734	1798	1819	1825	1823	1740
Maximum Temperature as per Algorithm (Kelvin) for Alumina Ramming Mass	300	1196.530884	1570.996582	1731.086182	1801.591919	1820.728149	1820.728149	1820.728149	1746.494019

Maximum Temperature as per Experiment (Kelvin) for Silica Ramming Mass	303	1161	1480	1590	1640	1651	1652	1650	1575
Maximum Temperature as per Algorithm (Kelvin) for Silica Ramming Mass	300	1166.422607	1478.912598	1594.286865	1638.307617	1649.007568	1649.007568	1649.007568	1577.902588

Table-II Life cycles with different probability

Sr. No.	1	2	3	4	5	6	7	8	9	10
Probability (%)	100	90	80	70	60	50	40	30	20	10
Number of days working for Zirconia	126.4	129	131.5	134	136.6	139.1	141.6	144.1	146.7	149.2
Number of working cycles for Zirconia	1138	1161	1184	1206	1229	1252	1275	1297	1320	1343
Number of days working for Magnesia Ramming Mass	39.8	40.6	41.4	42.2	43	43.8	44.6	45.3	46.1	46.9
Number of working for Magnesia Ramming Mass	358	365	372	379	387	394	401	408	415	422
Number of days working for Alumina Ramming Mass	38.6	39.3	40.1	40.9	41.6	42.4	43.2	44	44.7	45.5
Number of working cycles for Alumina Ramming Mass	347	354	361	368	375	382	389	396	403	409
Number of days working for Silica Ramming Mass	25.9	26.4	26.9	27.4	28	28.5	29	29.5	30	30.5
Number of working cycles for Silica Ramming Mass	233	238	242	247	252	256	261	266	270	275

IV. PROBABILITY CONCEPT DEVELOPMENT

We consider minimum life cycle is the life cycle calculated by developed algorithm and computer program. It is denoted as $L_{min.}$ Miscellaneous Factor is required to be found from various experimental data available from industries. Minimum life means the life span of furnace wall which is having 100 percentage probability in all possible cases. Here, it is assumed that Miscellaneous Factor is 5. Miscellaneous Factor can be assumed by comparison of probability results with experimental data available. Miscellaneous Factor can be in the range of 3 to 9 for various components under thermal fatigue conditions. It is required to use following equation to find life cycle of furnace wall with different probability. Using following equation, it is possible to predict No. of working cycles of induction melting furnace wall. Here it is also assumed that at least 9 cycles can be operated during a working day. With this assumption, it is possible to predict the life span in terms of Number of working days.

N (Number of working cycles) = L_{min}X (100-Probability) / (100 X Miscellaneous Factor)
In the current chapter, experimental results for
D (Number of working days) = N / (Number of working cycles per day)
Life cycle predictions with different probability are given in Table 2 for silica ramming mass, alumina ramming mass, magnesia ramming mass and zirconia. Table 2 includes number of working days as well as number of working cycles for all different refractory materials.
The temperature at different time interval is compared with the numerical results found by the help of computer program which is validation of it. There are many miscellaneous factors affecting the life cycle of induction furnace wall like skills of workers, efficiency of workers, raw material quality used for construction of wall, tools applied for ramming of it, row material employed for melting, etc.

To justify the effect of these miscellaneous factors, probability concept is developed. For example, Figure 2 indicates size of raw material used for melting which is one of the miscellaneous factors which affect the life cycle. Probability concept gives life cycle with different probability as per the effect of miscellaneous factors. The implementation of collective explicit finite difference method and stress life method is very complex. The computer program needs various input parameters and it gives output for that particular material only. To simplify the low cycle thermal fatigue life prediction methodology, an empirical correlation can be developed which can directly utilize the values of material properties and geometrical parameters for prediction of life cycle. Empirical correlation has been developed for the prediction of thermal fatigue life cycle of induction melting furnace wall which in covered in Chapter.

V. CONCLUSION

The same analysis is completed for four diverse refractory materials silica ramming mass, alumina ramming mass, magnesia ramming mass and zirconia. A probability concept is essential to justify the prediction of life cycle with numerous miscellaneous factors effected for the failure of the induction furnace wall. Probability concept is originally able to define a minimum life concept for furnace wall for a specific case then it is assumed to be variable with different probability depending upon several factors. All the situations with any set of variables of furnace wall must have minimum life but under some situations it may happen that furnace wall are having much longer life. It is due to some miscellaneous factors like skill of workers, effectiveness of workers, raw material quality used for construction of wall, tools applied for ramming of it, row material operated for melting, etc.

out by developed algorithm and results found out from computer program using S-log N curves for all materials are predicting life approximately accurate. It is validated from experimental work that the methodology used in this research work for prediction of low cycle thermal fatigue life is correct. This experimental work is done in the industries with the help of skilled workers available for taking reading of maximum temperature after different time interval.

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