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A Study of Transformation of Heat in Furnace for Melting Gun Metal

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Abstract

In this paper study of furnace oil fired furnace for melting Gun Metal and so as to enhance the working condition and performance of furnace for using operating condition, In that study of the three dimensional heat transfer preferred several method. Parameters are study and reviewed also motivation are use of procedure fluid dynamics software package as environmental considerations. The advanced pure mathematics and enormous range of parameters obtained within the furnace, because of this, an analytical resolution is tough, and thus one has to prefer numerical modeling. So industrial software system referred to as ANSYS FLUENT can used for modeling the unsteady-state three dimensional heat transfers in an exceedingly melting furnace. In that work primarily involves the utilization of coupled radiation and solidification/melting model to simulate the operational condition heat transfer in melting furnace. The simulated temperatures of charge and furnace flue gas exit purpose temperature are compared with the commercial oil dismissed furnace knowledge and check out to optimize it.

Keywords:*Discrete ordinate method, Melting furnace, Radiation heat transfer, Radiation transfer equation, Recuperator*

1. INTRODUCTION

For manufacturing of pure Gun Metal in which tin and zinc are brought in copper and this manner shaped with the help of furnace. Gunmetal, which casts and machines well and is resistant to corrosion from steam and water, it is used to make steam and hydraulic castings, valves, gears, statues and various small objects. In this paper, we look at approximately Gun Metal product and the specifications required for this study are taking from one enterprise.

1.1 Melting Furnace:

The maintaining ability of the melting Furnace (MF) is 25 tons and it produces 10 tons of liquid metal in a very amount of 4 hours and 10 minutes. This furnace having 2 burners used to soften the ingots. The air needed to burn furnace oil is preheated with the assist of recuperator. Blower of three power unit is employed to suck the air from surroundings to feed into the recuperator. The air for the burner is provided from a blower at strain 1100 metric linear unit water. For going for walks the melting furnace, 200 liters/hr. Furnace oil is required. Furnace oil stress is keep at 2 kgf/cm^2. The furnace oil intake is measured Associate in Nursingd recorded on an hourly basis. Furnace has 2 doorways, one is major door from that charging is achieved and different is once more door from that degassing and drossing operation is accomplished. For beginning the first door there could also be motor and block mechanism. The door is slippy at the wall. The furnace is insulated internal by means of 2 layers of refractory cloth one is insulation brick and completely different is hearth brick every having a pair of hundred metric linear unit thickness. This furnace is ready with warmth recovery device i.e. recuperator. On the opposite aspect of burners there's provision for flue gases to travel into in to the recuperator

1.2Tilting/holding furnace:

The maintaining potential of tilting/maintaining furnace (TF) is 8.5 tons every. This furnace having burner's facility, but presently simplest one burner is functioning. For running the tilting furnace, fuel intake is twenty eight liters/hr. For this furnace conjointly furnace oil intake is measured and recorded on an hourly basis. Furnace oil temperature and strain is equal as that of melting furnace. Primarily based wholly on the melted gift within the furnace the tilting is completed so correct amount of liquid bronze is given to non-stop casting machine. For tilting the furnace hydraulic mechanism is employed. On this furnace in addition there's provision for flue gases to enter into recuperator.

1.3 Recuperator :

Massive amount of warmth is carried with the help of flue gases. Thanks to this performance of furnace is reduced. To reinforce the potency of furnace waste heat recovery machine i.e. recuperator is put in to furnace. Its miles a double cylinder shell sort recuperator. Heat flue gases flows through inner shell that is product of stainless-steel and air flows among the inner and outer shell in reverse route in order that it's miles preheated before introducing into the burner. For equally improvement inside the potency of recuperator, it's miles insulated with the help of nonconductor.

2. LIETRATURE REVIEW

2.1 YUKUN HUA [2] is performed the experimental work in the Development of transient mathematical models for a large-scale furnace using CFD methods.

This paper thinks about with the event of a hybrid modeling approach to simulate transient thermal performances of an outsized scale reheating furnace. Specially, this new modeling approach combines the benefits of the zone technique and process Fluid Dynamics (CFD) in a very strong manner. The model has been valid exploitation comprehensive experimental information collected throughout an instrumented bloom period that has a protracted production delay. The results recommend that the model predictions area unit in smart agreement with actual measurements, which the model is ready to reply properly with reference to the assembly delay.

Conclusion of this paper is incontestable within the current paper that highlights a unique approach to adapting the classical zone technique with CFD-based internal flow model. A selected advantage of the developed model arises from the complete energy balance derived from 1st principles that facilitates analysis of the furnace specific fuel consumption and potency. The developed mathematical model has been valid by actual measurements from a large-scale reheating furnace and has been shown to outgo the semi-empirical level-2 model utilized in the prevailing plant. Further, up to a hundred and seventy times quicker than the particular run time, the model was still able to predict the general thermal behavior of the furnace with affordable accuracy. Combined with its comparatively short computing time the mathematical model is also fitted to incorporation into higher-up temperature system or as off-line model for work furnace optimization and management issues.

2.2 MICHAEL F. MODEST[4] established an Radiation Transfer Equation (RTE) in this paper study of though all modes of warmth transfer occur at the same time the warmth transfer by radiation could be a major contributor therefore, the tactic wont to model it ought to manufacture correct results. So the selection of strategies is additionally vital. Radiation is handled by radiation transfer equation (RTE). The fundamental of all strategies for the answer of radiation downside is that the RTE [4]. The radiative transfer equation is associate integro-differential equation, and its answer even for a one- dimensional, planar, grey medium is sort of tough. Most engineering systems are the opposite hand, area unit flat. Additionally, spectral variation of the radiative properties should be accounted for within the answer of the RTE for correct prediction of radiation heat transfer. These concerns build the matter even additional difficult. Therefore, it is necessary to introduce some simplifying assumptions for each application before attempting to solve the RTE in its general form.

$$s\nabla I(r,s) = -k(r)I(r,s) + Q(r,s) \qquad (1)$$

Equation 1 describes the radiative intensity field, I, within the enclosure, as a function of location vector r and direction vector s; Q represents the total attenuation of the radiative intensity due to the gas emission and the in-scattered energy from other directions to the direction of propagation, and k is the total extinction coefficient.

2.3 FLUENT USER GUIDE [10]

The radiation intensity could be operating of the placement the direction of propagation of radiation and of wavelength. Typically the angular dependence of the intensity complicates the matter since all potential direction should be taken under consideration. it's thus fascinating to separate the angular dependence of the intensity from its spatial dependence to alter the governing equations. If it's assumed that the intensity is uniform on given intervals of angle than the radiative transfer equation may be simplified because the integro-differential RTE equation would be reduced to a series of coupled linear differential equations in terms of average radiation intensities or fluxes. This procedure yields the flux ways.

When deciding that flux radiation model for melting furnace is to be used take into account the subsequent blessings of every model [5]

Optical thickness: The optical thickness αL may be a smart indicator of that model to use. If αL >>1, then best alternatives square measure the P-1 and Rosseland models. The P-1 model ought to generally be used for optical thicknesses>1. For optical thickness>3, the Rosseland model is cheaper and a lot of economical. A second-order discretization theme is additionally counseled for top optical thickness cases. The DTRM and therefore the DO model work across the vary of optical thicknesses; however square measure considerably dearer to use. Thus use the "thick-limit'' models, P-1 and Rosseland, if the matter permits it. For optically skinny issues (αL<1), solely the DTRM and therefore the DO model square measure acceptable.

Scattering and emissivity: The P-1, Rosseland, and DO models account for scattering, whereas the DTRM neglects it. Since the Rosseland model uses a temperature slip condition at walls, it's insensitive to wall emissivity.

Particulate effects: Only the P-1 and DO models account for exchange of radiation between gas and particulates.

Semi-transparent walls (interior and exterior): Only the DO model allows to model semi-transparent walls of various types (e.g. glass).

Specular walls: Only the DO model allows specular reflection (e.g., for dust-free mirror).

Partially-Specular walls: Only the DO model allows specular reflection (e.g., dusty mirror).

Non-gray radiation: Only the DO model allows computing non-gray radiation using a gray band model.

Localized heat sources: In problems with localized sources of heat, the P-1 model may over-estimate the radiative fluxes. The DO model is probably the best suited for computing radiation for this case, although the DTRM, with a sufficiently large number of rays, is also acceptable.

Enclosure radiative transfer with non-participating media:
The surface-to-surface (S2S) model is suitable for this type of problem. The radiation models used with participating media may, in principle, be used to compute the surface-to-surface radiation, but they are not always efficient.
Gas or oil fired industrial furnaces are localized radiation sources, DO approximation can give better a result for this reason we use DO method to solve radiation heat transfer in industrial furnace.

2.4 M.F. MODEST [7] gives the detail procedure of weighted total of grey gases model (WSGGM) for discretionary resolution ways in radiative transfer. The construct of weighted total of grey gases approach was 1st conferred by Hottel and Sarofim (1967) with within the frame work of the zonal methodology. the strategy could also be applied to discretionary geometries with varied absorption coefficients however is proscribed to non-scattering media confined among a black walled enclosure.

M.F. Modest incontestible that this approach may be applied to the directional equation of transfer and thus to any resolution methodology for equation of transfer (exact, P-N approximation, distinct ordinates methodology, etc). During this methodology the non grey gases is replaced by variety of grey gases, that the warmth transfer rates are calculated severally. the whole flux is then found by adding the fluxes of grey gases once multiplication with sure weight factors. He conjointly showed that methodology could also be utilized in conjunction with any spectral model (line-byline, slim band, wide band or total emissivity correlations) and administered to any desired accuracy.

2.5 R. VUTHALURU, H.B. VUTHALURU [11] studied the separate ordinates methodology (DOM)and separate transfer methodology (DTM) were evaluated from the viewpoints of each prognostic accuracy and process economy by scrutiny their predications with precise solutions obtainable from a box formed enclosure drawback with steep temperature gradients. They notice that comparative testing of S4 approximation produces higher accuracy in radiative energy supply term than in denseness in 3 orders of magnitude less central processor time than that needed by the DTRM. They counseled that the S4 approximation (DOM) will be utilized in conjunction with CFD codes

2.6 R.VISKANTHA [9] review the literature on strategies for finding the radiative transfer equation (RTE) and group action the energy quantities over the spectrum needed to predict the flow, the flame and also the thermal structures in with chemicals reacting and diverging combustion systems. The main target is on four strategies (differential approximation, distinct ordinates, distinct transfer, and finite volume) for predicting radiative transfer in three-D geometries that meet the required needs. Conjointly the strategies that square measure quick and compatible with the numerical algorithms for finding the transport equations victimization the process fluid dynamics techniques square measure reviewed. Within the higher than strategies, the interaction of turbulence and radiation is neglected.

3. *OBJECTIVES*

The objective is to simulate the furnace and charge melting temperatures by coupling radiation and solidification/melting model for unsteady state heat transfer.

1. To simulate the current efficiency of furnace
2. Simulation of furnace for current operating conditions
3. Simulation of charge melting temperature
4. Simulated result is to be validated with company data

4. *METHODOLGY*

The melting operation for a charge typically takes 4 hour and 10 minutes. The physical drawback of a melting furnace has been solved mistreatment the industrial machine fluid dynamics (CFD) package, FLUENT. The CFD code solves the sculptural 3 six dimensional Navier-Stokes equations over a boundary fitted grid employing a finite volume pressure correction procedure. This work is only involved with the simulation of the radiation for unstructured grid of melting furnace and charge hanging in air. For more details of the CFD techniques used see the flow chart Figure 1. The approach adopted in the present work is to assume that the furnace is working in an exceedingly simple unsteady state.
1. Commercial process Fluid Dynamics (CFD) package is accessible for 3-d analysis of the flow, combustion, and warmth transfer
2. Mathematical model for three dimensional analysis of melting furnace integrates sub models of flow, combustion and radiation heat transfer
3. Generation of Computational model in GAMBIT analysis of engineering drawing and meshing scheme and type.

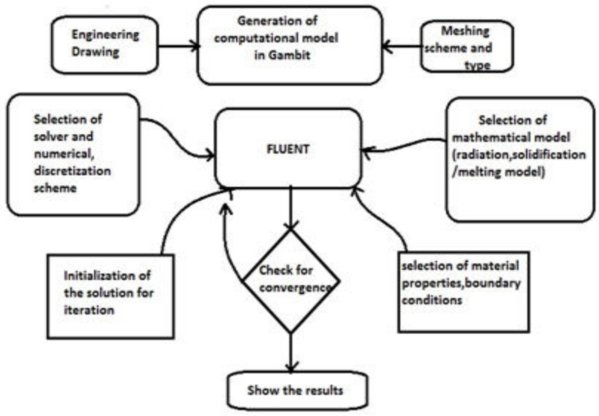

Fig.1. Flow chart of CFD techniques employed for reheating furnace

5. OPERATION OF OIL FIRED FURNACE

5.1 Melting Furnace:

The main furnace is charged with contemporary Gun Metal of ten tons for each 4 hrs 10 min. Hence, a minimum reserve liquid liquefied metal of fifteen tons are invariably there in furnace throughout steady operation. The charging is finished with the assistance of fork raise truck. Approximate size of the bundle is 60x60x60 cm^3. The liquefied metal is then transferred to tilting/holding furnace with the assistance of launders

5.2 Tilting/Holding Furnace:

The liquefied liquid metal from the Melting Furnace (MF) is then transferred to Tilting Furnace (TF) whereby degassing and drossing operations area unit dispensed. Basically, degassing refers to removal dissolved H from liquefied gun metal, that otherwise may end up in porousness in castings. Degassing operation is dispensed by adding C_2Cl_6 to the liquefied metal that liberates H2 from liquefied gun metal. This operation lasts for ten to fifteen minutes. Dross consist oxides of metal in solid type that can also entice some metal in it. In drossing operation, liquefied metal is stirred by a dross painful tool. Dross having light-weight weight than liquefied metal thus it's floatingabove liquefied metal. When adequate stirring the liquefied metal dross is collected, Color of gun metal dross is blood-red.

5.3 Recuperator:

The hot flue gas that start from furnace is tried and true the within shell of recuperator and therefore the cold air that is equipped by blower is passed between the inner and outer shell of recuperator. Air gets heated owing to physical phenomenon and convection heat transfer between flue gas and air. This preheated air is employed to burn furnace oil. The temperature of flue gas at the entry of recuperator is 900^0C and at exit its temperature is 500^0C. Flue gas temperature at the doorway of chimney is 300^0C to 350^0C.

6. COMPUTATIONAL MODEL OF REHEATING FURNACE

The Fluent is employed to make the process model of melting furnace.

6.1 Furnace geometry Assumption:

The furnace is simplified by not considering several structural a part of the furnace. In furnace charge of ten tons is to be dissolved for the four hours and ten minutes. In our assumption we tend to are presumptuous that everyone the ten ton charge is placed within the furnace. Additionally for the simplification in meshing whole charge is to put somewhat on top of from bottom face of furnace. Burners are created as single hole through that combusted oil with far-famed mass rate of flow is coming into the furnace. Because the furnace is cruciate on its dimension, just one 1/2 the furnace is taken into account for this modeling exercise.

6.2 Generation of Mesh:

After generating real and closed pure mathematics it's subjected to mesh operation. The quantity mesh command permits making mesh for one or additional volumes within the machine model. It meshes nodes throughout the quantity in line with presently specific meshing parameters.

6.3 Meshing parameters:

• Volume(s) to be meshed: the form and topological characteristic of the quantity similarly because the vertex sorts related to its faces determines the kind of mesh theme which will be applied. For melting furnace T-grid is applicable.
• Meshing node spacing: The 3 other ways to specify the quantity of node spacing

a. Interval count: Input the particular variety of mesh interval to be placed on the sting. Gambit meshes the sting with enough nodes to end in the desired variety of interval.

b. Interval size: Input Associate in Nursinginterval length. Gambit uses the interval length to work out the entire variety of interval on the sting.

c. Short Edge (%): Input Associate in Nursing interval size price expressed as a share of edge length. Gambit calculates the worldwide interval size for this edge meshing. Once choose the short edge (%) possibility Gambit highlight the graphics window show of the short edge.

• Meshing choices:
• Meshing theme: To specify meshing scheme 2 parameters are to be thought-about one is part and alternative is sort. The theme parts

6.4 Examine the Quality of the Mesh:

For the higher than parameter, pure mathematics is meshed and it's examined for mesh quality. As per recommendation of FLUENT. From higher than parameters the furnace pure mathematics is meshed. Table 3.4 and 3.5 shows cells zones and thirty seven faces minimum and most statistics. The whole pure mathematics grid size and nodes is shown in Table3.6.

Table 3.4 Volume statics

Volume statics	
Minimum volume (m3)	2.710736e-005
Maximum volume (m3)	4.545156e-003
Total volume (m3)	3.751031e+001

Table 3.5 Face area statistics

Face Area statics	
Minimum face area(m2)	2.389240e-003
Maximum face area(m2)	5.962248e-002

Table 3.6 Complete geometry grid count

Grid Size		
cells	Node Faces	cells
29348	7059	29348

6.5 Specifying zone varieties:

Zone kind specifications outline the physical and operational characteristics of the furnace model at its boundaries and at intervals specific domains. There are 2 categories of zone kind specifications.

Boundary type: It defines the physical and operational characteristics of the model at those topological entities that represent model boundaries.

Continuum type: It defines the physical characteristics of the model at intervals nominal region of its domain.

The boundary kind for process model is shown in Table 3.7. The time kind for process model is shown in Table 3.8. In thirty seven wall kind nine surface are common boundary in each zone, FLUENT can produce shadow of those common boundary.

Table 3.7 Boundary type for computational model

Boundary types
Mass flow rate
Pressure outlet
Wall
Symmetry

Table 3.8 Continuum type for computational model

Name of continuum	Type of continuum
Wall	Solid
Charge	Solid
furnace	Fluid

7. *MATERIAL PROPERTIES AND BOUNDARY CONDITIONS*

The Gun Metal and Graphite refractory properties areused. The Gun Metal properties are use from FLUENT info. Graphite refractory properties are to be else in FLUENT. The subsequent provide properties of fabric employed in simulation

- *Gun Metal Properties*
  - Chemical Formula – CuSnZn
  - Density – 8719 kg/m3
  - Specific Heat – 377 J/kg-k
  - Thermal Conductivity – 74.8 W/m-k
  - Melting Point – 1063^0c
  - Tensile Strength – 221 to 310 MP
- *Graphite Refractory Properties*
  - Chemical Formula – C
  - Density – 2090 to 2230 kg/m3
  - Specific Heat – 710 J/kg-k
  - Thermal Conductivity – 140 W/m-k

- *Boundary conditions used in melting furnace*
  - Symmetry Boundary
  - Wall Boundary Conditions
  - Fluid Condition
  - Solid Condition
  - Pressure Outlet Boundary Conditions

1. *Type - Burner*
   Momentum –
   - ✓ Mass flow rate=0.056 kg/s
   - ✓ Initial gauge pressure=0
   - ✓ Direction specification:
     X direction = 1.951
     Y direction = 0.966
     Z direction = -0.985

   Thermal –
   - ✓ Flame temp= 1673 K

   Radiation –
   - ✓External black body temp method=Boundary temp.
   - ✓Internal emissivity=1

2. *Type - Gun Metal Wall*
   Momentum - Stationary wall
   Thermal - Heat flux=0
   Radiation - Opaque BC type (Charge)

3. *Type - Wall (Graphite Refractory*
   Momentum - Stationary wall
   Thermal - Heat flux=0
   Radiation - Opaque BC type

4. *Type - Pressure outlet*
   Momentum - Gauge pressure=0 Pascal
   Thermal - Backflow total temp=300 k
   Radiation -
   External black body temp method: Boundary temp.
   Internal emissivity=1

8. *Result and Discussions :*

Observation and calculation followed by using the given and known quantities with the help of company data. This calculation just using an analysis of Commotional fluid dynamics result.

8.1Observations:

8.1.1 Melting furnace:

1. To charge 10 tons Gun Metal ingots furnace door will open for 16 times. For each time 25 seconds are required for opening and closing the door. So during charging, 6.67 minutes door is open.
2. Currently company is using thumb rule for reducing the FO is 'increase in air temperature by 10%, reduction of FO is 1%'.
3. The temperature inside the furnace is about 1150^0c to 1200^0C. When flue gas comes out from furnace its temperature is about 1250^0c to 1300^0c.

8.1.2Tilting/holding furnace:

1. For Tilting Furnace, air pressure is about 550 to 600 mm H_2O but oil temperature and pressure is same as Melting Furnace.

8.1.3 Recuperator:

The preheated air which is used to burn the furnace oil is first passed through recuperator. Estimated temperature of this preheated air is 130 to 140^0C. Due to preheated air temperature of FO is increased to 110 to 120^0C. However, no routine measurement of air temperature is carried out in the plant.

Because of recuperator insulation furnace oil consumption is reduced from 75 liters/ton to 68 liters/ton. Due to this they have obtain 44% furnace efficiency.

8.2. Calculation:

8.2.1 Heat and Mass Balance Calculation:

a) Known Quantities

1. Fuel oil flow rate (mf_o) = 200 lit/hr = 184 kg/hr
2. Charging quantity of Gun Metal (m)= 10 ton/4 hr 10 min = 2403 kg/hr
3. Fuel oil temperature (T_{FO}) = 120^0C = 393 K
4. Preheated air temperature (Tair)= 140^0C = 413 K
5. Specific heat of FO (cp_{FO}) = 2.09 KJ/kg K
6. Specific heat of air (cp_{air})= 1.007 KJ/kg K
7. Specific heat solid Gun Metal (cp_{solid})= 0.380 KJ/kg 0C
8. Specific heat of liquid Gun Metal (cp_{liquid})= 0.481 KJ/kg0C
9. Latent heat of fusion of Gun Metal (L)= 172.05 KJ/kg
10. Calorific value of FO (CV_{FO})= 10000 Kcal/kg= 41840 KJ/kg

8.2.2 Heat Input Calculation:

We are assuming that charge is at atmospheric temperature.

1. Heat given by Furnace Oil (FO):

$$\begin{aligned} Heat_{FO} &= m_{fo}.\ cp_{FO}.\ (T_{FO}-298) \\ &= 184 \text{ X } 2.09 \text{ X } (393-298) \\ &= 36533.2 \text{ KJ/kg} \end{aligned}$$

2. Heat given by Air:

$$\begin{aligned} Heat_{air} &= m_a.\ cp_{air}.\ (T_{air}-298) \\ &= 2790.5 \text{ X } 1.007 \text{ X } (413-298) \\ &= 323153.85 \text{ KJ/kg} \end{aligned}$$

3. Reaction heat Calculation

$$\begin{aligned} \text{Heat reaction} &= m_{FO}.\ \text{Calorific value} \\ &=184 \text{ X } 41840 \\ &=7698560 \text{ KJ/kg} \end{aligned}$$

8.2.3 Heat output calculation:

1. Sensible heat 1 (from temp. 298 K to 1336 K)

$$\begin{aligned} &= m\ .cp_{solid}\ .\ (Tmelt - 298) \\ &= 2403 \text{ X } 0.380 \text{ X } (1336\text{-}298) \\ &= 947839.32 \text{ KJ/hr} \end{aligned}$$

2. Latent heat of fusion

$$\begin{aligned} &= m\ .\ L \\ &= 2403 \text{ X } 172.05 \\ &= 413436.15 \text{ KJ/hr} \end{aligned}$$

3. Sensible heat 2 (from temp. 1336 K to 1373 K)

$$\begin{aligned} &=m\ .cp_{liquid}\ .\ (Tfinal - Tmelting) \\ &= 2403 \text{ X } 0.48 \text{ X } (1373\text{-}1336) \\ &= 42766.191 \text{ KJ/kg} \end{aligned}$$

8.3 Heat carried by flue gas:

$$\begin{aligned} \text{Heat flue gas} &= m\ .cp_{FG}\ .\ (Texhaust - 298) \\ &=184 \text{ X } 16.165 \text{ X } 1.08 \text{ X } (1573 - 298) \\ &=4095693.72 \text{ KJ/hr} \end{aligned}$$

8.4 Energy balance:

H FO + H air + H reaction = Sensible heat 1 + latent heat of fusion + sensible heat2 + H flue gas + losses

36533.2+32153.85+7698560= 947839.32+413436.15+42766.19+4095693.72+losses

Losses = 2558511.669 KJ/kg

G) Efficiency of furnace

$$\text{Efficiency} = \frac{\text{Energy absorbed by product}}{\text{Energy supplied}}$$

$$= \frac{1404041.66}{3058247.05}$$

= 0.4551

= 45.51 %

9. *CONCLUSION*

The coupled radiation and solidification/melting model are wont to simulate the close to real conditions of the melting furnace. The information provided by plant for chamber temperatures is used to analysis or simulate to furnace performance or efficiency also to decide the furnace is work at running well at this moment. as a result of process modeling is usually less expensive and quicker than building paradigm that square measure usually tested underneath controlled laboratory conditions before making an attempt them in out actual field installations. Any mathematical modeling is advantageous in terms of simulating the real world downside. Correct mathematical modeling can facilitate to grasp logically the quality concerned in melting furnace.

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