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Evaluation and Optimisation of Processes Time for the Hot Air Oven Containing Sleeves

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Abstract: The Hot air producing Oven is used to heat the sleeves which are used as raiser in casting purpose. The sleeves that are being manufactured are made of epoxy resin which consists of approximately 75% water and 25% mineral mix before heating and once the processes are complete i.e. the sleeves getting heated in the oven the product would turn into 35% water + 65% mix. The whole process would estimate the time around 4.5 hours. The first 2.5 hours the water is being removed from the sleeves in form of latent heat vaporization. The next 2 hours is use as the time for curing the them because of the flow of hot air through the sleeves. The processes time is evaluated keeping in mind that the heat transfer is happening in mixed convection. As they are placed vertically to the direction of air flow. The amount of heat transfer in terms of energy is evaluated for 4.5 hours in actual practise. The energy which is utilised in 4.5 hours is found and the same amount is consumed in 2.5 hours which is a solution solved theoretically by considering datum values.
Keywords: epoxy resin, sleeves, latent heat, heat transfer, mixed convection.

I. INTRODUCTION

Casting is the one of the ancient Manufacturing Technique. There are several elements that are very much useful while making the processes of casting. One of the most useful things that supports the processes is a riser, which supports the factor of solidification of metal during the process. The material used manufacturing of sleeves is the by-product or residue of other process. This reduces the cost of manufacturing of sleeves [1]. Several materials are used in the preparation of sleeves, the main substances used in the process of manufacturing the sleeves in our area epoxy resin, rice husk, aluminium powder. Epoxy resin is used as binder, aluminium powder reinforced as the material for insulation form heat and rice husk is used as highly inflammable substances. Rise husk is one of the kinds of binder used for making exothermic sleeves and the biomass material is a living thing which can be renewed in a short amount of time. Water is an essential part of this processes the rice husk is mixed with water and other binders and set for curing. A controlled space and thermocouple set up to heat the sleeve is done [3].

Rice husks contains of 44 percentage of hydrocarbons content and it can be used as the fuel to produce heat. As India is being top in cultivation of Rice, the availability of rice husk is very high. We will not use rice husk directly; the husk will undergo calcination. Initially Rice husk is collected from local rice mill in a rice processor. There will be 3 steps involved in to make the ash ready to use in manufacturing of sleeves. The main steps are Washing, Leaching and Calcination [9]. In the first step the husk is washed with water in room temperature to remove the dirt particles and solid particles remained in the husk. The rice husk undergoes leaching with sulphuric acid for 2 hours. In Calcination the husk is burnt in order to remove voltaic particles and other low melting elements. The residue remained after calcination can be used as the ingredient in manufacturing of sleeves. Using of reduces cost of the sleeves. The amount of heat energy is dependent upon amount of carbon content present in the hydrocarbons in rice husks and it has a calorific value of around 3500-3600 Kcal/kg, the value of fuel is same as the calories produced by the material [2]. In order to manufacture the sleeve, an oven is required to dehydrate the sleeves. There is a need these sleeves in the foundry as they are factors of increasing the solidification time and proceed properly and progressively [10]. The sleeves are interfaced with mould material can be insulating or exothermic. Some thermite reactions are involved with iron and aluminium oxide while they are getting heated up[11].

Hot air oven is originally invented by Pasteur, hot air oven is used to dry and heat to sterilize the material which is present in the oven. The heat which is in the hot air oven is ranges from 50°c to 300°c[4]. Several heat transfer processes are involved in heating up the sleeves, one of the crucial processes is by convection. The position of placing the sleeve decides whether the heat transfer is going to happen with forced convection or mixed convection.

The convection processes happen because of a fluid that is going to cater the need of heating mechanism is air as the air particle are going to strike the sleeves in a vertical direction. The mixed convection is generally determined by the buoyancy factor that curtails the source to proceed about the heat transfer processes [6]. For a typical hollow cylinder placed vertically, the processes that is going to happen is a mixed convection processes and it happens with the help gravity and Reynolds number and Grashof's number which determine the flow and buoyancy are brought into picture. There is a latent heat that is captured when the water is getting converted in to vapour [7]. The heat that is being converted stays inside for some time and leaves the space of the oven and this would be the great chance to capture the heat and get that guide into a space and release it. The whole processes time is optimized and several parameters are controlled and manipulated to optimize the process time with min. fuel consumption.

The oven consists of four sections or partitions to place the sleeves inside it with a maximum capacity of inserting 800 sleeves inside it. The hot air is pumped into the oven to remove the moisture from it. The source of heat which is used to provide hot air is combustion chamber which intakes the diesel to burn in it and the air is passed from the combustion chamber and enters the partitions inside the oven. The wet sleeves are placed on trays, which in turn are placed on trolleys and then pushed into a hot air oven. Presently hot air enters our existing oven from the bottom, goes up through the oven chamber, sucked by the exhaust, reheated in a heat exchanger, and again comes in through the bottom.

Fig.1. Partitions of the oven that intake

Fig.2. recirculation of air combustion chamber

Fig.3. Sleeves that are being manufactured

The whole process consists of removal of moisture from the sleeve and manipulate the composition of the sleeve with variation of properties. A slurry consisting of approx. 75% water and 25% mineral mix is vacuum formed and, in the process, the final product consists of 35% water + 65% mineral mix. The mineral mix normally are silica in the form of calcined rice husk + alumina in the form of aluminium dross + aluminium powder + phenolic resin.

The heat transfer mechanism

The heat transferred by the sleeve should evidently form a boundary layer which involves convection heat transfer. The convection heat transfer will lead to the formation of boundary layer. The oven is heated to a temperature of 1900 Celsius from which the heat is taken by the sleeves. A heat balance sheet for the oven is plotted to get all the heat transfer processes happen at everyplace inside oven. The alignment of sleeves to the oven plate is vertical in position so we need to consider this to be like this in the below figure. A thermal boundary layer is formed and there is a gravitational force also. The boundary layer is can be traced as shown in the following figure

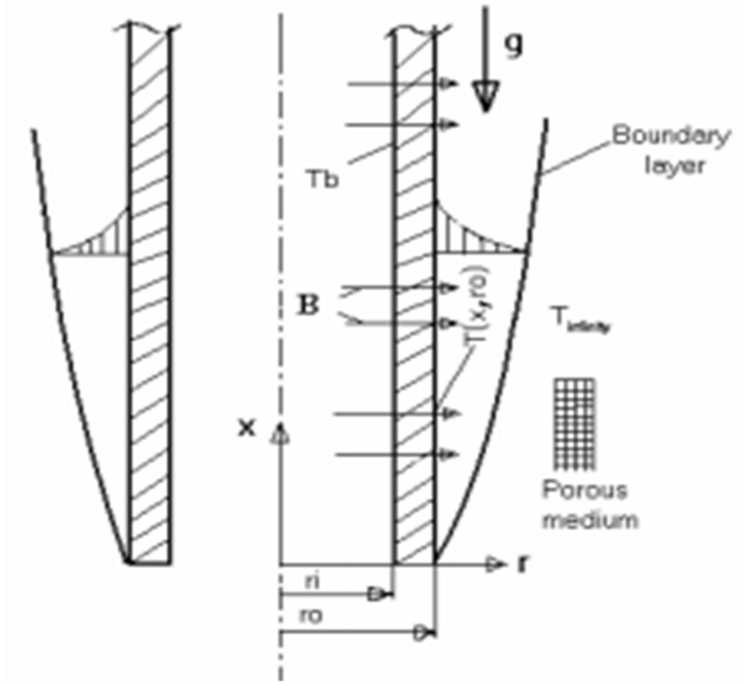

Fig.4. The boundary layer formed due to mixed convection flow.

There were several analyses done in making the boundary layer considerations while passing air through the sleeve. The approach is made by considering the particles of air in a molecular level. The first molecule or the particle of air would strike the sleeve at the lowest point and come to rest and stop. As the air is creating a drag force layers are following an increasing manner of velocity profile. The drag force is making up a profile. The convective heat transfer coefficient gives how much heat is getting transferred.

A. Equations and Calculations how heat Transfer is Happening

The Nusselt number which is helpful for finding out heat transfer coefficient is useful for making is a function of Peclet number and Rayleigh number. Here the Peclet number and Rayleigh numbers are considered for boundary layer analogy and buoyancy. The analysis conducted at several research papers was synthesised [8]. And the Nusselt number was concluded to be

$$Nu = Pe^{0.5} + Ra^{0.5}$$

And

$$Pe = PrRe$$

$$Ra = GrRe$$

The Nusselt's number decides the heat transfer coefficient "h" which can be helpful to find the heat transfer

$$Nu = (h \times L)/k$$

Where L is the length of the hollow cylinder

h is the heat transport coefficient

k is the thermal conductivity of air

The path of interest shown here is finding out Nusselt's number and heat transfer coefficient which is helpful for total heat transferred by convection

Grash of number

$$Gr = (g \times \beta \times \Delta T \times L^3 \times \rho^2)/\mu^2$$

Where $g = 9.8 m/s^2$ $\beta = 1/T_f = 0.0022\ K^{-1}$

Tf = temperature of the film

$\Delta T = T10 - T^*$

Length of the cylinder L= 0.1016m

density of hot air $\rho = 0.702 Kg/m^3$

absolute viscosity $\mu = 0.00002613\ N\text{-}s/m^2$

$Re = (u \times L)/\upsilon$

Velocity of air through the sleeve u = 1.1m/s2

Peclet number Pe = Re × Pr = 2081.894102

Prandtl number = 0.679

Rayleigh number = Re × Gr = 64675143.7

$$Nu = Pe^{0.5} + Ra^{0.5}$$

Convective heat transfer coefficient h(W/m2k)

$$h = (Nu \times k)/L \quad k = 0.0399$$

h = 4535.728289

T* = average temperature of the oven

T10 = surface temperature of sleeve

$$Q = h \times A \times T^* - T10 = 127.594252 \text{ watt}$$

Thickness of sleeve = 0.0254 m

A = L x thickness = 0.0254m2

B. *Latent Heat Capturing*

Latent heat is used in several applications which are actually used for storing energy. All the heat transfer processes that are established with phase changes are related to the latent heat. Latent represents the amount of energy that is hidden in a substance. Water that is kept in a bowl would evaporate when the bowl is heated and it is sent into the atmosphere. Imagine that the bowl is kept in a closed vessel the situation would be the water which is becoming vapour would reside inside the vessel. A lot of energy is emitted when water is staying inside the vessel. The water vapour might exceed the amount of fuel supplied which will be known as latent energy. This energy serves the most useful way of utilisation. There are several instances that can be observed where this latent heat is utilised in a productive way. Sometimes the latent heat emitted as by product would be useful for generating the power or running an air conditioner by throttling the latent heat or steam that is coming out of the system. Latent heat source is an excellent source for utilising thermal energy and saving the economy if it is an industrial application.

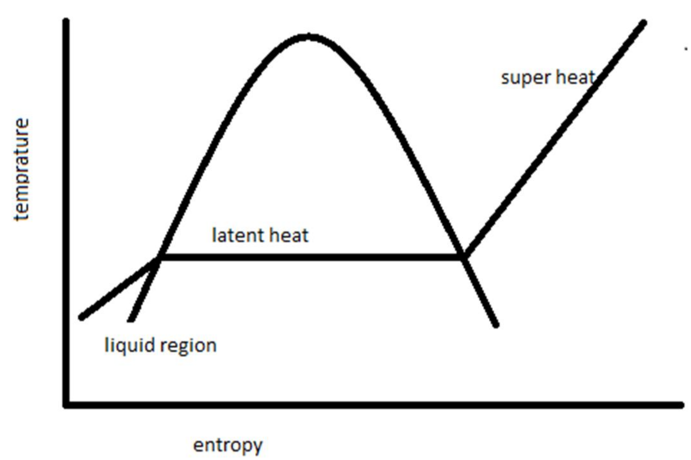

Fig.5: latent heat representation in water

The latent heat is also evaluated like in the T-S diagram in the further while representing the datum pints the latent will also be evaluated

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II. DEFINING ALL THE NECESSARY DATUM POINTS

The above all the mentioned parameters are set up and listed down

Time in Minutes	average Temperature of air inside oven T*	surface temperature of the sleeve inside T12	film temperature of sleeve (T*+T10)/2	Measured air flow velocity u in m/s	kinematic viscosity databook (m^2/s)	Reynolds number (u*L)/kinematic viscosity	Prandtl number (data book)
1	56.42	28	42.21	1.1	0.00001728	6467.592593	0.6995
40	88.9	73	80.95	1.1	0.00002109	5299.193931	0.692
80	90.3	107.32	98.81	1	0.00002368	4290.540541	0.688
120	93.05	110.9	101.975	1.2	0.00002469	4938.031592	0.685
160	118.32	128.23	123.275	1.1	0.00002764	4043.41534	0.684
200	138.05	149	143.525	1.1	0.00003057	3655.87177	0.682
240	164.12	174	169.06	1.2	0.00003601	3385.726187	0.678
270	167.82	180.66	174.24	1.1	0.00003645	3066.11797	0.679

Table.1: tabulated form of the experiment

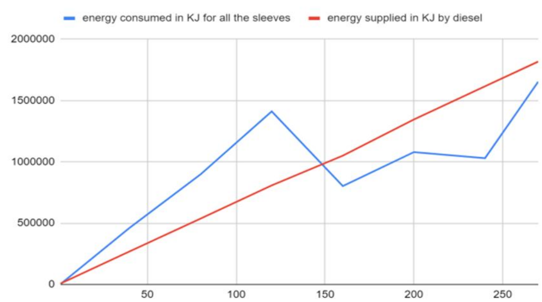
Peclet number PrRe	absolute viscosity Ns/m^2	density Kg/m^3	Grashof number $\frac{g \times \beta \times \Delta T \times L}{\mu^2}$	Nusselt number $(Ra^{0.5})+(Pe^{0.5})$ for h	thermal conductivity of air	heat transport coefficient Nu*k/L L= 0.1016
4524.081019	0.00001922	1.12	3146253.636	1841.029492	0.02766	501.2094069
3667.0422	0.00002118	1.021	379755346.1	19547.86855	0.03047	5862.436561
2951.891892	0.000022898	0.898	455415732.2	21394.80301	0.0329	5329.058865
3382.55164	0.00002279	0.868	266131462.1	16371.69587	0.03301	5319.18977
2765.696093	0.00002352	0.875	312947402.8	17742.90935	0.0348	4084.755798
2493.304547	0.00002486	0.815	231421761.9	15262.48577	0.03659	3978.809501
2295.522355	0.00002612	0.732	128183909.9	11369.74494	0.03968	3506.482725
2081.894102	0.00002613	0.702	132341927.1	11549.62391	0.0399	3850.690929

Table.2; continue

total heat one sleeve transferred in watt hA(T*-Ts) =Q'	for all the sleeves KW power consumed	power supplied	energy consumed in KJ for all the sleeves	energy supplied in KJ by diesel
36.75959446	29.40767557	112.314815	1764.460534	6724.8889
240.5485288	192.438823	112..3078704	461853.1752	269538.889
234.0655496	187.2524397	111.9247338	898811.7106	537238.7222
245.0254129	196.0203303	112.2052469	1411346.378	807877.7777
104.4641264	83.57130116	109.4001157	802284.4911	1050241.111
112.4332307	89.94658457	112.0930417	1079359.015	1345116.5
89.40381945	71.52305556	112.2052469	1029932	1615755.555
127.594252	102.0754016	112.2052469	1653621.506	1817725

Table3; continue

After relating the datum, a graph is plotted I n between the time in minutes and energy consumed in KJ for all the sleeves, energy supplied in KJ by diesel. The graph was evidently found as shown below



Graph: Power supplied and energy consumed in Y axis and time in X axis

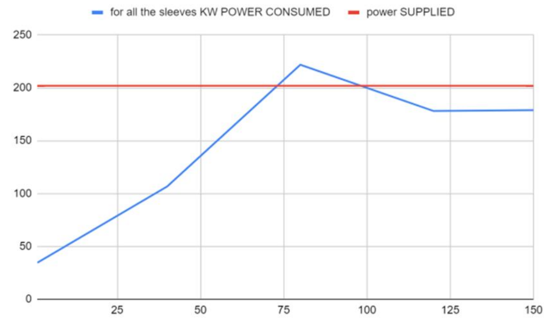
The above graph concludes that the heat supplied limits the heat that is provided outside it can be justified that the moisture is becoming vapour and staying inside for some time as it is being struck inside due to not opening of the gates. The gates after opening the energy exhibited is getting down and slowly the heat is heat is released out. The heat that slightly deviates in the graph positively from the energy supplied is the latent that can be assumed.

III.REDUCING THE PROCESSES TIME

The processes time is taking 270 minutes and this is a lot of consumption of time. The time should nearly be cut down to half of the time. One of the parameters must be variated. The parameter that is being variated can be velocity as it is found to be the most tangible parameter. So, the velocity is doubled to 2.2m/s so we can have the same processes here also the data is represented in the tabular form and graphical solution.

Time in Minutes	Heat transferred by sleeves in KW	Energy supplied
1	34.57611984	201.964
40	106.6823354	201.964
80	221.8456579	201.964
120	178.1221715	201.964
150	178.9116537	201.964

Table4: New oven analysis



Graph: Processes monitoring of the variated parameters system

IV. CONCLUSIONS

The heat transfer time is being evaluated in the system that is being taken for curing the sleeves The latent heat was observed higher than input, this implies exothermic sleeves emits vapour which contributes to increase the heat in the symstem and that also benifits to decrease thee processes time from 4.5 hours to 2.5 hours by varying the velocity from 1.1 to 2.2 m/s.

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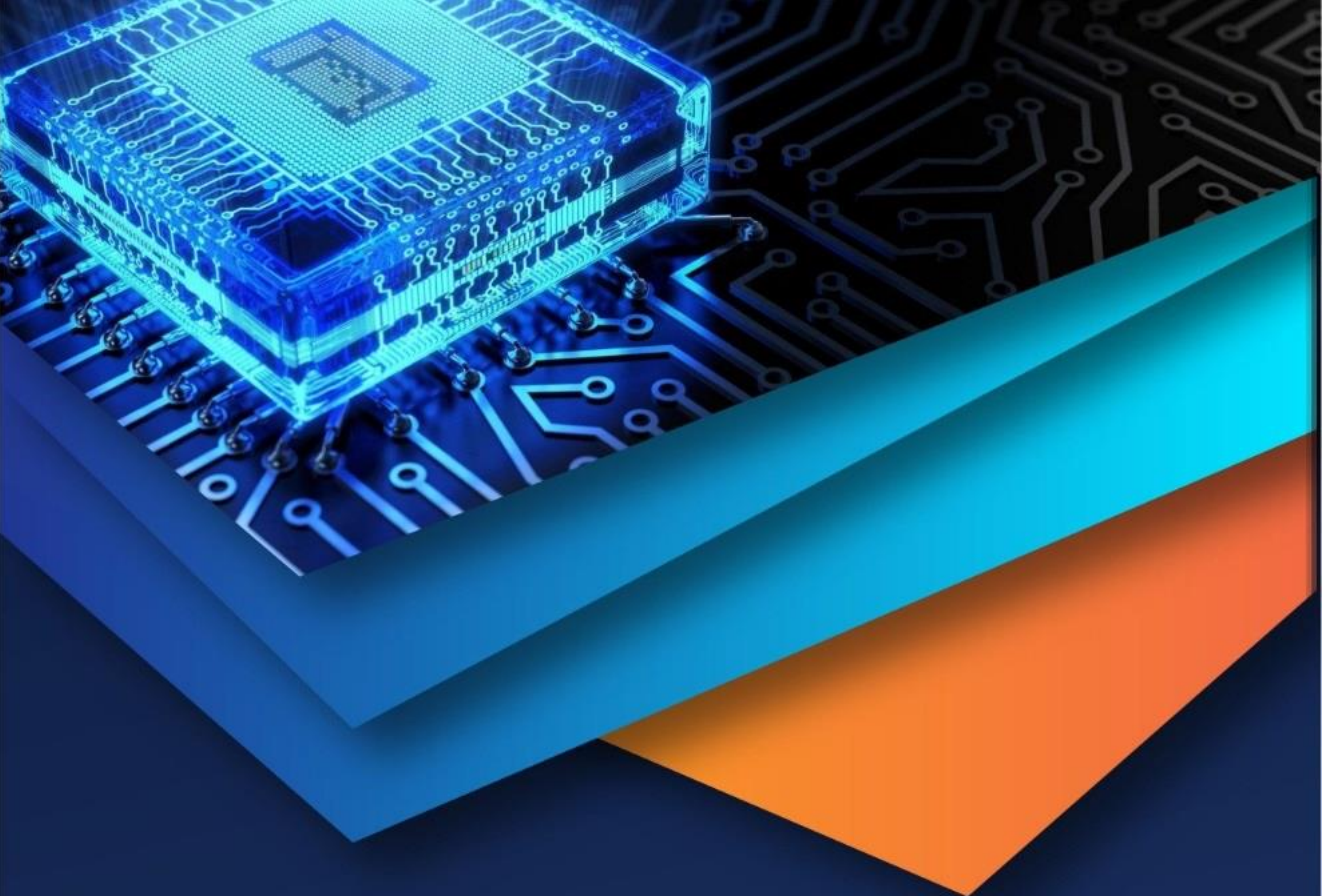

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