IJRAME

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.9,
September 2018
Pg: -41-53

Non-Metallic Multi Materials Casting for Solidification Time & Mold Constant

Sonu S. Bansod[1], Lokesh Singh[2], Sushil Kumar Maurya[3]

[1]Department of Mechanical Engineering & GD Rungta College of Engg and Technology,Bhilai, India

[2]Assistant Professor and head of Department of Mechanical Engineering & GD Rungta College of Engg and Technology, Bhilai, India

[3]Department of Mechanical Engineering & Modern Institute of Technology & Research Centre, Alwar , India

[1]bansod47@gmail.com; [2]lokeshsingh25@gmail.com; [3]mauryasushil86@gmail.com

***Abstract*: Casting is one of the most ancient techniques/method used for manufacturing parts. It is usually applied to manufacture near net shape components. Today's, there has been several casting techniques developed, each with its own characteristics, applications, advantages and disadvantages. During selection of any casting process, it should be kept in mind, no one method of casting process which produce or provide defect free casting, some defect is always present. So we use those process they give optimum result. The traditional method of metal casting is the sand casting. The traditional method of metal casting is the sand casting. Sand casting, which uses sand as the mold material, it is also the least expensive method as compared to other casting techniques. The purpose of this work is to review and analyze or identify the various perspectives of sand casting process based on available knowledge, experience of experts & perform experimentally setup of sand casting processes by using non metallic multi-material & measure the various parameter of sand casting such as solidification time, mold constant & parameter related to our cast shape which is truncated rectangular base pyramid or we simply called pyramidal frustum of rectangle base shape volume.**

Keywords: Casting, Solidification time, Volume of mould cavity, mould constant or solidification constants, Chvorinov's rule.

I INTRODUCTION

Metal casting is one of the most ancient techniques/method used for manufacturing metal parts [1]. It is usually applied to manufacture near net shape components around 6.5million kg of casting are produced every year [2]. The most common materials used for casting are grey iron, ductile iron, aluminum alloys and copper alloys. There has been several casting techniques developed, each with its own characteristics and applications. The traditional method of metal casting is the sand casting. This method is still important, as more than 70% of metal casting is performed using sand casting. Sand casting, which uses sand as the mold material, is also the least expensive method as compared to other casting techniques. There are many parameter and factor which affect the sand casting process. Solidification is a very crucial factor for any casting process. Generally directional solidification will help to achieve a good quality casting product. Different rate of pouring temperature will also affect the solidification rate of casting and so quality of casting [3].

One of the very important parameters to assess the properties of materials produced by casting process is the solidification time [4]. Solidification time can be measure by directly by using device such as watch & thermometer or we can also calculated by using formula. The formula of solidification time is called Chvorinov's rule or also called Chvorinov's principle.

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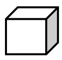
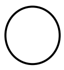
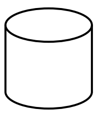
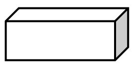
Chvorinov's rule"For calculation of the total time of casting solidification made also possible to determine chilling effect of foundry moulds (coefficient of heat accumulation of the mould, bf) [5]. The constant used in the solidification time is called solidification constant. The term of solidification constant was introduced in foundry specialized literature by N. Chvorinov [6]. Or we can say that,The word Chvorinov´s means solidification constants or also called solidification factor or mold constant. if we used Chvorinov's rule. We need many parameters such as relative casting thickness (modulus), bulk density of material, latent crystallization temperature, specific heat of material, metal casting temperature, casting solidification time that why, we calculating solidification time by used device & observation & to minimize the error during measurement we calculating more than one times than after we calculating average of solidification time.

Solidification time depends on what type of shape to be cast. if you wanted to calculated using by formula or we can be conclude is depend on ratio of V/SA.

Table 1 shows that ratio of V to SA for different shape

S. No.	**Shape**	**Formula** **V= volume** **SA= Surface area**	**ratio** $= \left(\frac{\text{Volume}}{\text{surface area}}\right)$ **called modules**
1.	Cube  Side = a	Volume = a^3 SA= $6a^2$	$\frac{a}{6}$
2.	Sphere  Radius = r Diameter = d	V = $\frac{4\pi}{3}r^3$ SA = $4\pi r^2$	$\frac{r}{3}$ Or $\frac{d}{6}$
3.	Cylinder  Radius = r Diameter = d Height= h	V= $\frac{\pi}{4}d^2$ h SA= 2 $\frac{\pi}{4}d^2$ +πdh	Let h=d d/6
4.	Cuboid  length= L breadth= B Height= h	V=l.b.h SA=2(lb+bh+hl)	$\frac{l.b.h}{2(lb+bh+hl)}$

Here we can conclude that for volume to surface area of sphere & cylinder are same.

But if any one surface of above shape is insulated, then above modulus result not be consider. it means volume to surface area is depend on type of shape & their surface.

Where Volume (V) = heat content

SA=that area which are communicate with surrounding (heat transfer area)

If SA is large, rate of heat transfer(amount of heat transfer) is high. It take small time to be solidify.If SA is less, rate of heat transfer is minimum. It take long time to be solidify

So we can say ts (solidification time) depend on surface area & Volume

II LITERATURE REVIEW

In this chapter we deals with what actually done & their view by different author related to casting, different casting process, casting defects, optimization of parameter & many more parameter related to casting. **Choudhari et. al**. worked on the shrinkage defects minimized approach by an intelligent method and simulation using casting software. he used Traditional casting approach for developing a new part involves manual method design of the 2D drawings of the cast part. This is followed by fabrication of tools, conducting trial runs and inspection. The simulations results were compared with the experimental trial and the comparison was found to be in good agreement. **Vekariya et. al.** shown the capability of generalization and prediction of pattern characteristics such as linear shrinkage, surface roughness and penetration of the wax patterns in IC process within the range of experimental data. The maximum deviations between experimental and fuzzy predicted values are minimal. **Joshi et al.** they work on Solidification Time by Varying Pouring Temperature in Investment Casting Process.he concluded that by increasing pouring temperature there no significance change in solidification time. **Hossain et al**. they investigate the physical and mechanical properties wax materials using uniaxial compressive strength test. This study explores the potential of diametral stress-strain behavior of natural beeswax and synthetic paraffin wax samples by the uniaxial compressive test to measure their strength. **N. Ukrainczyk et al.** worked on Thermophysical properties of Five Commercial Paraffin waxes produced by major Croatian oil company, INA d.d. Rijeka. An experimental investigation has been conducted, Based on results he obtained, the investigated paraffin waxes were evaluated in regard to their applicability as phase change material for latent heat thermal energy storage. The temperatures and enthalpies of melting and solidification (latent heat capacity) and specific heat capacities of solid and liquid paraffin waxes were measured by differential scanning calorimetry (DSC). The thermal diffusivity of paraffin waxes was determined utilizing transient method. The densities and the coefficient of thermal expansion were measured using Archimedes methods. **Gang Pu et al**. he enhancing the performance of paraffin wax based materials for barrier coating applications. he enhances stiffness, strength and ductility of the formed Nanocomposite The thermal stability of wax/clay nanocomposites were investigated using dilatometry. **Torresola** worked on solidification properties of certain waxes And paraffins wax. And finding the solidification properties of the microcrystalline wax such as enthalpy, specific heat, latent heat, thermal conductivity of the wax by using Calorimetric experiments. He also designed an apparatus to measure the temperature history of microcrystalline wax under one-dimensional transient solidification as well as give a theoretical investigation of solidification of materials that, like wax, release latent heat over a temperature range. he also performed molten droplet

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ISSN (ONLINE): 2321-3051

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Pg: -41-53

deposition experiments with octacosane, a paraffin with properties similar to those of wax except for its distinct melting point. **Abd Rashid et. al.** worked on packaging industry prefers to use hot melt adhesive based on polyolefin due to the fact that polyolefin provides ease of processing, low off-taste, low smell and heat-seal ability. he shows Ethylene Vinyl Acetate (EVA)-based hot melt adhesive with the same properties of polyolefin-based hot melt adhesive (HMA) since Eva offers lower cost than polyolefin. Hot melt adhesive with lower viscosity would have more flexibility to flow out, indicating that it had better wetting properties when applied to the substrate. **Banchhor et. al.** analyzed the various process and product design parameter in the green sand casting.

III MATERIALS & METHODOLOGY

3.1 CASTING MATERIALS

We used two main materials & one optional material for dyeing purpose
Wax (1st main material)
Hot Melt Adhesive (HMA)(2nd main material)
Wax crayons (additional /optional material)

		
Paraffin'sWax	Hot Melt Adhesive (HMA)	Wax crayons

Fig 1 casting materials

3.1.1 Paraffin's wax: Paraffin wax is a synthetic waxy material coming from petroleum Refinery[7]. Paraffin's are a family of saturated hydrocarbons with general formula C_nH_{2n-2} [8]. In the melt, paraffin wax has a low viscosity and a surface tension of approximately 25 mJ/m2.Paraffin wax is used in a variety of products and applications [9]. wax is composed of multiple hydrocarbons with different fusion points. Therefore, solidification of wax occurs differently from that of single-component substances that have a distinct melting point [10].

3.1.2 Hot-melt adhesive (HMA): Hot melt adhesives are thermoplastic polymer systems applied in a molten state. They must flow smoothly onto both surfaces and then rapidly cool to a tough, adherent solid at room temperature. Thus, viscosity as a function of temperature is a key to proper hot melt performance. It is also called Thermoplastic adhesive or hot glue. The performance of hot melt adhesive is characterized by DSC and Viscometer [11]. Applications of HMA in many areas such are Packaging, Graphic Arts, Nonwovens/Hygiene, Tapes and Labels, Product Assembly, Automotive, Textiles

ISSN (ONLINE): 2321-3051
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Properties of Paraffin's Wax & Hot melt adhesive

Table 2 Physical Properties of Paraffin's Wax [12]

S. No.	Properties	Value
1.	Colour	White
2.	Melting point between about	46 and 68 °C (115 and 154 °F)
3.	Boiling point	>370 °C (698 °F)
4.	Density around	900 kg/m^3 or 0.9 g/cm^3
5.	Heat of combustion	42MJ/kg.
6.	Specific heat capacity	2.14–2.9 $J\ g^{-1}\ K^{-1}$ (joules per gram Kelvin)
7.	Heat of fusion	200–220 $J\ g^{-1}$
8.	Electrical insulator with a resistivity	between 1013 and 1017 ohm meter
9.	Modulus of elasticity (E)	2800

Table 3 Physical Properties of Hot melt adhesive [13]

S. No.	**Properties**	**Value**
1.	Color (solid)	Clear
2.	Density (g/cm^3)	0.93-0.95
3.	Flashpoint (°F)	514-536
4.	Application Temperature	350-385°F (177-196°C)
5.	Viscosity (CPS)	5,000-6,000 @ 375°F
6.	Open Time (seconds)	40-45
7.	Delivery Time	55-60 seconds
8.	Heat Resistance	140°F/ 60°C
9.	Ball & Ring Melt Point	190°F/ 88°C
10.	Shear Strength	390 psi
11.	Store	Below 120°F (49°C).
12.	Modulus of elasticity (E)	10 MPa

3.2 EQUIPMENT/DEVICE/TOOLS USED IN CASTING

When we perform casting some basic equipment required for casting setup & for parameter measurement. Those equipment/device/tools shown below:

		
Weighing machine -for measurement of weight in proportion	Flask (molding box)-for actual casting is perform. in this we filled sand mould & cavity make.	Mobile-for picture click of each steps ,time measurement by stopwatch.

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Pattern-by the help of this we create cavity.it is a solid type of pattern.	Thermometer-for measurement of temperature of liquid casting material.	Crucible-in this container. We melt our casting materials which are wax &hot melt adhesive.

Fig 2 Equipment/device/tools used in casting

3.3 METHOD

How & which technique or method used for the process of casting discuss here.

The ramming time is 5-8min required for our experiment setup. The moisture content in green sand should always be maintained at 3.3% to 3.6%. It is continuously checked and Maintained during the experiments which provided good results. The number of mould that can be filled by each ladle manually, is mainly depend on ladle capacity and the weight of the molten material .Our the crucible capacity is 2-2.5kg.The crucible travel Time is 5-10 sec, which is time required /taken to the distance between the furnace/stove and the mould box. Hence the traveling time of the molten material is reduced and the molten temperature is maintained effectively. The pouring time also is controlled and interrupted pouring is avoided. Sand mixing time is 25-30min.

It is divided into three sections:
Before casting perform,
During casting perform &
After casting perform.

1. Before castings perform prepare the sand mould.

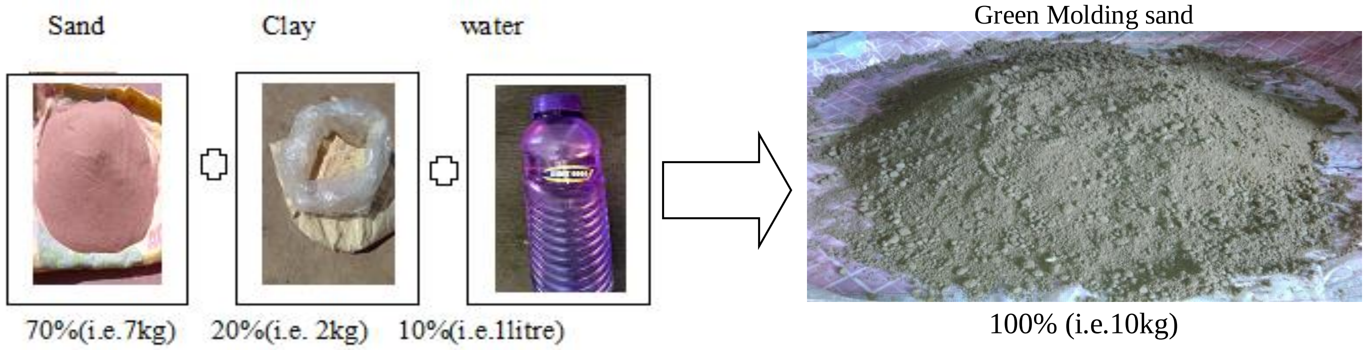

Fig 3 Sand mold preparations

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2. During casting, after preparation of sand mould, casting is performed. In this section includes

Step1. Making cavity on green mold sand.

Step2. After pouring the molten material into the mold cavity.

Step3. After solidification of molten material

Step4. Removal of cast product

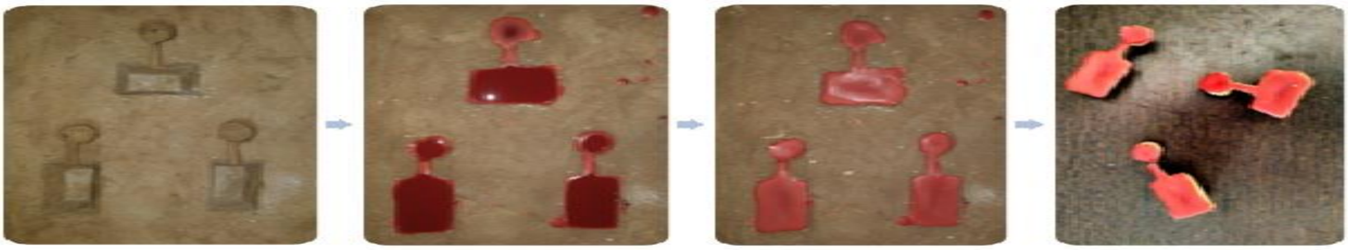

Fig 4 Before pouring molten material to cast product in sand casting

3. After casting: after casting complete. Click the picture of casting & measure dimensions of casting & other related parameter.

Fig 5 All Set of Cast Product Made from Mixing of Wax & Hot Melt Adhesive in weight%

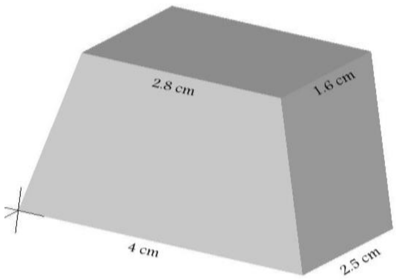

Fig 6 Dimensions of casting

IV CALCULATION

We calculate two parameters, which is Solidification time & Mould constant
Here we firstly calculate solidification time then secondly calculate mould constant.

4.1 Solidification Time

The time required to completely solidify the casting is called solidification time .which is calculated by using formula & observation.

Here we examine the solidification time by observation with the help of thermometer & stop watch, because solidification time formula needs mould constant(C).

All measurement is taken & extracted from while performing with two non-metallic materials (i.e. wax and hot melt adhesive) in sand casting process by using stop watch. & thermometer. Manual accuracy is not accurate, that why we calculated at 3 times & then find the average value of solidification time by using average formula.

$$\text{Average} = \frac{\text{Sum of observation}}{\text{Total no. of observation}}$$

So, Average Solidification Time, $t_{average} = \frac{ts1+ts2+ts3}{3}$ in min

Table 4 calculate Solidification time for our 21 sets of percentage weight of mixture, each Wt% of mixture for 3 times

S. No.	Percentage Amount (in %)		Solidification Time			Average Solidification Time ($t_{average}$) = $\frac{ts1+ts2+ts3}{3}$ In min
	Wax	HMA	1st time (t_{s1}) In min	2nd time (t_{s2}) In min	3rd times (t_{s2}) In min	
1	100	0	39:49	40:6	39:54	40:27=2427sec
2	95	5	39.48	39.53	39:45	39:48
3	90	10	39:44	39.45	39.45	39:44
4	85	15	39:42	39:40	39:32	39.38
5	80	20	39.27	39:33	39.30	39.30
6	75	25	39:17	39:11	39:10	39:12
7	70	30	38:54	38:51	38:53	38:52
8	65	35	38:48	38:46	38:47	38:47
9	60	40	38:36	38:40	38:35	38.37
10	55	45	38:22	38.24	38.20	38.22
11	50	50	38:10	37:56	37:58	38:14
12	45	55	38:02	37:46	37:55	38:07
13	40	60	37:49	37:53	37:50	37:50
14	35	65	37:45	37:43	37:46	37:44
15	30	70	37:39	37:33	37:36	37:36
16	25	75	37:28	37:24	37:23	37:25
17	20	80	37:17	37:10	37:15	37:14
18	15	85	37:05	37	36:55	37
19	10	90	36:47	36:45	36:44	36:45
20	5	95	36:33	36:39	36:35	36.35

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21	0	100	36:11	35:56	35:57	36:14

4.2 Mould Constant

Here we measure mold constant by using composition relation & by using formula both. After that we compare both the value & see both the value of mold constant are similar or not.

Table calculate mold constant for our 21 sets of percentage weight of mixture ,each Wt% of mixture for 3 times

S. No.	Percentage Amount (in %)		By relation & observation Mold constant(C) = mold constant of wax (214.80)×wt% + mold constant of HMA (192.3)×wt%(in min/cm)	Mold constant by formula (C) = $\frac{ts}{[\frac{V}{SA}]2}$ In min/cm^2
	Wax	HMA(hot melt adhesive)		
1	100	0	214.802	214.802
2	95	5	211.350	211.350
3	90	10	210.97	210.97
4	85	15	210.44	210.44
5	80	20	209.757	209.757
6	75	25	208.16	208.16
7	70	30	206.35	206.35
8	65	35	205.93	205.93
9	60	40	205.06	205.06
10	55	45	203.70	203.70
11	50	50	203.01	203.01
12	45	55	202.40	202.40
13	40	60	200.88	200.88
14	35	65	200.35	200.35
15	30	70	199.66	199.66
16	25	75	198.65	198.65
17	20	80	197.70	197.70
18	15	85	196.48	196.48
19	10	90	195.15	195.15
20	5	95	194.25	194.25
21	0	100	192.39	192.39

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V RESULTS & DISCUSSION

Due to the addition of hot melt adhesive on wax, which changes the properties of wax & Enhanced, strength and ductility of wax at room temperature.

All the observation, measurement, calculation, weighing of material should be very carefully done by me, on the basis of available resources, constraint of machine & equipment for test some more parameter & atmospheric condition. finally get the average value of solidification time.

How to change solidification time with respect to mixture of two non-metallic materials, shown in below graph.

. curve or graph shows weight % of wax - HMA & Solidification time, in which horizontal axis represent percentage amount of wax and hot melt adhesive(in Wt %) and vertical axis represent Average Solidification time, $(t_s)_{avg}$ in second.

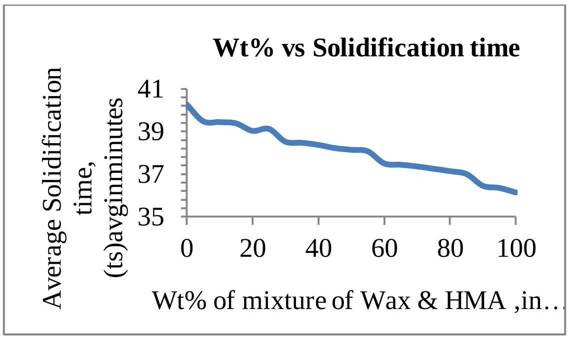

Fig 6 Graph between wt% of non-metallic mixture vs Solidification time

The graph for paraffin wax and hot glue adhesive at room Temperature($27°C\ i.e. 300K$) are mixed with percentage amount.we take paraffin wax as our main material(i.e.100%) which is equal to 40 gram then in this wax ,we increases the percentage amount of hot melt adhesive(HMA) by 5% which is equal to 2 gram. Gradually increased the amount of hot melt adhesive as well as decreases the amount of wax, one after one. Initially, when we pour liquid material by help of pouring container (i.e. funnel) of diameter 0.6cm on mold cavity volume is $19.055cm^3$, then average Solidification time $(t_S)_{avg}$ of paraffin's wax (i.e.100%=40 gram) is 40.27min(i.e.2427 seconds) then another material (HMA) is mixed in the wax. This simply means that after increases the amount of Hot melt adhesive on paraffin wax ,the Average Solidification time is decreases with increases the amount of HMA on wax and as well as decreases the amount of paraffin wax by polynomially. Finally the average Solidification time of HMA is 36.14 min (i.e.2174seconds). Thus range or difference of solidification time is 4 min 13 second (i.e.253 sec). Thus we can say that solidification time (t_s) depends on wt% (x) by equation:

$(ts)_{avg} = 2E\text{-}08x^4 - 8E\text{-}06x^3 + 0.000x^2 - 0.064x + 40.07$

Where $(ts)_{avg}$ = Average solidification time

x = weight percentage composition of wax and hot melt adhesive (in %)

how to change mold constant with respect to mixture of two non-metallic materials, shown in below graph.

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Figure 6.4 curve or graph shows weight % of wax - HMA & Mold Constant w.r.t solidification time, in which horizontal axis(x) represent percentage amount of wax and hot melt adhesive(in Wt %) ,and vertical axis represent (C) mold constant (in min/cm^2) calculated form by using formula & observation of weight% of mixture

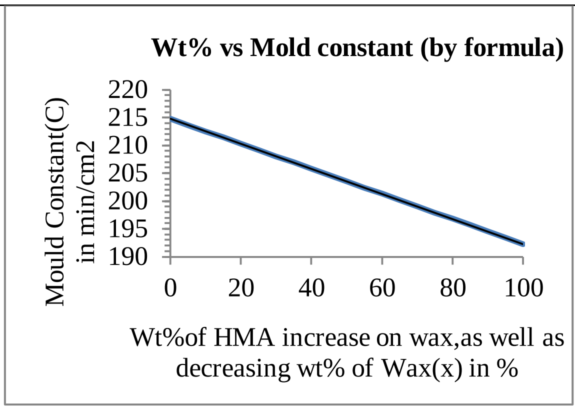	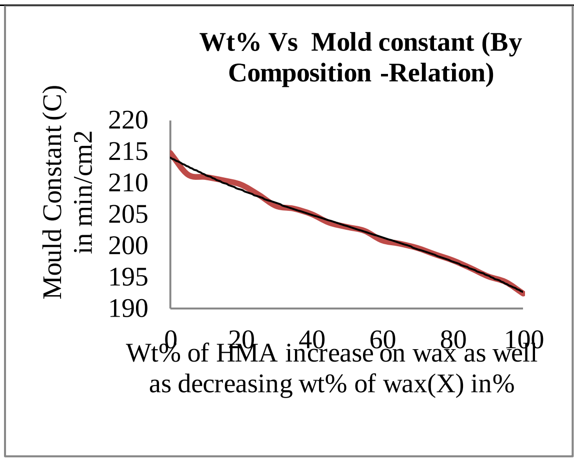
Fig 6.4 (a): wt% vs Mold constant by using formula	**Fig 6.4 (b)** wt% vs Mold constant by using relation

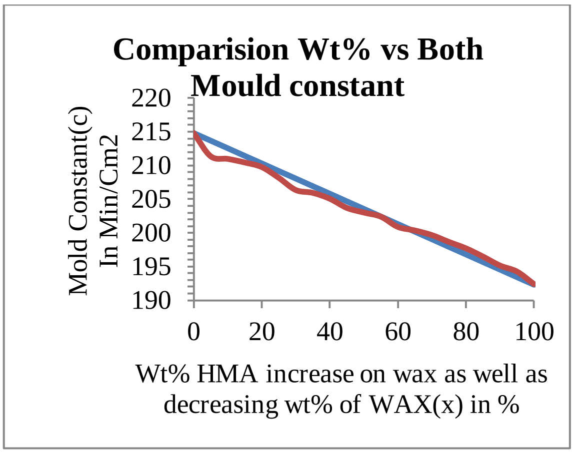

Fig 6.4 (c) Comparisons of both mould constant(C), which is calculated by using formula & observational relation of weight% of mixture

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$C = -0.225x + 214.8$ (by formula)

$C = -1E\text{-}05x^3 + 0.002x^2 - 0.297x + 214.0$ (by composition relation)

Where C = mould constant (in min / cm^2)

x = weight percentage composition of wax and hot melt adhesive (in %)

VI CONCLUSIONS

This paper has presented the mold filling time & volume flow rate of two non- metallic materials in the sand casting process. The following conclusions are drawn out of the experiments conducted on wax and hot melt adhesive (HMA) selection of optimum process parameters. Here we can see that by varying the pouring temperature & Weight percentage of mixture .we gets different value of solidification time & Mold Constant their range value are shown in below:

Table 5 Shows conclusion for casting parameter with their range value & final generalized equation

Factor related to sand casting		Result (in Range Value)	Conclusion
Average Solidification Time of mixture		40min27sec-36min14sec	It decreases polynomially.
		Equation: $(ts)_{avg} = 2E\text{-}08x^4 - 8E\text{-}06x^3 + 0.000x^2 - 0.064x + 40.07$	
Mold Constant of mixture	**By formula**	214.802-192.39 Min/cm^2	It decreases linearly.
		Equation: $C = -0.225x + 214.8$	
	By relation & observation	214.80-192.3 Min/cm^2	It decreases polynomially.
		Equation: $C = -1E\text{-}05x^3 + 0.002x^2 - 0.297x + 214.0$	

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