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Non-Metallic Multi Materials Casting for Mold Filling Time and Volume Flow Rate

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***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, 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 nonmetallic multi-material & measure the various parameter of sand casting such as mold filling time, volume flow rate & 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, Sand casting, Mould filling time, volume flow rate.

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 [2] around 6.5million kg of casting are produced every year. 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, applications, advantages and disadvantages. 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. This two most common parameter is Mould filling time and volume flow rate. Both play a vital role in the sand casting process. The first parameter is Mould filling time is the time required to fill the mould cavity of a particular volume. It depends on materials used in casting & volume of cavity. if cavity is more the time required for filling is also more. We can say that mould filling time is directly depends on fluidity of material say density material. The mold filling time denoted as t_f. it measured generally in seconds. It also measured in minutes for large cavity or large shape, size of casting. The second parameter is volume flow rate, which is defined as volume per unit time that means the volume of fluid which passes per unit time it is also called volume flow rate, rate of fluid flow or volume velocity or volumetric flow rate. The SI unit is m^3/s (cubic meters per second). Another unit used is sccm (standard cubic centimeters per minute)[3]. We used unit of volume flow rate for calculation in cm^3/sec because our casting size is small. Which is depend on Volume of mold cavity & Mold filling time .And we measure in volume in cm^3 and mould filling time in second.

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There are different type of flow rates are present such as mass flow rate, volumetric flow rate. First understand the term flow rate, If any pipe, inside it any liquid is present. This liquid flow from particular cross section, flow at particular time or in another word, the amount of liquid that is pushed through your system in a given amount of time called flow rate. There are many devices such as flow meters are present now, to measure flow rate.

II LITERATURE REVIEWS

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. **Hossain et al**. they investigate the physical and mechanical properties wax materials using uniaxial compressive strength test. This study explores the potential of diametric 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 Thermo physical 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. **Banchhor et. al.** analyzed the various process and product design parameter in the green sand casting. **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 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.

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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 [4]. Paraffin's are a family of saturated hydrocarbons with general formula C_nH_{2n-2} [5].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 [6]. 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 [7]. Their Physical Properties shown in table 1.

3.2.2 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 [8]. Applications of HMA in many areas are Packaging, Graphic Arts, Nonwovens/Hygiene, Tapes and Labels, Product Assembly, Automotive, Textiles. Their Physical Properties shown in table 2.

The properties of paraffin's wax & Hot-melt adhesive (HMA) are given in below

Table 1 Physical Properties of Paraffin's Wax [9]

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)

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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 2 Physical Properties of Hot melt adhesive [10]

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.
		
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

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Pg: -31-40

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 such that before casting perform, during casting perform & after casting perform.

1. Before castings perform prepare the sand mould.

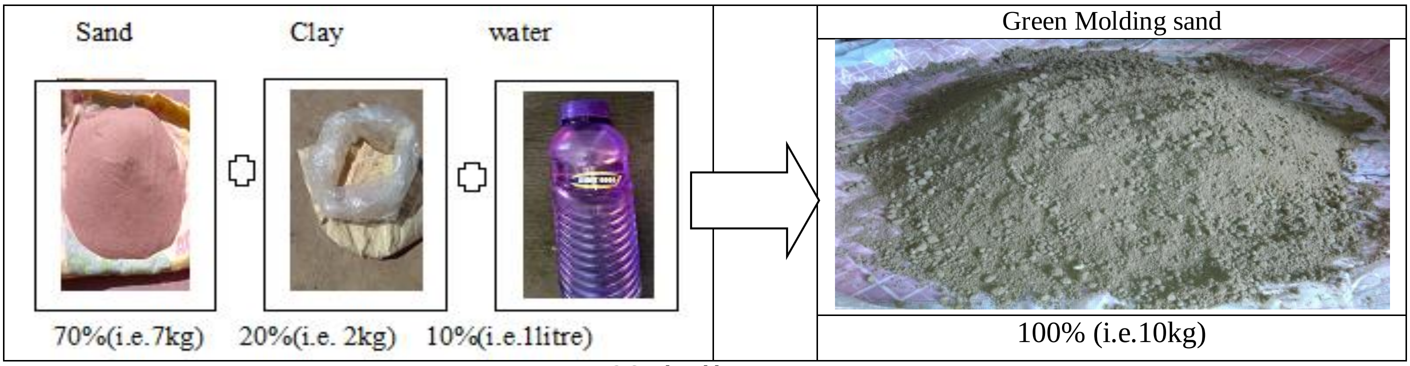

Fig 3 Sand mold preparations

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

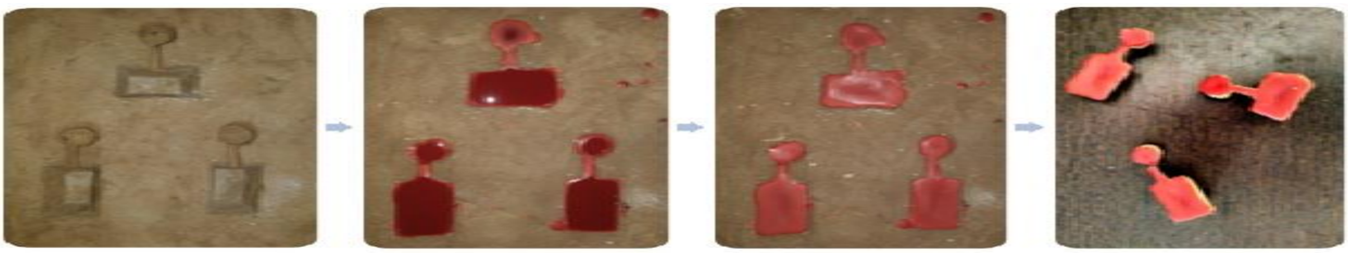

Fig 4 Before pouring molten material to cast product in sand casting

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Pg: -31-40

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%

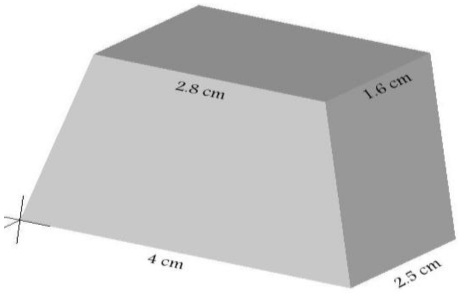

Fig 6 Dimensions of casting

IV CALCULATION

In this section, calculating two important parameters such are mold filling time & Volume flow rate.

4.1. HERE CALCULATE MOLD FILLING TIME.

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. Manual accuracy is not accurate, that why we calculated at 3 times & then find the average value of mold filling time.

Average value is the ratio of the sum of observation to no. of observations**.**

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

so the average mold filling time is

ISSN (ONLINE): 2321-3051

Vol.6 Issue.9,
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Pg: -31-40

$(T_f)avg = \frac{T1+T2+T3}{3}$ (in sec)

Table 3 Calculate mold filling time for our 21 sets of percentage weight of mixture ,each Wt% of mixture for 3 times.

S. No.	Percentage Amount (in %)		Mould Filling Time (T_1) in Sec	Mould Filling Time(T_2) in Sec	Mould Filling Time(T_3) in sec	Average Mould Filling Time, $(T_f)avg = \frac{T1+T2+T3}{3}$ (in sec)
	Wax	HMA				
1	100	0	2.1	2	2.2	2.1
2	95	5	2.3	2.2	2.2	2.23
3	90	10	2.4	2.3	2.4	2.3666
4	85	15	2.5	2.4	2.4	2.4393
5	80	20	2.5	2.6	2.7	2.6
6	75	25	3.7	3.5	3.4	3.5333
7	70	30	5	4.5	4.9	4.8
8	65	35	9.9	10.3	10.1	10.1
9	60	40	10.5	10.8	11.1	10.8
10	55	45	11.2	10.8	10.7	10.9
11	50	50	12	11	11.5	11.5
12	45	55	16	15	15.3	15.433
13	40	60	22	21.4	21.6	21.664
14	35	65	54	53.7	54.9	54.2
15	30	70	108.6	109.2	110	109.26
16	25	75	118	116	117	117
17	20	80	125	123.6	118	123.63
18	15	85	132.5	134	133	133.1666
19	10	90	145.4	146.6	147.2	146.4
20	5	95	174.4	176.1	175.7	175.4
21	0	100	182.3	181.9	180.6	181.6

4.2 Secondly, we measure volume flow rate by using formula and also find the average value of volume flow rate.

As we knows that, Average = $\frac{\text{Sum of observation}}{\text{Total no. of observation}}$

So, Average Volume Flow Rate ($Q_{average}$) = $\frac{Q1+Q2+Q3}{3}$ (in cm^3/sec)

Also w.k.t, Volume Flow Rate (Q_1) = $\frac{\text{volume of casting(V)}}{\text{mold filling time(Tf)}}$

or Q = $\frac{\text{area of cross section x distance}}{\text{mold filling time(Tf)}}$

Where, velocity= $\frac{\text{distance}}{\text{time}}$

So Q = velocity (v)x A
(in cm^3/sec)

Where, Volume = $\frac{h}{3}(A_1 + A_2 + \sqrt{A1\ xA2})$

1- Bottom rectangle (biggest rectangle) are length(a) = 4cm, breadth (b) = 2.5cm and 2- top rectangle (small rectangle) are length (c) = 2.8cm, breadth (d) = 1.6cm and height (h) = 2.7 cm..
A_1= area of bottom base or area of bottom rectangle, A_b= a x b = 4 x 2.5 = 10cm^2

A_2= area of top base or area of top rectangle, A_t = c x d = 2.8 x 1.6 = 4.48cm^2

Volume = $\frac{2.7}{3}\left(10+4.48\ +\sqrt{10\times4.48}\right)$

= 19.055cm^3

Table 4 Calculate Volume Flow Rate for our 21 sets of percentage weight of mixture, each Wt% of mixture for 3 times.

S.No.	Percentage Amount (in %)		Volume Flow Rate $(Q_1) = \frac{V}{T1}$ (in cm^3/sec)	Volume Flow Rate $(Q_2) = \frac{V}{T2}$ (in cm^3/sec)	Volume Flow Rate $(Q_3) = \frac{V}{T3}$ (in cm^3/sec)	Average Volume Flow Rate $(Q_{average}) = \frac{Q1+Q2+Q1}{3}$ (in cm^3/sec)
	Wax	HMA				
1	100	0	9.0738	9.3275	8.6613	9.0875
2	95	5	8.2847	8.6613	8.6613	8.5357
3	90	10	7.9395	8.2847	7.9395	8.0545
4	85	15	7.622	7.9395	7.9395	7.8336
5	80	20	7.622	7.3288	7.0574	7.3360
6	75	25	5.15	5.4442	5.6044	5.3995
7	70	30	3.811	4.2344	3.8887	3.9780
8	65	35	1.9247	1.85	1.8866	1.8871
9	60	40	1.8147	1.7643	1.7166	1.7652
10	55	45	1.7013	1.7643	1.7808	1.7488
11	50	50	1.5879	1.7322	1.6590	1.659
12	45	55	1.1909	1.2703	1.2454	1.2355
13	40	60	0.8861	0.8904	0.8821	0.8795
14	35	65	0.3528	0.3548	0.3470	0.3515
15	30	70	0.1754	0.1744	0.1732	0.1743
16	25	75	0.1614	0.1642	0.1628	0.1628
17	20	80	0.1524	0.1541	0.1614	0.1559
18	15	85	0.1438	0.1422	0.1432	0.1430
19	10	90	0.1310	0.1299	0.1294	0.1301
20	5	95	0.1094	0.1082	0.1084	0.1086
21	0	100	0.1045	0.1047	0.1055	0.1049

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 materials should be very carefully done by me, on the basis of available resources, constraint of machine & equipment for test as well as some parameter & atmospheric condition.

How to change mold filling time & volume flow rate with respect to mixture of two non-metallic materials, shown in figure 1 & 2 respectively.

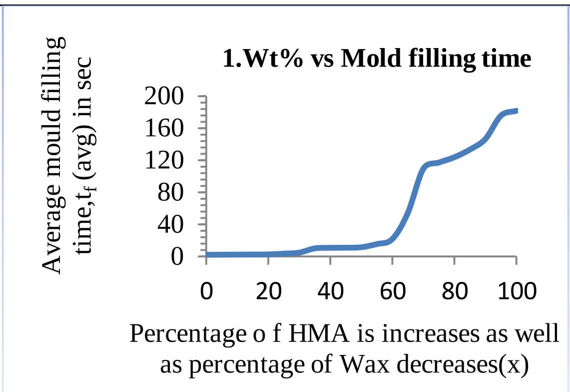

Fig 7 Graph between weights% of non-metallic mixture vs. mold filling time.

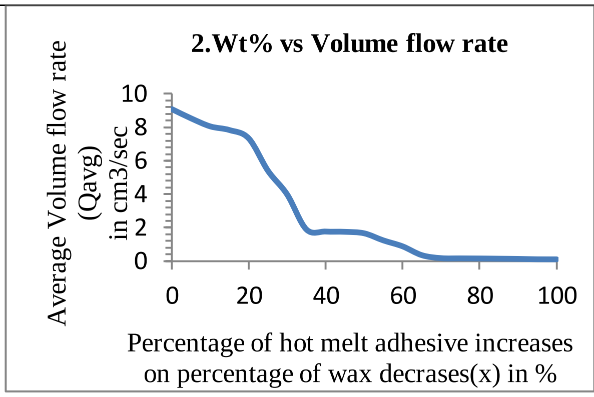

Fig 8 Graph between weights% of non-metallic mixture vs. volume flow rate

Fig 7 The graph for paraffin wax and hot glue adhesive at room Temperature (27℃ $i.e. 300K$) 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 when 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 of diameter (funnel) 0.6cm on mold cavity volume is 19.055cm^3, then average mold filling time ($T_{f\ avg}$) of paraffin's wax (i.e.100% = 40 gram) is 2.1 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 mould filling time is increase with increases the amount of HMA and as well as decreases the amount of paraffin wax. Finally the average mold filling time of HMA is 181.6 seconds that means filling time polynomially increases. These graphs shows mould filling time depend on wt% by equation:

$(T_f)_{avg}$ = -7E-08x^5+ 4E-06x^4+0.001x^3-0.079x^2 +1.360x – 1.138
Where $(T_f)_{avg}$ = Average mould filling time (in seconds)
x = wt% of mixture of wax & HMA (in %).
E = it is a scientific notation, also known as exponential notation. Which is written as a power of 10.the power can be positive or negative.
Here above notation means:
-7E-08 = -7×10^{-8} = -0.00000007 and
4E-06 = 4×10^{-6} = 0.000004

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Vol.6 Issue.9, September 2018
Pg: -31-40

Fig 8 This simply means that after increases the amount of Hot melt adhesive on paraffin wax, the Average Volume flow rate is decreases with increases the amount of HMA and as well as decreases the amount of paraffin wax by polynomial. Finally the average Volume flow rate of HMA is 0.1049 centimeter cube per seconds (i.e.cm^3/sec).

Thus we can say that volume flow rate (Q) depends on wt% (x) by equation:
Q_{avg} = -7E-07x^4+ 0.000x^3-0.007x^2- 0.039x+9.185
Where
Q_{avg} = Average volume flow rate(cm^3/sec)
x = wt% of mixture of wax & HMA (in %).
Here above notation means:
-7E-07 = $-7x10^{-7}$= -0.0000007

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 mold filling time & volume flow rate with their range value & equation 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 Mold Filling Time of mixture	2.1-181.6 sec	It increases polynomially
	Equation: $(T_f)_{avg}$ = -7E-08x^5+ 4E-06x^4+0.001x^3-0.079x^2 +1.360x – 1.138	
Average volume flow rate of mixture	9.0875-0.1049 cm^3/sec	It decreases polynomially
	Equation: Q_{avg} = -7E-07x^4+ 0.000x^3-0.007x^2- 0.039x+9.185	

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