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Study of the Effect of Varying Pouring Rate on Mechanical Properties of Al-Cu and SiC_p Reinforced Metal Matrix Composites (MMC)

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Abstract

The investigation studies of Metal Matrix Composites (MMCs) have emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications. Metal Matrix Composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There are several techniques to produce composites, such as liquid state, solid state and semi solid state production route. In this paper, we studied a composite with cheap and simple production route i.e. stir casting method. We have chosen 5% SiC as the reinforcement material and balanced Al + 4% Cu as matrix phase. The pouring rate is varying 2cm/sec., 2.5cm/sec. and 3cm/sec. The effects of input (independent) variables as pouring rate (2cm/sec.,2.5cm/sec. and 3cm/sec) and material type's on output (dependent) variables as hardness, impact strength and ultimate tensile strength, statistically analysis were performed by using SPSS 17.0. The best result value of BHN, Impact and UTS has been obtained at optimum pouring rate 2.5cm/sec. The pouring temperature kept constant at 700^0C for all composites. The mechanical properties as hardness, impact and tensile strength were enhanced with reinforcement SiC particles. The results were further justified by comparing with other investigators.

Keywords: Metal Matrix Composites MMCs, Stir, Pouring Temperature, Pouring Rate, UTM, and Hardness.

1. INTRODUCTION

A composite material is a material consisting of two or more physically and or chemically distinct phases. The composite generally has superior characteristics than those of each of the individual components. Usually the reinforcing component is distributed in the continuous or matrix component [1]. When the matrix is a metal, the composite is termed a Metal Matrix Composite (MMC). Metal Matrix Composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements [2].The use of cast aluminum alloys in automotive structural applications is growing rapidly because of the need to reduce weight. The service life of a cast component is determined by the micro structural distribution throughout the casting, especially in those regions that are critically stressed [3]. Among discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production [4], and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth [5]. In general, the solidification synthesis of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. In preparing Metal Matrix Composites by the stir casting method, there are several factors that need considerable attention, including the difficulty of achieving a uniform distribution of the reinforcement material, wettability between the two main substances, porosity in the cast Metal Matrix Composites, and chemical reactions between the reinforcement material and the matrix alloy. In order to achieve the optimum properties of the Metal Matrix Composite, the distribution of the reinforcement material in the matrix alloy must be uniform, and the wettability or bonding between these substances should be optimized. The literature review reveals that the major problem was to get homogenous dispersion of the ceramic particles by using low cost conventional equipment for commercial applications. In the present work, a modest attempt have been made to compare the dispersion of SiC particles in Al matrix fabricated with the help of different processes viz. (a) without applying stirring process (b) with manual stirring process (c) a two-step mixing method of stir casting. An effort has been made to establish a relationship between hardness, impact strength and weight fraction of SiC in particle reinforced MMC's developed with the help of two - step mixing method of stir casting technique.

2. EXPERIMENTATION

The melting was carried in a open hearth furnace in a range of 700± 100C. A schematic view of the furnace has been shown in Figure 1.

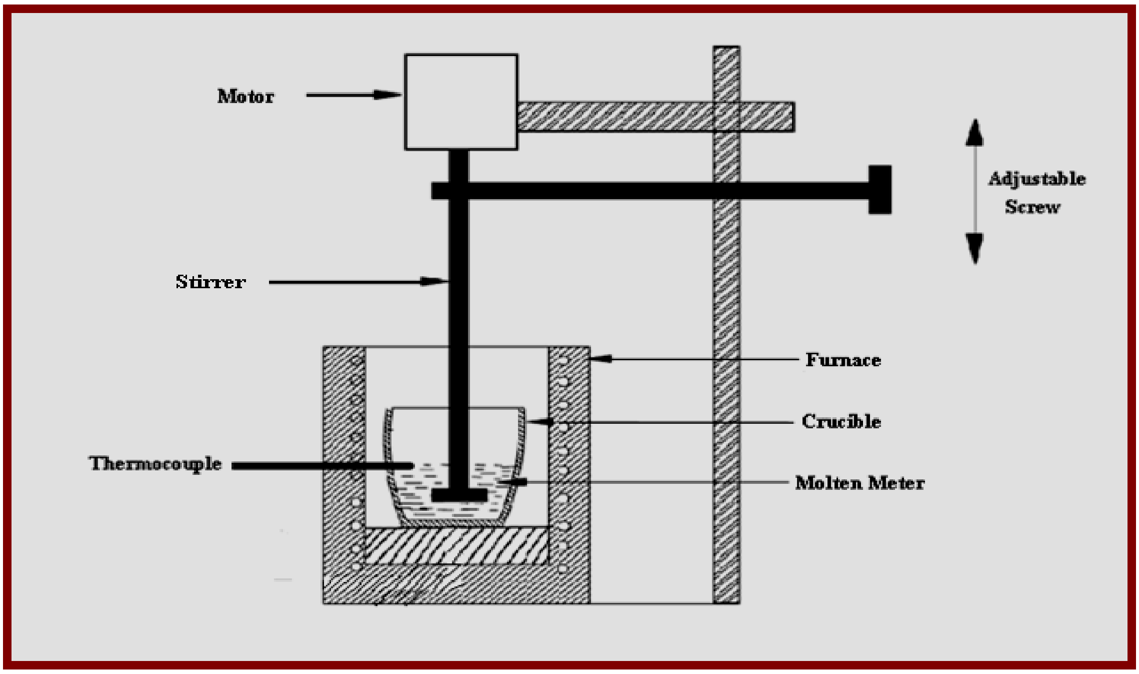


Fig.1 Schematic view of setup for Fabrication of composite

- Motor
- Shaft
- Molten aluminium
- Thermocouple
- Furnace
- Graphite crucible

In the present study, an open hearth furnace has been used. The crucible material was graphite. Coal was used as the fuel. A forced draft fan equipped with 900-rpm motor has been used for supplying the required quantity of air. The pouring temperature is maintained at 700^0C by the help of type k-thermocouple. For material-1(4%Cu+Balanced Al), crucible fill with 4%Cu and rest Al metal charge is place in furnace [6]. Automatic mechanical mixing is carried out with a normal stirring rate 600 rpm and with the different pouring rate. Sand mould use for collecting the molten metal. For material-2(4%Cu+5%SiC+ Balanced Al),take 4%copper and balanced Aluminium were preheated up to a temperature of 450^0C and particles of 5%silicon carbide was preheated up to a temperature of 1100^0C in the furnace. Crucible used for pouring of composite slurry in the mold was also heated up to 760^0C and with different pouring rate [7]. In the present study, a new stir caster was developed to fabricate MMC. It has been used to obtain an output of 600 rpm. The stir caster was mounted on the furnace with the help of four legs. Casted material was chosen as stirrer and impeller. During experimental work, the stirrer position should be such that 35% of material should be below the stirrer and 65% of material should be above the stirrer.

3. METHODOLOGY

First of all stirring system has been developed by motor with regulator and a casted stirrer. All the melting was carried out in a graphite crucible in an open hearth furnace. Preparation for material-1(4%Cu+Balanced Al), take a crucible fill with 4%Cu and rest Al metal charge is place in furnace and after fully liquid stage automatic mechanical mixing is carried out for about 3 minutes at normal stirring rate 600 rpm and with different pouring rates. Sand mould used for collecting the molten metal. Preparation for material-2(4%Cu+5%SiC+Balanced Al), take 4% Cu and balanced Al Scraps metal were preheated at 450^0C for 40 minutes before melting and mixing the 5% SiC particles were preheated at 1100^0C for 2 hours to make their surfaces oxidized.

The furnace temperature was first raised above the liquidus to melt the alloy scraps completely and was then cooled down just below the liquidus to keep the slurry in a semi-solid state. At this stage the preheated 5%SiC particles were added and mixed manually. Manual mixing was used because it was very difficult to mix using automatic device when the alloy was in a semi-solid state. After sufficient manual mixing was done, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at a normal stirring rate of 600 rpm. In the final mixing process, the furnace temperature was open hearth furnace within 760^{0}C and take different pouring rate. Sand mould use for collecting the molten metal. Pouring of the composite slurry has been carried out in the sand mould prepared according to the specifications for hardness, impact and ultimate tensile strength test specimens and show the respective fig. in below.

Fig.2 Hardness Testing

Fig.3- Izod Impact Test

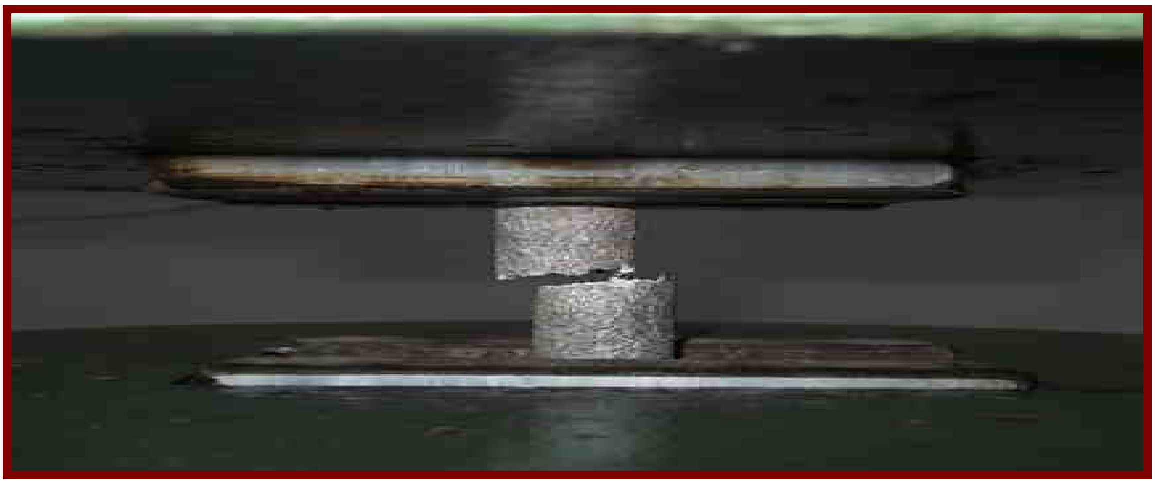


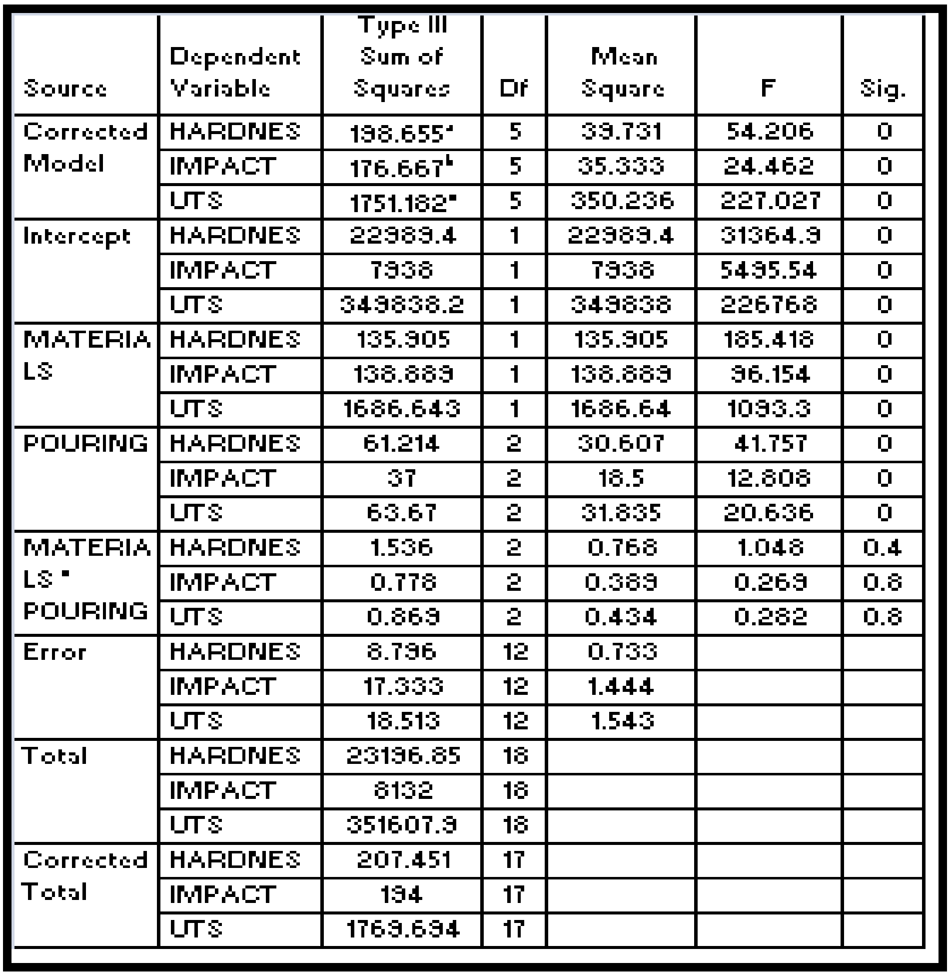
Fig.4- Tensile Test

4. RESULTS AND DISCUSSION

4.1 RESULTS

All statistical analysis was performed using SPSS 17.0.The result of Multivariable Analysis of Variance (MANOVA). Input (independent) variable as pouring rate and material type effect on output (dependent) variable as hardness, impact strength and ultimate tensile strength. It is clear from below table-1,which is get by analyzing data as shown in Appendix-I by Multivariable Analysis of Variance (MANOVA) using spss-17.0 soft ware, for materials hardness, impact strength and ultimate tensile strength value are found highly significant($P<0.0001$). Also for pouring rate [(a) 2cm/s (b) 2.5cm/s (c) 3cm/s)] effect the output variable Hardness($P<0.0001$),Impact Strength ($P=0.0011$) & UTS($P=0.0001$). And material types [material-1(4%Cu+ Balanced Al) and material-2 (4%Cu+5%SiC+ Balanced Al)] effect the output variable Hardness ($P<0.0001$), Impact Strength ($P<0.0001$) & UTS ($P<0.0001$). This is highly significant for 95% confidence interval. Our null hypothesis postulation is pouring rate and material type does not affected the mechanical properties of metal matrix composite casting. But result does not support the null hypothesis. Then alternative hypothesis may be concluded as “pouring rate and material type effect the mechanical properties of Metal Matrix Composite casting”.

Table.1 Summary of Result Analyzed by MANOVA



Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	HARDNES	198.655[a]	5	39.731	54.206	0
	IMPACT	176.667[b]	5	35.333	24.462	0
	UTS	1751.182[c]	5	350.236	227.027	0
Intercept	HARDNES	22989.4	1	22989.4	31364.9	0
	IMPACT	7938	1	7938	5495.54	0
	UTS	349838.2	1	349838	226768	0
MATERIALS	HARDNES	135.905	1	135.905	185.418	0
	IMPACT	138.889	1	138.889	96.154	0
	UTS	1686.643	1	1686.64	1093.3	0
POURING	HARDNES	61.214	2	30.607	41.757	0
	IMPACT	37	2	18.5	12.808	0
	UTS	63.67	2	31.835	20.636	0
MATERIALS * POURING	HARDNES	1.536	2	0.768	1.048	0.4
	IMPACT	0.778	2	0.389	0.269	0.8
	UTS	0.869	2	0.434	0.282	0.8
Error	HARDNES	8.796	12	0.733		
	IMPACT	17.333	12	1.444		
	UTS	18.513	12	1.543		
Total	HARDNES	23196.85	18			
	IMPACT	8132	18			
	UTS	351607.9	18			
Corrected Total	HARDNES	207.451	17			
	IMPACT	194	17			
	UTS	1769.694	17			

a. R Squared = .958 (Adjusted R Squared = .940)

b. R Squared = .911 (Adjusted R Squared = .873)

c. R Squared = .990 (Adjusted R Squared = .985)

4.1.1 Hardness test

The graphical analysis of the main effect of the input variables to output variables is shown in fig-5(For, Brinell hardness test). The hardness value initially increases with pouring rate 2cm/s and it also increase when pouring rate 2.5 cm/s. Thereafter it falls sharply when the pouring rate is 3 cm/s .The pouring rate 2.5cm/s which gave the best optimum value of hardness when the pouring temperature kept constant at 700^{0}C for material-1 (4%Cu+ Balanced Al) and material-2 (4%Cu+5%SiC+ Balanced Al).

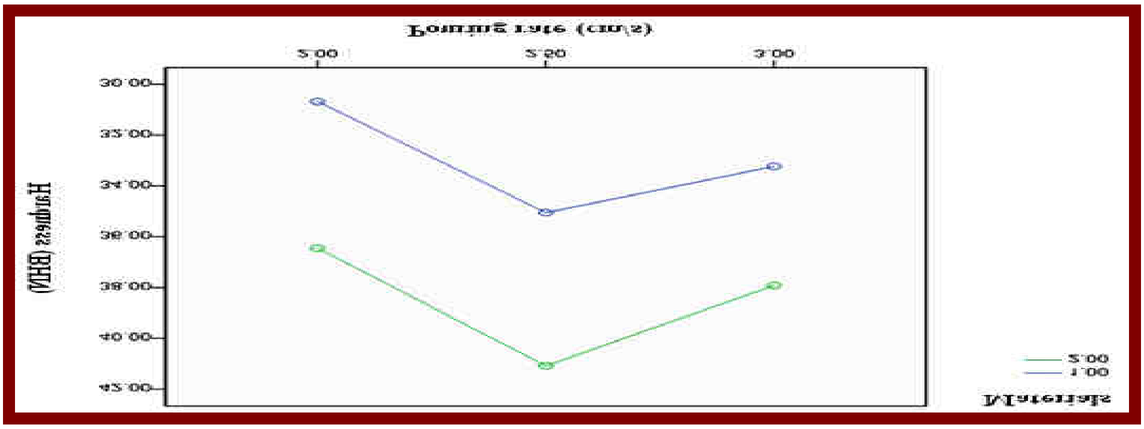


Fig.5 Graph of Hardness

4.1.2 Impact test

The graphical analysis of the main effect of the input variables to output variables is shown in fig-6 (For, Izod Impact Strength). The impact strength value initially increases with pouring rate 2cm/s and it also increase when pouring rate 2.5 cm/s. Thereafter it falls sharply when the pouring rate is 3 cm/s .The pouring rate 2.5cm/s which gave the best optimum value of impact strength for material-1 (4%Cu+ Balanced Al) and material-2 (4%Cu+5%SiC+ Balanced Al).

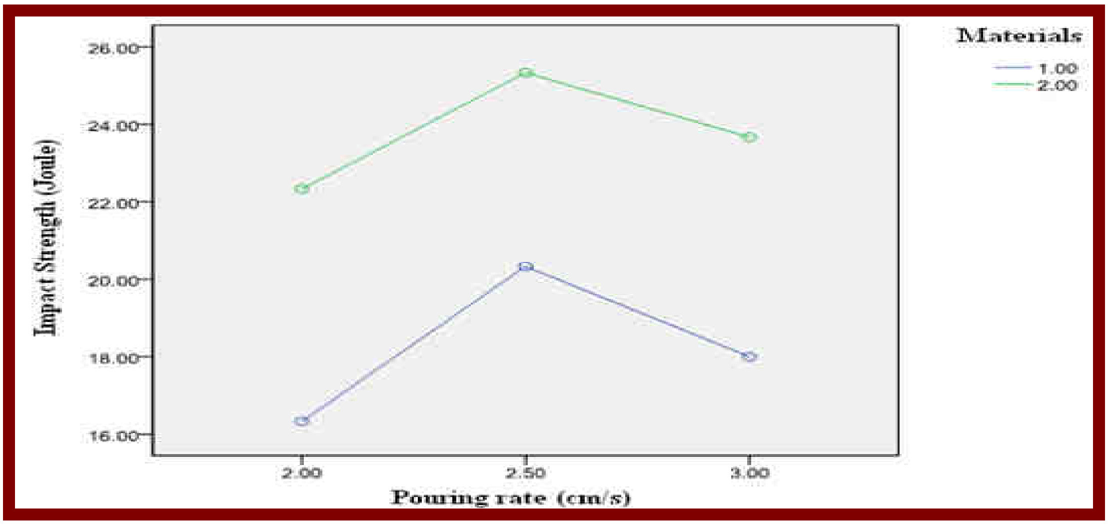


Fig.6 Graph of Impact Strength

4.1.3 Ultimate Tensile Strength (UTS) test

The graphical analysis of the main effect of the input variables to output variables is shown in fig-7 (For, ultimate tensile strength). The ultimate tensile strength value initially increases with pouring rate 2cm/s and it also increase when pouring rate 2.5 cm/s. Thereafter it falls sharply when the pouring rate is 3 cm/s .The pouring rate 2.5cm/s which gave the best optimum value of ultimate tensile strength for material-1 (4%Cu+ Balanced Al) and material-2 (4%Cu+5%SiC+ Balanced Al).

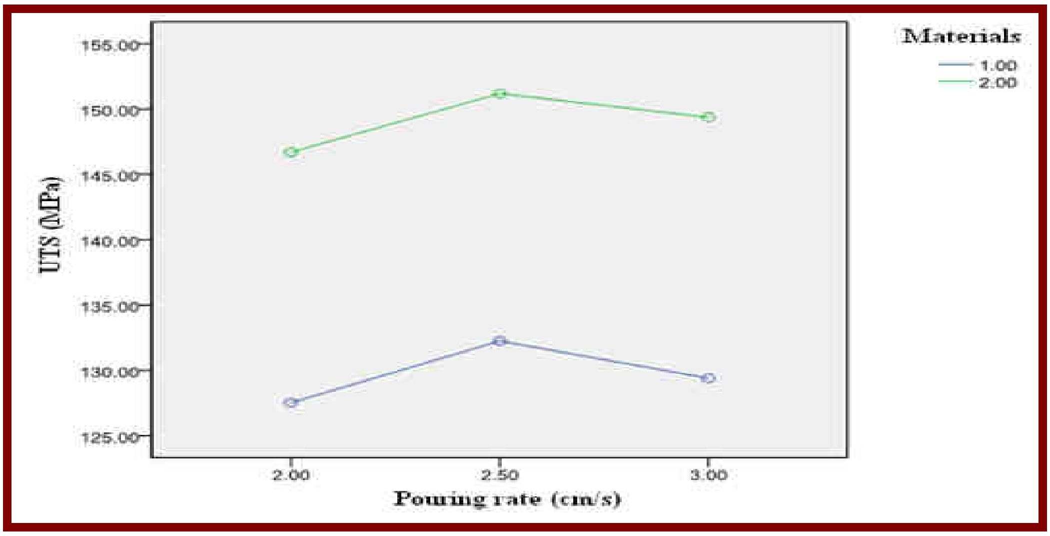


Fig.7 Graphs of UTS

Material-2(4%Cu+5%SiC+ Balanced Al) has high properties of hardness, impact strength and ultimate tensile strength. So, Material-2 (4%Cu+5%SiC+ Balanced Al) is much better than material-1 (4%Cu+ Balanced Al).

4.2 Discussion

In present investigation we found that with addition of 5%SiC in 4%Cu and rest Al casting mechanical properties are enhanced. Our result is supported by Manoj et al. (2009), as he concludes that with adding of SiC in Aluminium Metal Matrix Composite mechanical properties are tailored. Also our result show that from pouring rate [(a)2cm/s (b)2.5cm/s (c)3cm/s] 2.5cm/s at pouring rate has best result but afterwards we are not able to increase the pouring rate due to time constrain. It may be possible that at higher pouring rate the mechanical properties may be enhance or decline in properties. Our result is supported by M.B.Nadaliman & Akpan (2007) as he concludes best pouring rate are in between 2.0cm/s to 2.8cm/s for aluminium alloys casting practices. Present result shows that Input (independent) variable as pouring rate, material type effect on output (dependent) variable as hardness, impact strength and ultimate tensile strength. From the fig-5, 6&7 the pouring rate 2.5cm/s which gave the best optimum value of hardness, impact strength and ultimate tensile strength for both materials. When the pouring temperature kept constant at 700^{0}C Material-2 (4% Cu + 5% SiC + Balanced Al) has high properties of hardness, impact strength and ultimate tensile strength. So, Material-2 (4% Cu + 5% SiC + Balanced Al) is much better than material-1(4% Cu + Balanced Al). This result is not compared by the other resources as it is not found in literature survey.

5. CONCLUSION

1. The pouring speed 2.5cm/s which gave the best optimum value of hardness, impact strength and ultimate tensile strength. When the pouring temperature kept constant at 700^{0}C for material-1(4%Cu+Balanced Al) & material-2 (4% Cu + 5% SiC + Balanced Al). Material-2 (4% Cu + 5% SiC + Balanced Al) has high properties of hardness, impact strength and ultimate tensile strength. So, Material-2 (4% Cu + 5% SiC + Balanced Al) is much better than material-1(4% Cu + Balanced Al).
2. 5% SiC addition in (4% Cu + balanced Al) an increase in hardness, impact strength and ultimate tensile strength in Metal Matrix Composite also which gave the best surface finish.

6. SCOPE FOR FURURE RESEARCH

1. The further studies can be extended the basis of pouring temperature. Mechanical properties of Aluminium Metal Matrix Composite may be enhanced or decline.
2. In further studies also alteration percentage of SiC. We can improve the mechanical properties of Al- Metal Matrix Composite.
3. The studies should be developed investigation the different mesh size of SiC and doping the Al-Metal Matrix Composite.
4. In experimental work, by help of different casting process technique may be enhance or decline of Al- Metal Matrix Composite.
5. Furthermore we are unable to find out whether the homogeneous dispersion SiC is in Metal Matrix Composite or not. Which greatly affects the strength of casting?

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