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Stir-Casting: A Development Technique of Metal Matrix Composites

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Abstract- **In the current scenario of engineering production, it is very much required to have such a manufacturing technique which can develop the product/materialssmoothly and economically. The search of requisite economical technique is almost stopped now when the stir-casting route is emerged. Nowadays, stir-casting technique is most economical technique for the development of various metal matrix composites. Generally, stir-casting technique develops such metal matrix composites which have homogeneous distribution of reinforcements in matrix and isotropic property.**
Keywords:**Stir-Casting, Metal Matrix Composites, Reinforcements**

I. INTRODUCTION

The continuous increasing demands of metal matrix composites (MMCs) motivate researchers, engineers and scientist to develop these materials easily and economically. In MMCs, the addition of hard ceramic reinforcement particles to the soft matrix can improve the mechanical and others properties without any significant loss of its original properties [1-5]. Metal matrix composites, with their enhanced mechanical and other properties, offer a wide range of application in aerospace, automotive, marine, and defense industries in comparison with its unreinforced metal matrix [6-8]. The composite products are highly accepted due to requisite properties, such as high specific strength, Young's modulus, high strength, low thermal expansion coefficient, and wear resistance [9]. Metal matrix composites were developed by the addition of more than one reinforcement with different properties to the soft matrix and alloy [10-14]. There are several methods used to develop particle-reinforced metal matrix composites. Typically, these methods are categorized as vapor deposition method, liquid-state processing, and solid-state processing. Commonly, the solid-state processing and liquid-state processing are used to fabricate particle-reinforced metal matrix composites [15]. In the present study, the liquid-state process was used to develop the metal matrix composites due to its economical aspect.

II. MATERIALS SELECTION FOR STIR-CASTING

TABLE I shows the compositional details of developed various metal matrix composites (MMCs) using stir-casting. Compositional details of MMCs exhibit that the contents of reinforcements are very less compared to its matrix. It is just because of the poor propertied shown by the MMCs at significantly higher contents of

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reinforcement in soft matrix [5]. A higher content of reinforcements in metal matrix promotes its agglomeration which reduces the properties of MMCs. The compositions of MMCs are taken as wt% like Cu-1WC-1ZrO_2-2Cr designated as MMC-1 similarly Cu-1WC-1Al_2O_3-2Cr, Cu-1WC-2ZrO_2-2Cr, Cu-1WC-2Al_2O_3-2Cr and Cu-1.5WC-1.5TiC-2Cr are designated as MMC-2, MMC-3, MMC-4 and MMC-5, respectively.

TABLE I
SHOWS THE DETAIL OF COMPOSITIONS USED FOR THE DEVELOPMENT OF VARIOUS METAL MATRIX COMPOSITES (MMCs) USING STIR-CASTING

S. No.	Developed MMCs	Compositions	Purity (%)	Wt. (%)	Wt. (g)
1	MMC-1	Cu	99.5	96.0	960.0
		WC	98.0	1.0	10.0
		ZrO_2	99.5	1.0	10.0
		Cr	99.0	2.0	20.0
2	MMC-2	Cu	99.5	96.0	960.0
		WC	98.0	1.0	10.0
		Al_2O_3	~99.0	1.0	10.0
		Cr	99.0	2.0	20.0
3	MMC-3	Cu	99.5	95.0	950.0
		WC	98.0	1.0	10.0
		ZrO_2	99.5	2.0	20.0
		Cr	99.0	2.0	20.0
4	MMC-4	Cu	99.5	95.0	950.0
		WC	98.0	1.0	10.0
		Al_2O_3	~99.0	2.0	20.0
		Cr	99.0	2.0	20.0
5	MMC-5	Cu	99.5	95.0	950.0
		TiC	98.5	1.50	15.0
		WC	98.0	1.50	15.0
		Cr	99.0	2.00	20.0

Note:*MMCs – Metal Matrix Composites, Cu – Copper, Al_2O_3– Alumina, Cr – Chromium, WC – Tungsten Carbide, TiC – Titanium Carbide,and ZrO2 – Zirconia.*


Fig. 1.Stir-Casting Setup

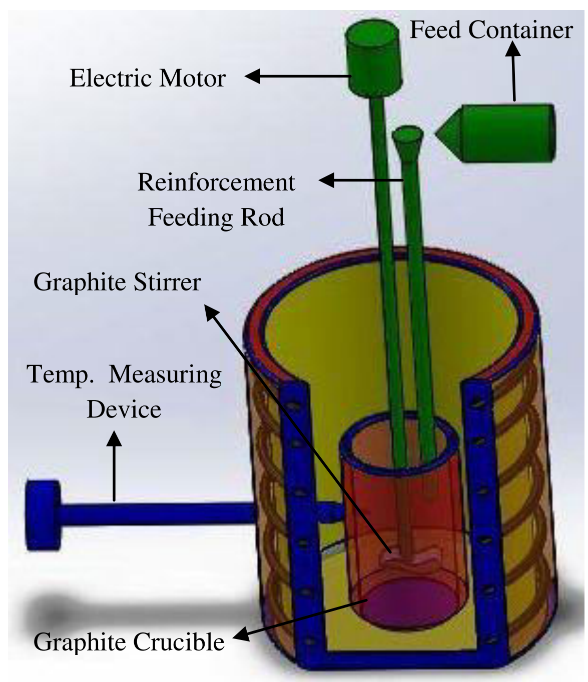

Fig. 2. Schematic Diagram of Stir-Casting Technique

Fig. 1 displays the stir-casting setup which is used to develop the various metal matrix

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composites. In this setup, basically an electric muffle furnace up to 1200 °C, a programming logic controller (PLC), electric motor of at 400 RPM, graphite crucible and graphite stirrer are assembled. Stir-casting technique was used to develop the various copper-basedMMCs as shown in TABLE 1. The commercial copper (Cu)was selected as the matrix, whereas the constant weightpercentages of WC, ZrO_2, Al_2O_3, TiC and Crwere used as reinforcements. The details of theirweight percentage and purity are given in TABLE1. Small piecesof Cu in calculated amount were placed in a graphitecrucible and kept in electric muffle furnace. The temperature of the furnace was set to 1200 ºC, heating rate of the furnace was 400 ºC/h, and holding time of the furnace at this temperaturewas set for 30 min. When the Cu pieces ingraphite crucible completely change its phase from solid tomolten state, the reinforcements of WC, ZrO_2, Al_2O_3, TiC and Crwereinserted one by one into molten metal as copper foil-wrappedpackets while continuously stirring for 5 min. After stirring, themolten admixture was poured into a permanent steel mold andkept in open air for cooling. The developed cast ingots can be used for various characterizations. The developed MMCs are designated asCu-1WC-1ZrO_2-2Cr as MMC-1, similarly Cu-1WC-1Al_2O_3-2Cr, Cu-1WC-2ZrO_2-2Cr, Cu-1WC-2Al_2O_3-2Cr and Cu-1.5WC-1.5TiC-2Cr are designated as MMC-2, MMC-3, MMC-4 and MMC-5, respectively.

Fig. 2 shows the schematic diagram of stir-casting techniques which reveals the function of each device like electric motor, graphite crucible, graphite stirrer, feeding rod etc. The schematic diagram very clearly explain the stir casting process such as where the materials is going to be melt and stirred, how the temperature is going to be measured etc.

III. RESULTS & DISCUSSION

Fig. 3 shows the schematic diagram of arrangement of reinforcements and matrix. It shows the larger grain size of reinforcing particle as compared to matrix grain in different MMCs. It is due to its larger atomic size compared to matrix atomic size which developed some strain and dislocation in the MMCs due to this the strength of MMCs generally improve.

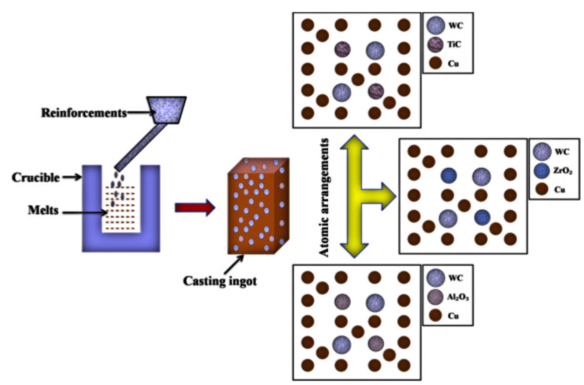

Fig.3. Schematic diagram of arrangement of reinforcement and matrix grains

Fig. 4 depicts the casting ingot of developed MMC. It shows a shiny and pores less gesture of the developed casting. Such casting ingot favors the stir-casting technique to be more famous for development of various MMCs. The casting ingot is having the shape of permanent steel mould's shape which was used to pour the molten materials and leave for the solidification in it.

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Fig. 4. Casting ingot of developed MMC

Fig. 5 and Fig. 6 show the microstructure of the MMC-1 and MMC-5 respectively. In both the microstructure the homogeneous distribution of reinforcing particle can be observed which provide the better results during its applications. A good interfacial bonding can also be observed between the grains of matrix and reinforcements. These good interfacials bonding always favour the better result in MMCs.

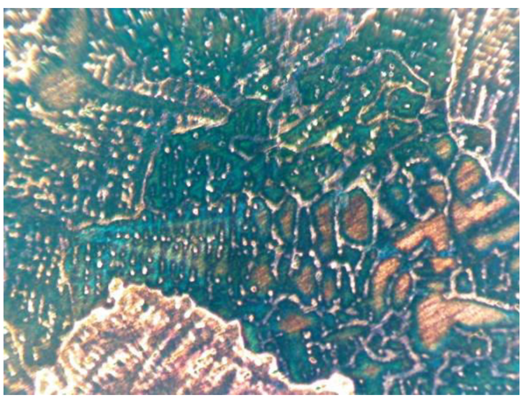

Fig. 5. Microstructure of 1WC-1ZrO_2-2Cr (MMC-1)

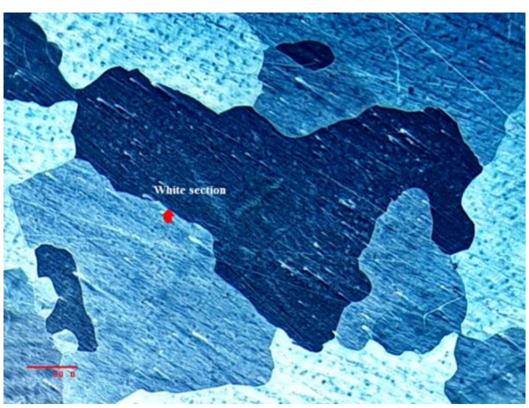

Fig.6. Microstructure of Cu-1.5WC-1.5TiC-2Cr (MMC-5)

IV. CONCLUSION

In the current study, it is observed that the stir-casting technique is very simple and economical and successfully develops the various MMCs without any defect in it.

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