Analysis of the stir casting parameters of Al 6000 series composites using TOPSIS method

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Abstract. This research focuses on the impact of stir casting variables namely, Stir speed, Melt temperature, Percent of reinforcement and Stir time on two characteristics namely Ultimate tensile strength and wear rate of Al 6063/TiB2/Al2O3 hybrid composites using Taguchi method. It also aims at developing a multi-response optimization technique using Taguchi based TOPSIS. Through the experiments, it was found that the highest and the lowest value of ultimate tensile strength (UTS) was in experiment 3 and 14 respectively. Likewise, the maximum and minimum wear rate (WTR) were noted down in the experiments 15 and 7, respectively. By using the TOPSIS method, the optimal solution for both UTS and WTR was identified to be the SD2 ‘ME3 PT4 SE1 set at 500 rpm, 800°C, 8 wt%, and 5 minutes. When the experiment was performed under these optimal conditions the tensile strength recorded were measured to be 229 MPa and wear rate of 0. 00272 mm³/Nm.

Keywords: Wear rate, UTS, TOPSIS, UTS, Optimizing

1 Introduction

MMCs are prepared with a matrix and reinforcement materials [1,2]. The reinforcement materials have high strength than the matrix materials and are used to be dispersed in the matrix to produce the composites [3]. Therefore, the composites turn out to have better properties than the matrix and degrade less than the usual reinforcement materials [4].

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Strengthening particles in the aluminum base enhances the strengthening of composites and this makes it to be widely demanded in industries.

The stir cast processing route has the following benefits as compared to other processing routes, namely: It is a simple process, flexible and versatile for different kinds of materials, economical and has a high production rate for large size composites.In this study, stir casting parameters are modelled for multiple responses by employing different strategies such as Grey Relational Analysis (GRA) [5], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)[5].Konada et al [6] used TOPSIS and Artificial Neural Network (ANN) integrated approaches in analysing the specific wear rate and coefficient of friction for the bronze fibre reinforced brake pads. The experiments' results were further validated using the ANN technique to satisfactorily explain the influence of different infrastructural development on economic growth. Regarding the TOPSIS technique used to find out theoretical optimal values of the parameters in order to minimize wear and having a certain desired coefficient of friction of the tested materials.Several researchers and Rathod et al. [7-10] employed Taguchi and TOPSIS to determine the best process parameters for turning the SS304 with the coated carbide tools. Which are the cutting speed, feed rate and depth of cut were considered. It also enhances tool durability but minimizes production time and surface roughness. Jamwal et al. studied copper–SiC–graphite MMCs synthesised by using liquid-stir casting process in terms of microstructure and mechanical and tribological properties [11-15]. The findings reveal that the density of the composite starts reducing with the increase of the reinforcement content. It was also found out that the more reinforcements added increases the ultimate tensile strength and wear resistance of the copper-based composites. Accordingly, the TOPSIS methodology was incorporated and implemented to optimize the physical and mechanical properties of Cu-MMC.

In this work , the Al7475/TiB2/ Al2o3 hybrid composites are prepared by stir casting route with aid of L16 orthogonal array parametric combination the output responses such as Ultimate tensile strength an d wear rate are analysed by multi response TOPISIS technique.

2 Experimental setup

Reinforcement in the aluminium matrix is reported in this paper, along with the manufacture of hybrid composites.Ensuring stir casting delivers improved properties at a lower cost makes it an effective technique [16-20].Aluminium 6063 plates segmented and disposed into small parts or splines, when it is easier to dry and melt in a graphitecrucible.
The reinforcement materials TiB2 and Al2o3 were preheated at 600C in an electrical resistive furnace.as previously stated, it should cater for the desired weight proportions for a 6 min duration [21-24].

Table 1. Stir casting factors with levels

factors	level			
	1	2	3	4
Stir speed (SD)	400	500	600	700
Melt temperature (ME)	600	700	800	900
Percent of reinforcement (PT)	2	4	6	8
Stir time (SE)	5	10	15	20

Optimum levels of critical factors are SD, ME, PT, and SE are identified based on the pilot experiments in a laboratory Using mechanical stirrer placed in to the surface of the melt the stirring speed and time as set were carried. Reaction time has been maintained constant to 10 min after performing pilot experimental trials, which show that higher properties (ultimate tensile strength and wear rate) can be due to fairly and uniform distribution of the reinforcement material in the Al matrix. Degassing is done to eliminate the contamination of absorbed gases in the melt. The molten metal was cleaned and degasified and then the molten metal was allowed to flow into the preheated mold cavity. Last but not the least; the synthesized composites are evaluated for mechanical properties[25-29].

Table 2. L16 orthogonal array -factors levels combination

Exp. No	SD	ME	PT	SE
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Table 3. Stir casting factors with corresponding levels

Exp. No	SD	ME	PT	SE
1	400	600	2	5
2	400	700	4	10
3	400	800	6	15
4	400	900	8	20
5	500	600	4	15
6	500	700	2	20
7	500	800	8	5
8	500	900	6	10
9	600	600	6	20
10	600	700	8	15
11	600	800	2	10
12	600	900	4	5
13	700	600	8	10
14	700	700	6	5
15	700	800	4	20
16	700	900	2	15

3 Result and discussion

Figures 1 & 2 above shows the over all UTS and WTR results obtained from the experiment. As per the results, the maximum and minimum UTS are established in the experiment no: 7 and 18 similarly the , the maximum and minimum WTR are established in the experiment no: 14 and 7 respectively. These relationships between the factors on UTS and WTR are demonstrated in the following Figure. 3 and 4 respectively.UTS is examined through the analysis of S/N ratio technique in MINITAB software [30-34]. Figure.5 presents the mean S/N ratio of UTS at various levels of the input process variables. As depicted in Fig. 5, the optimal combination for maximizing UTS is SD1-ME1-PT3-SE3, corresponding to the values of 400rpm,600°C ,6wt% and 15 mins.In stir casting, reinforcing particles are added into the molten metal and mixed continuously to ensure that they are well distributed [35-39]. Longer mixing times ensure that the reinforcement particulate is well mixed which helps in eliminating problems of agglomeration and clustering. The even distribution of reinforcements causes regular mechanical characteristics, and, therefore, increased tensile strength.

WTR is examined through the analysis of S/N ratio technique in MINITAB software [19,20]. Figure.6 presents the mean S/N ratio of WTR at various levels of the input process variables. As depicted in Fig. 6, the optimal combination for minimizing WTR is SD4-ME1-PT2-SE3, corresponding to the values of 700rpm,600°C ,4wt% and 15 mins.As the stirring speed increases there is increased possibility that the reinforcement particles will be in a good condition of being wetted by the molten matrix. This results in enhanced interfacial adhesion between the reinforcement particles and the matrix [40-43]. This way, it provides a good interface for load transfer and makes it more difficult for the particles to be pulled out during wear.

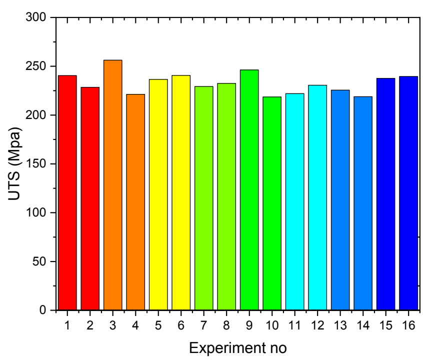

Fig.1. Ultimate Tensile strength results

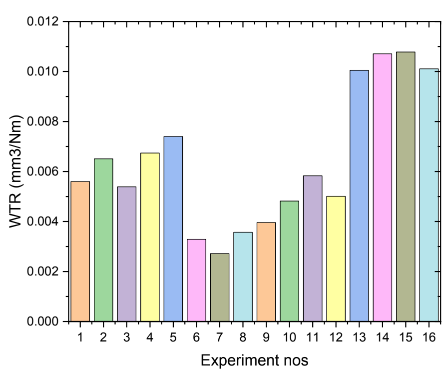

Fig. 2. Wear rate results

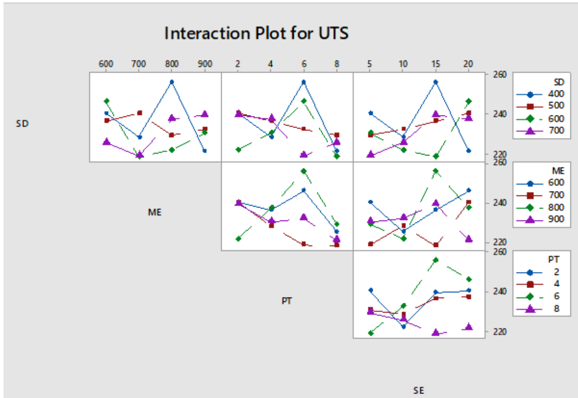

Fig. 3. Interaction plots in UTS

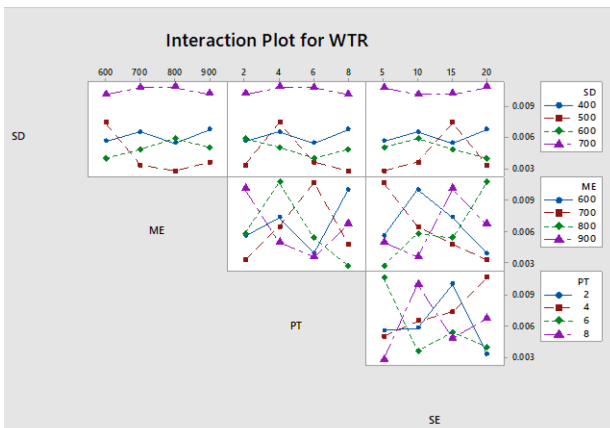

Fig. 4. Interaction plots in WTR

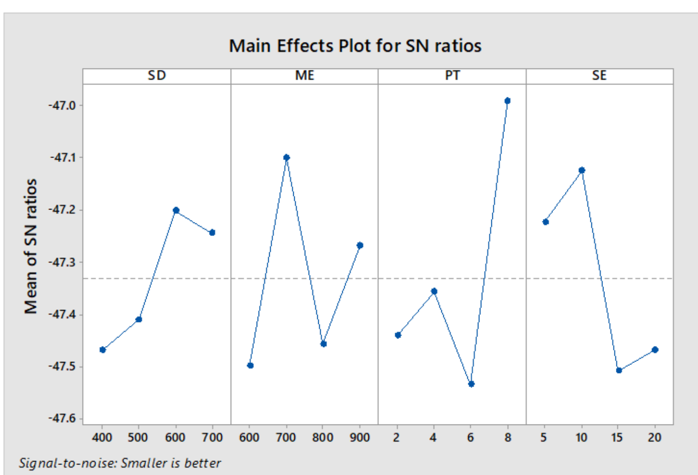

Fig. 5. SN ratio plot-UTS

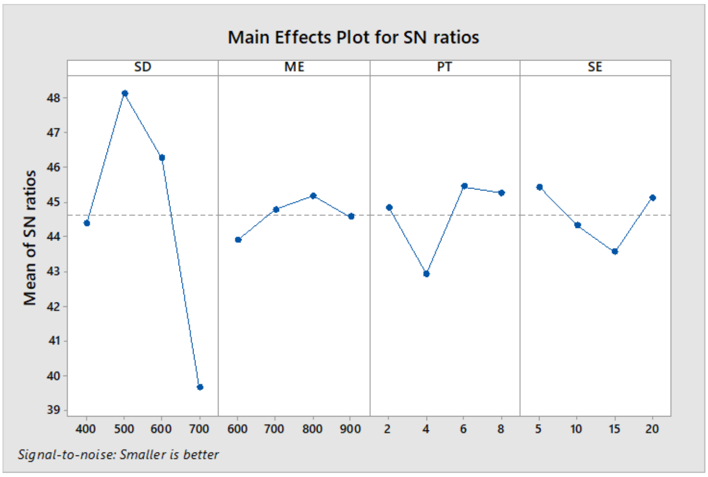

Fig. 6. SN ratio plot-WTR

TOPSIS is a multi-criteria decision making (MCDM) technique in which the selection is made based on the order preference of the identical solution. It aids also in ordering and choosing a number of options by their degree of closeness to the ideal solution [21-24]. below are some of the steps in performing topsis method for multi response optimization of mechanical properties (1) constructing the decision matrix (2) Normalizing the decision matrix (3) Weighting the normalized decision matrix (4) Identifying the ideal and negative ideal solution and separation measures (5) computing the relative closeness (6) ranking the options.

The TOPSIS method determined that the optimal combination for both UTS and WTR is SD2-ME3-PT4-SE1 with corresponding values of 500rpm,800°C,8 wt% and 5 mins. An experiment was conducted under this optimal condition, resulting in the following values: tensile strength of 229.3MPa and a wear rate of 0.00272 mm³/Nm.

Table 4. TOPSIS result

Exp.no	Normalized		Weighted Normalized		SP_i^+	SP_i^-	RE_i	Rank
	UTS	WTR	UTS	WTR				
1	0.258028	0.167139	1.71949E-05	0.000905	0.03037	0.06816	0.69178	8
2	0.245153	0.194299	1.29183E-07	0.001567	0.03959	0.05785	0.59370	10
3	0.274979	0.160872	0.0001016	0.000778	0.02966	0.07198	0.70820	7
4	0.237428	0.201164	9.38245E-06	0.001763	0.04210	0.05495	0.56617	11
5	0.253736	0.220863	6.99414E-06	0.00239	0.04896	0.04971	0.50378	12
6	0.253736	0.098194	6.99414E-06	3.55E-05	0.00651	0.09143	0.93348	2
7	0.246011	0.081182	3.48262E-09	1.09E-13	0.00006	0.09690	0.99939	1
8	0.249445	0.106551	1.30556E-06	7.88E-05	0.00895	0.08829	0.90794	3
9	0.26425	0.118191	4.00008E-05	0.000168	0.01441	0.08531	0.85546	4
10	0.234532	0.143859	1.66215E-05	0.000481	0.02231	0.07462	0.76982	5
11	0.238179	0.174004	7.84124E-06	0.001055	0.03261	0.06436	0.66372	9
12	0.247406	0.14953	1.84167E-07	0.000572	0.02393	0.07336	0.75406	6
13	0.242042	0.299955	2.09784E-06	0.005863	0.07658	0.02271	0.22870	14
14	0.234853	0.319654	1.57157E-05	0.006966	0.08356	0.01557	0.15708	16
15	0.254916	0.321743	9.34955E-06	0.007089	0.08425	0.02009	0.19256	15
16	0.257062	0.301746	1.45063E-05	0.005959	0.07729	0.02536	0.24702	13

4 Conclusion

This work investigates the effects of stir casting parameters on the mechanical properties of the ultimate tensile strength and wear rate in Al 6063 /TiB2/Al2O3 hybrid composites.For single optimization, the optimal combination for maximizing UTS is SD1-ME1-PT3-SE3, corresponding to the values of 400rpm,600°C ,6wt% and 15 mins and the optimal combination for minimizing WTR is SD4-ME1-PT2-SE3, corresponding to the values of 700rpm,600°C ,4wt% and 15 mins. Finally the multi response optimization, The TOPSIS method determined the optimal combination for both UTS and WTR as SD2-ME3-PT4-SE1, corresponding to parameters of 500 rpm, 800°C, 8 wt%, and 5 minutes. An experiment conducted under these optimal conditions resulted in a tensile strength of 229.3 MPa and a wear rate of 0.00272 mm^3/Nm.

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