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OPTIMIZATION OF TRIBOLOGICAL CHARACTERISTICS OF AL7075-BORON NITRIDE COMPOSITES USING TAGUCHI METHOD

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Abstract: The Taguchi method of quality control is an approach to engineering that emphasizes the roles of research and development, and product design and development in reducing the occurrence of defects and failures in manufactured goods. Stir casting is an economical method to produce aluminium matrix composites (AMCs). In the present work, Aluminium alloy AA7075 reinforced with various amounts (1, 2 and 3wt. %) of BN particles were prepared. The matrix alloy was melted in a furnace and stirred to form a vortex.BN particles were added to the periphery of the vortex and the composite melt was solidified in a permanent mold. The microstructures of the AMCs were studied using microscope. BN particles was observed to refine the grains and were distributed homogenously in the aluminium matrix. BN particle clusters were also seen in a few places. BN particles were properly bonded to the aluminium matrix. The reinforcement of BN particles improved the Wear analysis in Taguchi method of the AMCs.

Keywords: Aluminium Matrix Composites (AMCs), Particles Cluster, Taguchi Method.

I. INTRODUCTION

Casting is a manufacturing process where a solid is melted, heated to proper temperature (sometimes treated to modify its chemical composition), and is then poured into a cavity or mold, which contains it in the proper shape during solidification. Thus, in a single step, simple or complex shapes can be made from any metal that can be melted. The resulting product can have virtually any configuration the designer desires. In addition, the resistance to working stresses can be optimized, directional properties can be controlled, and a pleasing appearance can be produced. Cast parts range in size from a fraction of an inch and a fraction of an ounce, to over 30 feet and many tons. Casting has marked advantages in the production of complex shapes, parts having hollow sections or internal cavities, parts that contain irregular curved surfaces, very large parts and parts made from metals that are difficult to machine. Because of these obvious advantages, casting is one of the most important of the manufacturing processes.

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

Aluminium alloy in which aluminium is predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc.

Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. Aluminium alloy surfaces will develop a white, protective layer of aluminium oxide if left unprotected by anodizing and/or correct painting procedures. Referred to as dissimilar-metal corrosion, this process can occur as exfoliation or as intergranular corrosion.

II. MATERIALS AND METHODS

2.1 METHODOLOGY

The literature review has given an insight of the alloy research work and the gaps found in it enabled to identify problem areas find solution through the experimental methodology fulfilling the objective. Figure 1 shows the methodology to be followed.

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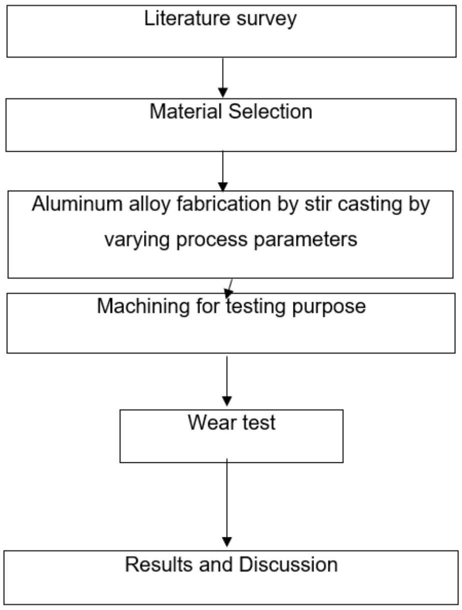

Fig 1 Methodology

The experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2kg. The maximum operating temperature of the furnace is 1000°C. The current rating of furnace is single phase 230V AC, 50Hz.

2.2 MATERIAL SELECTION

2.2.1 Matrix Material: Aluminium Alloy 7075

Castings are standardized in the precipitation treated (TE) condition, solution treated, artificially aged and stabilized (TF7) condition and the fully heat treated (TF) condition.

2.2.2 AA7075 alloy chemical composition

Table 1 chemical composition of AA7075 alloy

Copper	1.20-2.00 max
Magnesium	2.10-2.90 max
Silicon	0.40 max
Iron	0.50 max
Manganese	0.30 max
Titanium	0.20 max
Zinc	5.10-6.10 max
Chromium	0.18-0.28 max

2.2.3 Properties of AA7075

Table 2 properties of AA7075 alloy

Density	2.81 g/cm^3
Young's modulus	572 Mpa
Melting point	477 ^{0}C

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Specific heat capacity	714.8 J/Kg-K
Tensile strength : Ultimate (UTS)	572 Mpa
Rockwell Hardness	87 HRB
Thermal Conductivity	196 W/Mk
Elongation	11 %

The mechanical properties of AA7075 depend greatly on the temper, or heat treatment, of the material.

2.3 REINFORCEMENT MATERIAL:

Boron Nitride (BN)

2.3.1 EXPRIMENTAL DETAILS:

Table 3 proposition of reinforce material

SL.NO	REINFORCED PARTICLES MIXING RATIO
1	AA7075 + 1% of Boron Nitride
2	AA7075 + 2% of Boron Nitride
3	AA7075 + 3% of Boron Nitride

2.3.2 REINFORCEMENT MATERIAL CHEMICAL COMPOSITION

Total Boron	Min 76.5%
Total Carbon	21.5%
Total B+C	Min.98.0%
Iron	0.2%

2.3.3 REINFORCEMENT MATERIAL PROPERTIES

Density	2.27 g/cm^3
Young's modulus	20 -103 Mpa
Melting point	3000 ^{0}C
Hardness(knop 100g)	400 kg.mm-^{2}
Color	Brown

2.4 SAMPLE FABRICATION

The AA6061 aluminium alloy is introduced to the melt furnace and it is melted. After melting of actual, the molten metal is made to pour on the cylindrical die. After solidification of cast, then die end is removed. Then the casted sample are collected. The sample were fabricated by varying the process parameters.
The samples were casted as per the experimental plan to prepare specimens for various testing and investigating the properties of these fabricated samples.

III. RESULT AND DISCUSSION

3.1 WEAR TEST

Table 4 PIN ON DISC READING

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s.no	Load(N)	Speed (rpm)	Time (min)	Reinforce (%)	Wear rate (μ)	Friction force (N)
1	10	300	5	1	79	1.5
2	10	400	5	2	26	0.1
3	10	500	5	3	38	2.3
4	20	300	5	2	36	1.5
5	20	400	5	3	19	7.3
6	20	500	5	1	131	6.2
7	30	300	5	3	58	5.9
8	30	400	5	1	88	5.9
9	30	500	5	2	52	9.3

3.2 Wear Rate

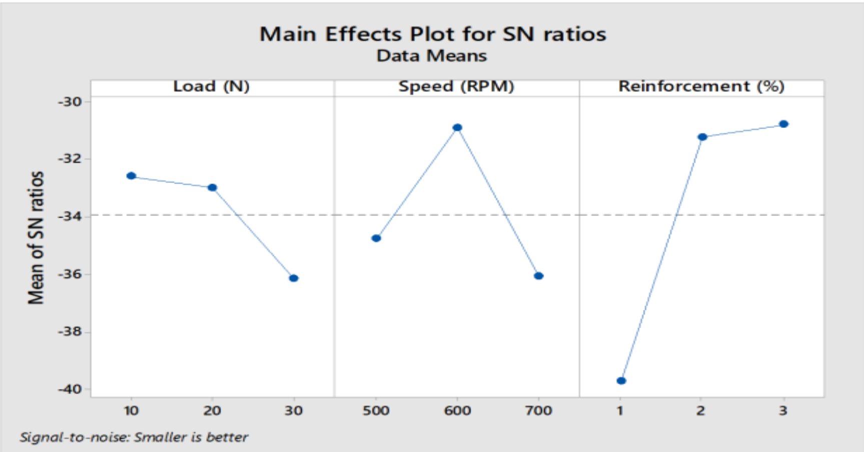

Fig 2 Main effect plot for SN ratios for wear rate

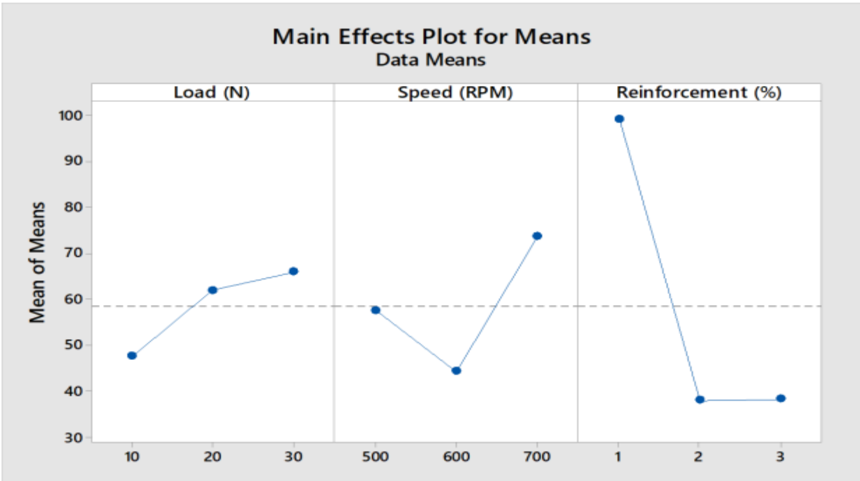

Fig 3 Main effect plot for means of SN ratio of wear rate

From the Figure 4 it is seen that the addition of particulate reinforcement Boron Nitride into the Al 7075 matrix results in lesser wear rate. The hybrid composite exhibited superior wear resistance when compared with the base aluminium alloy Al 7075.

It can be seen that the sample 5 showed lesser wear rate when compared to other samples.

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3.3 Taguchi Design

Design Summary

Taguchi Array	**L9(3^3)**
Factors:	3
Runs:	9

Linear Model Analysis: SN ratios versus Load (N), Speed (RPM), Reinforcement (%)

Estimated Model Coefficients for SN ratios

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	-33.9303	0.7767	-43.685	0.001
Load (N) 10	1.3144	1.0984	1.197	0.354
Load (N) 20	0.9148	1.0984	0.833	0.493
Speed (R 500	-0.8521	1.0984	-0.776	0.519
Speed (R 600	3.0089	1.0984	2.739	0.111
Reinforc 1	-5.7989	1.0984	-5.279	0.034
Reinforc 2	2.6818	1.0984	2.441	0.135

Model Summary

S	**R-Sq**	**R-Sq(adj)**
2.3301	95.24%	80.98%

Analysis of Variance for SN ratios

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Load (N)	2	22.60	22.60	11.300	2.08	0.325
Speed (RPM)	2	43.29	43.29	21.647	3.99	0.201
Reinforcement (%)	2	151.61	151.61	75.804	13.96	0.067
Residual Error	2	10.86	10.86	5.429		
Total	8	228.36				

Linear Model Analysis: Means versus Load (N), Speed (RPM), Reinforcement (%)

Estimated Model Coefficients for Means

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	58.5556	6.656	8.797	0.013
Load (N) 10	-10.8889	9.414	-1.157	0.367
Load (N) 20	3.4444	9.414	0.366	0.750
Speed (R 500	-0.8889	9.414	-0.094	0.933

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Speed (R 600	-14.2222	9.414	-1.511	0.270
Reinforc 1	40.7778	9.414	4.332	0.049
Reinforc 2	-20.5556	9.414	-2.184	0.161

Model Summary

S	R-Sq	R-Sq(adj)
19.9694	92.13%	68.51%

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Load (N)	2	557.6	557.6	278.8	0.70	0.589
Speed (RPM)	2	1294.2	1294.2	647.1	1.62	0.381
Reinforcement (%)	2	7482.9	7482.9	3741.4	9.38	0.096
Residual Error	2	797.6	797.6	398.8		
Total	8	10132.2				

Response Table for Signal to Noise Ratios

Smaller is better

Level	Load (N)	Speed (RPM)	Reinforcement (%)
1	-32.62	-34.78	-39.73
2	-33.02	-30.92	-31.25
3	-36.16	-36.09	-30.81
Delta	3.54	5.17	8.92
Rank	3	2	1

Response Table for Means

Level	Load (N)	Speed (RPM)	Reinforcement (%)
1	47.67	57.67	99.33
2	62.00	44.33	38.00
3	66.00	73.67	38.33
Delta	18.33	29.33	61.33
Rank	3	2	1

3.4 FRICTION FORCE

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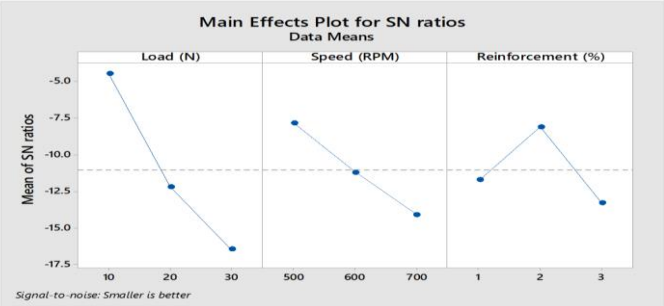

Fig 4 Main Effect plot for SN ratios of Friction force

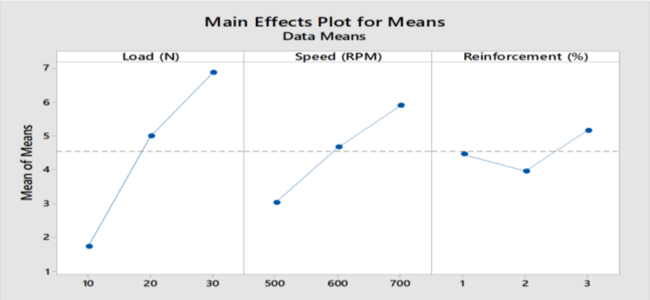

Fig 5 Main effect plot for means of Friction force

Linear Model Analysis: SN ratios versus Load (N), Speed (RPM), Reinforcement (%)

Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	-11.0626	1.501	-7.370	0.018
Load (N) 10	6.5869	2.123	3.103	0.090
Load (N) 20	-1.1494	2.123	-0.542	0.642
Speed (R 500	3.2133	2.123	1.514	0.269
Speed (R 600	-0.1565	2.123	-0.074	0.948
Reinforc 1	-0.6921	2.123	-0.326	0.775
Reinforc 2	2.9355	2.123	1.383	0.301

Model Summary

S	R-Sq	R-Sq(adj)
4.5029	88.88%	55.54%

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Load (N)	2	222.82	222.82	111.41	5.49	0.154
Speed (RPM)	2	59.08	59.08	29.54	1.46	0.407
Reinforcement (%)	2	42.39	42.39	21.19	1.05	0.489
Residual Error	2	40.55	40.55	20.28		
Total	8	364.84				

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Linear Model Analysis: Means versus Load (N), Speed (RPM), Reinforcement (%)

Estimated Model Coefficients for Means

Term	Coef	SE Coef	T	P
Constant	4.53333	0.8579	5.284	0.034
Load (N) 10	-2.80000	1.2132	-2.308	0.147
Load (N) 20	0.46667	1.2132	0.385	0.738
Speed (R 500	-1.50000	1.2132	-1.236	0.342
Speed (R 600	0.13333	1.2132	0.110	0.923
Reinforc 1	-0.06667	1.2132	-0.055	0.961
Reinforc 2	-0.56667	1.2132	-0.467	0.686

Model Summary

S	R-Sq	R-Sq(adj)
2.5736	80.62%	22.47%

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Load (N)	2	40.507	40.507	20.253	3.06	0.246
Speed (RPM)	2	12.407	12.407	6.203	0.94	0.516
Reinforcement (%)	2	2.180	2.180	1.090	0.16	0.859
Residual Error	2	13.247	13.247	6.623		
Total	8	68.340				

Response Table for Signal to Noise Ratios

Smaller is better

Level	Load (N)	Speed (RPM)	Reinforcement (%)
1	-4.476	-7.849	-11.755
2	-12.212	-11.219	-8.127
3	-16.500	-14.119	-13.306
Delta	12.024	6.270	5.179
Rank	1	2	3

Response Table for Means

Level	Load (N)	Speed (RPM)	Reinforcement (%)
1	1.733	3.033	4.467
2	5.000	4.667	3.967
3	6.867	5.900	5.167
Delta	5.133	2.867	1.200
Rank	1	2	3

IV. CONCLUSION

The composite sample of Aluminium Alloy 7075 as matrix, Boron Nitride Particulates as reinforcement were fabricated using stir casting process. The Tribological properties such as wear test were optimized from the fabricated samples. The hybrid composite exhibited superior wear resistance when compared with base aluminium 7075 matrix alloy and the wear resistance get increased. It is clear from the S/N ratio that Load is the most significant factor followed by speed and time. From the comparison charts we can concluded that when the load increased the wear rate increases tremendously at low speed. And also the wear rate decreases with increases in the speed.

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