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OPTIMIZATION OF NACL BASED SPRAY CORROSION TEST PROCESS PARAMETERS OF HEAT TREATED HYBRID METAL MATRIX COMPOSITES

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ABSTRACT. Aluminium hybrid metal matrix composites (AHMMCs) have widely employed in aerospace, transportation, and automotive applications since for their excellent mechanical qualities and high corrosion resistance. In this research, Al8079 is selected as a matrix material. The titanium diboride (TiB_2) is selected as hard reinforcement and molybdenum disulfide (MoS2) is used as soft reinforcement. The Al8079/15 wt.% TiB2/x wt.% MoS2 (x = 0, 2.5, 5 and 7.5) HMMCs are fabricated by using stir casting. The composites are heat treated under T6 condition. The density and micro hardness tests are conducted. The optimization on NaCl based spray corrosion test process parameters is done using grey relational analysis (GRA). The selected input process parameters are Al8079/15 wt.% TiB_2/wt.% MoS_2 (x = 0, 2.5 and 5), pH value of NaCl solution (x = 6, 9 and 12), hang time (x = 24, 48, and 72 h) and pressure (x = 0.7, 0.9 and 1.1 kg/cm^2). The selected response parameters are micro hardness, mass loss and wear loss. The L9 Taguchi design is used for optimization. The wear test is conducted at the constant speed of 0.5 m/s, loading rate of 20 N and the sliding distance of 1000 m. The percentage of improvement of GRG from initial setting to experimental is 10.4%.

KEY WORDS: Reinforcement, Stir casting, Optimization, GRA, NaCl

INTRODUCTION

Aluminum-based hybrid composite materials have largely replaced traditional aluminium alloys due to the enhanced wear resistance, high strength-to-weight ratio, and energy-saving properties. [1]. Due to its superior mechanical and physical qualities, AHMMC is widely employed in structural and automotive applications. The addition of reinforcement with conventional alloys enhances properties of AHMMCs [2]. The reinforcements such as Titanium carbide, aluminium di- oxide, silicon carbide, boron carbide and titanium nitride are used for enhancing the properties of conventional alloys [3]. The wear resistance, tensile strength and hardness of Al6061/SiC and Al7075/SiC have been analyzed. The addition of silicon carbide with Al6061 and Al7075 increases wear resistance, tensile strength and hardness [4, 5]. The time and temperatures are two important factors in stir casting method and they are carefully chosen. The mechanical properties and wear resistance are improved by the addition of aluminium dioxide with aluminium matrix material [6]. The inclusion of silicon carbide increases the ultimate tensile and yield strength. The increasing of size of particles of SiC decreases the tensile and yield strength of Al/SiC composites. The ductility of Al/SiC composites reduces as the weight proportion of silicon carbide increases. [7]. The AA2024 with 6 wt.% graphite exhibits better wear resistance than other combinations and its conventional alloy. The homogenous distribution of reinforcing agents in the composite materials increases mechanical properties and wear resistance [8]. Metal matrix composites have a lower wear resistance than hybrid metal matrix composites. The hard reinforcement increases

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the load bearing capacity and soft lubricant decreases the friction [9, 10]. The addition of graphite reinforcements increases the corrosion resistance, wear resistance and micro hardness [11]. The addition of titanium di boride into the matrix improves the load bearing capacity and wear resistance of the composite materials [12, 13]. In addition of molybdenum disulfide forms the mechanically mixed layer and it causes to prevent the metal to metal contact. As a result, molybdenum disulphide reduces the wear resistance of composites [14, 15]. Among the different optimization strategies for composites, grey relational analysis is the best [16]. Previous study has made no attempt to examine the manufacture and characterization of Al8079/TiB_2/MoS_2 hybrid metal matrix hybrid composites. In this research, optimization of NaCl based spray corrosion test process parameters of Al8079 based hybrid metal matrix composites for its micro hardness, mass loss and wear loss is done by using GRA.

EXPERIMENTAL

Materials

Al8079 has been widely used in automobile, marine and aircraft applications. Al8079 possesses moderate strength and wear resistance properties. As a result, Al8079 reinforcement is required to develop the strength, wear, and corrosion resistance qualities. The chemical composition of Al8079 is Cu (0.05 wt.%), Fe (1.4 wt.%), Zn (0.1 wt.%), Si (0.3 wt.%), other (0.15 wt.%) and Al (Rem. wt.%). Titanium diboride (TiB_2) has been used as a strong reinforcement to improve corrosion and wear resistance.

The molybdenum disulfide (MoS_2) is chosen as soft reinforcement for enhancing the wear resistance by reducing friction. The particle size analyzer is used to determine the particle size of the reinforcements [17]. The particle size of TiB_2 ceramic reinforcement and MoS_2 soft reinforcement is 10 µm and 2 µm, respectively.

The 10 µm particle size of titanium diboride is used and 2 µm particle size of molybdenum di sulfide is used in the fabrication of composite. These two different types of reinforcements are given better bonding strength than other combination of particle size of the reinforcements in earlier research.

The purity of matrix AL8079, titanium diboride and molybdenum disulfide is 98.5, 98 and 99%, respectively. The purity of molybdenum disulfide is higher than other materials. The density of AL8079, titanium diboride and molybdenum disulfide is 2.72, 7.52 and 5.06 g/cm^3, respectively. The modulus of elasticity of AL8079, titanium diboride and molybdenum disulfide is 72, 410 and 254 MPa.

The tensile strength of AL8079, titanium diboride and molybdenum disulfide is 241, 336 and 226 MPa. The titanium diboride has higher modulus of elasticity and tensile strength than other materials. The melting point of AL8079, titanium diboride and molybdenum disulfide is 850, 2248 and 1185 ºC. The titanium diboride has higher melting point than other materials. The mass loss of the composites is increased by the impurities presented in the matrix and reinforcement materials. The impurities accelerate the corrosion rate.

Fabrication and heat treatment of Al8079 hybrid composites

The matrix and reinforcements are well bonded with each other in the stir casting method while comparing with other fabrication method [18]. In this study, stir casting is used to create Al8079/15 wt.% TiB_2/x wt.% MoS_2 (x = 0, 2.5, 5 and 7.5) hybrid metal matrix composites. The percentage of matrix and reinforcements are selected based on the particle size, melting temperature, density, hardness, Poisson ratio and tensile strength. The matrix material Al8079 is acquired from champion advanced materials, Mumbai, India in round rod form. The reinforcements are purchased from Subra Scientific Company, Chennai.

The Al8079 round rod is cut into small pieces for placing into crucible furnace of stir casting setup. The reinforcements are weighed by electronic weighing machine, which has a high accuracy of 0.0001 g. The hard reinforcement TiB_2 and MoS_2 reinforcement are preheated in the pre heater setup to 30 min. The Al8079 round rods are heated up to 750 °C for attaining liquid form. The melting temperature of aluminium matrix material is influenced the bonding strength of the matrix and reinforcement materials. The optimized melting temperature easily allows the reinforcements to disperse in the AL8079 matrix material. The optimized melting temperature eliminates the occurrence of porosity during casting.

The preheated reinforcements are feed into the graphite crucible furnace. The 1 wt.% magnesium is used to increase the wet ability between matrix and reinforcement material. The stirrer is rotated at 600 rpm for 25 min duration to uniformly mixing the reinforcements with matrix material. The Al8079 based hybrid composite is poured into the mould to solidify. Similarly, all kind of composites are fabricated. The all fabricated Al8079 composites are subjected to T-6 tempering. The fabricated composites are heated to 450 °C for 180 min followed by oil quenching and naturally aged at room temperature for 25 days. The oil quenching is done with the help of shea nut oil. The shea nut oil exhibits better result than water. The specific gravity and pH value of shea nut oil is 1.5 and 4.22. The viscosity of oil is 2.4 Cp. The specific heat capacity of shea nut oil is 3.4 kJ/kg ºC. The density of the oil is 923 kg/m^3.

The heat treated composites are subjected to artificial aging at 210 °C for 7 hours followed by normal cooling [19-23]. The fabricated composites are cut to required size as per ASTM for various tests with the help of wire cut EDM. The formulation of the AL8079 based composites are mainly influenced by the particle size of the reinforcements. The small size of the reinforcements decreases the porosity and increases the hardness by increasing the density. The small particle size of the reinforcements increases the bonding strength of the matrix and reinforcement materials.

The GRA determines the relationship between the multiple responses with respect to input parameters. The GRG is determined for knowing the relational degree between different responses. The GRA analysis has been done in four steps [24]. The primary step is used to standardize the data for GRA analysis. The micro hardness should be as high as possible whereas mass loss and wear loss should be as low as possible. The normalization has been done by using equation 1 and 2. The Equations are used from Nithiyanandham *et al.* [25].

Zi = 1 - [Yi*/max (Yi)] higher the better (1)

Zi = 1 - [min (Yi)/Yi*] lower the better (2)

where Zi represents normalized value, Yi* represents current value, min (Yi) and max (Yi) represent minimum and maximum values. The conversion of same unit has been done by using the equation 3.

$$Z_{jk}= \frac{y_{jk}-min(y_{jk, j=1,2,3,\ldots m})}{max(y_{jk\ j=1,2,3,..m})-min(y_{jk\ j=1,2,3,..m})} \quad (3)$$

Y_{jk} – data sequence, m – experimental data.

$$y_j^k = \frac{min_j min_k|Z_0(j)-Z_J(k)| + max_k max_l|Z_0(j)-Z_J(k)|}{|Z_0(k)-Z_k(j)| max_k max_l|Z_0(j)-Z_k(j)|} \quad (4)$$

The grey relational coefficient is calculated with the help of using the equation 4. y_j^k - Grey Relational Coefficient, Z0j - deviation sequence, Z_{max} andZ_{min}- max and min values of the absolute differences (Z_{0i}). The grey relational grade is calculated with the help of using the equation 5.

$$GRG_{jk} = \frac{1}{n}\sum_{i=1}^{n} y_j^k \quad (5)$$

GRG_{jk} represents grey relational grade.

Testing of Al8079 based composites

The heat treated Al8079/15 wt.% TiB_2/x wt.% MoS_2 (x = 0, 2.5, 5 and 7.5) hybrid composites are subjected to EDAX and microstructural analysis. The EDAX test is conducted to identify the presence of elements. The microstructure is used to confirm that the reinforcements are distributed uniformly in the matrix material. The Jeol make JSM - 6510LV is employed to analysis the microstructure of heat treated Al8079 based composites. The heat treated Al8079 based composites are cleaned and polished with the help of abrasive grade sheets (200, 400 and 600). The 4 mL HF, 6 mL HCl, 40 mL HNO_3 and 320 mL H_2O composition of killers agent is used to etch the each specimen to generate the micrograph by using scanning electron microscope. The killers agent is used to remove the dust and dirt form the each specimen. The density test is conducted on the heat treated Al8079 based hybrid composites by using Archimedes principle [26]. The micro hardness of the heat treated Al8079 based composites is determined with the help of Vickers microhardness tester (Model V - 5 series, Range 1 – 2970 HV, eyepiece 10x).

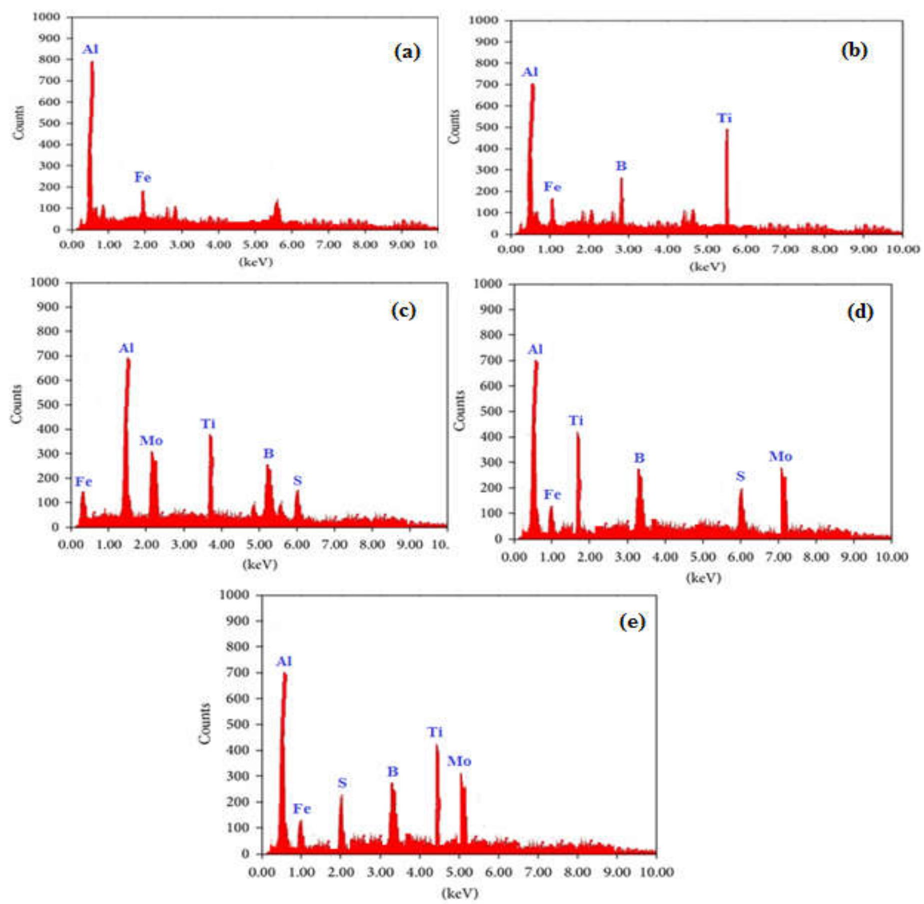

Figure 1. EDAX test result of Al8079 and its composites.

The microhardness test is conducted as per ASTM E407. The microhardness test is conducted at the load of 0.3 kg for the duration of 10 s [27]. The salt spray corrosion test is conducted on all heat treated Al8079 based hybrid composites. The NaCl based spray solution contains 5% sodium chloride, 1% magnesium chloride and 94% deionized water. The NaCl based spray corrosion test is conducted as per ASTM B117-14. The high concentration of spray solution contains high amount of NaCl. The high amount of NaCl accelerates the mass loss of the AL8079 based composites. The optimization of NaCl spray corrosion test process parameters is done on heat treated Al8079/15 wt.%TiB_2 composites by accounting MoS_2 wt.% of reinforcement (x = 0, 2.5 and 5), pH value (x = 6, 9 and 12), hang time (x = 24, 48 and 72 h) and pressure (x = 0.7, 0.9 and 1.1 kg/cm^2) as input process parameters and mass loss, micro hardness and wear loss as response parameters. The spray process parameter is chosen for this investigation is mainly based on the responses. The micro hardness, wear loss and mass loss are mainly influenced by the pH value, wt.% of molybdenum disulfide, pressure of spray and hanging time. The orthogonal array L9 Taguchi design is used for optimization. The L9 orthogonal array is used for this investigation because of its prediction is better than other orthogonal array.

The GRA is used to identify the influence parameter of salt spray corrosion test. The mass loss of heat-treated composites is determined by weighing the specimen before and after the corrosion test with electronic weighing equipment. The wear test is conducted in the DUCOM model, TR20, M-16. The EN 31 is used for counter disc material in the wear test. The ASTM G99 is employed for conducting wear test on all heat treated composites. The polished composite surface is 1 µm and it is confirmed by the surface roughness tester.

The wear test is conducted at constant speed of 0.5 m/s, loading rate of 20 N and the sliding distance of 1000 m [27]. Weight of the specimen as well during the wear test with electronic balance equipment estimates the wear loss.

RESULTS AND DISCUSSION

Microstructural analysis

The heat treated Al8079-based hybrid composites are subjected to an energy dispersive X-ray analysis test that validate the percentage of weight in element present. The EDAX test result of Al8079/15 wt.% TiB_2/x wt.% MoS_2 (0, 2.5, 5 and 7.5) – T6 is shown in Figure 1. The composition of heat treated Al8079 based composites is shown in Table 1.

Table 1. EDAX test result of Al8079 and its composites.

S. No.	Composition	Series	Elements wt.%					
			Al	Fe	Ti	B	Mo	S
1	Al8079	K. Series	98.6	1.4	-	-	-	-
2	Al8079/15wt.TiB_2	K. Series	83.5	1.3	11.23	3.77	-	-
3	Al8079/15wt.TiB_2/2.5wt.%MoS_2	K. Series	82.9	1.25	9.45	3.34	1.66	1.4
4	Al8079/15wt.TiB2/5wt.%MoS_2	K. Series	80.46	1.4	9.12	3.2	3.15	2.67
5	Al8079/15wt.TiB_2/7.5wt.%MoS_2	K. Series	78.65	1.32	8.9	3.6	4.62	2.91

The scanning electron microscope is utilized to analysis the microstructure of heat treated Al8079 based composites. The SEM images of heat treated Al8079 based hybrid composites are shown in Figure 2. Heat treated Al8079-based hybrid composite SEM images indicate the homogeneous distribution of TiB_2 and MoS_2 reinforcements in the Al8079 matrix material. The scanning electron microscope images of AL8079/TiB_2/MoS_2 composites are confirms that reinforcements are uniformly dispersed in the matrix material.

The higher concentration of molybdenum disulfide causes to high accumulation of molybdenum disulfide in the Al8079/15 wt.% TiB_2/7.5 wt.% MoS_2 composites.

The oxide occurs at the surface of the heat treated Al8079 based hybrid composites in humid atmosphere during cooling process. The oxide formation is due to conversion of molybdenum disulfide into MoO_3 during cooling process [28]. The TiB_2 is well bonded with Al8079 matrix material and it is shown in SEM images of heat treated Al8079 based composites. Besides, the molybdenum disulfide is better bonding with titanium di boride and matrix material Al8079.

Density and microhardness testing

The heat treated Al8079 based composites are subjected to density test for finding the density. The Archimedes principle is employed to conduct the density test. The Vickers hardness tester is used to perform the microhardness test. The density and micro hardness of untreated and heat treated Al8079/15 wt.% TiB_2/x wt.% MoS_2 (0, 2.5, 5 and 7) based composites are shown in Table 2. The well bonding between the Al8079 matrix and reinforcements (TiB_2 and MoS_2) causes to increase the density of heat treated Al8079 based composites [29].

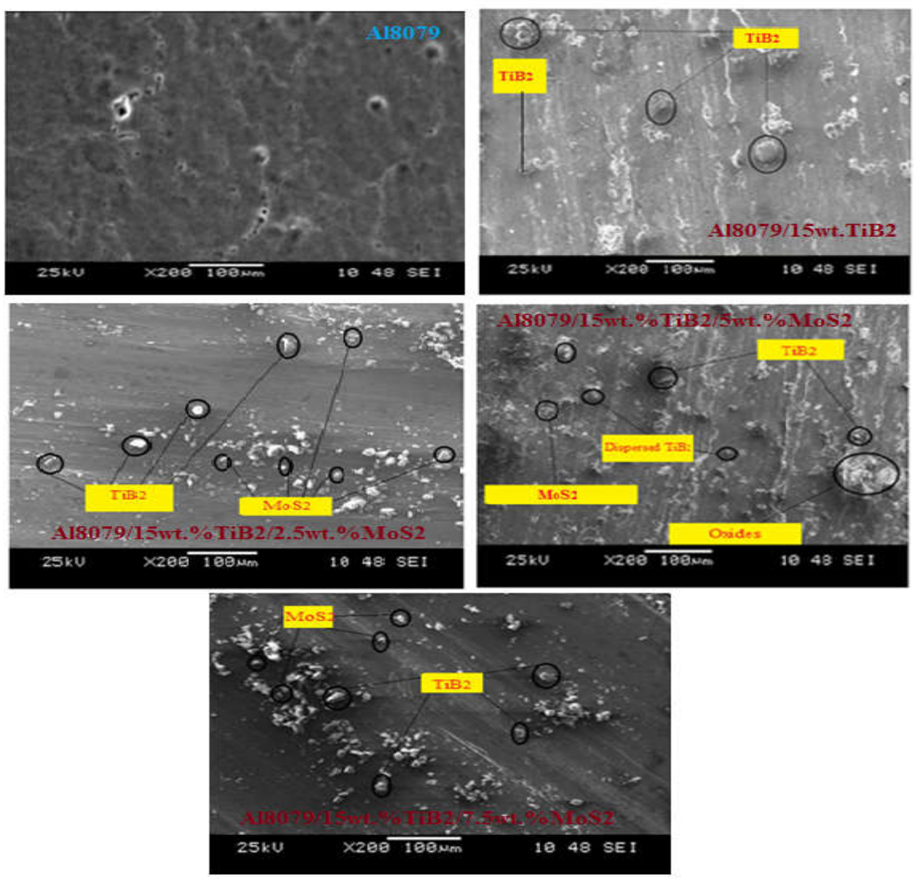

Figure 2. SEM picture of Al8079 and its composites.

The smaller particle size of reinforcements increases the density of the composites. The density of heat treated A8079 based composites increases by the incorporation of reinforcements. Besides, the addition of molybdenum disulfide increases the density up to 5 wt.% and decreases by the addition of 7.5 wt.%. The microhardness of the heat treated composites increases up to 5 wt.% MoS_2 and decreases by the addition of 7.5 wt.%. The good bonding strength between matrix and reinforcement increases the micro hardness by avoiding dislocation of particles while loading. Besides, the wettability of matrix and reinforcements increased by the addition of magnesium during stir casting and it is also increases the microhardness of the heat treated Al8079 based composites. The heat treating under T6 condition also enhances the micro hardness of the composites [30].

Table 2. Density and micro hardness.

S. No.	Material	Density g/cm^3		Microhardness (HV)	
		Unheated	Heat treated	Unheated	Heat treated
1	Al8079	2.811	2.816	90	96
2	Al8079/15 wt.% TiB_2	2.829	2.836	118	123
3	Al8079/15 wt.% TiB_2/2.5 wt.% MoS_2	2.839	2.849	128	138
4	Al8079/15 wt.% TiB_2/5 wt.% MoS_2	2.852	2.861	136	149
5	Al8079/15 wt.% TiB_2/7.5 wt.% MoS_2	2.49	2.56	131	141

Optimization by GRA

The NaCl based spray corrosion test process parameters are optimized with the help of GRA method. The L9 Taguchi design is used in the experiments. Table 3 Shows the L9 orthogonal array with their input parameters and responses. The high concentration of spray solution contains high amount of NaCl. The high amount of NaCl accelerates the mass loss of the AL8079 based composites. The first stage in the GRA is to normalize the input data using equations 1 and 2. The data of micro hardness response is normalized by using the larger the better normalization. The mass and wear loss responses are normalized based on the smaller the better normalization. The normalized data is converted into same unit by using equation 3. After converting the responses into same unit, the microhardness, mass and wear loss responses that transformed into grey relational coefficient by using equation 4. Equation 5 is used to calculate the grey relational grade. Table 4 displays the grey relational coefficient and grey relational grade with rank for numerous responses of salt spray test procedure parameters.

The greatest GRG score indicates the best combination of input variables among alternative combinations in L9 orthogonal array design. The rank is given to GRG value of input process parameters in descending order [31].

The experiment no 8 has highest GRG in the L9 orthogonal array experimental trails. The 5 wt.% MoS_2, 9 PH value, 1.1 pressure and 24 hours hang time exhibits better performance for the micro hardness, mass loss and wear loss responses than the other experimental trails.

The influence of different degrees of input process parameters is displayed in the Table 5. The high level of molybdenum di sulfide, lower level of pH value, hang time and pressure (A3B1C1D1) exhibits better micro hardness, mass loss and wear loss responses. Figure 3 shows that better combination of input process parameters in connection with GRG. The influencing salt spray process parameter sequence is MoS_2 wt.%, hang time, pressure and pH value. The ANOVA method is used to determine the effect of salt spray process variables on the micro hardness, mass, and wear loss responses. The ANOVA is formed based on the GRG and it is shown in Table 6.

The p value of all input salt spray process parameters is lesser than the 0.05 and it reveals that all input salt Spray process parameters are significant [32]. The R square (adj) value is 97.66%.

The contribution percentage of the MoS_2 wt.%, pH value, Hang time and pressure is 69%, 5.4%, 15.3% and 8% and it is shown in ANOVA Table 6.

Table 3. L9 orthogonal array (OA) with input parameters and responses.

Ex. No.	MoS_2 wt.%	pH value	Hanging time (hours)	Pressure (kg/cm^2)	Microhardness (HV)	Mass loss (mg)	Wear loss (mg)
1	0	6	24	0.7	108	36.2	35
2	0	9	48	0.9	102.4	40.2	40.4
3	0	12	72	1.1	93.1	49.8	49.8
4	2.5	6	48	1.1	106.6	36.4	38.1
5	2.5	9	72	0.7	105.7	37.9	36.2
6	2.5	12	24	0.9	106.9	36.1	36.7
7	5	6	72	0.9	109.9	34.1	34
8	5	9	24	1.1	111.1	32.3	34.5
9	5	12	48	0.7	110.2	33.8	32.6

Table 4. The calculation of sequence differences, GRC and GRG.

Source	L1	L2	L3	Best Optimal	Max-Min	Condition	Rank
MoS_2 wt.% (A)	0.5237	0.661	0.9053	0.9053	0.3816	A3	1
PH value (B)	0.7427	0.7013	0.646	0.7427	0.0414	B1	4
Hang time in hrs (C)	0.781	0.697	0.612	0.781	0.084	C1	2
Pressure in kg/cm^2 (D)	0.7617	0.687	0.6413	0.7617	0.0747	D1	3

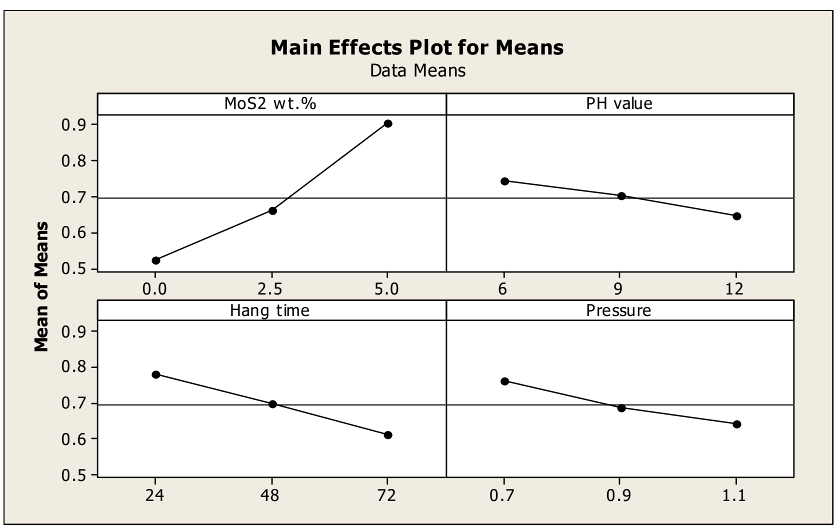

Figure 3. Effect of salt spray process parameters (hang time in h, pressure in kg/cm^2).

Table 5. Effect of input parameters on GRG.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
MoS_2 wt.%	1	0.210938	0.210938	0.210938	118.188	0.0004063	69%
pH value	1	0.016017	0.016017	0.016017	8.974	0.0401125	5.4%
Hang time	1	0.046288	0.046288	0.046288	25.935	0.0070184	15.3
Pressure	1	0.024193	0.024194	0.024194	13.556	0.0211707	8%
Error	4	0.007139	0.007139	0.001785	-	-	2.3%
Total	8	0.304575	-	-	-	-	100%

The influencing of salt spray corrosion test process parameter sequence is MoS_2 wt.%, hang time, pressure and pH value. The confirmation test was performed for the best combination of input process parameters (A3B1C1D1). The better combination of input salt spray process parameters is confirmed by the means table and ANOVA Table 6. The GRG for initial setting (A3B1C1D1) is 0.739. The GRG for prediction is 0.812. The percentage of improvement of GRG from initial setting to prediction GRG is 9%. The percentage of improvement of GRG from initial setting to experimental GRG is 10.4%. The better combination (A3B1C1D1) of salt spray input process parameters exhibits 140.7 HV microhardness, mass loss 17 mg and wear loss 24 mg responses.

Table 6. ANOVA for GRG.

Run	Evaluation of Δ_{0i}			GRC			GRG	Rank
	Microhardness	Mass loss	Wear loss	Microhardness	Mass loss	Wear loss		
1	0.172	0.223	0.140	0.744	0.692	0.782	0.739	4
2	0.483	0.451	0.453	0.508	0.526	0.524	0.519	8
3	1.000	1.000	1.000	0.333	0.333	0.333	0.333	9
4	0.250	0.234	0.320	0.667	0.681	0.610	0.653	6
5	0.300	0.320	0.209	0.625	0.610	0.705	0.647	7
6	0.233	0.217	0.238	0.682	0.697	0.677	0.685	5
7	0.067	0.103	0.081	0.882	0.829	0.860	0.857	3
8	0.000	0.000	0.110	1.000	1.000	0.819	0.940	1
9	0.050	0.086	0.000	0.909	0.854	1.000	0.921	2

The confirmation test reveals that high weight percentage of addition decreases the mass loss (17 mg), wears loss (24 mg) and increases the microhardness (140.7 HV) of the heat treated composites and it is shown in Table 7. The lower level of hang time, pH value and pressure also decreases the mass loss and wear loss of the heat treated composites. The lowering the mass loss and wear loss and increasing of microhardness are attained by the addition of 5 weight percentage of MoS_2. The corroded surface of the confirmation test specimen reveals that matrix material is removed due to corrosion and the corrosion is decreased by the titanium di boride and molybdenum disulfide.

Table 7. Confirmation test.

Setting	Initial setting A1-B1-C1-D1	Prediction A3-B1-C1-D1	Experimental A3-B1-C1-D3
Microhardness (HV)	108	0.812	140.7
Mass loss (mg)	36.2		17
Wear loss (mg)	35		24
GRG	0.739		0.907
Percentage improvement in GRG	9%		10.4%

The corroded surface reveals that high bonding strength between matrix and reinforcement materials reduced the mass loss. The tribo lubrication forms on the surface of Al8079 composites surface during wear test. This layer reduces the wear loss. The SEM image of wear debris confirms that wear mechanism is abrasion [33].

The contribution percentage of the MoS_2 wt.%, PH value, Hang time and pressure is 69%, 5.4%, 15.3% and 8%, respectively and it is shown in ANOVA table. The influencing of NaCl based spray corrosion test process parameter sequence is MoS_2 wt. %, hang time, pressure and pH value. The better combination of input salt spray process parameters is confirmed by the means table and ANOVA table and the combination is 5 wt.% MoS_2, 24 h, 0.7 kg/cm^2 and 6 pH value. The better combination (A3B1C1D1) of salt spray input process parameters exhibits 140.7 HV micro hardness, mass loss 17 mg and wear loss 24 mg responses. The percentage of improvement of GRG from initial setting to experimental GRG is 10.4%.

CONCLUSIONS

The present research aimed to analyze the influence of the salt spray input process parameters on its corresponding micro hardness, mass loss and wear loss response parameters. The Al8079/15 wt.% TiB_2/x wt.% MoS_2 (x = 0, 2.5, 5 and 7.5) hybrid composites were fabricated by using stir casting method. The stir casted hybrid composites are heated under T6 condition. The density and micro hardness of the untreated and heat treated composites were determined. The addition of MoS_2 increases the density and micro hardness up to the addition of 5 wt% and decreases by the addition of 7.5 wt.%. The selected NaCl based spray corrosion test process parameters for optimization is MoS_2 wt.%, pH value, hang time and pressure. The selected response parameters are micro hardness, mass loss and wear loss. The optimization is done by using GRA with Taguchi design. The contribution percentage of the MoS_2 wt.%, PH value, hang time and pressure is 69%, 5.4%, 15.3% and 8%, respectively and it is shown in ANOVA table. The influencing of NaCl based spray corrosion test process parameter sequence is MoS_2 wt.%, hang time, pressure and pH value. The better combination of input salt spray process parameters is confirmed by the means table and ANOVA table and the combination is 5 wt.% MoS_2, 24 h, 0.7 kg/cm^2 and 6 pH value. The better combination (A3B1C1D1) of salt spray input process parameters exhibits 140.7 HV micro hardness, mass loss 17 mg and wear loss 24 mg responses. The percentage of improvement of GRG from initial setting to experimental GRG is 10.4%.

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