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DEVELOPMENT OF MATHEMATICAL MODEL AND OPTIMIZATION OF FSW PROCESS PARAMETERS

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ABSTRACT

Despite widespread use, monolithic metals and alloys continue to be in high demand because to the exceptional strength, endurance, and other features they provide. New materials, technologies, manufacturing processes, etc., are constantly being developed as a result of ongoing study in various fields, raising expectations for the future of the human quality of life. Hybrid metal matrix composites may be made by combining several reinforcements with an aluminum alloy matrix. Because of their unique collection of characteristics and reactions, conventional welding procedures are sometimes infeasible for AMCs. The Friction Stir Welding (FSW) technique is a cutting-edge method of connecting solids without melting or recasting the work material.

KEYWORD: Friction stir welding; dissimilar; response surface methodology; interlayer; tensile strength.

INTRODUCTION

The metal matrix composites industry makes extensive use of aluminum as a base alloy. The fascinating qualities of these alloys include a low density, superior corrosion resistance, high electrical and thermal conductivity, and enhanced fatigue resistance. Industries as diverse as transportation, aircraft, military, sports equipment, and electronics packaging have all found uses for aluminum matrix composites (AMCs). Changing the composition and relative amounts of the components allows one to control the resulting attributes. AMC's give a great mix of qualities that renders the monolithic material obsolete, and although Sic, Al2O3, B4C, Sin, etc. are often used reinforcements, there are many more. There have been many experiments and uses of AMCs in both structural and non-structural engineering applications throughout the years. The performance, economical, and environmental advantages of AMC are driving its adoption in various fields. In the automobile industry, AMCs are especially useful because of their reduced fuel consumption, less weight, and fewer pollutants. The adoption of AMCs has been slowed by a lack of technical understanding, as well as details regarding the various production techniques and their potential applications.

Equiaxed ceramic particles having an aspect ratio of fewer than five are often seen in PAMCs. Particles of oxides, borides, and carbides are employed as ceramic reinforcements for wear resistance and structural purposes. PAMCs may be produced using either solid-state (powder metallurgy) or liquid-state processes (stir, squeeze, infiltration and in-situ). Particulate composites undergo secondary forming processes such forging, extruding, and rolling, all of which contribute to their isotropic character. As compared to continuous fiber reinforced aluminum matrix composites, these materials are more cost effective (CFAMCs).

The non-continuous form of reinforcement used in SFAMCs often has an aspect ratio higher than five. One of the most common composites used in piston production is short alumina reinforced aluminum matrix composites. Whisker-reinforced composites may be produced by either the powder metallurgy or infiltration manufacturing processes. Whisker reinforced composites have superior mechanical properties compared to PAMCs.

LITREATURE REVIEW

Manroo, Suhail& Khan (2022). The aerospace and automotive sectors are rapidly transitioning from aluminum alloys to magnesium alloys and their composites. Because of the great strides that have been achieved in their production, these composites are now the materials of choice in their respective fields. Composites with qualities that can compete with trendy materials can only be realized via careful consideration of the manufacturing process. Fabricating magnesium alloys and composites using traditional processes has significant limitations due to flaws such as porosity and particle clustering. To overcome these obstacles, friction stir processing (FSP) is emerging as a potential manufacturing method. The process's solid-state nature makes it ideal for manufacturing surface-modified composites with desirable mechanical and tribological characteristics. The ability to quickly and easily alter the surface layers and include reinforcing particles is the primary selling point of FSP. Reinforcement particles are absorbed into the matrix and distributed evenly thanks to the underlying plastic deformation in FSP. This work aims to provide an update on the development of FSP as a method for facilitating the manufacturing of surface composites of magnesium alloys and their subsequent surface modification. The purpose of this article is to provide a synopsis of the work done so far on two systems to realize magnesium alloys with surface modifications: the Mg-AZ system and the Mg/rare earth system. Fabrication of three representative systems, namely, magnesium-metal oxide (Mg-MO), magnesium-metal carbide (Mg-MC), and magnesium-carbon nano tube (Mg-CNT) systems, is used to summarize the operating conditions (and process parameters) and their effect on mechanical and tribological properties of the fabricated composites.

Manish, Maurya & Maurya (2022) Nowadays, surface composites are often created via friction stir processing (FSP). Grain refinement is enhanced by this procedure, which reduces the grain size of the material locally close to the stir zone. The material's tensile strength and hardness are greatly enhanced as a result of grain refining. Numerous reports in the archival literature detail the research efforts of many researchers into FSP. The primary goal of this research was to compare and contrast the different studies' findings on the material's mechanical characteristics. This article provides a synopsis of studies conducted on various materials and reinforcing materials used in the creation of composites and the implementation of the FSP method.

Gaurav Kumar (2022) Friction stir processing is an emerging innovation in solid-state technology for making composites (FSP). To successfully adjust surface properties using solid-state plastic deformations, surface modification is required. Initially, FSP was utilized primarily for producing metal matrix composites from aluminum and other light metal alloys. Recently, its position as a manufacturer of composites comprised of nonferrous and ferrous metal alloys and polymers has become increasingly desirable. In addition to its use in composite production, FSP has been a game-changer in the creation of functionally graded systems/surfaces (FGS) with a metal matrix. This article details the complete FSP procedure for making composites and FGS by fusing reinforcement particles into a base matrix. It offers a thorough analysis of how different reinforcing particles affect the characteristics of composites and the latest developments in FGS production. Numerous urgent issues, challenges, and forthcoming duties are thoroughly discussed and tackled.

S. Vijayakumar (2022) This study used the Taguchi method to examine the dry sliding wear rate of a friction stir welded AA6262/AA5456 composite. Experiments on wear are conducted by varying process factors such load (LD), sliding speed (SS), and sliding distance (SE) to identify the effects of each variable alone and in combination. The L27 mode of the orthogonal array is used to conduct a series of tests in order to determine both the maximum and minimal wear possible. ANOVA, interaction plot between parameters, and a regression model are just some of the statistical analyses that can be run with the help of MINITAB software after the experimental work has been completed using a Pin on Disc (POD) apparatus to measure the weight of samples before and after testing to determine wear rate (WR). The findings showed that the highest wear rate occurs at 50 N, 600 m, and 4 m/s in the grouping process, whereas the lowest wear rate occurs at 30 N, 400 m, and 6 m/s. According to the results of the analysis of variance, load is the most important variable, followed by sliding distance, sliding speed, and any combination of the three. The maximum wear rate of the developed AA6262/5456 composites is mostly dependent on e load, which is estimated to account for 83.75 percent of the total. Distance traveled while sliding contributes 3.75 percent, while velocity adds 1.85 percent.

AbdulbasitAbdulqadirHamza (2022) The thermoplastic polymer material's surface or joint qualities, such as impact, hardness, wear resistance, and core ductility, are more important than the overall material features in various technical applications. Friction stir processing has recently gained popularity, allowing composite production of polymer-based matrices to go beyond its previous use to Aluminum alloy (FSP). The purpose of this research is to use data collected from the literature to examine how different tool design and friction stir processing factors affect the morphology, wear, powder dispersion, and mechanical characteristics of Sped polymers. The studies that give enough data to estimate it are taken into account in the present study. The key results from each study were summarized, as well as the processing settings and parameters the authors used. The results of this study showed that stationary shoulder tools outperformed conventional ones. Rotational and welding speeds have a major impact on heat production, mixing, and surface quality. Also, the impact of vibration on surface composite performance was analyzed.

GENETIC ALGORITHM

Based on the idea of natural genetics and the natural selection process that mimics biological evolution, the Genetic Algorithm (GA) is a powerful optimization tool for addressing limited and/or unconstrained optimization problems. Navigating a potentially huge space of possible optimum combinations of process parameters is a task well suited to GA. GA is not like other methods or algorithms for finding the best answers. In contrast to the restricted solutions provided by many traditional algorithms, GA examines a large search space to find a large number of locally optimal solutions. The fitness function used in any given optimization problem will depend on those variables and will ultimately lead to convergence. To optimize the fitness function of the variables, GA is used in this study.

Genetic Algorithm Methodology

In order to begin the optimization analysis, the genetic algorithm (GA) needs a regression model of the process parameters. The regression model's accuracy should be assessed using ANOVA. When sufficiency is established, the fitness function for the genetic algorithm analysis may be interpreted as a maximizing or minimization model in the design space. Finding the optimal solution that maximizes the intended output is challenging since it involves a significant investment of time, effort, and other resources to do it the traditional method. While the genetic algorithm iteratively searches for the required output within the space, the optimal answer may be predicted using the regression formula.

Regression Analysis

Table 1 displays the results of a regression analysis performed on experimental responses used to derive empirical equations for use in modeling the friction stir welding process. Optimization of the UTS of the design matrix was the answer of interest. Table 2 displays the obtained empirical equations.

Table 1 UTS values of design matrix

S.NO	TRS (r/min)	WS (mm/min)	AF (kN)	Ultimate tensile
				Strength (Mpa)
1	900	30	8	147.3
2	900	30	10	142.9
3	900	30	12	149.5
4	900	40	8	153.6
5	900	40	10	150.6
6	900	40	12	152.4
7	900	50	8	123.3
8	900	50	10	109.7

9	900	50	12	117.8
10	1000	30	8	179.8
11	1000	30	10	181.7
12	1000	30	12	180.8
13	1000	40	8	201.5
14	1000	40	10	200.1
15	1000	40	12	200.4
16	1000	50	8	175.5
17	1000	50	10	173.3
18	1000	50	12	174.9
19	1100	30	8	160.7
20	1100	30	10	154.2
21	1100	30	12	158.4
22	1100	40	8	186.4
23	1100	40	10	188.3
24	1100	40	12	184.7
25	1100	50	8	177.8
26	1100	50	10	165.5
27	1100	50	12	179.7
S. No	**Empirical equation**			**R^2 value**
1	98.82%			

Taking into account the adaptability of the machine, the number of process parameter levels has been extended from 3 to 9. Hence, the optimization's design space goes from 33 = 27 to 93 = 729.

Implementation of Genetic Algorithm

The optimization problem's solution string, or chromosome, can't be defined without using the genetic method. The chromosomal bits, also known as genes, may be interpreted as either a binary or a real integer number. In this study, the parameters of the friction stir welding process are considered to be the rotational speed of the tool, the welding speed, and the axial force. These variables are all represented as real numbers. The total length of the string is 3, with each bit being utilized to indicate the rotational velocity of the tool, the welding velocity, and the axial force, in that order. The range of allowed values for the procedure parameters is shown by the strings (111), ("low") and (999), ("high"). Parameters for friction stir welding are encoded in Table 2.

Table 2 Coding for the FSW process parameters

Tool rotation speed (TRS), rpm	Welding speed (WS), mm/min	Axial Force (AF), kN	CODE
900	30	8	1
950	35	9	2
1000	40	10	3
1050	45	11	4
1100	50	12	5

Evolution

Each chromosomal string in a population is assigned a fitness value using an empirical connection in a genetic algorithm. The highest R2 empirical equation is used to build the fitness function, For the purpose of the genetic algorithm study, the following fitness function was used:

$f(x) = F(x)$ for the maximization of output

So, the final fitness equation may be written as,

$$f(x) = \mathrm{UTS} = -2557 + 5.75 * \mathrm{TRS} + 4.1 * \mathrm{WS} - 58.5\,\mathrm{AL} - 0.00307 * \mathrm{TRS}*\mathrm{TRS} - 0.218\,\mathrm{WS}*\mathrm{WS} + 2.66\,\mathrm{AL}*\mathrm{AL} + 0.01312 * \mathrm{TRS}*\mathrm{WS} + 0.0062\,\mathrm{TRS}*\mathrm{AL} - 0.026\,\mathrm{WS}*\mathrm{AL}$$

Table 3 provides an ANOVA table for the aforementioned formula. According to the table's P-value, the tensile strength of friction stir welded composites is greatly affected by process factors such tool rotation speed, welding speed, and axial force. Interaction and square components in the study also impact the final tensile strength. Due to inconsistencies in the calculations, the influence of the interaction between welding speed and axial force has been eliminated.

Table 3 Analysis of Variance (ANOVA) for the fitness function

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	9	15162.7	1684.75	158.37	0.000
TRS	1	4509.4	4509.36	423.89	0.000
WS	1	136.5	136.54	12.84	0.002
AL	1	62.6	62.62	5.89	0.027
TRS*TRS	1	5264.9	5264.86	494.91	0.000
WS*WS	1	2719.3	2719.30	255.62	0.000
AL*AL	1	95.7	95.73	9.00	0.008
TRS*WS	1	1600.8	1600.83	150.48	0.000
TRS*AL	1	0.5	0.48	0.05	0.834
WS*AL	1	2.2	2.17	0.20	0.657
Error	17	180.8	10.64		

Genetic Algorithm Parameters

Table 4 shows the results of taking into account the population size, the likelihood of cross-over, and the probability of mutation. To guarantee that the following generation inherits the optimal set of parameters, the cross-over rate has been set at 0.70. The population variance is optimized by setting the mutation rate to 0.033, which results in a single bit being altered in a population of 10. As may be seen in Table 5 the corresponding decoding of the levels has taken place.

Table 4 Parameters Used In GA

S.No	Genetic parameter	Value
1	Population size	10
2	Length of Chromosome	3
3	Selection operator	Roulette wheel
4	Crossover operator	Single point operator
5	Crossover probability rate	0.70
6	Mutation probability rate	0.033
7	Fitness parameter	Ultimate tensile strength

Table 5 Initial population lot

CODE	TRS	WS	AF	FITNESS VALUE	Proportion, β	Expected Count, E	Cumulative probability, C	Random number, R	String , S
144	900	45	11.00	132.58	0.080166	0.801657	0.080166	0.591438	6
331	1000	40	8.00	**206.52**	0.124874	1.248742	0.124874	0.278694	3
223	950	35	10.00	178.32	0.10782	1.078198	0.10782	0.674104	7
321	1000	35	8.00	**203.21**	0.122873	1.228727	0.122873	0.330808	4
314	1000	30	11.00	181.38	0.109673	1.09673	0.109673	0.358550	4
143	900	45	10.00	130.81	0.079095	0.790954	0.079095	0.349063	4
441	1050	45	8.00	**203.76**	0.123202	1.232023	0.123202	0.683037	7
224	950	35	11.00	180.66	0.109235	1.092347	0.109235	0.067781	1
244	950	45	11.00	169.04	0.102209	1.022085	0.102209	0.210924	3
231	950	40	8.00	189.63	0.114658	1.146584	0.114658	0.135435	2
Sum of fitness values, F_{sum}				1775.9					
Average of fitness values, Favg				177.6					

Selection and Reproduction

At this cross-over phase, we employ a roulette wheel approach to determine which parents will produce the healthiest offspring. After the first iteration of population dynamics, a random number is chosen. The length of the string is determined by the amount of space the random number takes up.

Table 6 displays the first iteration's findings. Values for codes 5, 6, and 9 are consistently reported to be lower than the Favg. Due to the linear relationship between the diameter of the roulette wheel and the predicted count, the likelihood that these values will be drawn from the population pool is lowest. Furthermore, the values 1, 2, 3, 4, 7, 8, and 10 have an anticipated count higher than Favg, hence they will most likely be picked from the population. From this anticipated number, E, we may get the cumulative probability, C. Thus, row 6 has a C value of 2.

The code is written such that 10 random integers are created, and their parents are chosen according to the cumulative probability intervals of the string S. Rows 2, 3, 5, 7, and 9 have no parents chosen, whereas rows 1, 4, 6, 8, and 10 have two parents selected each. In step with this, new individuals are added to the population and bred with those of the preceding generation,

Table 6 First Generation

Population pool		**Cross over site**	**New generation**	**Random bits for mutation**	**Modified new generation**	**Fitness value**
441	134	1	434		441	**200.6**
331	331	-	331		331	**206.5**
321	441	-	321		321	**203.2**
321	331	2	321		321	**203.2**
134	251	-	134	3	154	107.1
134	552	2	132		134	148.6
441	441	-	441		441	**203.8**
331	331	2	331		331	**206.5**
251	321	-	251		251	157.0
435	235	2	435		435	**208.7**
			Sum of fitness values, F_{sum}			1845.3
			Average of fitness values, F_{avg}			184.5

It should be noticed that the number of bits mutated is determined to be 1, and that the bit in the first position of the fifth row is modified. In order to probe the universe of possible designs that has yet to be found, the bit chosen for mutation is designed in such a way that it does not choose the old codes. After the first round of refinement, the Favg value increased from 177.6 to 184.5. The same steps are taken until every permutation has been confirmed.

CONCLUSION

The settings for Friction stir welding are optimized with the use of a Genetic Algorithm, which proves to be very useful. By changing the tool rotation speed, weld speed, and axial force while leaving the other FSW parameters constant, we were able to friction stir weld the stir cast hybrid composite Al 6063-SiC-B4C. Joining aluminum alloys using friction stir welding of aluminum matrix composites is a time and energy saver. Friction stir welding settings affect the tensile strength of the welded composite. There is an influence of each parameter on the tensile strength. The highest ultimate tensile strength of the hybrid composite was investigated using GA-based optimization. From the design space, the greatest tensile strength is maximized using a genetic algorithm implemented in C. Tool rotational speed (TRS) of 1050 rpm, axial force (F) of 12 kN, and weld speed (WS) of 40 mm/min are the optimal parameters for Friction stir welding of Al 6063-SiC-B4C hybrid composite. Trial welds' tensile testing supports

REFERENCE

1. AbdulbasitAbdulqadirHamza, Shawnam Rashied Jalal, A review on manufacturing the polymer composites by friction stir processing, European Polymer Journal, Volume 178, 2022, 111495, ISSN 0014-3057, https://doi.org/10.1016/j.eurpolymj.2022.111495.

2. S. Vijayakumar (2022),” Wear Investigation of Aluminum Alloy Surface Layers Fabricated through Friction Stir Welding Method,” Hindawi Advances in Materials Science and Engineering Volume 2022, Article ID 4120145, 8 pages https://doi.org/10.1155/2022/4120145

3. Gaurav Kumar (2022),” A critical review of recent progress in the fabrication of composite materialvia friction stir processing,” International journal of research in engineering and innovation (IJREI), vol 6, issue 5 (2022), 321-326

4. Manish, Maurya&Maurya, Ambrish& Kumar, Sudhir. (2022). An Overview of Recent Development and Application of Friction Stir Processing Technique. Evergreen. 9. 0-00. 10.5109/4843113.

5. Manroo, Suhail& Khan, Noor & Ahmad, Babar. (2022). Study on surface modification and fabrication of surface composites of magnesium alloys by friction stir processing: a review. Journal of Engineering and Applied Science. 69. 10.1186/s44147-022-00073-9.

6. Koilraj M, Sundareswaran V, Vijayan S, KoteswaraRao SR (2012) Friction stir welding of dissimilar aluminum alloys AA2219 to AA5083 – optimization of process parameters using Taguchi technique. Mater Des 42:1–7.

7. Kumar S, Kumar S (2015) Multi-response optimization of process parameters for friction stir welding of joining dissimilar Al alloys by gray relation analysis and Taguchi method. J BrazSocMechSci Eng 37:665–674.

8. Bokov DO, Jawad MA, Suksatan W, Abdullah ME, Świerczyńska A, Fydrych D, Derazkola HA (2021) Effect of pin shape on thermal history of aluminum-steel friction stir welded joint: computational fluid dynamic modeling and validation. Materials 14(24):7883

9. Janeczek A, Tomków J, Fydrych D (2021) The influence of tool shape and process parameters on the mechanical properties of AW-3004 aluminium alloy friction stir welded joints. Materials14(12):3244.

10. Mishra RS, Ma ZY (2005) Friction stir welding and processing. Mater Sci Eng R Rep 50(1–2):1–78.