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Research Article

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Comparing Computer Numerical Control Machining of Dissimilar Metals AA1050 and AA7075 Welded by SiO_2 Nanofiller Infused Novel Friction Stir Processing with Conventional Friction Stir Welding for Improving Machinability

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Abstract

This research investigation focuses to explore the effects novel friction stir processing (FSP) in dissimilar metals joining AA1050 and AA7075 by using novel SiO_2 nanoparticles as filler in improving the machinability of welded plates in CNC (Computer numerical control) milling machine and comparing such performance with conventional friction stir welding (FSW) under same condition. The control group samples of dissimilar aluminum pieces were joined by FSW, and experimental group samples are joined by proposed novel FSP with SiO_2 nanofillers. The sample size was predicted as 16 per group with the setting of G-power 80% and hence a total of 32 samples involved. The machined welded samples were carried out for surface roughness test and readings were observed. The observations were statistically tested with independent samples t-test and obtained a significant value (p) of < 0.001 for surface roughness. Therefore, there is a statistically significant difference between the two groups. The results reveal that the proposed novel FSP of SiO_2 nanofiller infused joining method improves surface roughness significantly by reducing surface roughness by 82.77% when compared to conventional FSW.

Keywords

Friction stir processing, Friction stir welding, Dissimilar metals joining, Surface roughness, Nanoparticles

Introduction

This study aims to improve the weldment quality (AA1050 and AA7075 plates) which was joined by novel FSP and thereby improving the CNC machined surface quality of CNC machined surface. To evaluate the surface roughness of different metallic plates of AA1050 and AA7075 that were welded using unique SiO_2 nanofiller infused FSP and comparing the surface roughness with traditional FSW, the novel FSP was presented in this regard [1]. According to Mironov et al. [2], FSW is the process of attaching the plates by mixing the microstructure while traversing the plate's parting line with a non-cutting tool that is rotated quickly and lowered to a depth. To reduce the weight and cost of material join the dissimilar joining plays a vital role for the use [3]. FSW was implemented in NASA for increasing the tank strength (External tank) which has lower mechanical properties made of Al-Li 2195 [4]. The housing of the fuel tank in the Ford GT is in the central tunnel welded by the friction stir lap welding [5].

There are 167 and 11 journal papers published in Science Direct and Google Scholar. Welding dissimilar friction stir lap joint welding AZ31B and AA7075 interlayer with Sn foil led to the formation of Hook defect and increase in nugget due to the increase in thickness [6]. AA6082 – T6 plates were joined using FSP of Al_2O_3 nanoparticle fillers using hexagon profile pin tool of tungsten carbide material and got the result of 154.9 MPa, 227.61 MPa, 10.5% increase of yield strength, ultimate tensile strength, and elongation percentage at the 3 passes done at the speed of 900 rpm and 40 mm/min tool transfer speed [7]. FSP of AA7075- T651 with 3.5% NaCl of stable pH value 7 shown the improved corrosion resistance in the material when the tool speed, feed and tilt angle are at 1500 rpm, 20 mm/min, and 0.3° [8]. Hybrid joining of thermoplastic polymers and metals using friction stir lap joint welding AA6061-T6 and acrylonitrile butadiene styrene at the speed of 0.2 - 0.6 m/min travel speed resulted in improved interfacial strength in joining between metals and thermoplastics polymers [9]. Titanium sheet FSW plates to nanoparticles of tricalcium phosphate-titanium has increased using different profiled pins for improving the roughness [10]. The work by Wu et al. [10] was the one with the most relevance among the ones mentioned.

Though dissimilar metals were joined through FSP the proposed materials joining process with SiO_2 nanofiller was not reported in the literature. The unanswered question is the SiO_2 nanofiller used by FSP will influence the joining of AA1050 and AA7075 plates to control surface roughness? If so, it will increase or reduce the surface roughness. This research is designed to address such a delay in the joining of the commercial aluminum alloy series AA10xx and AA70xx. Hands-on experience in machining and the mechanical department field increases my interest in the research. The aim of this research is to compare and identify the best joining method that has a good surface finish.

Materials and Method

The research and the machining were done in Saveetha School of Engineering and Saveetha Engineering Industry, Chennai (Tamil Nadu, India). For this research two groups were used: Group 1 was the FSW of dissimilar metals of AA1050 and AA7075 and group 2 was the novel FSP of AA1050 and AA7075 with SiO_2 fillers. The numbers of samples 16 per group which is 32 samples in total was obtained from ClinCalc.com with the setting of 80% G-power and mean of 49.176 and standard deviation of 2.3569 was used for the same [11].

Group 1 samples are welding by FSW of dissimilar materials AA1050 and AA7075 plates were brought from the Coimbatore metals. For the control group the sample preparation is simpler, i.e., simply edge preparation through a grinding machine [12-14]. The AA1050 and AA7075 plates were pre-machined to the size of 6 x 75 x 250 mm (thickness x breadth x thickness).

Group 2 samples are welding by FSP of dissimilar materials of AA1050 and AA7075 plates were brought from the Coimbatore metals. For the experimental group the sample preparation is similar to the control group, that is simply edge preparation through a grinding machine. The AA1050 and AA7075 plates were prepared to the size of 6 x 75 x 250 mm (thickness x breadth x thickness).

Materials were pre-machined in YCM EV1020A vertical machining center CNC machine shown in figure 1 to the size of 6 x 75 x 250 mm (thickness x breadth x thickness). The AA1050 and AA7075 plates were assembled in the machine vice as the butt weld position.

Figure 1: Vertical milling center.

The plain pin tool of Ø 6 mm, shoulder of Ø 18 mm and 5.6 mm depth were used to do FSW of high-speed steel (HSS) tool was used for the FSW and FSP shown in figure 1 and figure 2. Then machined on the FSW zone for finding surface roughness. Group 2 materials are prepared similar to the group 1 but adding SiO_2 nanoparticles fillers of size 30 - 50 nm of 2 g was sprinkle over the butting line shown in figure 3 and figure 4 using the similar high-speed steel of Ø 6 mm plain pin having Ø 18 mm shoulder and 5.6 mm depth.

The HSS tool was rotated at 900 rpm and the plain pin was plunged into the base plate at 5.8 mm depth for the dwell duration of 5 s, during the dwell duration the powder was pored over the plate at the parting line, then the tool was moved at the 30 mm/min as shown in figure 3 due to the heat generated by the plates the nanoparticles fuse with the base plates and was stirred the nano-powder homogeneously into the plates [15].

Figure 2: FSW tool.

Figure 3: FSW process.

Figure 4: Mitutoyo-SJ-410 surface roughness tester while testing the samples.

The Mitutoyo-SJ-410 surface roughness tester was used to measure average surface roughness with a sampling length of 4 mm, travel speed of 0.5 mm/s and λc of 0.8 shown in figure 4. Three readings were taken, and the average surface roughness value (Ra) was tabulated for all 16 samples (Table 1 and table 2).

Statistical analysis

After experimental trials, average surface roughness was tabulated. The mean value, standard deviation, and standard error were computed using SPSS v28 statistical software. The statistical significance is considered when the observed p value is <0.001. Surface roughness is the dependent variable. G-graph with bar mean of surface roughness by methods are shown in figure 5. Feed and speed are independent variables. ClinCalc software was used to find sample size [16].

Results

The chemical composition and properties of the AA1050 and AA7075 materials were mentioned below (Table 3 and table 4).

The weld joint made by the SiO_2 nanoparticles infused novel FSP had tunnel defect at the end, higher the travel

Table 1: Surface roughness of FSW at various speed and feed.

S. No.	Total rotational speed (rpm)	Total travel speed (m/min)	Surface roughness (Ra)
1	800	16	14.477
2	800	18	14.368
3	800	20	13.506
4	800	22	13.405
5	875	16	12.57
6	875	18	12.501
7	875	20	12.396
8	875	22	11.468
9	950	16	12.287
10	950	18	10.53
11	950	20	11.779
12	950	22	10.355
13	1025	16	9.614
14	1025	18	9.429
15	1025	20	9.618
16	1025	22	9.339

Table 2: Surface roughness of FSP with infused SiO_2 at various speed and feed.

S. No.	Total rotational speed (rpm)	Total travel speed (mm/min)	Surface roughness (Ra)
1	800	16	3.27
2	800	18	3.188
3	800	20	3.371
4	800	22	3.407
5	875	16	2.659
6	875	18	2.561
7	875	20	2.362
8	875	22	2.191
9	950	16	1.991
10	950	18	1.706
11	950	20	1.342
12	950	22	1.208
13	1025	16	0.633
14	1025	18	0.815
15	1025	20	0.86
16	1025	22	0.761

Table 3: Chemical composition of AA1050.

Material	AA1050	AA7075
Al	Bal.	Bal.
Cu	0.05% max	1.2 - 2.0%
Fe	0.4% max	0.50% max
Mg	0.05% max	2.1 - 2.9%
Mn	0.05% max	0.30% max
Si	0.25% max	0.40% max
Ti	0.03% max	0.20% max
V	0.05% max	0.18 - 0.28%
Zn	0.05% max	5.1 - 6.1%

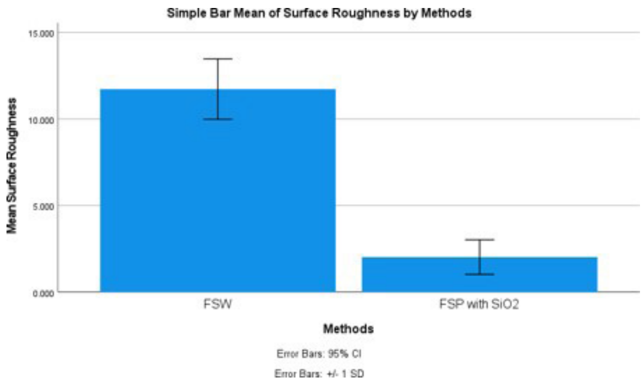

Figure 5: Simple bar mean of surface roughness by methods at 95% confidence level and +/- 1 standard deviation, which shows the mean surface roughness values in Y-axis and X-axis shows the FSW and FSP with SiO_2 joining methods.

Table 4: Chemical composition of AA1050 and AA7075.

Material	AA1050	AA7075
Tensile strength (MPa)	137	572
Yield strength (MPa)	76	503
Elasticity modulus (GPa)	69	72.6
Brinell hardness (HB)	90	150
Melting point (°C)	577	482
Elongation (%)	28	12
Density (g/cm³)	2.71	2.8

speed increased the tunnel defect with the improved surface roughness compared to FSW (Without SiO_2 nanoparticles). Maximum of 3.407 and minimum of 0.633 surface roughness in SiO_2 infused FSP was achieved. Likewise, in FSW, maximum of 14.477 and minimum of 9.399 surface roughness was achieved which was approximately 5 times greater than FSP joining. Detailed results were tabulated in table 5 and table 6.

Discussion

Coconut shell ash nanoparticles infused with FSP of AA7075-T651 metal matrix composite produced the highest 379.9 MPa of universal tensile strength among the cow bone ash, palm kernel shell ash, coconut ash and wood fly ash [17]. The coconut shell was hard in nature compared to the other experimented nano carbonaceous particles so, while in the carbonaceous form it increases the hardness and reduces the ductility due to the presence of carbon compared to non-filler FSW [18].

Joining AA6061 and AA7075-T651 alloys with the 1 mm offset pin tool shows the maximum tensile and bending stress achieved without breakage of the component and pre-heating was done to increase the bonding strength [19]. The pre-heating of the plates increased the bonding, and the stir volume was increased due to the offset of the pin 0.5 mm and 1 mm. AA1050 plates were joined by the mischmetal oxide nanocomposite by running 6 passes decreases the coefficient of friction 17% compared to the base plate due to the lubrication and improved corrosion-wear resistance rate led to pitting reduced [20]. Due to the lubrication of liquid flow while machining the temperature was controlled and the resistance to flow was decreased so, the material joining can be suited for the underwater and piping applications.

The surface is smoother in Al_2O_3 nanoparticles compared to the TiO_2 nanoparticles. The heterogeneous mixture of TiO_2 nugget zone has increased grain size compared to the Al_2O_3 [21]. The dispersion of Al_2O_3 is greater than the TiO_2 so the improper mixture shows the Al_2O_3 superior to TiO_2 nanoparticles. T-joining of dissimilar composites AA6082 and poly-methyl-methacrylate infused friction stir with Al_2O_3 flow through the tool has produced the cavity behind the base plate [22]. The dissimilar material has different melting temperature, thermal conductivity, and properties, which makes the way to create the weaker joints.

Joining the laminated Al-Zn/Al-Zn-Cu_p composite by FSP infused with copper and aluminum at 800 rpm rotational speed and 40 mm/min travel speed the aluminum layer caused the hook defect in the stir zone shown 17.24% and 325.20 MPa elongation percentage and ultimate tensile strength [23]. Interface of the base material is weakened due to the aluminum nanoparticles causing hook defects.

This research has been limited to SiO_2 nanoparticles infused weldment and the profile has a rectangular cross section. The size of these plates made this research to do only surface roughness tests. Hence in future the welding turns from conventional arc, gas, fusion welding to the friction stir joining due to the improved properties of the base metals compared to the conventional joining methods. Further analysis of bending

Table 5: Group statistics on surface roughness.

	Methods	N	Mean	Std. deviation	Std. error mean
Surface roughness	FSW	16	11.728	1.749	0.437
	FSP with SiO_2	16	2.020	1.002	0.250

Table 6: Independent samples test results of t-test for equality of means.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
									Lower	Upper
Surface roughness	**Equal variance assumed**	6.093	0.019	19.268	30	<0.001	9.707	0.503	8.678	10.736
	Equal variance not assumed			19.268	23.885	<0.001	9.707	0.504	8.667	10.747

strength, fatigue life, ageing and corrosion properties can be done.

Conclusion

The SiO_2 ceramic nanoparticle behaves in a different manner which affects the bonding with the AA1050 and AA7075 processing and makes the surface roughness higher compared to welding. The surface roughness was improved in the FSP. The processed material showed the greater improvement that the other type of ceramic nanoparticles may or may not improve compared to SiO_2 nanoparticles. The significant value (p) of < 0.001 was obtained with the reduction of 82.77% surface roughness in the proposed method.

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None.

Conflict of Interest

None.

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