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Experimental Investigation Joining Al 5083 and High-density Polyethylen by Protrusion Friction Stir Spot Welding Containing Nanoparticles using Taguchi Method

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ABSTRACT

One of the most important challenges of the Friction Stir Spot Welding (FSSW) process is the appearance of a void in the welded parts. This causes the stress to be stacked against the created void, and as a result, the mechanical properties would be reduced. To solve this problem in this research, the aluminum and polyethylene sheets are joined by means of H13 steel tools, protruding fixtures, and also three types of nanoparticles. Appending three types of Nano-particles, namely Al_2O_3, TiO_2, SiO_2, the constituent materials of Al 5083 and high-density polyethylene sheets have been prepared. To improve the mechanical properties of the welded samples, these three types of Nano-materials are integrated to the Stir Zone (SZ). In order to find the maximum strength of welded composite plates, the Design of Experiment (DOE) is performed using the Taguchi method. The Rotation Speed, Dwell Time, Tool d/ Protrusion d besides the type and percentage of Nano-material are chosen as input parameters. The maximum fracture force and the maximum strength are respectively as 2249 N and 4.13 MPa. Without using nanoparticles, a rupture is occurred in the tensile tests of polyethylene samples. Thus, the polyethylene samples capture more sediment by addition of nanoparticles, and the nanoparticles' deposition improves the mechanical properties of the Al/PE composite. Compared to the base material of pure aluminum and polyethylene, a nearly eightfold increment of the mechanical properties of the Al/PE composite sample is observed by addition of nanoparticles in the welding nugget. According to the S/N ratio analysis, the rotation speed of 2500 rpm, dwell time of 12 s, tool d/ protrusion d of 3 mm, Nano-material's type of Sio_2 and percentage of 10% are considered as the optimum states.

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1. INTRODUCTION

Aluminum alloys and high-density polyethylene are very useful materials in various industries [1]. Al 5083 contains 4% magnesium and about 0.25% chromium [2]. The properties of aluminum include excellent corrosion resistance, good fatigue resistance, welding ability and moderate strength [3]. High-density polyethylene belongs to the family of thermoplastic polymer and is used due to its high flexibility and bending ability [4]. The composite joining of these two materials helps different industries to reduce weight and maintain performance. Weight loss is a major challenge in various industries to maintain performance and reduce fuel consumption [5]. Composites can also be structurally better by compromising between two materials that operate independently. From polymer/metal joints, lighter, safer, less polluting and environmentally friendly products are obtained [6]. FSW welding is a solid-state welding process that was invented in 1991 [7]. In solid-state welding, FSW welding is developing rapidly. It is possible to join non-uniform materials with excellent quality in this process [8]. Protrusion friction stir spot welding (PFSSW) is one of the newest FSW welding methods for eliminating keyhole defects in a pin-less tool with a protrusion in the middle of the fixture [9].

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Zarghani et al. [10] studied the protrusion friction stir spot welding (PFSSW) on the plates of Al 2024. A pin-less tool and a specially designed fixture (protrusion) have been used with a clamp plate on the surface. The effect dwell time of 6, 12 and 18 seconds were investigated on the microstructure and mechanical properties of samples. The appearance of the welding surface showed that the keyhole would not form and the weld was relatively smooth. Microstructure and mechanical results showed that the welding zone was a uniform and refined structure since the structural regeneration gives more resistance to the base metal while it can be influenced by stress relaxation time. The penetration depth of the tool increased with increasing the dwell time, stir zone (SZ), and heat-affected zone (HAZ) of the two sheets. The maximum failure load (6000 N) was achieved in the present work compared to other methods of welding. Shahrabadi et al. [11] investigated PFSSW as a new method for producing welds without a keyhole on the specific carbon steel, which eventually introduced the technique to be a high-quality method for welding effects of the parameters such as tool rotational speed and penetration depth on mechanical and metallurgical properties. The microstructure and hardness of the welding region were affected by the dispersion and deformation of materials in the welding zone. The amount of hardness of the weld zone by this method was much lower than the weld produced by resistance welding due to the lack of martensitic in the metallic microstructure in the weld zone. Nateghi and Hosseinzadeh [12] investigated a new method of interconnected friction welding process, including cooling the weld to increase the weld strength and reduce the angular distortion of friction-welded polyethylene sheets. The taguchi experimental method and the response surface methodology were used to analyze the effects of tool rotation speed, passage speed and cooling gas inlet pressure on tensile strength and angular distortion. Also, non-destructive ultrasonic evaluation was used to measure residual stress to justify the change in angular distortion. The results showed that the use of cooling caused to a better combination of plastic materials. It also released residual stress and reduced angular distortion. Abibe et al. [13] examined two traditional techniques for joining metals and polymers, including fastening brackets and adhesive fasteners. Abibe et al. [13] argued that the use of the adhesive method creates a continuous relationship between the surface of the parts, which manifests the uniformity of the stresses and exhibits good mechanical properties while affected by stretching. They bound the polyetherimide (PEI) aluminum fusion joints (F-ICJ) of the 6080-T6 series F-ICJ method, which increased the resistance of the ultrasonic method by 18%. Moreno et al. [14] have investigated the effects of rotational speed and welding on the mechanical properties and thermal behavior of high-density polyethylene friction welded joints using non-rotating combs on their study. The results showed that tensile strength, hardness and crystallization decreased with increasing rotational speed and the effect of welding speed. Lambiase and Genna [15] studied on Laser-Welding technique (LAJ) and the welding on dissimilar AA5053 materials into PVC that had the tensile strength of 15.3 MPs, which compared to the previous ones and achieved 71% tensile strength. Geo et al. [16] investigated dissimilar lap joints of high-density polyethylene (HD-PE) and acrylonitrile butadiene styrene (ABS) sheets in the presence of multilayer carbon nanotubes (MWCNT) by immersion friction welding. Complete microstructural joints made in different process parameters were observed using field diffusion scanning electron microscopy (FESEM). Some defects such as pores and cracks were observed in improper processing parameters. Dashatan et al. [17] joined dissimilar ABS to PMMA by friction stir spot welding method. The thermal distribution and the thermal penetration of the sample indicated a suitable thermal distribution for welding. With the parametric evaluation of the dwell time of the velocity and degree of penetration, it was found that these parameters affect the strength of welding, so that in the test section, by increasing the dwell time, welding resistance increases. Gonçalves et al. [18] created a new method for joining polymer materials using the FSPW method, which resulted in maximum tensile strength of 1700 N. Haghshenas and Khodabakhshi [19] in a review paper examined solid-state technology for the dissimilar bonding of metals and non-metals such as polymers. This type of joint design was very interesting for structural applications, especially in the automotive industry. Goushegir et al. [20] used the FSPJ method to join dissimilar Al 2024 into phenyl sulfide. They studied three welding regions for spot welding and the results of their work that showed the temperature of the welding zone increases with a rotational speed of 2900 rpm to about 400 °C. Sahu et al. [21] have investigated the possibility of welding the Al6063 friction mixing spoon with polypropylene for cylindrical and threaded tool pin profiles in various tool positions such as tool compensation and slotted edge base plate as edge joining to improve weld quality. The joint behavior due to tensile load and the coupling mechanism in the weld stirrer region have been investigated using stress-strain diagrams and scanning electron micrographs, respectively. The weld joining interface was the weakest region instead of the weld stirring region due to the presence of carbon maturation steps due to micro-hardness changes through the weld midline along with energy dispersion spectroscopy analysis. The maximum join efficiency was 23.33% at tool rotation of 700 rpm and scrolling speed of 30 mm/min using a threaded pin in the slotted edge-based design. Khodabakhshi et al. [22]

were able to weld two dissimilar materials, aluminum and polyethylene by friction stir welding for the first time. In this research, the effective parameters on mechanical properties for PFSSW joining aluminum sheets to polyethylene sheets are studied. Whereas polymer and aluminum have different properties such as thermal conductivity, electrical conductivity, flexibility, tensile strength, and many other properties, they are also used in conjunction with a variety of industrial and commercial applications. Besides, the production of plates with low weight and cost and high efficiency has become a challenge for engineers to use these compounds and methods to join metals and polymers. To achieve this goal, first, the Al 5083 sheet welding High-density polyethylene with the PFSSW method was investigated.

Based on previous research, appropriate studies have been performed on the effect of different nanoparticles on two metal/polymer composites. In the present study, an approach based on optimization of a PFSSW method of Al 5083/HD-PE composite sheets using nanomaterials has been investigated. Three nanoparticles can improve the quality of welded nuggets due to their different properties. In this research, the effect of adding three nanoparticles with different weight percentages along with experimental design in PFSSW process was investigated. Figure 1 shows a schematic of the PFSSW process.

2. MATERIALS AND METHOD

In this study, the new PFSSW method was used to join Al 5083 sheet and high-density polyethylene. The dimensions of the samples used are 45×100×4 mm with a joint surface of two materials of 30 mm. In this process, the standard dimensions of AWS C1.1M/C1.1:2012 spot welding were used. Before starting the welding operation, the aluminum sheets were subjected to annealing operation. Acetone was used to clean the weld area. To investigate and optimize the effect of nanoparticles on the mechanical properties of the welded area, Al_2O_3, T_iO_2, S_iO_2 nanomaterials of Tecnan company of Spain with weight ratios of 1, 5 and 10 % were used. The mechanical properties of the samples Al 5083 and HD-PE stated in Table 1.

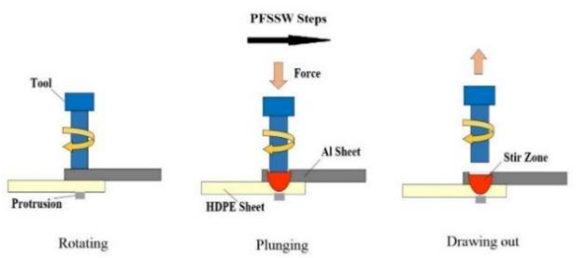


Figure 1. Schematic of the PFSSW process

TABLE 1. Mechanical properties of Al5083 and HDPE samples

Type metal	Properties	Test results
Al 5083	Tensile Strength (MPa)	225
	Yield Strength (MPa)	318
	Elongation (%)	19
HD-PE	Tensile Strength (Kg/cm^2)	287.2
	Yield Strength (Kg/cm^2)	307.8
	Elongation (%)	655

In this study method, a specially designed fixture with a protrusion in the center with a diameter of 7 mm was used. This bulge and space around it improved the mechanical properties during the process. The reason for using specially designed fixtures was the forces involved in the work-piece and the slipping of the sheet due to the lack of coordination of the tools. In order to control the applied torque forces and increase the welding quality, two M12 straps and four screws were used to close the parts. The sheet and nanomaterials are shown in Figure 2. The FP4M milling machine was used for welding and the desired fixture was mounted separately on the machine. A measuring clock with an accuracy of 0.05 mm was used to center the tool with the protrusion. After placing the samples and fixing the sheets on top of each other, the welding adjustment process was applied by adjusting the considered parameters. The spot welding process in the present study was performed in three stages. Penetration of the tool to a depth of 0.6 mm, dwell time in the sample and removal of the tool from the welding site were performed. The tool used was made of H13 steel without pins with three diameters of 7, 14 and 21 mm. Figures 3 and 4 show machine tools and dimensions and geometry of the tools accessories used in the experiments, respectively.

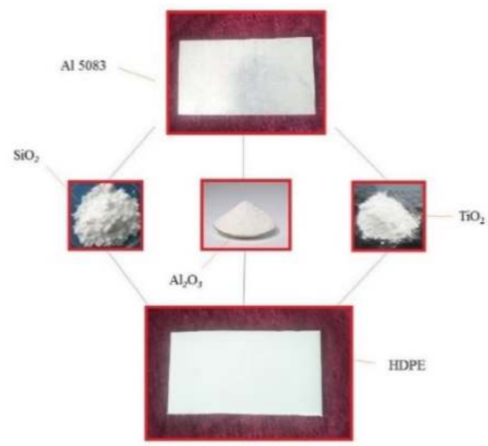


Figure 2. Nanomaterials and samples in this research

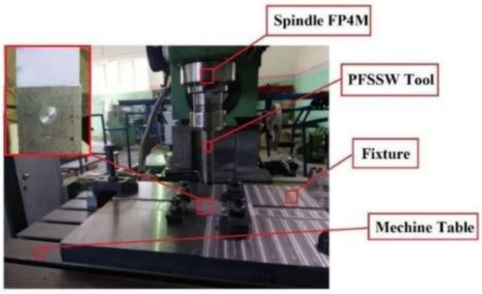


Figure 3. Machine tools and accessories used in empirical test

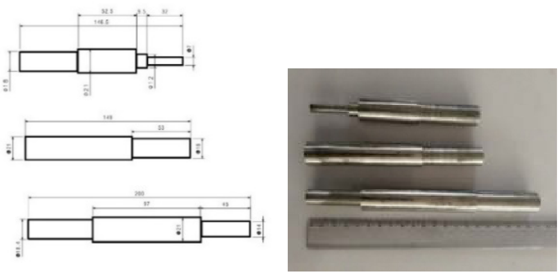


Figure 4. Dimensions and geometry of the tool

Figure 5, shows a composite Al/PE jointed sample in the PFSSW process with the presence of nanoparticles. Mini-tab software was used to design experiments with five parameters in three levels, according to the design of Taguchi experiments, L27 array was used.

3. DESIGN OF EXPERIMENTS

The purpose of designing an experiment is to make purposeful changes in the effective factors of the process and to examine the changes in the output. In designing an experiment, the first step is to determine the response variables. The experiments are performed according to the parameters and levels intended for each parameter. These effective factors are divided into two categories of response variables: the first group of material parameters including the type and percentage of base materials and nanomaterials used, the second group of process parameters including rotation speed, dwell time and tool diameter. After identifying the response variables and parameters affecting the problem, the next step is to determine the number of levels studied and the range of parameters. Table 2 shows the parameters and scope of work at three levels. According to studies, rotation speeds of 500, 1250 and 2500 rpm were selected. The purpose of selecting the minimum rotation speed of 500 rpm was not to join polyethylene and aluminum samples. The diameters of the tool were 7, 14 and 21 mm, respectively. The ratio of tool diameter to the protrusion in three ratios of 1, 2 and 3 and pause time is considered as the third parameter of 6, 12 and 18 seconds. Given the number of variable parameters and the number of levels associated with each variable in the problem, the number of tests required to analyze and evaluate the research was in the full factorial model. This means that this experiment consists of 125 tests to examine the types of possible cases for experimental research that requires a lot of time and cost. Due to available resources, it was not possible to perform all of these tests. Therefore, it is necessary to use a suitable test plan to reduce the number of tests. Test design methods such as the Taguchi method are known as a method that reduces the number of tests. According to the conditions, the orthogonal array L27 was selected by the Taguchi method. This test design is shown in Table 3.

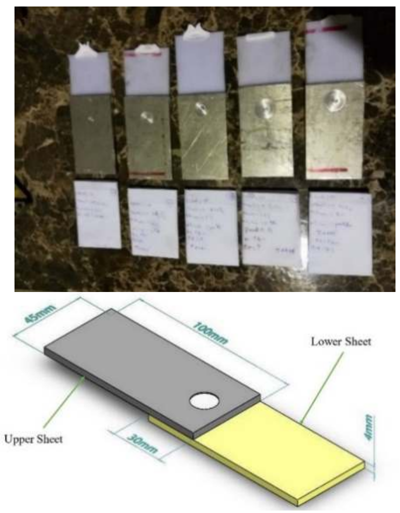


Figure 5. Composite Al/PE jointed sample in the PFSSW process with the presence of nanoparticles

4. RESULTS AND DISCUSSION

4. 1. Tensile Test

The mechanical properties of the joined composite samples were measured from the tensile test. The experiment was performed at ambient temperature at a rate of 10 mm/min. Tensile tests were performed on 27 design samples. The tensile test was performed by the Ryan-Joyner method with a tensile

TABLE 2. Parameters and level of research

Factor	Unit	Levels	Values
Rotational speed	rpm	3	500, 1250, 2500
Dwell Time	s	3	6, 12, 18
tool d/protrusion d	mm	3	1, 2, 3
Nano type	Type	3	Al_2O_3, TiO_2, SiO_2
Nano Material Percentage	(%)	3	1, 5, 10

TABLE 3. Designing experiments by the L27 Taguchi array

Exp. No.	Rotational Speed	Dwell Time	Tool d/ Protrusion d	Nano Material Percentage	Nano Type
1	500	6	1	1	Al_2O_3
2	500	6	1	5	Al_2O_3
3	500	6	1	10	Al_2O_3
4	500	12	2	1	T_iO_2
5	500	12	2	5	T_iO_2
6	500	12	2	10	T_iO_2
7	500	18	3	1	S_iO_2
8	500	18	3	5	S_iO_2
9	500	18	3	10	S_iO_2
10	1250	6	2	1	S_iO_2
11	1250	6	2	5	S_iO_2
12	1250	6	2	10	S_iO_2
13	1250	12	3	1	Al_2O_3
14	1250	12	3	5	Al_2O_3
15	1250	12	3	10	Al_2O_3
16	1250	18	1	1	T_iO_2
17	1250	18	1	5	T_iO_2
18	1250	18	1	10	T_iO_2
19	2500	6	3	1	T_iO_2
20	2500	6	3	5	T_iO_2
21	2500	6	3	10	T_iO_2
22	2500	12	1	1	S_iO_2
23	2500	12	1	5	S_iO_2
24	2500	12	1	10	S_iO_2
25	2500	18	2	1	Al_2O_3
26	2500	18	2	5	Al_2O_3
27	2500	18	2	10	Al_2O_3

testing device of Urmia University. The highest fore of failure was in 27 samples from the polyethylene sample.

4. 2. Joint Line Metallography The analysis of Al/PE composite elements from X-ray diffraction made by the German broker company with the D8ADVANCE model and Cobalt lamp. Figure 6 shows the x-ray diffraction of an Al/PE composite sample. Complete mixing and proper joining border indicate that the resulting weld is approved. After performing the tensile test on Al/PE composite samples, light microscopy and SEM was used to observe and examine the fracture surfaces. The spot welding area with and without the presence of nanomaterials is studied for the joining boundary and the welding nugget. Figure 7 the sample connected in the process PFSSW was shown. Samples from the bottom and top and sides and section A-A was examined. In solid-state thermal joining, it was observed that aluminum and polyethylene are homogeneously joined at a certain boundary. Figures 8 and 9 show the macrostructure of the spot welding zone with and without the presence of nanomaterials.

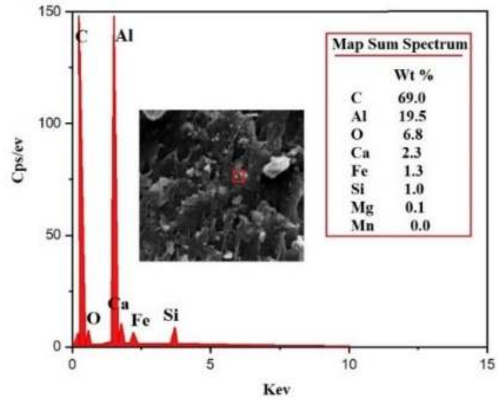


Figure 6. X-ray diffraction from Al/PE composite sample

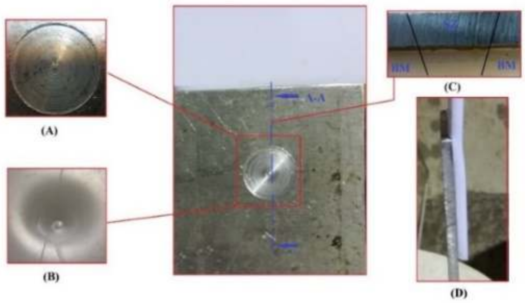


Figure 7. Sample connected in the process PFSSW: a) Top surface, b) bottom surface, c) cutting section A-A along and d) side view

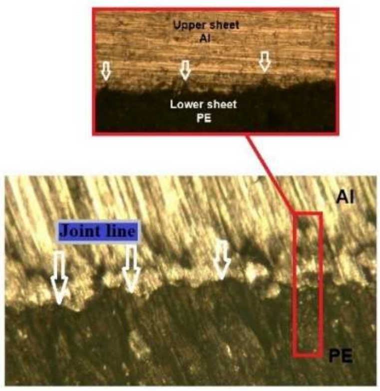


Figure 8. Boundary join of Al/ PE composite without the presence of nanoparticles with X100 magnification

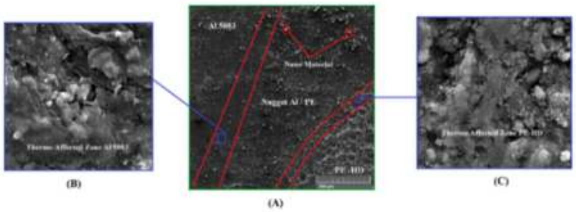


Figure 9. SEM microscope images of fracture mode after tensile test; a) Al/ PE composite, b) Thermal affected zone Al5083, c) Thermal affected zone PE-HD

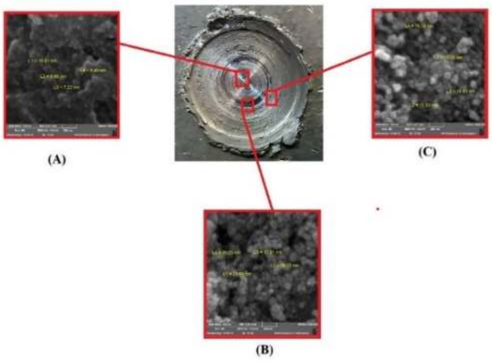


Figure 10. SEM microscope image of the composite Al /PE nugget area; a) Stir Zone, b) Thermal affected zone, c) Base metal

Figure 10 showed SEM microscope images of the fracture after a tensile test on the weld joint. In Al/PE composite, the welding microstructures vary Rotational speed, Dwell Time, on the tool d/protrusion d. Compared to welds produced by pin-less tools, Keyhole is not visible. Due to the lack of depth of tool penetration in the samples in this process, keyhole defects, hook defects and surface cracks were not seen in the microstructure. The reason for this is the thermal zone and the onion ring structures (mechanical) are not available due to the lack of tool pins. The keyhole defect was completely removed and no other defect was detected.

4. 3. Optimization

4. 3. 1. Analysis of Tensile Test Results

By analyzing the results and adding these results in Minitab software, the normal diagram of the output data obtained is presented in Figure 11. Equation (1) is the statistical modeling of the larger-better equation, which is why the choice of this equation is to find the maximum force of choice. According to the analysis of the results in Table 4, the P-value increased by 0.05, indicating that the tensile strength results of the welded samples follow the normal distribution.

$$S/N = -10 \log\log \left[\sum_{i=1}^{n} \frac{1}{y_i^2}\right] \quad (1)$$

Regression YTS = 1057.9 - 738.2 RS1 - 202.3 RS2 + 940.5 RS3 - 1.6 DT1 + 116.5 DT2 - 114.8 DT3 - 408.2 D/d1 + 91.4 D/d2 + 316.8 D/d3 + 90.2 NT1 - 332.5 NT2 + 242.3 NT3 + 48.2 NMP1 + 8.6 NMP 2 - 56.8 NMP3

Based on the P-value of the analysis of the variance table, which shows that the rotation speed has a greater effect on the tensile strength of welded samples than other welding parameters. Besides, the R-Sq value was 89.62%, indicating that this model covers more than 90% of the data. It should be noted that for higher R-Sq values, it's more realistic and consistent with the regression model.

TABLE 4. Analysis and variance of tensile test results

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Rotational speed	2	13233863	6616931	51.96	0.000
Dwell Time	2	240848	120424	0.95	0.409
tool d/protrusion d	2	2477759	1238880	9.73	0.002
Nano type	2	1596512	798256	6.27	0.010
Nano Material Percentage	2	50661	25331	0.20	0.822
Error	16	2037443	127340	-	-
Total	26	19637086	-	-	-
R-sq=89.62%		R-sq(adj)= 83.14%		R-sq(pred)= 70.45%	

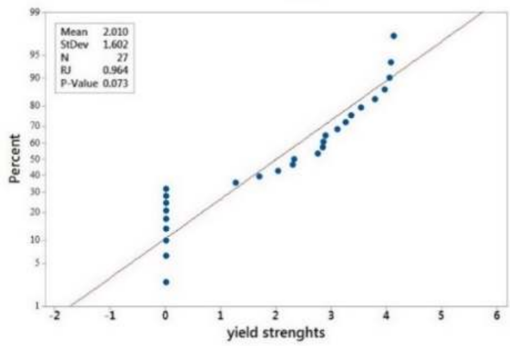


Figure 11. Normal diagram for experimental data of Al/PE composite

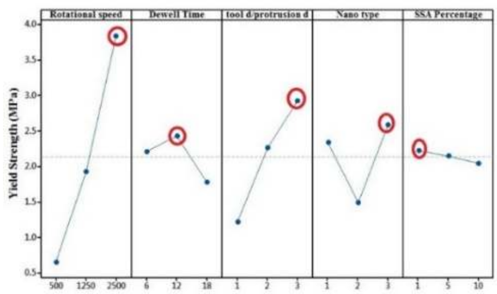


Figure 12. Effect of processing parameters on tensile strength

Since in the study of tensile strength, the aim is to maximize the amount of response, signal-to-noise (the larger is better) analysis has been used to investigate the main effects of the parameters and the order of their importance on the tensile strength of the samples. The maximum fracture force was 2249 N and the maximum tensile strength was 4.13 MPa in the tensile test (Figure 13). Due to the normal distribution of data, analysis of variance of the data obtained from the tensile test is considered. Also, Figures 14 and 15 show the diagrams of the response surface method and the contours of the tensile test. Based on the results of these graphs, the effects of variable effective factors on each other and finally on the yield strength are presented. Eq. 2 regression model is the criterion for submission to an analysis of variance.

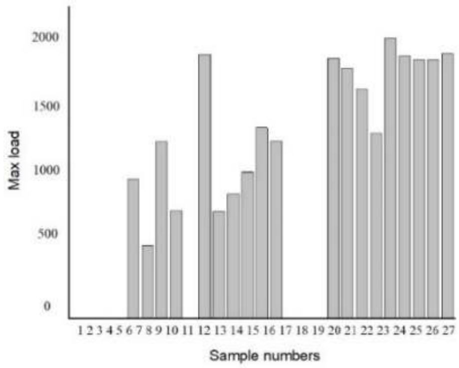
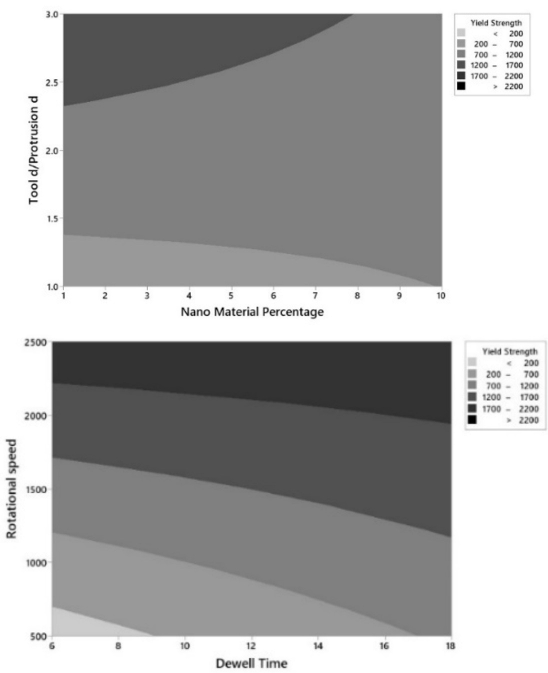


Figure 13. Tensile test results for the basis of yield strength



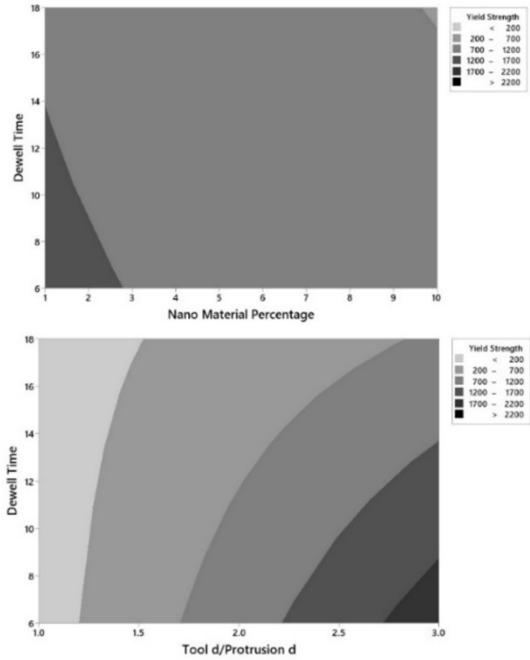
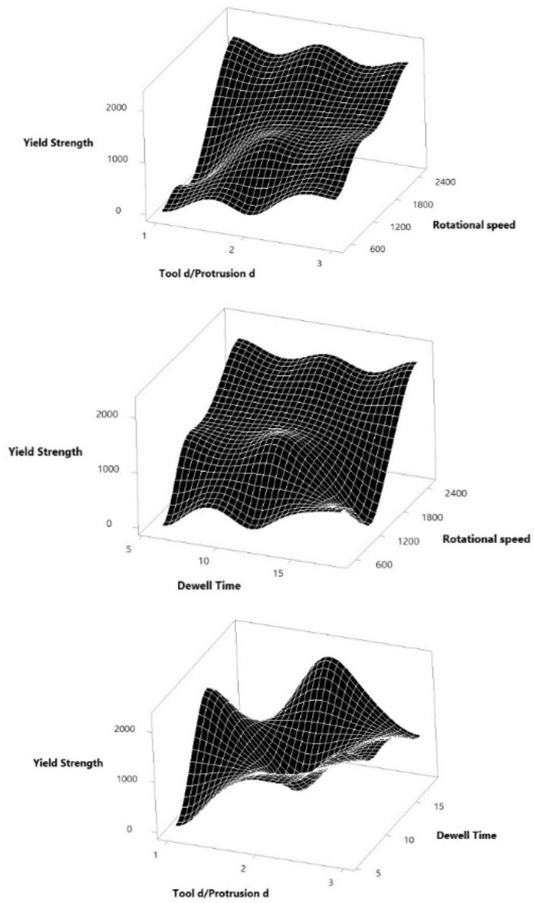


Figure 14. Contours of effective factors based on yield strength



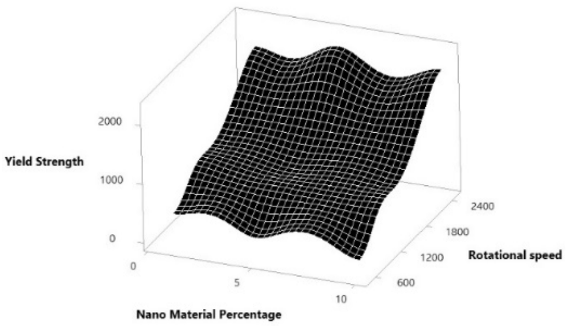


Figure 15. Effective parameter response surface method

The interaction effect of the parameters on the maximum strength is depicted in Figure 16.

4. 3. 2. Signal to Noise Tensile Test Results According to the results of signal-to-noise analysis in Table 6, for the tensile strength of the samples, the parameters are ranked based on impact degree, tool speed, Tool d/protrusion d, nanomaterial type, dwell time and percentage of nanoparticles, respectively, with the results and percentage. The share corresponds to the analysis of the variance table. The ratings are obtained from the delta values and the delta values are obtained from the difference between the maximum and minimum column values of that factor. According to the results of signal-to-noise analysis in Table 5, for the tensile

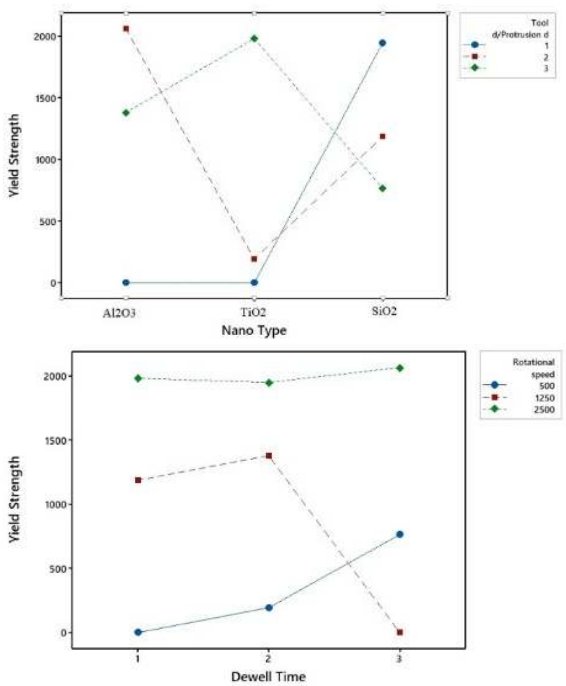


Figure 16. Interaction effect of the parameters on maximum tensile force yield strength

strength of the samples, the parameters are ranked based on impact degree, tool speed, Tool d/protrusion d, type of nanomaterial, pause time and percentage of nanoparticles, respectively with the results and also Corresponds to the percentage share of the analysis of variance table. The ranking is obtained from the delta values and the delta values are obtained from the difference between the maximum and minimum column values of that factor.

Table 5 shows the signal-to-noise results of the test design. In these results, the effect of 5 input factors with three levels has been investigated. According to the analysis of variance presented in Table 5, the percentage of participation in the parameters shows that the rotational speed had the greatest effect on tensile strength and other parameters such as Tool d/protrusion d, nanomaterial type, static time and percentage of nanoparticles had the most effect, respectively.

The optimal value of the parameter for the rotation speed of the maximum level tool with the maximum speed (2500 rpm) is considered to be the third level. Because increasing the temperature due to increasing the speed of the tool, causes more friction of the material. As the temperature increases, the strength of the melt and viscosity decrease and the materials in the weld zone integrate well and ultimately lead to an increase in tensile strength. The optimal parameter value for the dwell time in the second level was 12 seconds. The reason for this was that the low and excessive heat required (due to tool friction) reduced the mechanical properties of the welding area. The optimal value was in 12 seconds and a more uniform cross-section was achieved at the welding surface than in 6 and 18 seconds.

The optimal parameter for Tool d / Protrusion d is in the third level with a diameter of 21 mm. The reason for this was the greater contact of the work-piece and the presence of useful friction. The optimal effect of the studied parameters for the nanomaterial was the third level of the nanomaterial (S_iO_2) which had the greatest effect on the tensile strength of the welded parts. Also, the last parameter was the effect of the optimal percentage of nanoparticles. At the first level, 1% of the nanoparticles were selected. In nanoparticles about 1% to the welding area, the tensile strength of the welded

TABLE 5. Signal-to-Noise Analysis Table Tensile strength results

Level	Rotational speed	Dwell Time	Tool d/ protrusion d	Nano type	Nano Percentage
1	0.6513	2.2084	1.2213	2.3362	2.2240
2	1.9296	2.4316	2.2660	1.4911	2.1484
3	3.8344	1.7753	2.9280	2.5880	2.0429
Delta	3.1831	0.6562	1.7067	1.0969	0.1811
Rank	1	4	2	3	5

samples increases. The reason for this increase was good nanoparticle distribution, stress distribution and tensile strength.

5. CONCLUSION

In this study, a novel approach called the PFSSW process was investigated in order to join different materials, consisted of high-density polyethylene and Al5083, with different parameters at the ambient temperature and normal conditions. To discover the impact of process parameters on mechanical properties, these materials were applied using DOE analysis. The high-density polyethylene and Al5083 besides the structural and mechanical properties of flawless welds, such as debarment of void defects on the welding surface, were employed. The results of S/N Analysis and Analysis of Variance reveals that the most effective parameter on the tool's tensile strength is the rotation speed, and other parameters are respectively as the Tool d/ Protrusion d, Nano-materials' percentage, Nano-materials' type, and dwell time. At the next level, the same results of maximum tensile strength are applied. The increment in both the welding area and the joint spot is due to the heat exchange resulting from the friction between the tool and the upper sheet (Al5083).

In this research, the chosen parameters of Taguchi experiments play an important role in rising the welded areas' temperature. As the temperature increases, whether soft or hard materials' mass would be proliferated and a better balance struck. For the lack of strength, TiO_2 nanoparticles have no impact on enhancing the welding properties. In the absence of nanoparticles, a rupture was witnessed in the tensile tests of polyethylene samples. Therefore, more sediment was grabbed by the polyethylene sample through adding nanoparticles and so the mechanical properties of the Al/PE composite are improved by deposition of nanoparticles. The analysis of variance was attained at reliability of R (Sq) = 89%. Based on the S/N ratio analysis, the optimum states of input parameters are considered as the rotation speed of 2500 rpm dwell time of 12 s, Tool d/ Protrusion d of 3 mm, Nano-material's type of Sio_2 and percentage of 10%.

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Persian Abstract

چکیده

یکی از مهمترین چالش‌های جوشکاری اصطکاکی اغتشاشی نقطه‌ای وجود یک جای پین در قطعات جوش داده شده است. این جای پین باعث جمع شدن تنش در حفره حاصل شده و در نتیجه باعث کاهش خواص مکانیکی آن می‌شود. برای حل این مشکل در این تحقیق، ورق‌های آلومینیوم و پلی اتیلن با استفاده از ابزارهای فولادی گرم کار H13 و سه نوع نانوذرات اتصال داده شدند. آلومینیوم و پلی اتیلن با چگالی بالا با افزودنی سه نوع نانوذرات Al_2O_3، T_iO_2، S_iO_2 اتصال داده شد. برای بهبود خواص مکانیکی نمونه‌های جوش داده شده، سه نوع نانو مواد به ناحیه ناگت جوش اضافه شد. طراحی آزمایشی با استفاده از روش تاگوچی برای یافتن حداکثر مقاومت صفحات کامپوزیت جوش داده شده انجام شد. سرعت دورانی، مکث زمانی، نسبت قطر ابزار به قطر پین، نوع نانو و درصد مواد نانو به عنوان پارامترهای ورودی انتخاب شدند. حداکثر نیروی خرابی ۲۲٤۹ نیوتن و بیشترین مقاومت ٤.١٣ مگاپاسگال بود. در آزمایشات کششی نمونه‌های فاقد نانوذرات، پارگی توسط نمونه پلی اتیلن انجام شد. برای این منظور، نمونه پلی اتیلن با افزودن نانوذرات رسوب بیشتری جذب کرده و رسوب نانوذرات باعث بهبود خواص مکانیکی کامپوزیت Al / PE می‌شود. علاوه بر این، در نمونه همراه با نانوذرات، خواص مکانیکی نمونه کامپوزیت Al / PE در مقایسه با ماده پایه آلومینیوم و پلی اتیلن، حدود ۸ برابر افزایش یافته است. تجزیه و تحلیل نسبت سیگنال به نویز نشان داد که سرعت چرخش ۲۵۰۰ دور در دقیقه، زمان ساکن ۱۲ ثانیه، قطر ابزار بر قطر برآمدگی ۳ میلی متر، نوع نانو S_iO_2 و درصد مواد نانو ١٠٪ شرایط بهینه هستند.