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The Effect Of Adding Metal Powders To the Spot Welded Area Of Dissimilar Metals

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Abstract: The process of spot welding has been and remains one of the most important manufacturing processes; the vehicle industry requires the use of this process frequently. To reduce the cost and improve the quality of the products in some applications, it was necessary to weld different metals, and due to the different specifications of welded metals it is necessary to study this situation and try to improve the specifications of the welding area. In this work, 304 stainless steels and SAE1006 was spot welded at different weld current and welding duration values because of their wide use. The aim of this research is improve the welding zone mechanical characteristics and reduce the amount of energy used by using two different types of metal powders have acceptable resistivity which added to the welding area to prevent thermal energy from dissipating rapidly allowing for a stronger bonding, This addition helped to create an extra bond between the base metal and metal powder which improved the mechanical properties of the nugget. It was found that increasing the amount of weld current and welding duration improved the mechanical features of the welding area, and from the results it was clear that the effect of the addition of titanium powder was more effective than nickel powder.

Keywords: metal powders, spot welding, dissimilar metals.

Introduction

The process of spot welding is characterized as quick and clean and does not require high skill [1]. Therefore, it was the process used in the manufacture of vehicles. A modern auto-body assembly needs 7000 to 12,000 spots of welding according to the size of a car [2]. Many factors affect the durability of the welding area, but the most important is the welding current and the welding time. Because the change in the values of these factors leads to a significant change in the value of the strength of the nugget during the shear tensile test and the microhardness test, increase welding current has been found to raise the weld nugget size and in turn the weld strength. [3] Similarly the increase in weld cycle has been found to raise the weld nugget growth and the shear tensile strength until the occurrence of metal ejection. [4]. Because the spot welding process is not always performed on two similar metals, the effect of change in current value and welding time when welding different metals should be studied. A number of researchers have studied the effect of variables on spot welding of different metals, including; M.R.A. Shawon.[5] has study the welding by resistance spot welding technique for strips of austenitic stainless with 1.5 mm thick sheet metal and plain low carbon steel. The behavior of the structure and the mechanical features of the welds were studied at different values of welding current within range 3-9 KA. The structure was studied in three scales visual, micro, and with ESM technic. Mechanical properties were evaluated by shear tensile testing and micro hardness measurements.

In the welded joint, weld nugget was found to have formed but with not symmetrical shape, which increased in dimensions with an increase in welding current. A Cast structure was found in the fusion zone had a coarse columnar grain and dendritic with excess delta ferrite in austenitic matrix. due to martensite formation, Microhardness of the weld nugget was biggest.

Due to increasing in the welding current an increment in the strength of the weld coupon was appear. An attempt has also been made to relate the mode of fracture with the welding current. Aravinthan Arumugam, Mohda Amizi Nor .[6] has checked the parameter optimization when RSW steels with dissimilar type and thickness using (Grey Based Taguchi Method) . The experimentation in this research used three variables, each one having three levels in a L9 orthogonal array. The three variables used are electrode force, welding current, and weld cycle. The three weld parameters that were optimized are weld nugget size, weld indentation, and weld strength. The analysis of variance (ANOVA) that was carried out showed that weld current gave the most important contribution in the optimum welding schedule. The comparison test that was achieved to compare the current schedule and the optimum welding schedule showed distinct decrease in electrode indentation as well as optimization in the increase of weld strength and weld size. While Mohamed El-Shennawy [7] he show that the effect of main governing factors of spot welding process on dissimilar welded joint between low carbon steel, LCS with 0.6 mm thickness sheets and 430 grade ferritic stainless steel , FSS with 0.5 mm thickness . Factors investigated were electrode pressure, welding duration and welding current. Metallurgical and mechanical features were determined through microstructure, microhardness and shear tensile examinations. The results of this work showed that the suitable electrode pressure in this dissimilar conjunction of steels; LCS and FSS; was 2x106 Pa. It was clear also that the welding current is the most effective factor on weld quality. The best strength for weld was get at 3400 A. Increasing welding duration and welding current up to a specify extent raises the weld strength, up to this certain extent, the weld strength will experience a drop in their values . Inspections showed also that the basic structure of the welding are is martensite. The failure due to shear tensile inspection was mainly intergranular in ferritic stainless steel side and the fracture configuration was button pullout. at carbides existed beside the martensite highest values for Microhardness where found. H. L. Lin, T Chou [8] he study spot weld factor optimization using artificial neural network and taguchi method, the taguchi used to show optimum setting for the electrode tip diameter, electrode force, time and weld current, while ANN was used to model the process and estimate the strength of welds for different variables. N. Akkaş E. Ferik, E. İlhan [9], they study the effect of weld current and welding duration on the SPA-C steel sheets used in sidewall and roof in rail vehicles. SPA-C steel sheets having 2.3 mm thicknesses were joined by using resistance spot welding as lap joint, the results show, in low welding current intensity, small weld nugget widths were obtained due to low heat application to welding zone. As a result, break type was observed as separation. In high welding current intensity, cross-section area decreases. This project will be evaluating the effect of adding two different metal powders e.g. (Ni metal powder and Ti metal powder) for dissimilar metals which are stainless steel 304 and low carbon steel SAE1006, and this work will consider different welding current values and different welding time values to show their effect on the mechanical features of the nugget, through shear tensile test and microhardness test , maximum shear tensile load and microhardness Vickers have been considered as an evaluating factors for the quality of the spot welds.

In most cases, the welds of dissimilar metals are weak in toughness because of the different mechanical and thermal properties of each metal. Therefore, the aim of this study was trying to improve the strength of the bonding by creating an additional secondary bond between metal powders and base welded metals.

Experimental Methods

Samples of low carbon steel and stainless steel sheets is prepared by the dimensions recommended by the American welding society using a shearing machine of type (ÉCLAIR) and then spot welded together with nickel powder once and with titanium powder again using welding machine ZP18 The first group of experiments was achieved at different welding current values with constant welding time value, while the second group was done at different welding time values but with constant welding current value. Then these two groups were tested to evaluate the effect of adding these two powders on the mechanical features of the nuggets, by comparison the results before and after the addition.

The welded materials used for resistance spot welding were SAE 1006 low carbon steel (LCS) and austenitic stainless steel 304 (SSt). The thickness of the welded sheets was 1 mm. Both metals were taken in cold rolled state. The standard chemical content of the steels is given in Tables 1[10], and 2 respectively , while the results of the chemical content of the metals are shown in the tables 3and 4, which enhances the accuracy of the type of metal used.

Table 1 The standard percentage of SAE 1006 low carbon steel

	Elements			
Designation	S	P	Mn	C
SAE 1006	0.05 max	0.04 max	0.45 max	0.08 max

. Table 2 The standard percentage of 304 stainless steel sheet

Elements							
Designation	C	Mn	Si	Cr	Ni	P	S
SSt304	0.08	2.00	1.00	18.-20	8-10.5	0.045	0.03

Table 3 The elements of the tested SAE 1006 metal

Elements				
Designation	S	P	Mn	C
SAE1006	0.003	0.04	0.213	0.056

. Table 4 The element of the tested 304 stainless steel sheet

Elements							
Designation	C	Mn	Si	Cr	Ni	P	S
SSt304	0.05	0.94	0.53	18.79	7.83	0.028	0.005

It was necessary to take various features of the welded metals into consideration، e.g. thermal conductivity and electrical resistivity.

The thermal conductivity of SST and LCS is about 16.2 W·m−1 ·K−1 and 52 W·m−1·K−1, respectively.Not symmetric weld nugget configuration is due to the difference in the properties of the welded metals. The electrical resistivity of SSt is approximately 72 $\mu\Omega \cdot$ cm, while the electrical resistivity of LCS is 14.2 $\mu\Omega \cdot$ cm [11].

Resistance Spot Welding Machine

Resistance spot welding machine ZP18 spot welding machine. This is a pneumatically operated, electronically current-and-timing controlled welding machine. With nominal maximum power 15 KVA, main voltage frequency 50-60 Hz, and maximum welding secondary current 8.2 KA. Truncated with tip has diameter 6 mm electrodes was used.

Specifications of specimens

Samples used in this work are in accordance with the standards of the American welding society (AWS) [12], which is illustrated in Figure 1. These samples consist of two pieces, the first one is SAE1006 and the second is SSt. 304, which includes a cavity with depth 0.2mm and diameter 5mm as shown in figure 2.

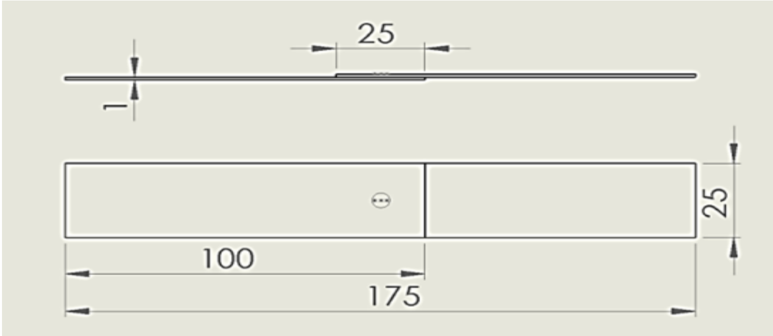

Figure (1) The dimensions of the used specimens (all dimensions in mm)

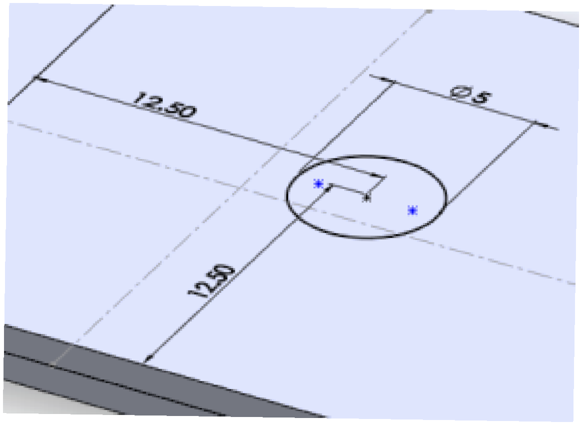

Figure (2) The cavity where metal powder was added

Two different types of metal powders used in this study are nickel powder and titanium powder. These two types were chosen because their melting point is close to the melting point of iron and they are available in the market at a reasonable price. The specifications of these two metals powder are shown in Table no.5.

Table 5 Specifications of metal powders [BDH chemicals ltd.]

Features	Ni metal powder	Ti metal powder
assay	99.995% trace metals basis	99.98% trace metals basis
form	powder	powder
resistivity	6.97 μΩ-cm, 20°C	42.0 μΩ-cm, 20°C
particle size	<150 μm	<45 μm
bp	2732 °C(lit.)	3287 °C(lit.)
mp	1453 °C(lit.)	1660 °C(lit.)
density	8.9 g/mL at 25 °C(lit.)	4.5 g/mL at 25 °C(lit.)

The welding achieved by overlapping two samples using the machine mentioned above, two key factors have been adopted to demonstrate the effect of adding metal powders on the mechanical properties of the welding area. Two sets of experiments were performed; the first group was to change the welding current values and to keep the welding time constant. In the second phase the case was reversed. The welding current value was kept constant while the welding time value was changed. In both cases, it has been added nickel powder and titanium powder into the cavity located in the sample shown in Figure (2). This addition on the basis of volumetric, not weight.

The effect of adding metal powders was evaluated through two main tests: microhardness test and shear tensile test.

In the microhardness test, spot welded samples then conducted on (INNOVA TEST) microhardness test device, the dwell time was 20 seconds and the force at 4.904 N, then three measurements were taken in the welding area and the average of these measurements was then calculated to enhance the accuracy of the readings as shown in figure (3) . This group of experiments was performed at different values of welding current and welding time, with the presence and absence of metal powders for nickel and titanium.

Another test is the shear tensile test, which is one of the basic tests to determine the strength of the weld. This test was done on samples with dimensions shown in the figure (1). In this group of shear tensile tests, three samples were tested for each value of welding current and welding time then the averages were calculated to improve the accuracy of the results. The specimens were conducted on Tinius, H100KU tension machine. This test is also achieved in the presence of powders and in the absence thereof.

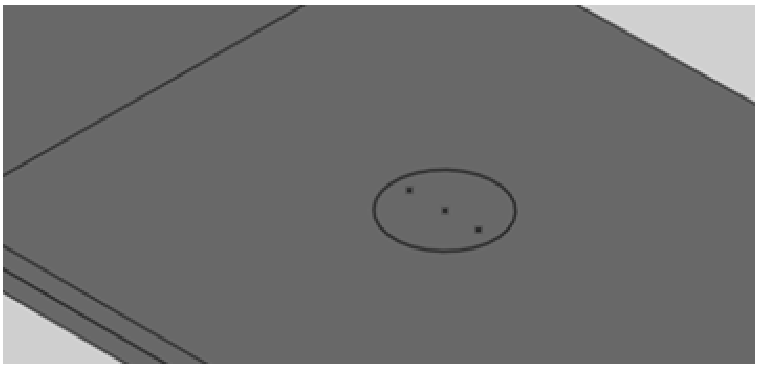

Figure (3) The positions of microhardness measurements

Results and Discussions

Microhardness test:

It is noticeable from the results of the experiments there is a clear improvement in the value of microhardness values when adding nickel powder at constant welding current and constant welding time when compared with the results of the microhardness test without adding nickel powder as shown in figure (4), and (5) the same behavior which can found at adding titanium powder as shown in figure (6) and (7) respectively, which ensures an additional secondary bond between SSt. and LCS and metal powders. This is same line with the results of researchers whom work on adding Mg, Mn , and Cu powders to aluminum sheets at different values of weld current[13].

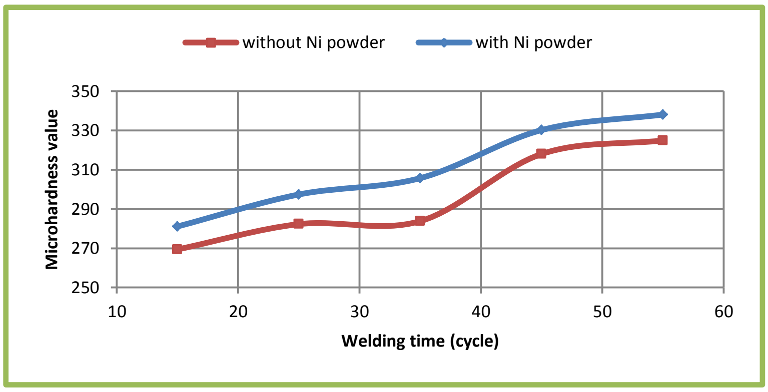

Figure (4) Effect of adding Ni metal powder on the microhardness values at constant welding current

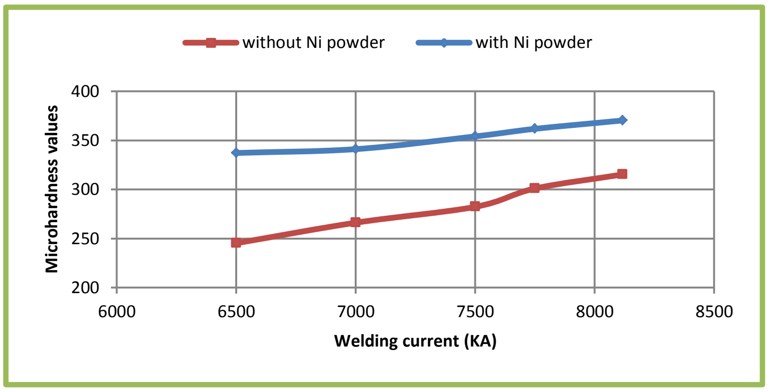

Figure (5) Effect of adding Ni powder on the microhardness values at constant welding time

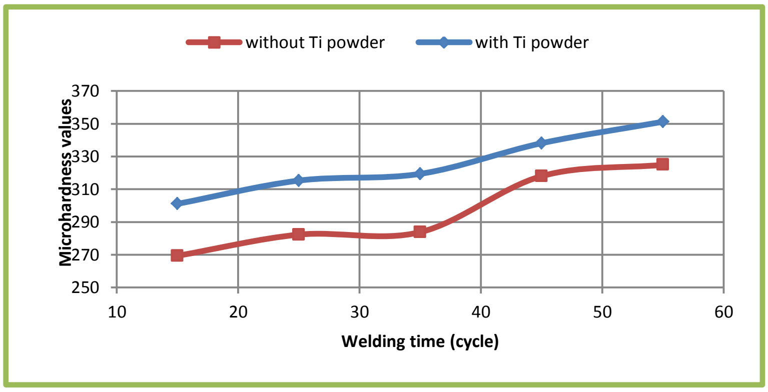

Figure (6) Effect of adding Ti powder on the microhardness powder at constant welding current

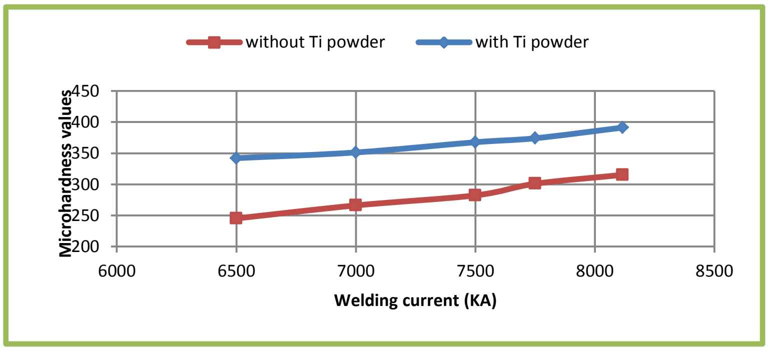

Figure (7) Effect of adding Ti powder on microhardness values at constant welding time

Another comparison can be achieved between the effect of nickel metal powder and titanium metal powder addition in terms of which is more influential on the microhardness values, which clearly shows the superiority of titanium powder on nickel in its effect on microhardness values, this is graphically recorded in figure (8), and (9) for constant welding current and welding time respectively.

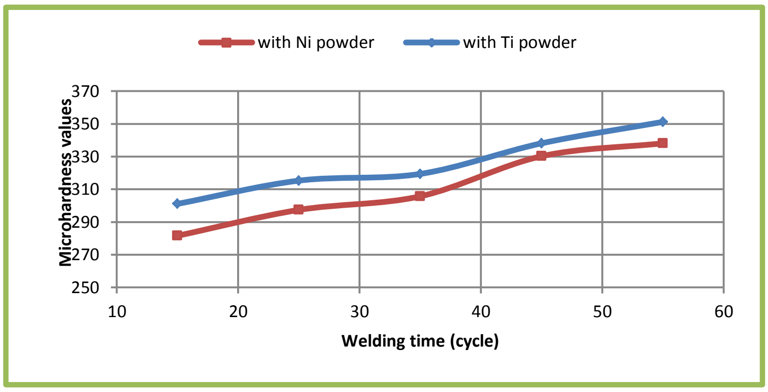

Figure (8) Comparison between Ni & Ti powders effect on the microhardness values at constant welding current

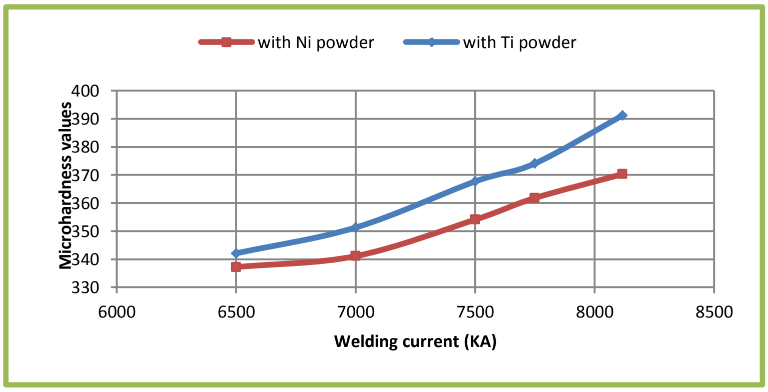

Figure (9) Comparison between Ni & Ti powders effect on microhardness values at constant welding time

Shear tensile test:

It is known that the shear tensile test regard as a major test that contribute to a clearer understanding of the mechanical properties of the nugget in a resistance spot welding. Therefore, a large number of samples were tested at different welding currents and different welding times to evaluate the effect of these factors on the mechanical properties of the welding area, this is illustrated in figures (10), (11) for different welding current values and (12) ,(13) for different welding time. All these tests were achieved with adding nickel powder and titanium powder to the weld area to demonstrate their effect on the mechanical properties of the welds.

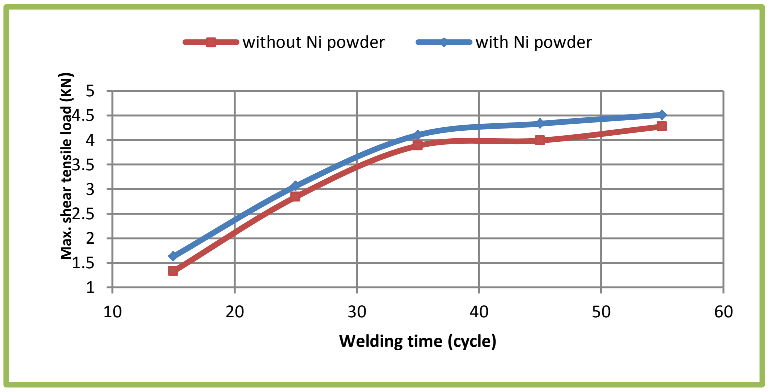

Figure (10) Effect of adding Ni powder on Max .shear tensile load at constant welding current

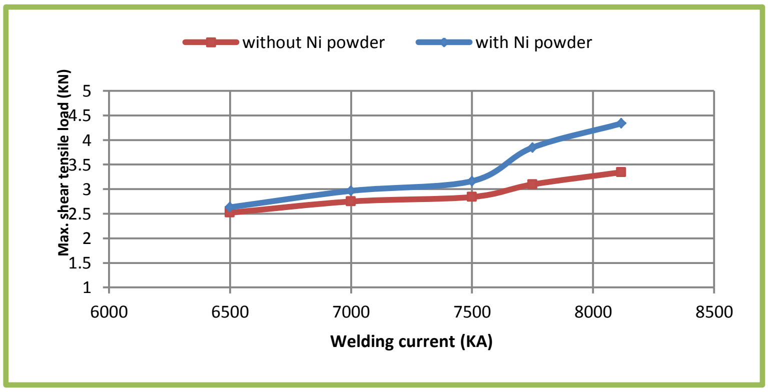

Figure (11) Effect of adding Ni powder on the Max. shear tensile load at constant welding time

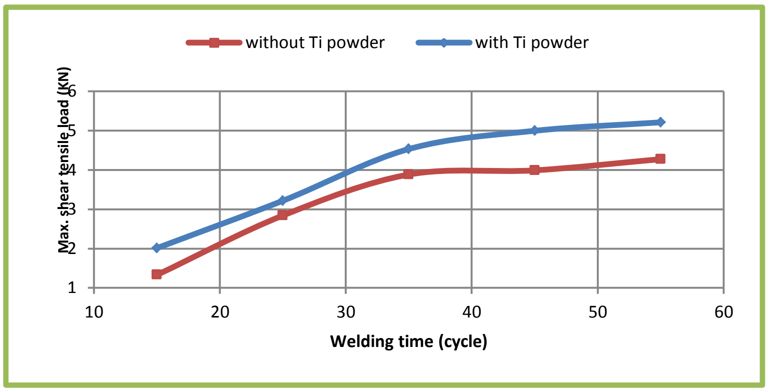

Figure (12) Effect of adding Ti powder on the Max shear tensile load at constant welding current

It is noted that the results of the shear tensile test take the same trend as the results of the microhardness test, which enhances the accuracy of the results and this also applies to the figure (13). This is consistent with the results obtained in a search [14].

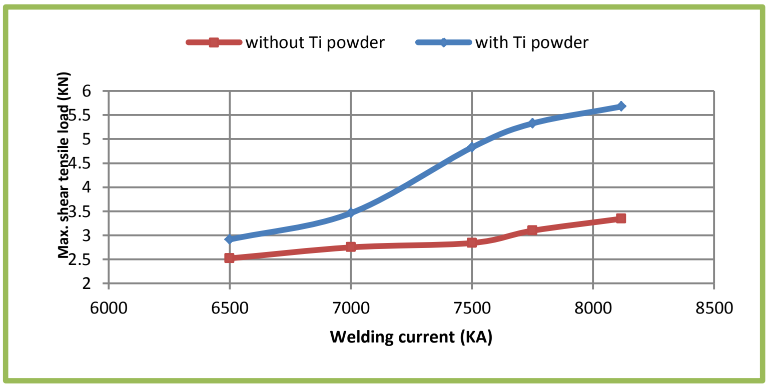

Figure (13) Effect of adding Ti powder on Max. Shear tensile load at constant welding time

The comparison between nickel powder and titanium powder can show superior titanium powder better on nickel in improving the mechanical characteristics of the welding area when added. This is because titanium powder has higher resistivity than nickel powder. Which mean stronger bonding between the metal and the powder, making the welds more strength. This is evident in the graphical representation of this comparison as in Figure (14), and (15).

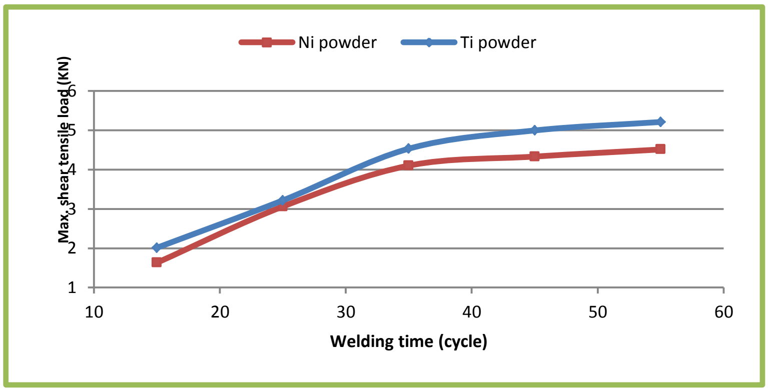

Figure (14) Comparison between the effect of Ni and Ti powders on the Max. shear tensile load at constant welding current

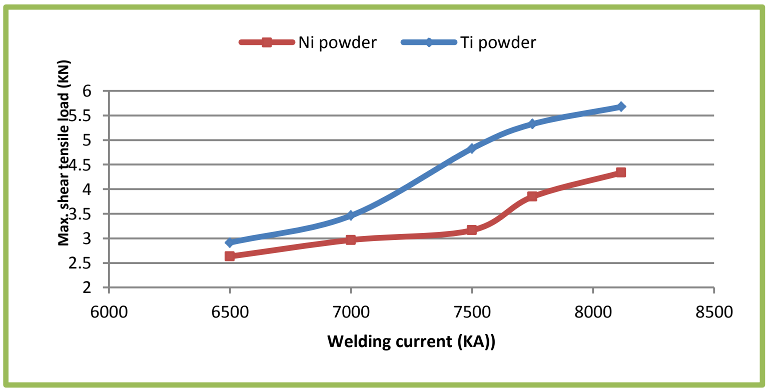

Figure (15) Comparison between the effect of Ni and Ti powders on the Max. shear tensile load at constant welding time

Conclusion

This study shows that there is no doubt that increasing the value of the welding current leads to the improvement of the mechanical specifications of the welding area for dissimilar metals. The reason for this is that any increase in the current value leads to a significant increase in the amount of thermal energy generated in the welding area, thus ensuring the completion of the fusion process, This also applies to the case of increased welding time as the increase in welding time increases the strength of the weld, and this is evident clearly from the upward shape of the curves of microhardness and max. shear tensile load. It was also clear that the addition of nickel micro-powder and titanium micro-powder had a clear effect on increasing the microhardness and maximum shear tensile load of the same welding current value as well as the same welding time value, which confirms that the addition of these metal powder improved mechanical specifications of the nugget. It was clear that the effect of the addition of titanium micro-powder was greater than the nickel micro-powder on the results of microhardness and max. Shear tensile load, this is due to the resistivity of titanium is higher than nickel, which allows the temperature of the weld area to be increased more and to ensure more melting.

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ملخص الدراسة

إن عملية اللحام النقطي كانت ولا تزال تعتبر احدى اهم العمليات التصنيعية، حيث ان صناعة المركبات تتطلب استخدام هذه العملية بشكل واسع، ولتقليل الكلفة وتحسين النوعية في بعض التطبيقات كان من الضروري لحام معادن مختلفة ونتيجة اختلاف مواصفات المعادن الملحومة فقد اصبح ضرورياً دراسة هذه الحالة ومحاولة تحسين مواصفات المنطقة الملحومة. تم في هذا البحث لحام نوعين مختلفين من المعادن وهما فولاذ واطيء الكاربون يحمل الرمز SAE1006 وفولاذ مقاوم للصداء يحمل الرمز sst. 304 عند قيم مختلفة لتيارات وازمنة اللحام وذلك للاستخداماتهما الواسعة معاً. ان الهدف من هذا البحث هو محاولةً لتحسين المواصفات الميكانيكية لنطاق منطقة اللحام ولتقليل مقدار الطاقة المستخدمة حيث تم اضافة نوعين مختلفين من المساحيق المعدنية لهما ممانعة كهربائية مقبولة الى منطقة اللحام وذلك لتقليل الطاقة الحرارية المتبددة وبالتالي الحصول على ترابط اقوى، هذه الإضافة ساعدت في خلق رابط اضافي ثانوي بين المعدن الاساس وبين المسحوق المعدني والذي يحسن من الخواص الميكانيكية للحامه. كما انه قد وجد ان اي زياده في كمية تيار و زمن اللحام يحسن من السمات الميكانيكية لمنطقة اللحام، ومن النتائج فان من الواضح ان تأثير اضافة مسحوق التيتانيوم اكثر فعالية من اضافة مسحوق النيكل .

الكلمات المفتاحية: مسحوق معدني، لحام نقطي ، معادن مختلفة