Studying the Effect of Adding Metal Powders on the Mechanical Properties of Spot Welds for Low-Carbon Steel Sheet

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Abstract. Spot welding process is one of the most widely applied processes in the industry. This is due to the ease of the process and it's a quantitative process. The addition of metallic powders to the spot welding area has not been widely emphasized as a solution to amelioration the mechanical characteristic of the welding area therefore the effect of adding two types of metallic powders, (namely nickel powder and titanium powder), to the spot welding area on mechanical properties was studied. This effect was studied at the values of different welding currents and at different welding times to indicate the impact of these factors on the mechanical properties of the welding area. The results show that the increasing in welding time and welding current enhanced the mechanical properties of the weld nugget, in addition to that the addition of Ni and Ti metal powder improve the strength of the welds and the Ti metal powder had a higher effect on the mechanical properties than the Ni powder metal.

Keywords: Spot welding, Welding current, welding time, Metal powder, Ti metal powder, Ni metal powder.

1. Introduction
The process of welding is one of the most important linking of materials because of its relatively low cost, easy to apply and rapidity and because it gives a permanent link [1]. Electric Resistance Welding is one of the most common types of welding operations because of its wide applications especially in the field of vehicle manufacturing. The best welding resistance model is spot welding because it is fast and does not require high skill in the application. For example, the car has 5000 points of spot welding approximately, so the spot welding must be studied and improved as much as possible [2]. Spot welding process is used widely compare with other resistance welding processes. It involves the homogenous application of pressure and current of the right magnitudes and format. Resistance spot welding is considered as a major process in sheet metal fabricating in the automotive and vehicle industry. Low cost, speed, and Ease of operation, as well as other features that make it very useful [3-7].

The importance of metallic powders is great in the industry and has become widely applied. This work offers a new and useful way to use the metal powder in a very important manufacturing process, which...
is spot welding. The use of mineral powders as an additive in welding operations in general and in the spot welding area, in particular, has not been studied extensively. Many researchers studied spot welding and examined the effect of the variables that affected the process in terms of manufacturing, metal and cost. Although the type of metal is different, however, these studies may give us an idea of the behavior of the welds. Many researchers studied and tested different welding processes and studied the variables that affect them, for example; D.S. Sahota et al. [8] Study of the effect of some variables (welding current, welding time and electrode strength) during local welding for the purpose of improving the hardness of the materials ASS316. The results showed that the variables significantly affect the strength values of the material ASS316. ĽubošKaščák et al. [9] they have improved the properties of resistance spot welding made from a combination of high strength low alloy steel and galvanized advanced high-strength steel and the quality of welded joints by non-destructive tests and destructive tests. A. K. Muhammad [10] has improved 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 stronger bonding.

Bouyousfi et al. [11] have evaluated the influence of spot welding process parameters (arc intensity, weld time and weld force) on the mechanical properties and characteristics of the spot welds between two 304 Sts. sheets with a similar thickness. Other researchers studied the formation of the nugget and the effect of variables on the size and strength and the other of the mechanical specifications one of them was M. Pouranvari [12] investigated the influence of weld current, as a major spot welding process variables, on the weld nugget figure and mechanical behavior of spot resistance welds of 1.25 to 2.5 mm thickness LCS. Sheets. The mechanical features of the welds were described in terms of max. Load and failure efficiency. Results appeared that in opposite to spot welding of sheets with similar thickness, a Pear-like the figure of the weld nugget was formed due to heat variation resulted from the difference in bulk resistivity of the sheets.

Y.R. Wang et al [13]. Resistance spot welding was done on 1 mm magnesium alloy sheets (AZ31B). The effect of weld cycles on the microstructure and shear tensile load was evaluated. Some special lineaments for nugget growth were observed during the spot welding of Magnesium alloy. Generally few researchers studied the effects of adding metal powder to the welds and the least they studied the effects of adding metal powder to the spot welding process, one of them was Moneer H. Al-Saadi et al [14] They show the rise of the strength of spot lap joint for commercial Al. by adding metal elements to the welding area in the form of powder. While Ihsan K. Al Naimi et al [15] they investigate the improved welding resistance of aluminum plates by adding metal powder, in order to ensure good quality welds between aluminum sheets by spot welding. Three different types of metal powders (pure aluminum and two types of powders within AA2024 and AA7075 alloys) were studied to study the spot welding resistance of AA1050 aluminum plates with 3 different thicknesses. The powder is particularly used when welding machines are used with insufficient weld current capacity to produce the desired mass size. In such cases, the best results are obtained from pure aluminum powder.

2. Experimental Details

2.1. Specification and compositing of material used.

The specimens were cut from SAE1006 sheet of 1000mm x 2500mm. The samples were cut at 0 degree to the direction of rolling. sample Dimensions are 100 mm and 25 mm for length and width
respectively as in Figure 1. The overlap is equal to 25mm same as width. This overlap was selected according to the AWS recommendation [16]. Has been done circular cavity diameter 5mm and depth 0.2mm to be placed powder inside and the center of the cavity distancing by 12.5 mm on the edge of the sample as in Figure 2. Sheet of low carbon steel, SAE (1006) are used without surface coating. A chemical composition test was carried to check the percentage of elements and shown in Table 1.

![Figure 2. The cavity of the powder](image)

**Table 1. SAE1006 composition**

| Element | Wt. %age |
|---------|----------|
| C       | 0.056    |
| Cr      | 0.016    |
| Ni      | 0.024    |
| Mn      | 0.213    |
| Si      | 0.036    |
| S       | 0.003    |
| P       | 0.004    |
| Mo      | 0.002    |

As shown in Figure 3. Photomicrograph magnified at 50X was taken on the (metallurgical microscope- model MT7100-for vertical illuminator).

![Figure 3. Show the Microstructure of SAE1006 magnified at 50×](image)

Ti and Ni metallic powders were used in this research to study their influence on the mechanical properties of the nugget weld; the specifications of these powders are listed in table (2)
Table 2. Show the specifications of the metallic powders

| Properties    | Ni metal powder | Ti metal powder |
|---------------|-----------------|-----------------|
| Assay         | 99.995% trace   | 99.98% trace     |
|               | metals basis    | metals basis    |
| Particle size | <150 μm         | <45 μm          |
| Density       | 8.9 g/mL at 25°C | 4.5 g/mL at 25°C |
| Resistivity   | 6.97 μΩ·cm, 20°C | 42.0 μΩ·cm, 20°C |
| mp            | 1453 °C(lit.)   | 1660 °C(lit.)   |
| bp            | 2732 °C(lit.)   | 3287 °C(lit.)   |
| form          | powder          | powder          |

2.2. Welding process
Experiments were performed by adding titanium powder and nickel powder respectively between the faying surfaces and controlling one variable and keeping the other variables constant, each testing group contained three specimens, the average was taken for results of each group to get the higher accuracy, Overlapping is still equal to the width of the specimen. Size of electrode diameter has been same as per AWS recommendation [15]. Water-cooled copper is used as the electrode material. The electrode shape is flat-ended with a contact diameter of 5 mm. The experiments were performed on CEA type ZP18 spot welding machine. This is a electronically current-and-timing controlled pneumatically operated, welding machine. The weld current values of the machine range from 3.25KA to 8.2 KA.

2.3. Experimentation
Two parameters: welding Current, welding time was selected to be the governing variable while the other parameters kept constant. The quantity of powder added was based on volume not on the weight. The process parameters effect on the Nugget Microhardness and the strength of the weld was studied for the material SAE1006.

The microhardness of the spot welded area was measured through a group of tests, with different values of welding parameter (welding current and welding time), with presence and absence of Ni and Ti metal powder. The test was performed on (INNOVA TEST) microhardness tester machine. The specimens which used in these tests sets have configuration shown in Figure 1. Each group of specimens was tested, and 3 values of microhardness were obtained in three different places in spot weld area, as shown in Figure 4, finally, the average was taken.
As in Figure 4 there were three measurements for each specimen were conducted, the average was taken, and each group was tested after the welding process was finished. Another important test was conducted which is shear tensile test for each group of specimens and for each group (3) samples were tested and the average was taken to increase the accuracy of the results. All these tests were done at different welding current and welding time values, with and without presence of Ni and Ti metallic powder.

3. Results And Discussions

3.1. Microhardness Test

It is observed from the microhardness that this characteristic is improved significantly for weld nuggets with the addition of Ni and Ti powders for the same welding time at different welding current values (see Figures 5 and 6, respectively). The same trend was taken by the microhardness values at constant welding current but with different welding time. This is shown in Figures 7 and 8, respectively.

![Figure 5. Effect of welding duration on microhardness values with Ti metal powder](image)

![Figure 6. Effect of welding current on microhardness values with Ni metal powder](image)
Figure 7. Effect of welding current on microhardness values with Ti metal powder

Figure 8. Effect of welding duration on microhardness values with Ni metal powder

Microhardness values increased by increasing weld current values and welding duration values. However, adding nickel and titanium powder improved the microhardness values at a constant welding time and constant welding current due to an additional bond between the SAE 1006 and these powders. See Figures 9, 10, 11, and 12, respectively.

Figure 9. Effect of adding Ni powder on microhardness values at constant welding time
It is evident that microhardness values increased when titanium powder was added more than nickel. Titanium powder has higher resistivity than nickel (see Figures 13 and 14) at constant welding current and time, respectively. This shows an increase in electrical resistance between faying surfaces. In turn, it increases heat energy generated and improves weld strength.
3.2. Shear Tensile Test

Tensile testing is one of the main and important tests to understand the mechanical behavior of metals. Several groups of samples were examined with different conditions (welding current, welding time) all of these conditions were done with adding Ti and Ni metal powders, and each group consisted of three samples. Five groups were tested with different welding current values with constant welding time, the results of these groups of test shown in Table (3) and (4) for Ni and Ti powders respectively, it's clear that this trend confirm the results of the microhardness test, through any increase in the value of the welding current leads to an increase in the maximum shear tensile load value before failure.

Table 3. Effect of welding current on maximum shear tensile strength with Ni powder

| No. | Welding current (A) | Welding time (cycle) | Adding Ni powder | Max. shear tensile load (KN) |
|-----|---------------------|----------------------|------------------|-----------------------------|
| 1   | 6500                | 25                   | Yes              | 2.422                       |
| 2   | 7000                | 25                   | Yes              | 2.533                       |
| 3   | 7500                | 25                   | Yes              | 2.541                       |
| 4   | 7750                | 25                   | Yes              | 2.698                       |
| 5   | 8117                | 25                   | Yes              | 2.842                       |
Table 4. Effect of welding current on maximum shear tensile strength with Ti powder

| No. | Welding current (A) | Welding time (cycle) | Adding Ti powder | Max. shear tensile load (KN) |
|-----|---------------------|----------------------|------------------|-----------------------------|
| 1   | 6500                | 25                   | Yes              | 2.770                       |
| 2   | 7000                | 25                   | Yes              | 2.776                       |
| 3   | 7500                | 25                   | Yes              | 2.821                       |
| 4   | 7750                | 25                   | Yes              | 3.620                       |
| 5   | 8117                | 25                   | Yes              | 3.947                       |

Another addition for Ni and Ti powders was done with five groups of samples. It was tested with constant welding current and different values for welding time because welding time was regarded as the second most important factor after welding current. Results of these tests are shown in Figures 15 and 16 for Ni metal powder and Ti metal powder, respectively.

**Figure 15.** Effect of welding time changing at constant welding current on maximum shear tensile strength with Ni powder

**Figure 16.** Effect of welding time changing at constant welding current on maximum shear tensile strength with Ti powder

The results of the shear tensile test for the samples were compared when welding time was constant and welding current value was changed by the presence and absence of Ni and Ti powders. This showed the effect of adding the powders on the maximum shear tensile load values. See Figures 17 and 18.
A comparison between the results of the shear tensile test of the samples at the addition of Ni and Ti showed that the ultimate shear tensile load values in the case of Ti is higher for all current values at the same time and for all welding time values at the same welding current than the maximum tensile load values in the case of nickel. This is graphically represented in Figures 19 and 20, respectively. This confirms the results of the microhardness test.

**Figure 17.** Effect of adding Ni powder on maximum shear tensile load

**Figure 18.** Effect of adding Ti powder on maximum shear tensile load

**Figure 19.** Comparison between the maximum shear tensile load values for Ni and Ti metal powder addition at constant welding time
Figure 20. Comparison between maximum shear tensile load values for Ni and Ti metal powder addition at constant welding current

4. Conclusions
Based on this experimental work, the following facts can be drawn:
1. The increase in welding current creates higher maximum tensile force and higher microhardness values (e.g., higher strength).
2. When welding with enough time, the ultimate tensile force and microhardness also increase (e.g., increases strength of the spot-welding area).
3. Adding Ni powder to the spot-welding area enhances the mechanical properties of the nuggets.
4. Adding Ti powder to the spot-welding area increases microhardness and maximum shear tensile load of the welds.
5. The effect of Ti is more active than Ni powder on the mechanical features of the welds.

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