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EXPERIMENTAL ANALYSIS OF RESISTANCE SPOT WELDING PARAMETERS FOR LOW CARBON STEEL SHEET

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Abstract: Resistance Spot Welding (RSW) is one of the most efficient fusion welding processes which known as a thermo – electric process used in joining metal by a combination of adjustable parameters (heat, pressure and time), it is high speed, flexible and highly productive process. It is extensively used for many industrial purposes in particular in the automotive industry. The aim of the present work is to study the effect of welding nugget area on the tensile strength of the resistance spot welded joints, the present discussion deals with effect of the parameters of resistance spot welding process (current, time, electrode force) on nugget formation and on failure load of the spot weld joints (the relation between nugget size and strength with input parameters). The test material of the specimens which used in this study is low carbon steel. The mechanical performance (peak load, failure mode) of the welded joints was determined by tensile testing, the testing results were analyzed which were obvious the effectiveness and the necessaries of the suitable or proper welding parameters for the strength of the spot weld joints.

Keywords: *Resistance spot welding, Nugget, Welding parameters, Tensile strength.*

التحليل العملي لتأثير عوامل لحام المقاومة النقطي على ألواح الصلب المنخفض الكاربون

الخلاصة: ان لحام المقاومة النقطي عملية كهروحرارية ويعتبر أحد عمليات اللحام الاكثر كفاءة انصهار تستخدم لربط المعدن لاغراض تصنيعية وانتاجية وخصوصا في صناعة السيارات لمرونتها وسرعتها وانتاجيتها العالية وبتوظيف توليفة مناسبة لعوامل اللحام الرئيسية (التيار،الزمن،الضغط. يهدف البحث الى دراسة وتقييم تأثير مساحة او قطر عقدة اللحام (Nugget) على مقاومتها من خلال تقييم الاداء الميكانيكي للوصلات الملحومة بدراسة تأثير عوامل اللحام(التيار،الزمن،الضغط) على تكوين عقدة لحام الربط وانعكاس ذلك على المقاومة وقيمهامن خلال تحليل نتائج اختبار الشد الذي اجري على نماذج ألواح بسمك(1 مليميتر) من الصلب المنخفض الكاربون(low carbon steel) والتي تم لحامها او ربطها بهذا النوع من اللحام..

1. Introduction

Resistance Spot Welding (RSW) is among the oldest of the electric welding method that used in the industry and it is useful and accepted method in joining metal [1], which not used flux, and is very rare to use filler metal with it [2]. The actual time of welding in this process is a small fraction of second and this makes it a high speed [3], the time periods of mostly resistance spot welds processes is very short , which procedures may be based on a 60 cycles time (1 second = 60 cycles)[4].

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It is one of the most efficient and cleanest welding processes and has widely used in sheet metal fabrication [3], with different thickness such as very thin foils or thick sections but is rarely used above 6mm thickness. It has used in a wide range of the assembly of sheet metal steel vehicle bodies [5]. This process has important using in mass production of automotive, metal furniture and appliances. The large number of spot welds which are required for an automotive body is necessary to bear the various loadings that will be subjected to the automotive [6], so this process is very important and has excellent role in the automotive industry by joining process [7].

Furthermore, resistance spot welding is useful in metal-to-metal connections by joining wire-to-wire in the electronic industry [2]. It can be used instead of screws, rivets, soldering and brazing, the internal forming of the actual weld nugget with relation to the surface of the base metal makes it unique process [8]. Dissimilar metals are widely used in sheet metal fabrication, especially in automotive and aircraft, mainly due to corrosive resistivity and it is economical as compared to the one made by stainless steel only. When welding dissimilar metals there are several problems arise. These are mainly related to the different physical, chemical and mechanical properties of welded material, with the increasing usage of various types of dissimilar metals joints in automobile and aircraft industries; research on resistance spot weld-ability of dissimilar metal attracts more and more attention [9].

The durability and safety design of the vehicles depend on the strength and quality of the spot welds. The development of the new materials and the lack of experience in combinations of them often results in the use of the spot welding parameters [7].

Spot welding can be used on a variety of materials such as magnesium, nickel, aluminum, copper, low carbon steel and austenitic stainless steel [9], in the field of automobiles, cabinets, furniture and similar products, the process is used on wide side to join low and mild carbon steel sheet metal components [8], so low and mild carbon steel compose large percentage of materials can be welded with this process. With suitable or proper use of equipment and procedures, all low-carbon steels are readily weld able with the process [2], due to its thermal and electrical properties which have lower thermal conductivity than the electrode that made from copper and higher electrical resistance , (the carbon present in the material may affect the properties of material after the welding; the joint may become hard and brittle) [1], also Stainless steel, aluminum and copper alloys are spot welded commercially [8], the resistance welding of aluminum is more difficult than steel because of the characteristics of aluminum [10], and because of their weld ability characteristics carbon steels and stainless steels are more frequently welded joints than any other materials [11]. In general, the application of the resistance welding process variables depends on the physical metallurgy of the materials to be welded [12].

The effect of the three main parameters which control the quality of resistance spot welding are, Welding Current, Weld Time, and Welding Pressure. The welding cycle are shown in figure (1).

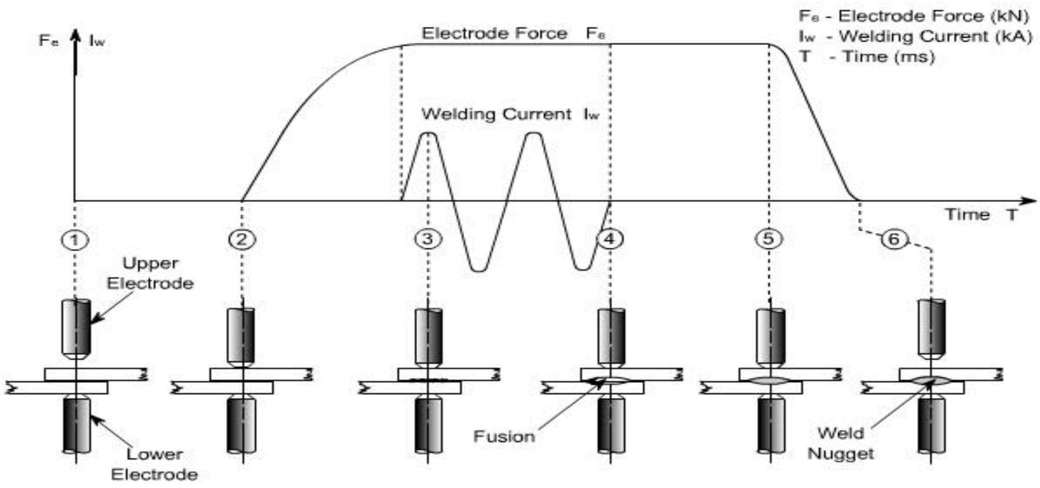

Figure 1: Resistance spot welding cycle [13]

Resistance spot welding is normally automatic operation , therefore, all its parameters are pre-set and maintained constant [2].Variations parameters will affect the mechanical performance of the weld joints, therefore suitable combination of these parameters is required to achieve a spot weld with the desired weld characteristics (nugget diameter, tensile shear strength and indentation) [14].Studying the weld ability depends on mechanical testing ; such testing is either for revealing weld nugget diameter or weld button size, or for obtaining and evaluating the weld's strength [15].

2. Experimental Work

The test material used to be weld in this work as a base-metal is low carbon steel sheet metal due to its good weldability (carbon steel is quite weldable at carbon content below 0.35% [16]) . A (60) pieces from the base-metal sheet with (1.0 mm) thickness were cut into equal dimensions (155 mmx 25 mm) and all the surfaces of them were polished and cleaned by sand paper and grinding and appropriate alcohol before welding operation which involved joining each two pieces with contact overlap (45mm) as shown in figure (2). The prepared samples were divided in two groups each one (30) piece to get (15) pair after welding process which were accomplished by changing welding current and welding time during it. The first group was welded with variable welding current (with a current interval of 0.5KA) &constant welding time (constant, pressure). The second group was welded with constant welding current & variable welding time (variable pressure). Welds were carried out on pedestal-type pneumatically operated 50/ 60 Hz single phase AC spot welding machine, which is insulated in welding work shop at mechanical department/Al-mustansiriya Engineering as shown in figure (3). Size of electrode diameter according to the following equation which generally used for low carbon steel and applicable for it and may not correct for other material:

$$\text{Electrode tip diameter} = 0.100'' + 2t$$

Where "t" is the thickness (in inches) of one thickness of the welded metal,[4]**.** One general criterion of resistance spot welding, diameter of the electrode contact surface should be slightly larger than the nugget diameter [1], the electrode which used in experimental work with diameter (d) of (6.5 mm) and outer diameter (D) of (13 mm).

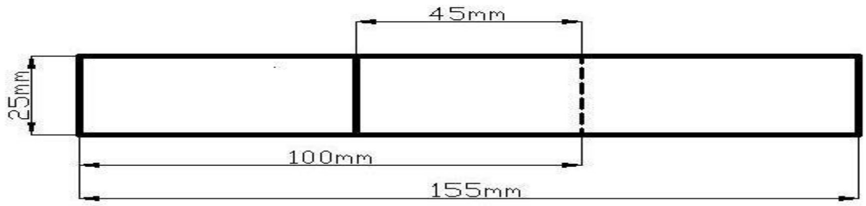

Figure 2: Dimensions of specimen

Figure 3: Pedestal-type spot welding machine

Spot welding was done on the samples with a current in a range of (7.0 to 10.0 KA) with a current interval of (0.5 KA), and with welding time in a range of (5 to 25 cycles), only (18) pairs of samples were succeed welding (10 pairs first group & 8 pairs second group) without any visible defects**,** and the other pairs failed in welding because expulsion occurred with them due to high current and long time.

Spot welding performance and quality depend on nugget size and strength of weld joint, so the experimental work focused on the investigation of resistance spot welding parametric changes on tensile strength of the welded joint with consideration to its nugget formation, and this need to study the mechanical performance of welded joints by tensile testing ,the succeed weld pairs (18 pairs) of welded samples were developed for tensile tests to evaluate the mechanical performance and failure mode of them**,** the tests were done by a standard tensile testing machine ,figure (4) shows a tensile tested sample, figure (5) and figure (6) each one shows one sample sheet graph tensile test of welded joint for each pairs groups.

Figure 4: Tensile tested sample.

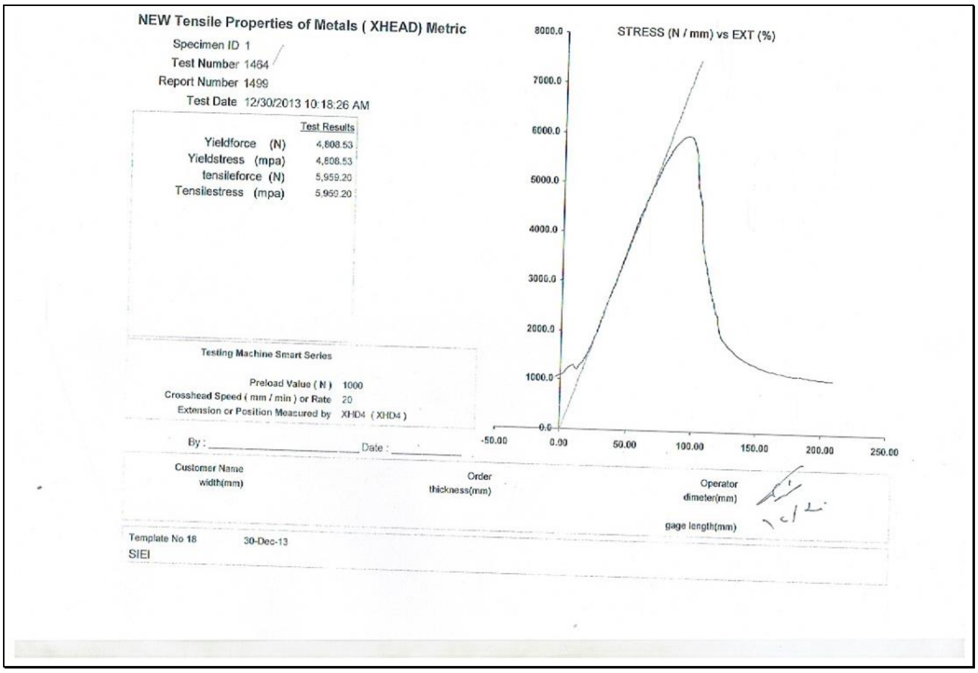

Figure 5: Tensile test for first group of the samples.

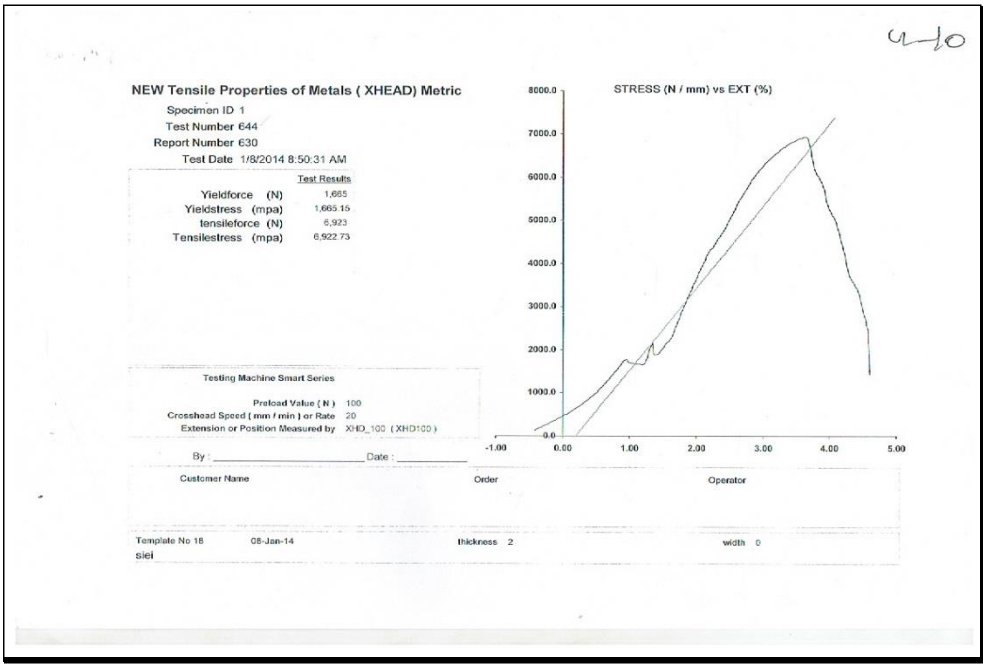

Figure 6: Tensile test for second group of the samples.

3. Results and Discussion

The graph sheets of tensile tests of the samples that be jointed of the two groups were analyzed and the results recorded in table (1) and table (2) as shown which remarking to the most variable; ultimate stress (peak load with maximum extension), fracture stress and the nugget diameter, these results can be used to evaluate the mechanical performance of the welded joints.

Table 1: The results of tensile tests for first group of spot welding samples

Test number	Yield stress (N/mm^2)	Ultimate stress (N/mm^2)	Fracture stress (N/mm^2)	Elongation (%)	0.2% offset stress	Area of welding Nugget (mm^2)
1457	1650	5510	1110	32.56	40	10
1459	1700	5600	1110	25.5	32	12
1460	2000	5700	900.1	50.25	24	15
1462	3000	5750	970	50.76	28	16
1461	3020	5760	1010	51.81	18	17
1466	3500	5750	980	100	24	18
1463	4500	5900	1100	94.3	28	25
1465	5500	5950	1010	96.1	32	35

Table 2: The results of tensile tests for second group of spot welding samples

Test number	Yield stress (N/mm^2)	Ultimate stress (N/mm^2)	Fracture stress (N/mm^2)	Elongation (%)	0.2% offset stress	Area of welding Nugget (mm^2)
637	290	810	200	1	1.6	2
638	576	940	250	2	0.6	4
639	650	1200	270	3	1	5
640	700	1300	300	4	0 .9	6
641	750	1750	305	5	1	8
642	770	1800	310	6	2	10
643	800	1850	320	7	1.6	12
644	850	2150	350	8	1	14

The nugget diameter is the main variable which increase with increasing in welding current and welding time and this caused increase in the tensile strength of the weld samples ,the required nugget diameter was obtained at welding currents greater than (8 KA) ,also the results indicated increasing in the strength at weld current greater than (8KA) and the maximum value was obtained at a current of (9 KA), but the nugget diameter was decreased slightly at a current of (9.5 KA) because the expulsion occurred at the faying surface, and with this decreasing ,the tensile strength was decreased due to decreasing the strength in the bonds in sample joints.

Similar results were obtained with weld time but the results indicated that weld current Caused more weld indentation and produced larger nugget size and more values of the strength (ultimate stress) of joints compared with welt time which produced small nugget areas and this means that with increased weld time slightly increased the nugget diameter, the figures (7 and 8) shows the relationship between nugget area and stress under tensile test for the two groups of sample joints.

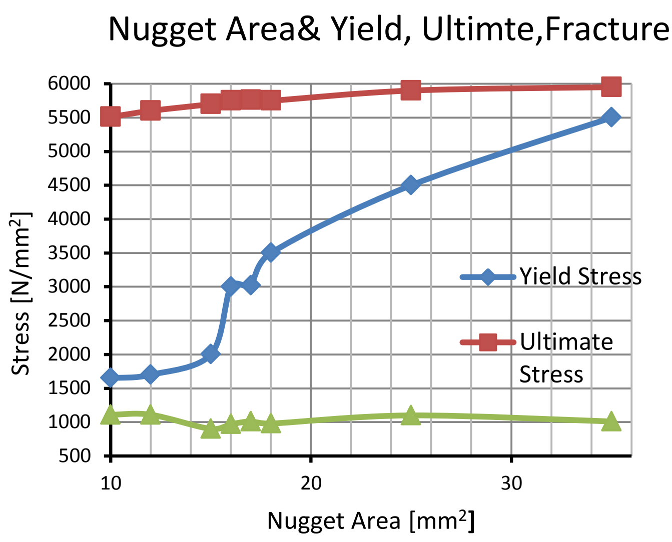

Figure 7: Relationship between Nugget area and stress under tensile test for first group samples

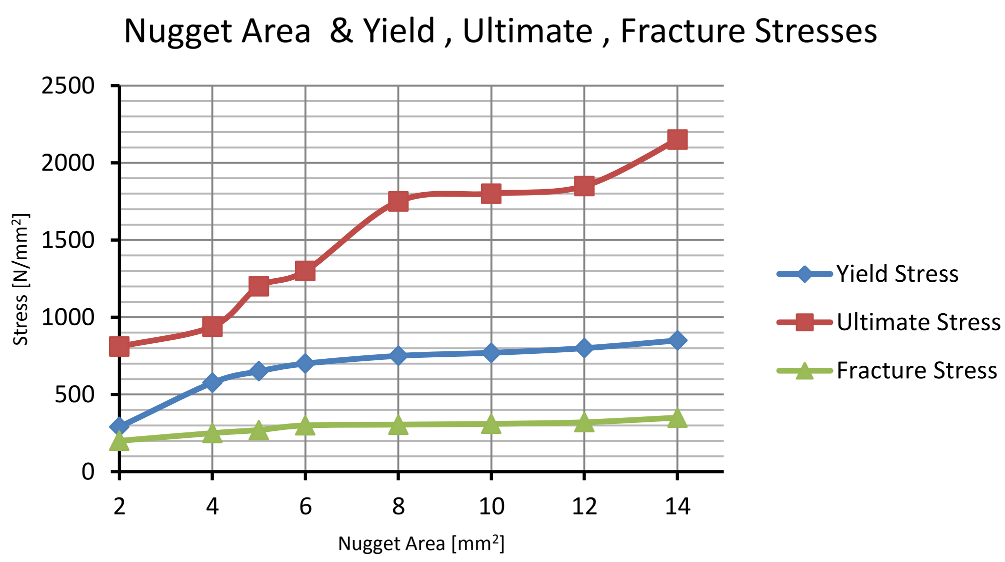

Figure 8: Relationship between Nugget area and stress of spot welding under tensile test for second group samples considering the effect of applying force.

4. Conclusions

In this study, the present experimental investigation on the influence of the parameters of welding (time, current and pressure force) in resistance spot welding process on nugget diameter and strength of welded joints which were performed on(1.0 mm thick) low carbon steel sheet metal and analyzed their mechanical performance by tensile testing indicates the following:

1. The quality and performance of spot welds determine by weld nugget size and joint strength which they increase proportionally.
2. Resistance spot welding parameters (current, time, pressure force) are significantly effect on nugget diameter and strength of weld joint, if one of welding parameters increases the weld nugget diameter increases and this causes an increase in the strength of weld joint, therefore the suitable combination of welding parameters is needed to get higher require strength of weld joint.
3. Analyzing tensile strength testes indicates that increasing any one of welding parameters will increase the failure load joints with consideration that welding current is greatly effective parameter on require strength of weld joint more than the other parameters.
4. Uncontrolled the weld parameters (high welding current, longer welding time) will great electrode indentation and excessive heat generation and expulsion occurred and this causes decreasing in the strength of weld joint.

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