

Developing Pneumatic Control for a Manual Electrical Resistance Spot Welding Machine

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Abstract: In this research; manual electrical resistance spot welding machine which is used in manufacturing of agricultural machineries fit to automation by revised. Pneumatic cylinder and valve were used in the modification process from mechanical control to automation. System can be adjusted for a determined welding pressure and time. St37 sheet iron in 2 mm thickness were connected under the condition of 6 bar pressure, 4 sec. welding period and 8 kVA apparent power established by electrode in modified welding machine. Second test was realized by an experienced welder for same test conditions. Both for research applications, the tensile-shear and peel resistance tests applied on the weld zone and the tests results compared.

According to the results; it is determined that the modified welding machine worked well for adjusted conditions. There are no big differences for measured tensile strength and tensile peel resistance because applied current, voltage, and pressure were constant during the welding in the tests. Relationships between welding methods and tensile shear and tensile peel resistance was found significant

Key words: Electric resistance spot welding machine, pneumatic, welding area, tensile peel test, pressure

Manüel Kontrollü Elektrik Direnç Nokta Kaynak Makinesinde Pnömatik Kontrolün Geliştirilmesi

Özet: Bu çalışmada; tarım makineleri imalatında kullanılan, manüel kontrollü elektrik direnç nokta kaynak makinesi, yeniden revize edilerek otomasyona uygun hale getirilmiştir. Sistemin dönüştürülmesinde pnömatik devre elemanlarından yararlanılmıştır. Sistemde istenilen basınç ve kaynak periyodu ayarlanabilmektedir. Revize edilen makine ile 2 mm kalınlığındaki St37 sac malzemeden hazırlanan test parçaları, 6 bar basınçta, 4 sn'lik kaynak periyodunda ve 8 kVA görünür güç uygulanarak birleştirilmiştir. İkinci uygulamada ise aynı özelliklerdeki test parçaları tecrübeli bir kaynak teknisyeni tarafından manüel olarak birleştirilmiştir. Araştırmada her iki uygulama için, kaynak bölgesine çekme-makaslama testleri ve soyulma direnci testleri yapılarak karşılaştırılmıştır.

Sonuçlar incelendiğinde makinenin istenilen şekilde çalıştığı saptanmıştır. Sistem de uygulanan akım, gerilim ve kaynak basıncı sabit tutulduğu için gerçekleştirilen birleştirmelerde ölçülen çekme-makaslama ve çekme-soyulma dirençlerinde büyük farklılıklar ölçülmemiştir. Kaynak yöntemi, çekme-makaslama ve çekme-soyulma dirençleri arasındaki ilişki önemli bulunmuştur.

Anahtar kelimeler: Elektrik direnç nokta kaynağı, pnömatik, kaynak bölgesi, çekme-soyulma testi, basınç

INTRODUCTION

The most widespread method in manufacturing constructions is welding. Regarding the type of process, welding methods diverge into two: fusion welding and pressure welding. Among the pressure

welding methods, the most commonly used one in the automotive sector is electric resistance spot welding machine. Its principle is fusing the heat caused by the resistance of work-pieces against the current passing

through those sheets, which are held together under pressure by electrodes (Anik, 1983, 1991; Anonymous, 1990a; Anik et al., 1999).

Electric resistance spot welding, which is used in most sheet iron applications in manufacturing of agricultural machinery, is getting more and more common in serial production and robotic applications.

It is particularly important to provide with the ideal welding conditions for combining non-corrosion stainless steel and galvanized sheet iron. Therefore, controllable welding pressure and welding time is getting more significant.

Electric resistance spot welding is generally used to join metal sheets of the same composition and gravity. In addition, it can be used to join more than two metal sheets, metal sheets of different composition and gravity or sheets of iron which are coated with other metals. Combined pieces of pressed components, which do not require gas or water tightness, can be joined economically at a high production speed by the electric resistance spot welding. Its biggest advantages are its high speed, adjustability to automation and its usability in high capacity manufacturing lines. Controlled current, time and electrode strength might help to obtain everlasting and identical spot welding in high speed manufacturing (Gould ve Chang, 1986).

Electric resistance welding stands for joining two metal sheets by melting them through much heat resulting from the sheet resistance against pressure and high current at low voltage, which is applied by electrodes on the welding metal. In application, electrodes exert pressure to the sheets at a constant rate (Figure 1).

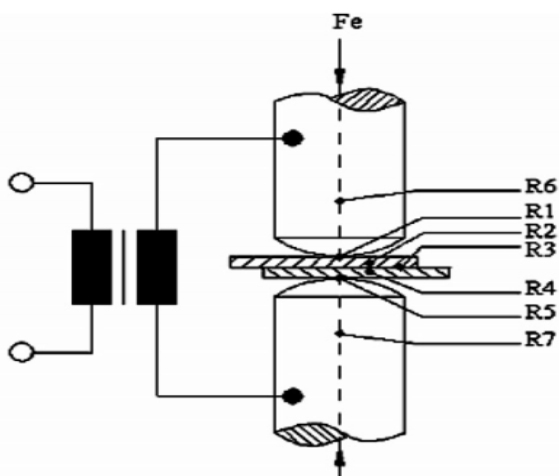


Figure 1. The principle of electric resistance spot welding (Anonymous, 1990b)

According to the Joule law, J unit heat comes out as I current passes through R ohmic resistance at t time.

$$Q = I^2 R t \quad (1)$$

Here;

$$R = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7 \quad (2)$$

that means, it is total resistance in secondary cycle. This resistance is seen in Figure 1.

Materials resistance

Fe = Electrode Force

R1 = Upper Specimen Resistance

R2 = Upper Specimen - Upper Electrode contact Resistance

R3 = Upper Specimen - Bottom Specimen contact Resistance

R4 = Bottom Specimen Resistance

R5 = Bottom Specimen - Bottom Electrode contact Resistance

R6 = Upper Electrode Resistance

R7 = Bottom Electrode Resistance

Material resistance results from the physical properties of the material, but it isn't variable. Contact resistances however, change depending on positions of the poles of the material and the electrodes.

During welding, R3 is selected as the resistance at which the greatest heat will come out. Less warming is recommended at other resistances. This is obtained by selecting I_k welding current, t_k welding time and Fe electrode strength. R1, R3, R5 contact resistances affect quality of connection (Eryurek, 1976, 1983; Lheureux and Belotte, 1965). Temperature in R3 welding area surpasses the melting temperature of the material. The material liquefying here forms the welding core after welding.

Warming in R1 and R5 contact areas should be smaller. This is provided by good thermal conductive electrode and material surfaces. There mustn't be any poor thermal conductive surface layers such as rust, oil and paint. Contact resistances cause heat amounts of varying degrees and differing connection strength properties (Fritz and Schulze, 1991).

The most significant factors influencing formation of heat at welding area are electrical resistance of the material, its contact resistance, pressure, gravity of

the sheet, welding time, voltage and current strength (Cimen and Akkus, 1999).

In this study, mechanical electric resistance spot welding machine, which is mostly preferred by small-scale businesses, has been revised and transformed into a pneumatic system of controllable electrode strength (pressure) and welding time.

MATERIAL and METHOD

Material

This study has utilised the electrical resistance spot welding machine of Baykal trademark at the Machinery Workshop of Namik Kemal University Vocational School of Technical Sciences. This manually controlled machine has been adapted for automation by being integrated to a designed pneumatic system. Technical specifications of this machine are stated in Table 1.

Table 1. Technical specifications of electric resistance spot welding machine

MODEL		NPA 10
%50 productive welding power	kVA	10
Level number	n	5
Open circuit voltage	V	2,5
Welding current	kA	4
Network voltage	V	380
Fuse (retarded)	A	35
Input wire cross area	mm ²	3*4
DIMENSIONS		
Lever length	mm	500
Electrode course	mm	50
Lever diameter	mm	40
Electrode diameter	mm	18

In the pneumatic system, in order to maintain electrode strength and mobility, a double-effect cylinder of 50 mm diameter and 50 mm stroke is used. This cylinder is controlled by 5/2 and 3/2 direction controlling valves. Furthermore, a time retarding valve is used in the system to control the welding time.

Copper electrodes used in welding processes are conic shaped, with 8-mm small diameter, 18-mm large diameter and 10-mm cone length. Chemical specifications of electrodes are shown in Table 2 (Arslan, 1998).

Table 2. Chemical specifications of copper electrode material

Electrode type	Chemical composition	Heat conduction (J/cm ² K)	Electrical conduction (m/Ωmm ²)	Tensile resistance (N/mm ²)
CRM 16 X CuCrZr (ucl)	g.k.Cu %0.40Cr %0.03Zr	320	48	540

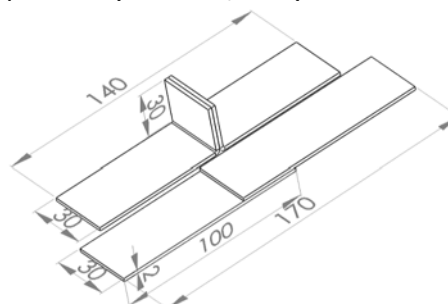
In order to measure the machinery performance, tensile shear and tensile peel tests, which usually check the quality of electric resistance spot welding, have been selected as the testing method.

For welding tests of the modified machine, specimens of 2 mm thickness have been made of Fe37 sheet iron. Current resistance of St37 is 225 N/mm², and its tensile strength is 340 M/mm² (Ozkan et al., 2006). Chemical specifications of St37 material are shown in Table 3. Shapes and dimensions of test elements are seen in Figure 2 (Aslanlar et al., 2005). As seen in the figure, apart from tensile shear, tensile peel sheets are 90° twisted at end points in a 30-cm distance.

Table 3. Chemical specifications of St 37 (Erdemir 3237) material

Material norm	DIN EN St-37						
Material type	C	Mn	P	S	Si	Al	N
Material rate %	0,17	1	0,025	0,025	0,4	0,015	0,009

After being cut by a guillotine shears in identified measures as in Figure 2, specimens have been cleared off rust, oil and dust by a clean cloth washed in ethyl alcohol (Anik et al., 1999).



**Figure 2. The sizes of specimens
A-Tensile peel specimens, B- Tensile shear specimens
(Dimensions in mm).**

In the study, tensile shear and tensile peel tests have been realized by Shimadzu AGX universal testing device with the capacity of 50 kN. SPSS programme has been used for variance analysis.

Method

The electric resistance spot welding machine has been modified to be working as automatic or semi-automatic by adding required circuit elements drawn in the scheme in Figure 3.

As seen in the same figure, 3/2 direction controlling valve with number 7 is the key initiating welding process. Regarding needs, the valve can be positioned to work automatically by sensing the position of hand, foot or welding sheet.

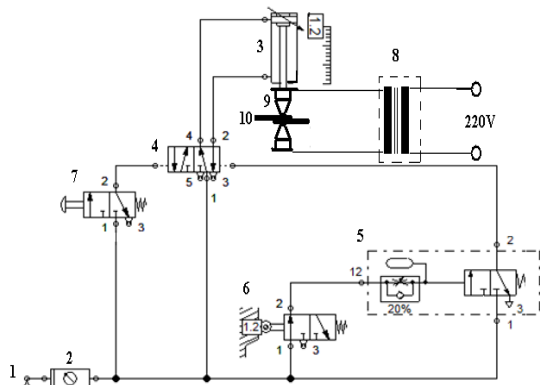


Figure 3. Designed scheme for pneumatic controlled system 1-Compressed air source, 2-Conditioner, 3-Double-effect cylinder, 4-5/2 direction controlling valve, 5-Time retarding valve (normally closed), 6-3/2 Direction controlling valve, 7-3/2 Direction controlling valve, 8-Transformer,9- Copper electrodes, 10- Specimens

The machine used in this research is exhibited in Figure 4.



Figure 4. Electric resistance spot welding machine

After modifying and connecting required element on the machine, electric resistance spot welding of prepared test sheets has been done.

The second step has been manual welding of identical test sheets by an experienced welder technician. During research, tensile shear and tensile peel tests have been done and contrasted for both applications in the welding area.

The machine has worked at 8-kVA apparent power level in machinery-based application. The technician has decided on the applied pressure and welding time.

During technician-based application, Shimadzu AGX universal testing device has also been used to carry out tensile shear and tensile peel tests. Tests have been done at a constant speed of 10 mm/min. and 50 mm/min. Trials have been repeated 10 times and SPSS programme has been used to perform variance analysis.

Tensile shear test:

Fe7 sheet iron test elements of 2 mm thickness have been used for tensile shear test. Spot welding has been done by putting the sheets in 30 mm and applying tensile shear test for them (Figure 5). The machine has worked under 4-bar pressure at 8-kVA apparent power level in 4-second welding time.

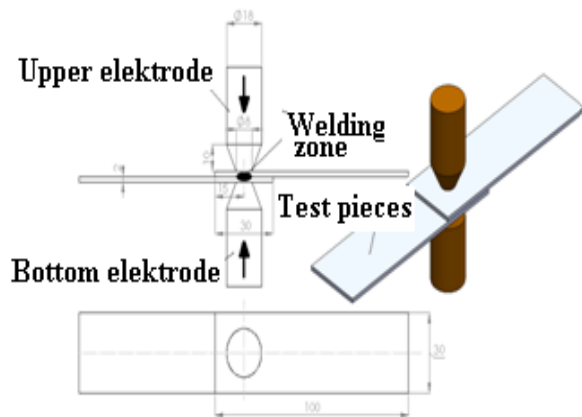


Figure 5. Preparing tensile shear test elements by electric resistance spot welding

Tensile shear tests have been carried out by Shimadzu AGX universal testing device at a constant speed of 10 mm/min (Figure 6). Trials has been repeated 10 times and SPSS programme has been used to perform variance analysis.



Figure 6. Tensile shear test

Tensile peel resistance test:

Fe7 sheet iron test piece of 2 mm thickness have been used for tensile peel resistance test. As seen in Figure 7, test pieces have taken tensile peel test after being exposed to spot welding. During welding, the machine has worked under 4-bar pressure at 8-kVA apparent power level in 4-second welding time.

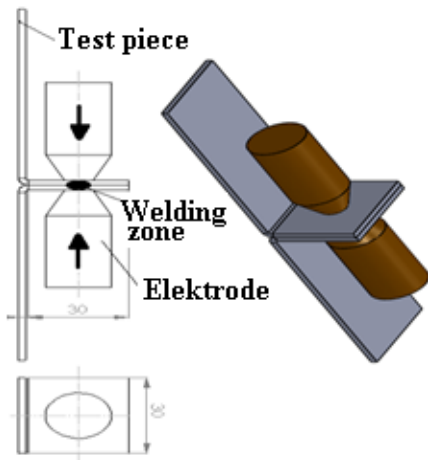


Figure 7. Preparing test elements for tensile peel resistance test

Tensile peel tests have been carried out by Shimadzu AGX universal testing device at a constant speed of 50 mm/min. Trials have been repeated 10 times and SPSS programme has been used to perform variance analysis.

RESULTS and DISCUSSION

Figure 8 displays tensile -% stretching graphics of tensile peel and tensile shear test results of the pairs

welded by the electric resistance spot welding machine. It is observed that in tensile peel test % stretching value is higher than tensile shear test. The difference is due to the shape of tensile peel test elements. During that test, applied tensile power forces the sheets first to expand on their twists. Therefore, an additional stretching is observed until the tensile reaches the welding area. (Figure 9).

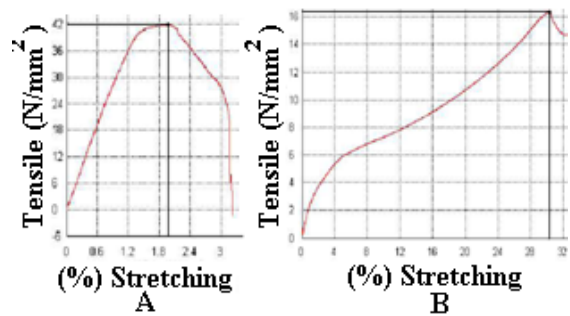


Figure 8. Tensile -% stretching graphics of A-Tensile shear, B-Tensile peel



Figure 9. Formation of % stretching during tensile peel test

Table 4 exhibits tensile shear resistance and tensile peel test results obtained at 6-bar pressure and 8-kVA apparent power level in 4-second welding time as well as the maximum results reached at technician-based applications.

Regarding tensile, welding method is more important in tensile shear tests than in tensile peel tests.

Regarding stretching, welding method is not important in tensile shear tests whereas it seems important in tensile peel tests.

Table 4. Tensile shear resistance and tensile peel test results

		Average	Max.	Min.	SD	F
		Tensile peel test for 90-degree twisted sheet iron				
Tensile strength (N/mm²)	Machinery-based application 6 bars 8 kVA 4 sec.	24,6	32	16	5,9	0,000ns
	Technician-based application	24,5	32	18	5,6	
Stretching (%)	Machinery-based application 6 bars 8 kVA 4 sec.	28,3	34	20	4,9	23,84**
	Technician-based application	20,0	24	17	2,3	
		Tensile shear test for straight sheet iron				
Tensile strength (N/mm²)	Machinery-based application 6 bars 8 kVA 4 sec.	65,5	74	58	6,0	9,25**
	Technician-based application	54,3	67	40	9,9	
Stretching (%)	Machinery-based application 6 bars 8 kVA 4 sec.	1,3	1,6	0,8	0,3	0,38ns
	Technician-based application	1,2	1,5	0,8	0,4	

Eye-controlled examination shows that heat prevalence tracks have closer measures in spot welding by the modified machine in tensile shear test, whereas more variable in spot welding by the technician. Comparing and contrasting two methods, this finding also explains the greater sd obtained in technician-based welding (Figure 10).

Similar examination in tensile peel test displays that technician-based welding has closer measures. Comparing and contrasting two methods, this finding also explains the greater sd obtained in machinery-based welding. (Figure 11).

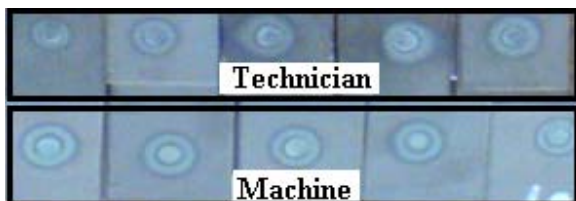


Figure 10. Eye-controlled examination of technician-based and machinery-based spot welding heat prevalence in tensile shear test sheets

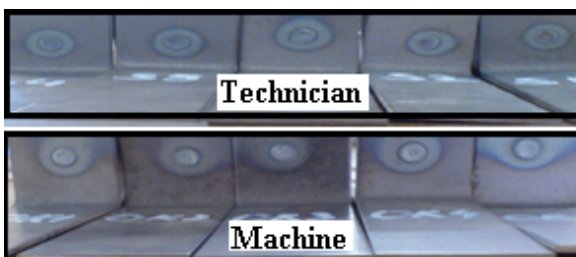


Figure 11. Eye-controlled examination of technician-based and machinery-based spot welding heat prevalence in tensile peel test sheets

Split welding errors in tensile shear and tensile peel tests have been analysed. This analysis shows that splits during tensile shear test have been in the form of branching on the surface of welding core. This reveals that shear resistance of welding core is smaller than the resistance of sheet iron (Figure 12).

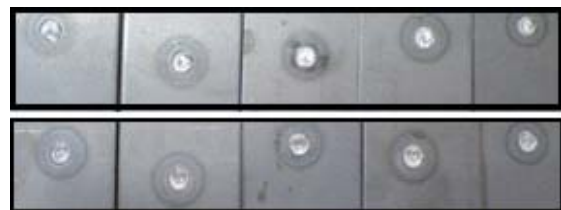


Figure 12. Splitting due to tensile shear test

Eye-controlled examination of tensile peel tests show that welding core (weld nugget) has detached as a whole from the sheet iron hulls (Figure 13).

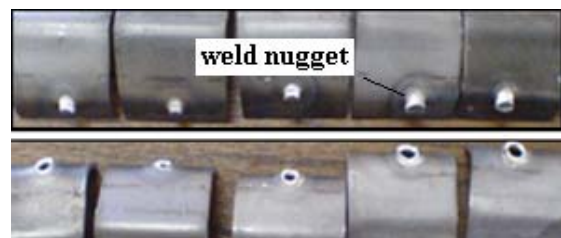


Figure 13. Splitting due to tensile peel test

This indicates that heat interaction area created by welding during peel tests is the weakest area.

CONCLUSION and RECOMMENDATIONS

In conclusion, the mechanical electric resistance spot welding machine which has been modified into a pneumatic machine is seen to reach the targeted performance. Since no study has been done on an ideal welding current strength and welding time, not a very high split resistance has been detected in the spot welding. Regarding its own aim, the machine has

managed to realize as high quality spot welding as a welder technician does. That means, enterprises can initiate such an application in accordance with their needs. After trials, ideal working conditions for the experimented sheet iron and electrode types will be provided. Manufacturers will also be able to transform their current electric resistance spot welding machines to automatic pneumatic machines with low cost.

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