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Department of Metallurgical Engineering

Welding and it's effect on properties of steel plates

This project is submitted to the University of Babylon / College of Materials' Engineering Department of Metallurgical as a part of requirement for bachelor degree in Metallurgical Engineering

Submitted By

Mohammed Kefah

Under The Supervision

Miss. Wafa Mahdi Jodia

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بِسْمِ اللَّـهِ الرَّحْمَـنِ الرَّحِيمِ

((وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ

وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى

عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا

كُنْتُمْ تَعْمَلُونَ))

صَدَقَ اللهُ العَلِيُّ العَظيم

التوبة اية 105

الإهداء

الى بلدي العزيز موطن الانبياء والاوصياء وارض الخير والعطاء
الى الشهداء الابرار.

الى قدوتي الاولى، الى من رفعت رأسي عاليا افتخارا به (ابي العزيز)
اطال الله في عمره.

الى نبع الحنان السامي ، الى من علمتني معنى الحياة (امي الحبيبة)
حفظها الله لنا.

الى زملائي ، اقدم لكم جميعا هذا المشروع المتواضع واسأل الله ان يمن
علينا بالنجاح الدائم والتوفيق.

مع التقدير.......

الشكر والتقدير

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

على الله في كل الامور توكلي......... وبالخمسة اصحاب الكساء توسلي

محـــمدا رســـــــوله وفاطمــة......... وابنيـــــها والمرتضى علــــــي

الحمد لله رب العالمين على النعمة التي مَنَ بها علينا ورزقنا ووفقنا الى مقامنا هذا بعد التوكل على الله لا يسعني الا ان اتقدم بالشكر الجزيل الى اساتذتي الكرام الذين لم يتوانوا عن تقديم العون والعلم لأجل نجاحنا ، وفي مقدمتهم استاذتي الكريمة الفاضلة (أ. وفاء مهدي) التي بذلت كل جهدها من اجل ان تساعدني في مسيرتي العلمية ليس في هذه المرحلة فحسب بل منذ ان بدئنا في هذه الكلية المحترمة فقد غمرتني بكرم اخلاقها ورصانة علمها متمنية لها العمر المديد والعطاء الدائم ، وفي الختام اتمنى ان اكون قد وفقت في اعداد هذا المشروع والحمد لله والصلاة والسلام على سيدنا محمد (ص) واله الطيبين الطاهرين.

ABSTRACT

Resistance welding is the joining of metals by applying pressure current for a length of time through the area which is to be joined. The key advantage of resistance welding is that no other materials are needed to create the bond, which makes this process extremely cost effective. Spot welding is a process of sustainable metal joining which is significantly important in automotive, aerospace, nuclear and electronics industries. This project studies the effect of some parameters like (welding current, welding cycle time and thickness) on the welding joint strength of three types thickness(1, 2, 3)mm of low carbon steel plates. Lapping joint are used to weld two similar plates using the spot welding machine type DN – 25 spot welder. The welding current are (4000, 5000, 6000 and 7000) Amp. and the welding cycle time are(0.6, 0.8, 1, 1.2)s. After welding is done, the samples are subjected to the tensile test on universal testing machine. The resultants show that by increase welding cycle time and welding current the welding strength increase in three types of thickness. Some values increase and decrease at high welding current and welding cycle time. The effect of welding current on strength joint is more than welding cycle time. At 7000amp and 0.6s of welding parameters gives the good improvement in welding joint strength for all three types of low carbon steel thickness. The results were tabulated and the diagrams were drown.

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Chapter One

Introduction Part

Chapter One

"Introduction"

1.1. Introduction.

Resistance welding operations are the mostly used process in joining steel sheets[1].In order to find spot welding conditions in production operations, many experiment investigations have to be performed, because the resistance spot welding process is a combination of three physical fields which are the mechanical field, the electric field, and the thermal field [2].

Spot welding electrodes are made of materials which have high electrical, thermal resistivity, and the strength to withstand high pressure at high temperatures, and it is important to make the electrodes with proper shape, and the current density is depending on the contact area between the welding electrodes and the welded parts [3].

Resistance spot welding (RSW) is an inexpensive and effective way to join metal sheets [4]. RSW is a widely used joining process for fabricating sheet metal assemblies such as automobiles, truck cabins, rail vehicles, and home applications due to its advantages in welding efficiency and suitability for automation [5]. Like any other welding process, the quality of the joint in RSW is directly influenced by welding input parameters. A common problem faced by manufacturer is the control of the process input parameters to obtain a well welded joint with required strength. Therefore the tensile strength and tensile-peel strength of the joint in RSW is an important index to welding quality [6].

The principle used in spot welding generated of heat by the passage of welding current through a point of locally high electrical resistance created by pressure from the electrode [7].

Resistance spot welding (RSW) is the most important technique joining automobile sheets. RSW is a widely used welding technique in automobile industry. At the present time, RSW is the most used joining method in new generation vehicles. In addition, RSW is suitable for automation and is a fabrication method in automobile manufacturing [8–9].

Global demand for energy saving and increasing concern for environmental pollution and global warming affect the scientific community and relevant studies are on the rise. The improvement of strength, capacity and properties of materials, most importantly metals, reduces material cross section, the reduction of part weight and the resultant decrease in fuel consumption, has made possible to reduce greenhouse gas emissions. For various functional requirements of current vehicles, advanced high strength steel is the ideal solution [10]. One of the most important and most valuable properties of advanced strength steels is the excellent strength-ductility relationship.

Due to strict energy-efficiency regulations aimed at reducing exhaust emissions, researchers are making an effort to reduce vehicle weights to enhance vehicle fuel efficiency. Innovative high-strength steels are frequently used to both reduce the vehicle weight and to improve passenger safety[11,12].

RSW is the major joining technique utilized for automobile production and manufacturing. A common automotive body consists of a broad number of RSW, between 3000 and 5000 spots [13]. During RSW, broad changes in the mechanical and metallurgical properties of the weld metal and the heat affected zone (HAZ) are taking place. The investigation of these changes is important and relevant for the safety, protection and strength of the welded joints [14].

Chapter Two

Theoretical Part

Chapter Two

"Theoretical Part"

2.1. Introduction.

Welding is a metal joining process which produces coalescence of metals by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material. Basically, welding is used for making permanent joints. It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

Joints of two or more parts used in practice are usually divided into removable and rigid ones. Removable joints, made e.g. using screws, washers and nuts, we can repeatedly dismantle and assemble without damage of above mentioned parts. On the contrary, rigid joints are permanent. They can be "dismantled" (effect of strength or heat), but at the cost of their irreversible damage (destruction). It is a case of joints made by riveting, adhesive bonding of metallic and non-metallic materials**.**

2.2. Resistance Welding.

Resistance welding is a group of thermo-electric processes in which coalescence is produced by the heat obtained from resistance of the work to electric current in a circuit of which the work is a part and by the application of pressure.

The electric resistance welding is commonly used. It can be applied to any metals. Electric current passes through the materials being joined. The resistance offered to the flow of current results in raising the temperature of the two metal pieces to melting point at their junction. Mechanical pressure is applied at this moment to complete the weld. Two copper electrodes of low resistance are used in a circuit. The mechanical pressure or force required after the surfaces are heated to a plastic temperature is approximately 0.3 N/m2 at the welded surface. This method of welding is widely used in modern practice for making welded joints in sheet metal parts, bars and tubes etc.

2.3. Parameter Affecting Resistance Welding.

Successful application of Resistance welding process depends upon correct application and proper control of the following factors.

1. Current: Enough current is needed to bring the metal to its plastic state of welding.

2. Pressure: Mechanical pressure is applied first to hold the metal pieces tightly between the electrodes, while the current flows through them called **weld pressure**, and secondly when the metal has been heated to its plastic state, to forge the metal pieces together to form the weld, called **forge pressure**.

3. Time of Application: It is the cyclic time and the sum total of the following time period allowed during different stages of welding

a. Weld Time. Time period during which the welding current flow through the metal pieces to raise their temp.

b. Forge Time. Time period during which the forge pressure is applied to the metal pieces.

c. Hold Time. Time period during which the weld to be solidify.

d. Off Time. The period of time from the release of the electrodes to the start of the next weld cycle.

4. Electrode contact area: The weld size depends on the contact area of the face of the electrodes.

2.4. Types of Resistance welding.

1. Spot welding
2. Butt welding
3. Flash welding
4. Seam welding
5. Projection welding

2.4.1. Seam Welding.

The metallic plates are held by two copper roller electrodes with one roller driven by motor so that the plates are moved between the rollers at a suitable speed. The high current is passed between the electrodes holding metallic plates pressed together with suitable force and pushes together to travel between the revolving electrodes as showing in Fig. 1.

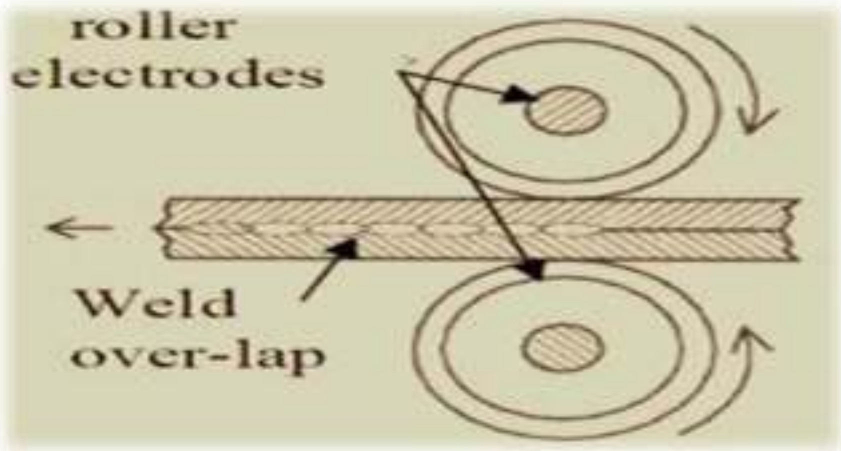


Fig. 1. Seam Resistance Welding

2.4.2. Butt Welding (Upset Welding).

The pieces to be welded are held edge to edge in copper clamps. The ends are brought together under a light pressure. A heavy welding current is switched on. The resistance between the contacting faces causes a rise in temperature to the fusion point. A further mechanical pressure is applied to obtain a welded joint. The current is switched off. This process is mainly used on non-ferrous materials for joining bars, rods, wires, tubing, etc. Fig 2.

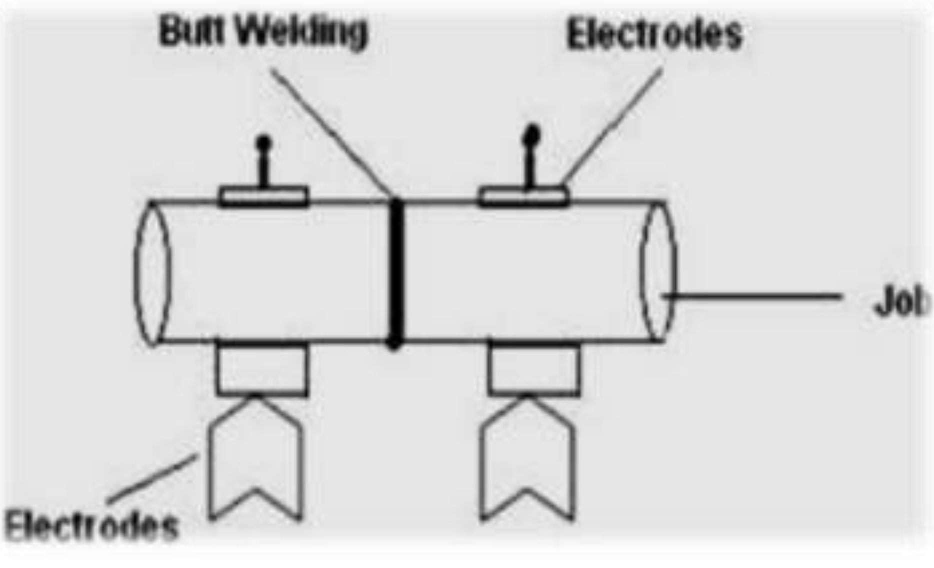


Fig. 2. Butt Resistance Welding

2.4.3. *Flash Welding.*

The current is switched on and the ends of the work pieces to be welded are slowly brought closer. An arc is produced between the contacting faces of the work pieces and intense heat is generated.

The faces are brought rapidly together under high pressure (350 to 1650 kg/cm2). The current is then switched off and the weld is forged, as shown in Fig. 3.

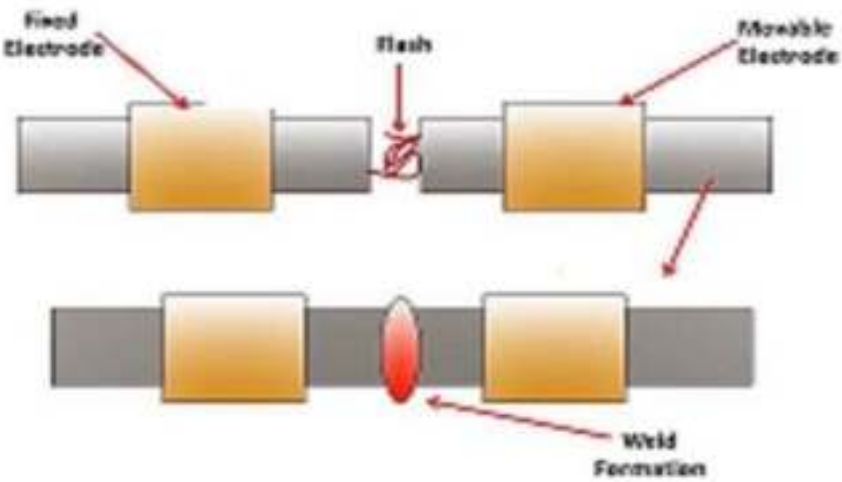


Fig. 3. Flash Welding

2.4.4. *Projection Welding.*

There are raised projections in the work piece at all points where a weld is desired as shown in Fig. 4. As the current is switched on the projection are melted and the work pieces pressed together to complete the weld. The melted projections form the welds. This method enables production of several spot welds simultaneously.

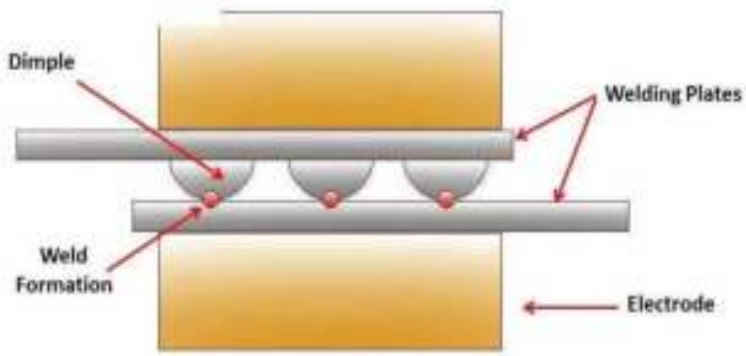


Fig. 4. Projection Welding

2.4.5. *Resistance Spot Welding.*

Spot welding is a process of sustainable metal joining which is significantly important in automotive, aerospace, nuclear and electronics industries. The principle used in spot welding generated of heat by the passage of welding current through a point of locally high electrical resistance created by pressure from the electrode. Fig 5.

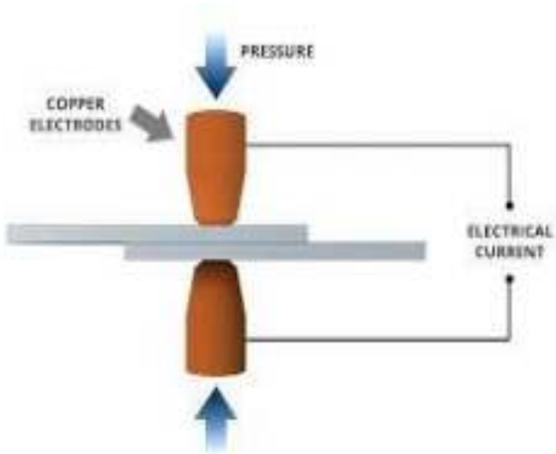


Fig. 5. Resistance Spot Welding

2.5. *History of Resistance Spot Welding.*

RSW is considered to be invented in the 1880s by Elihu Thomson, when he discovered the principle of joining metals by melting through resistance heating. The RSW processes in use today are based on the same basic principle.

Today, the main application of RSW is in the automotive industry. However, in Other products such as in the aerospace industry, appliances, furniture and small scale circuit elements are joined using RSW.

2.6. *Physical Phenomena in Resistance Spot Welding.*

As the current is passing through the sheets, the resistances of the circuit cause generation of heat energy. The heat energy (Q) is a function of the current (I), resistance (R) and time (t) as defined by Joule's law, according to equation **1** below.

$$Q=I^2 R t$$

The heat generation rises the temperature of the materials above the melting point mainly due to surface resistances between the sheets. After the metal sheets have molten the current is stopped and no further heat is generated. The temperature will decrease again and the joined sheets form a solid nugget, joining the sheets. The outline of the spot welding process is illustrated in Figure 6.

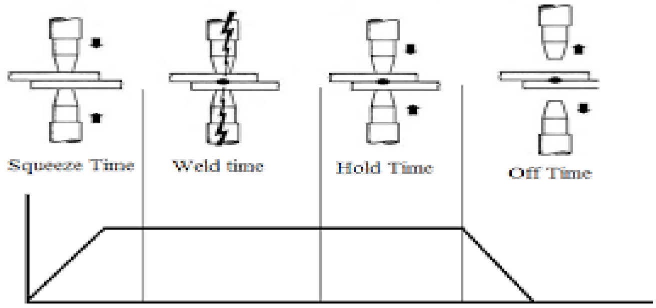


Fig. 6. The RSW process timeline

2.7. *Thermo-electrical processes of resistance spot welding.*

An integral part of the resistance spot welding is the thermo-electrical processes which cause the heat generation of the welding. The heat generated due to the electrical current is defined through Joule's law, equation 1. The resistances, and thus heat generation, of the circuit are located at four major sources: Typical values of resistances of materials used in RSW can be seen in Figure 7.

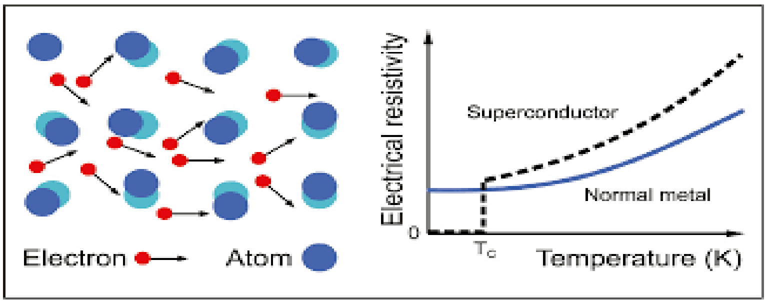


Fig. 7. Electrical resistivity of RSW materials

The resistance of the electrodes .

The contact resistance between the electrodes and the sheets .

The bulk resistance of the sheets .

The contact resistance between the sheets.

For stack-ups with more than two sheets, bulk resistances and contact resistances are added accordingly.

2.8. *Resistance Spot Welding Parameters.*

The resistance spot welding process can be described by a number of parameters.

2.8.1. *Weld current.*

The welding current is the most effective and common parameter to influence welding result of a given material configuration. A too low current will not provide sufficient heat to create a nugget while a too high current will result in expulsion and even temperatures above the boiling point. Expulsion decreases the nugget size and may also defect surrounding equipment and parts. If the boiling point is reached, there is higher risk for porosity in the finished weld. Another result of too high currents is too large indentations in the metal surface. The current level also affects the distortion of the base metal and the size of the heat affected zone (HAZ). Common welding current amplitude lie in the range of 5kA -10kA depending on sheet configuration, other process parameters and weld requirements.

2.8.2. *Weld time.*

As Joule's law, Equation 1, suggests, the welding time is of importance when calculating heat generation and resulting weld formation. Traditionally, as AC was used, the weld time was measured in periods. As the use of DC has increased, the weld time is now more commonly measured in milliseconds. As with weld current level a too short weld time will not generate sufficient heat to form a weld a too short weld time may lead to over-heating or expulsion. In production, there is a need to keep manufacturing times as low as possible to keep costs low. Thus, a shorter weld time is desirable and is more likely to be compensated by higher weld current to give adequate results. In production, typical traditional weld times range between 200 - 700 ms depending on material configuration, other process parameters and weld requirements.

2.8.3. *Electrode force.*

In order to assure contact between the electrodes and the sheets during the entire weld process, the electrodes are clamped to the work piece. The force magnitude is another variable which will affect the outcome of the weld. If the force is too big, the electrical resistance will decrease at the contact surfaces and decreasing heat generation and not melting enough material. It may also cause conduction heat away from the weld area, which is undesirable for nugget formation. Furthermore, too high forces may cause damage to the work piece or excessive deformations. The surface deformations are especially important in areas where visual quality is of high importance. Examples of such areas may be outer sides of car bodies. On the other hand, a too low force will increase the risk of geometrical instability of the welding process and excessive heat generation. In other words, the risk for expulsion is increased with a lower force. Typical electrode forces in automotive manufacturing range between 3 - 6 KN depending on sheet material and thickness. Many conventional modern weld guns are capable of applying weld forces up to 5 kN, while higher forces may require stronger guns or custom modification of weld guns.

2.8.4. Electrode geometry.

In production, the shape and size of the electrodes have an effect on the weld outcome. The geometry of a different electrode geometries are shown in Figure 8. The most important parameter in the electrode geometry is the contact area between the electrode and the metal sheet. As a general rule the diameter of the electrode tip should be approximately equal to, where is the thickness of the sheet. The contact will affect both the contact pressure and the current density of the weld. In optimization of weld parameters, it may be ideal to use different electrodes on each side of the stack-up. The tip curvature of the electrode is a measure against the degradation of the electrode tip. As the electrode degrades the initial curvature will deform into a flat surface. An initially flat surface would cause a concave tip after continuous welding.

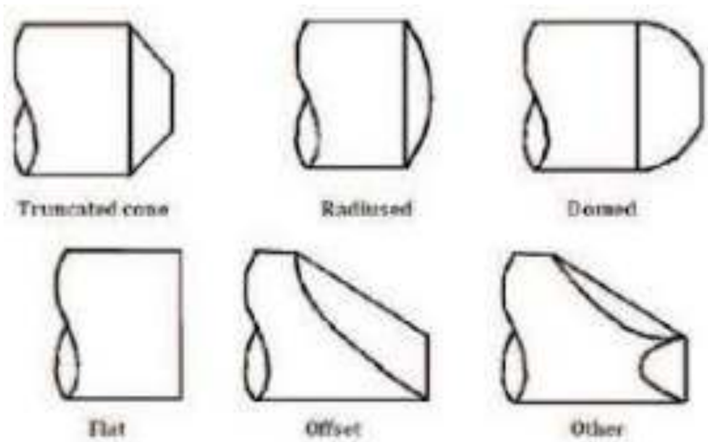


Fig. 8. Electrode geometry types

2.8.5. Electrode material.

The most important functions of the electrodes is to conduct electric current and to squeeze the sheets together. Therefore, electric conductivity, compressive strength and hardness are important factors in finding an appropriate electrode material.

The material that fits the demands best is copper and copper-based alloys, as described in the standard ISO 5182:2008.

The most common electrode material is a cupper-chromium-zirconium alloy, while higher resistance alloys of nickel, beryllium and/or cobalt may be used for higher strength steels and stainless steels.

2.8.6. Electrode degradation.

Due to wear during repeated spot welds the electrodes suffers from degradation. Five degradation mechanics have been identified: softening, recrystallization, alloy formation, tip diameter growth and pitting.

In order to extending the electrode life a number of different measures can be applied. Most importantly, electrode dressing is used. It involves inserting the electrodes to a revolving metal cutter to remove typically about 0.1 mm to recover new cupper material. It is also possible to improve electrode degradation by optimizing weld parameters by keeping electrode forces low.

2.9. Weld quality.

For most industrial applications the overlap shear strength of a resistance spot weld reflects the weld quality. Strength is usually specified in kN or pounds-force and results from a variety of factors such as nugget size, fusion penetration, micro-hardness, amount of defects, or different microstructural features etc. Strength can be evaluated by variety of tests such as tension-shear test, cross-tension test, mechanized peel test etc. Overlap tension-shear testing is by far most common strength evaluation test for RSW due to its simple set-up. Minimum tension-shear strength requirements in kN or pounds-force specified by different standards such as AWS, ISO and SAE. The requirements of the standards are based on the strength of the materials and thickness of the sheets to be welded.

2.10. Advantage of resistance spot welding.

- Comparatively low cost.
- RSW method doesn't need highly skilled worker.
- Distortion or warping of parts is eliminated though it leaves some depressions or indentation.
- The joint made is highly uniform.
- Automatic or semi-automatic operation both can be done.
- There is no need for edge preparation.
- Welding can be done in quick succession. It just needs a few seconds to make the joint.

2.11. Disadvantage of resistance spot welding.

- The equipment cost is high so it can has an effect on the initial cost.
- Skilled welders or technicians are needed for the maintenance and controlling.
- Some metals need special surface preparation for making the RSW a success.
- The thick jobs are not easy to weld.

2.12. Application of resistance spot welding.

- Spot welding of thick steel plates has been done and it has replaced the need for riveting.
- The welding of two or more sheet metals can be joined by mechanical means more economically by using the spot welding methods, we don't need gas tight joints.
- Spot welding can be used for attaching braces, pads or clips with cases, bases and covers which are mainly product of sheet metal forming.
- Automobile and aircraft industries rely greatly of spot welding these days.

2.13. Low carbon steel.

Steel with a low carbon content has the same properties as iron, soft but easily formed. Steel with less than 0.3% carbons, ductile, malleable, high toughness and non- harden able by using heat treatment. Due to high toughness these are used for producing nails, rivets, gears etc. Due to its cheap cost it is used for making from tools and also wood working tools. Steels having carbon percentage 0.15 to 0.30 are preferred to use in construction of structures, buildings . .Structural shapes, etc.

2.13.1. General Properties.

In order for steel to be considered low carbon steel, there are certain characteristics it must meet. For instance, the steel has to have less than .3 percent carbon in its total makeup to be considered low carbon. Low carbon steel also contains pearlite and ferrite as major components. Low carbon steel is generally used straight from the forming process, whether that process is hot forming or cool forming, because that's when it's most workable and easiest to form.

2.13.2. Weld ability.

Low carbon steel has some of the best weld ability of any metal. The reason for this is precisely due to the low carbon content of the metal. As carbon is added to steel, the steel gets harder and harder. This is a desirable outcome if the steel is going to be used structurally, or in a situation where strength is of the utmost importance. However, the harder the steel gets with more carbon, the more prone to cracking it is when you attempt to weld it. As such, low carbon steel doesn't have that problem.

2.13.3. Formability.

Low carbon steel also possesses good formability. This means that low carbon steel is easier to form into certain shapes, through such methods as pouring, molding and pressing. Also, low carbon steel is used for case hardened machine parts, chain, rivets, stampings, nails, wire and pipe. The ability of the steel to be turned into a number of different forms makes it quite versatile. When using low carbon steel, strength isn't the primary concern, because what you lose in rigidity, you gain in formability .

2.13.4. Application.

Typical applications: tin cans, automotive body components. Also, low carbon steel is used for case hardened machine parts, chain, rivets, stampings, nails, wire and pipe.

2.13.5. Carbon Steel types.

The Table (1) below describe the carbon steel and it's properties and users.

Table 1: The properties and users of carbon steel

Name	***Properties***	*Uses*
Low Carbon Steel (Mild Steel) (Carbon0.1%-0.3%) iron + carbon	*Fairly Strong | - Rusts easily*	*girders, car body panels, nuts and bolts, Food cans, car body panels/*
Medium Carbon Steels (Carbon0.3%-0.7%) iron + Carbon	*-Harder than low carbon | Steel/*	*Nails and screws, TT ital. chains, wire ropes, screwdriver blades, engine parts, bicycle wheel rims*
High Carbon Steel (tool steel) (Carbon0.7%-1.3%) iron + Carbon	*Harder than medium carbon steel .Brittle*	*Chisels, hammers, drills, files, lathe tools, taps and dies*
High Speed Steel (Carbon 0.6%) iron + carbon + tungsten + chromium	*Harder and more lasting than high carbon steel |Can retain its hardness at high temperature (700 ° C)*	*Cutting tools for lathes and drill bits*

Chapter Three

Experimental Part

Chapter Three
"*Experimental* Part"

3.1. Materials

The material used in this project made of low carbon steel which used for construction, machining frames, bolts and others and the chemical composition was indicated in Table 2. The samples were prepared and divided into 3 groups each group contains 16 samples of equal dimensions but differing in thickness. Each group has one of these thicknesses respectively (1mm, 2mm and 3mm), the dimensions and shape of test samples were shown in Fig.9.

Table 2: Chemical Composition of low carbon steel

Element	C	Si	Mn	P	S	Fe
Wt. %	**< 0.17**	**< (0.12-0.3)**	**0.5 <**	**< 0.04**	**< 0.035**	**Rem.**

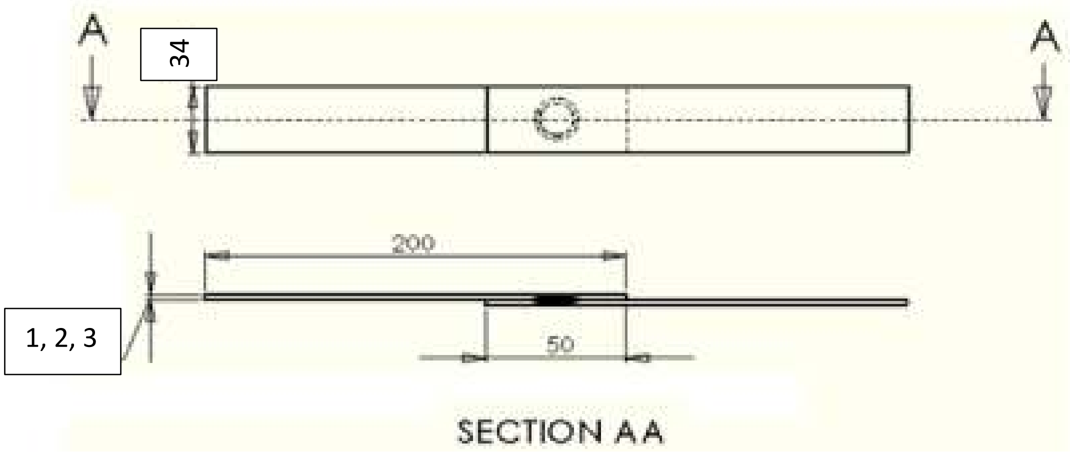


Fig. 9. Dimensions and shape of samples

3.2. Experimental method.

3.2.1. The devices used.

1. Resistance spot welding machine:

- For welding of the sample consisting two plates of the same thickness with lap joint the spot welder machine type Dn -25 was used. Welding electrodes are made of copper with contact area has diameter (d= 4mm) and cone shape. The illustration of technique parameter and spot welding machine was shown in Table 3 and Fig. 10.

Table 3: The technique parameter of spot welding device.

Technique parameters							
model	**Input voltage**	**Rated capacity**	**Rated frequency**	**Rated duty cycle**	**Grate of regulation**	**Welding time**	**Max welding thickness**
	V	KA	Hz	%		S	MM
DN-10	220	10	50	20	7	0-2	1.5+1.5
DN-16	220	16	50	20	7	0-2	2+2
DN-25	220	25	50	20	7	0-2	3+3

Fig. 10. Spot welding machine

- The welding cycle time was changed to (0.6, 0.8, 1.0, 1.2) s and the welding current were changed to (4000, 5000, 6000, 7000) Amp. The compressive force of electrodes depend upon food pressure of the welder.

3. Tensile testing machine:

After welding, all samples were tested by using computer control electronic universal testing machine model WAW-200 with max load capacity 200 kn. Shown in Fig. 11 below.

Fig. 11. Tensile testing machine

2.3.2. Prepare samples and welding.

1. 48 samples were prepare according to dimensions in Fig.9 and divided into 3 groups, each group contains 16 samples with same thickness for tensile testing.

2. The surface of preparation of testing samples before welding is very important. All potential dirt on the material surface decreases the joint strength, or makes impossible the weld formation. Therefore the surface of all testing samples was cleaned by using grinding machine and scribbling papers especially on one end (determined for welding) on both sides during 50mm. after cleaning all samples were degreased using acetone and dried.

3. The two electrodes of spot welding were cleaned from any dirty by using grinding papers to prevent the samples from sticking during welding process and get a good welding area.

4. Lap joint was used to weld each two plates by resistance spot welding with the parameters were shown in Table 4. Fig. 12. Shown the samples (1, 2 and 3)mm after welding. Fig. 13 shown the spot welding process.

5. All samples then have been tested by tensile testing machine to record the results.

(a)

(b)

(c)

Fig. 12. Samples thickness: a. 2mm, b. 3mm, c. 1mm.

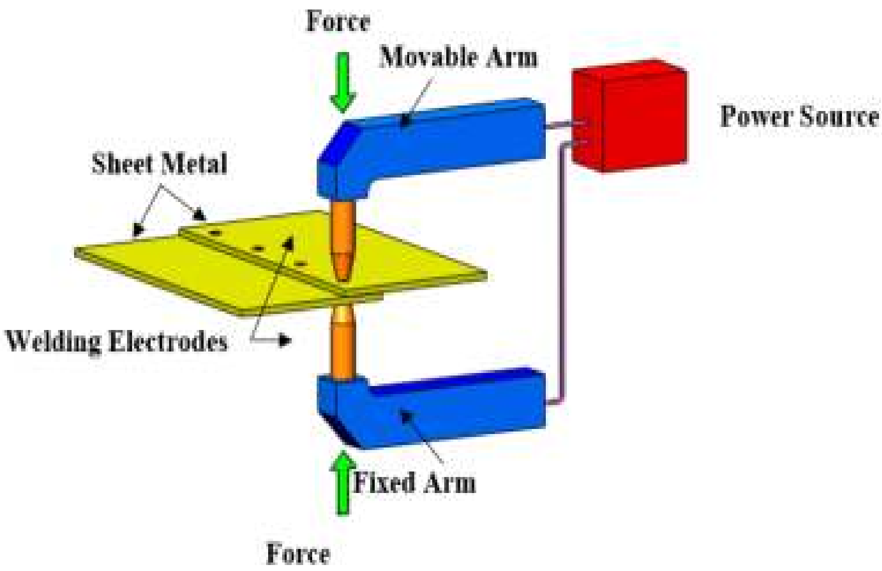


Fig. 13. Spot welding process

Table 4. Welding parameters

Thickness, mm	Welding time cycle, s	Welding current, Amp
1.0	0.6	4000
2.0	0.8	5000
3.0	1	6000
	1.2	7000

Chapter Four

Resultants and Discussion Part

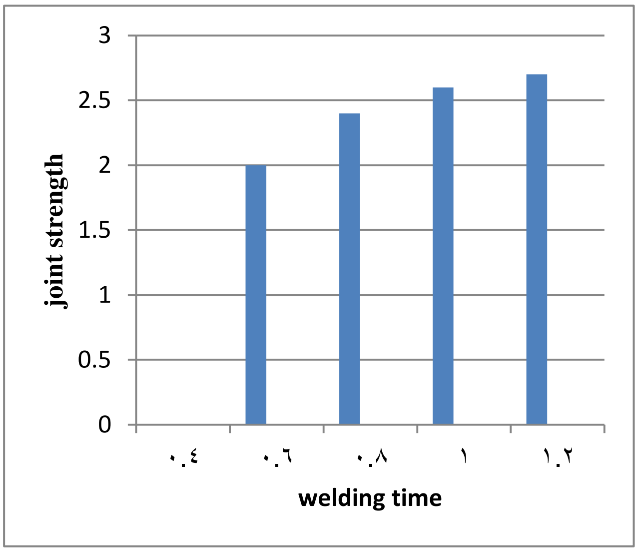
Chapter Four
"*Results and Discussion* Part"

In this project, welding strength is an indicator on the resistance spot welding quality. Welding parameters changed by changing one factor and fixing the other factors. Tensile test was done on each of the welded samples.

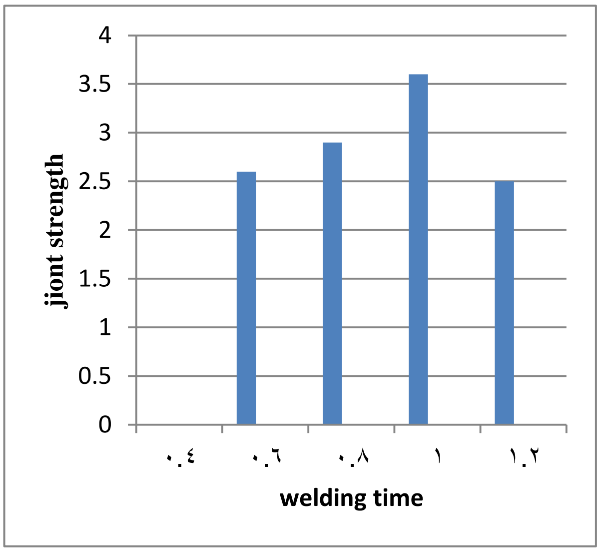
4.1. Plates of (1mm) thickness.

Tensile test was done for each samples with welding parameters which represent the welding current (4000, 5000, 6000, 7000) Amp and welding cycle time (0.6, 0.8, 1, 1.2) second.

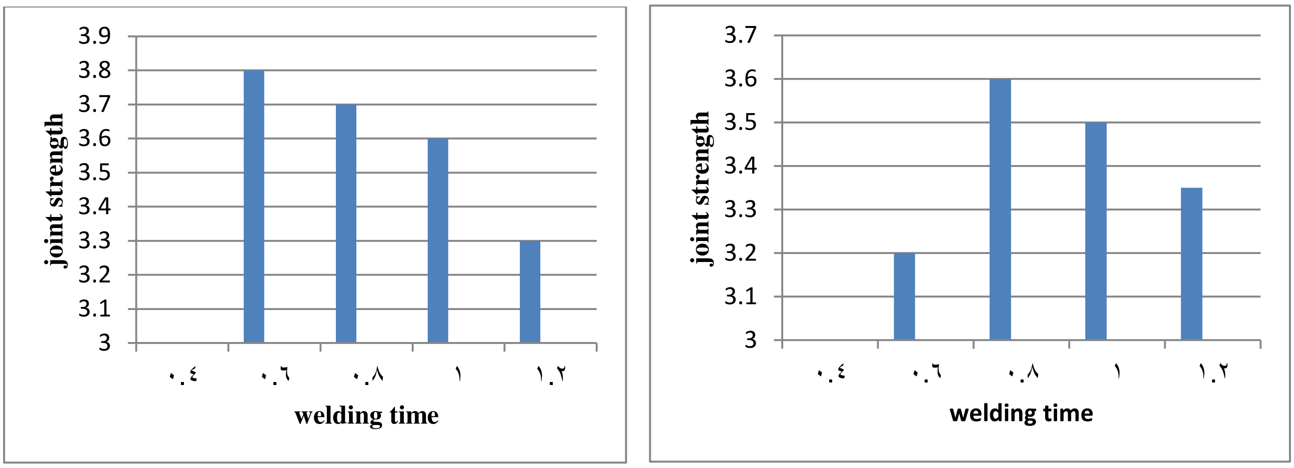
From Fig. 14 below Which represent the results of weldment strength of 1mm thickness. It show that joint strength increase with increase the welding time this due to increase heat input to the welding at (4000, 5000)Amp and same thing happen in (6000, 7000)Amp but the welding strength start decrease after welding time (0.8 and 1)s. This was of high heat generate and give to some defect to formed like cavities. The maximum welding strength was (3.8 KN) at 7000 Amp and 0.6s.



(a)



(b)

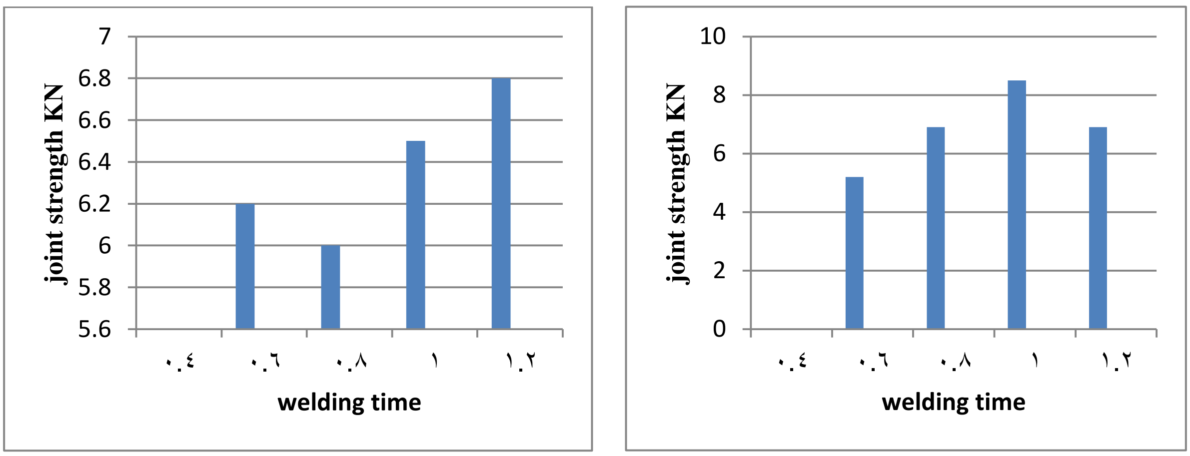


(c) (d)

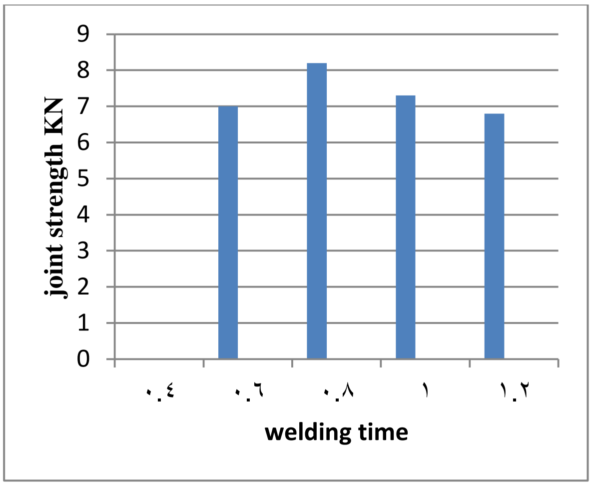
Fig. 14. Relationship between welding cycle time and strength joint of (1mm)thickness: (a) at 4000amp. (b) 5000amp. (c) 7000amp. (d) 6000amp

4.2. Plates of (2mm) thickness.

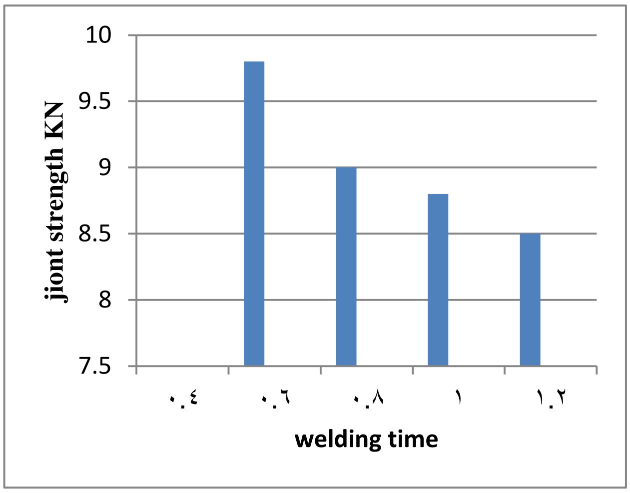
From Fig. 15. The joint strength in welding current 5000Amp have good results than at 4000Amp in 2mm thickness and this results was less than of 1mm results it can be explained that when thickness plate was increase it used more heat input to done weld. At(6000 and 7000)Amp the joint strength start decrease at (1 and 1.2)s. The maximum welding strength of 2mm thickness found was (9.8) KN at 7000Amp and 0.6s.



(a) (b)



(c)

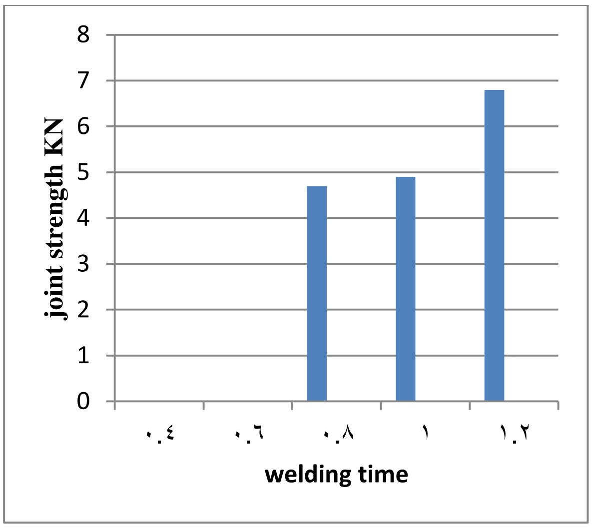


(d)

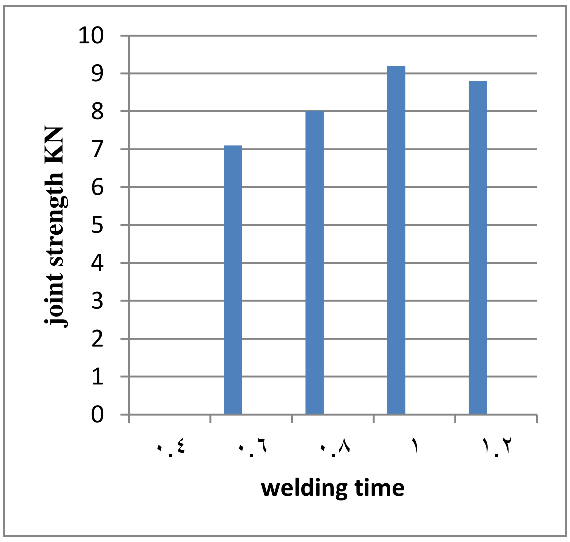
Fig. 15. Relationship between welding cycle time and strength joint of (2mm)thickness: (a) at 4000amp. (b) 5000amp. (c) 6000amp. (d) 7000amp

4.3. Plates of (3mm) thickness.

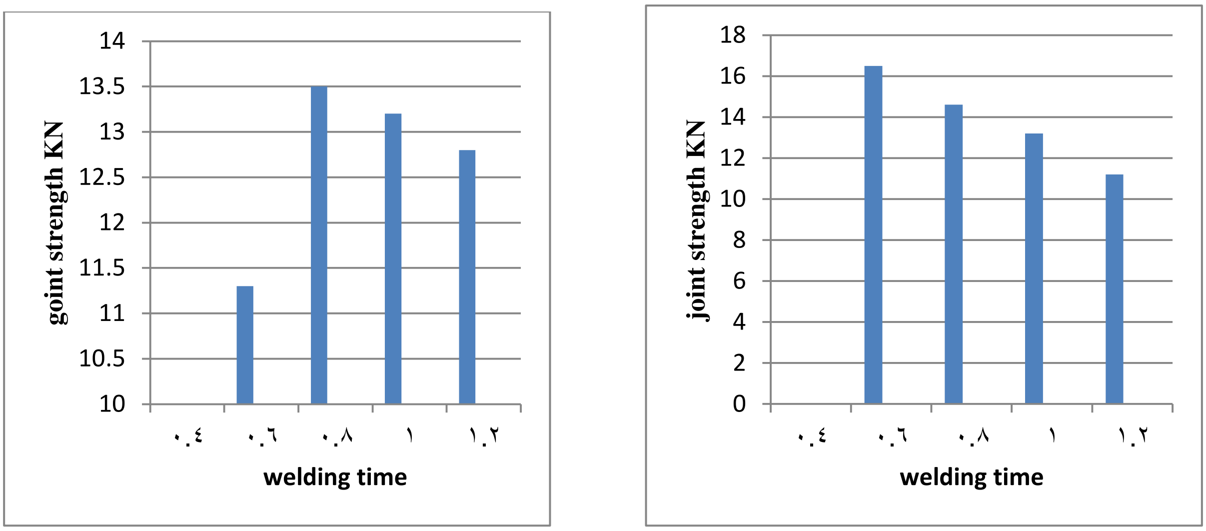
From Fig. 16. The samples in 4000Amp at 0.6s were failed and the weld wasn't done while the weld was done at 5000Amp and above with all welding time values. This was due to the heat for weld the samples of 3mm thickness was less. The joint strength after that increase after 1s and at (6000, 7000)Amp the strength start decrease at (1, 1.2)s. the maximum value of strength was (16.4) KN at 0.6s.



(a)



(b)



(c) (d)

Fig. 16. Relationship between welding cycle time and strength joint of (3mm)thickness: (a) at 4000amp. (b) 5000amp. (c) 6000amp. (d) 7000amp

4.4. Final results.

All results of all samples at (1, 2, 3)mm thickness and at (4000, 5000, 6000, 7000)Amp with (0.6, 0.8, 1, 1.2)s welding cycle time can be collected in one diagram shows the relationship between the welding strength and welding cycle time in each current. Fig. 17, 18, 19 below shown that.

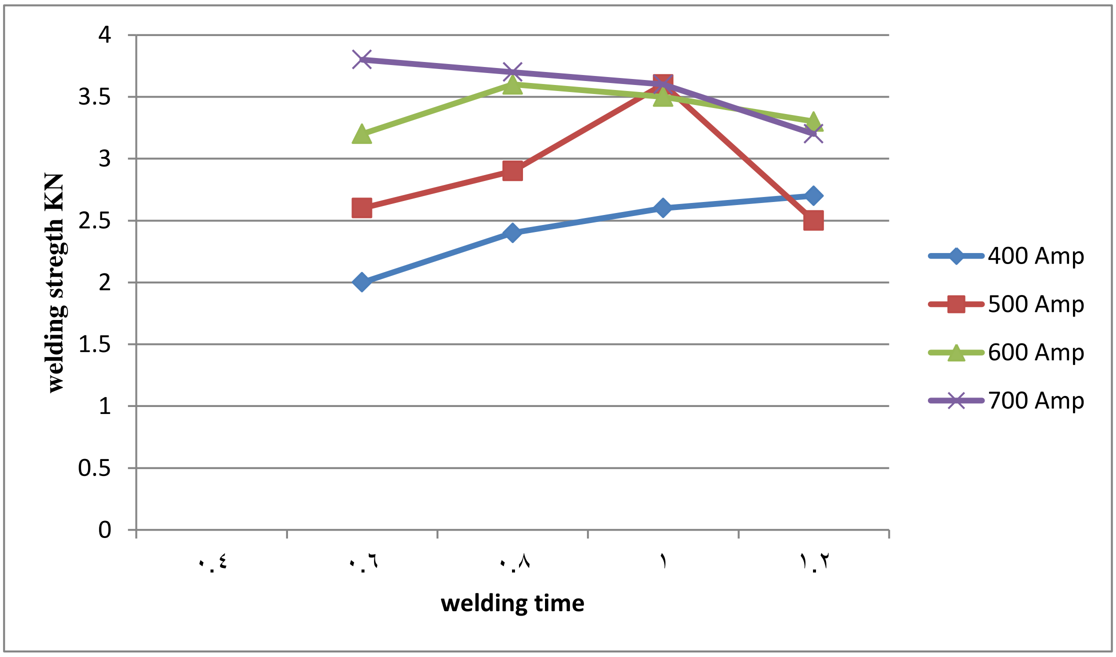


Fig. 17. Welding cycle time and welding strength of (1mm) thickness.

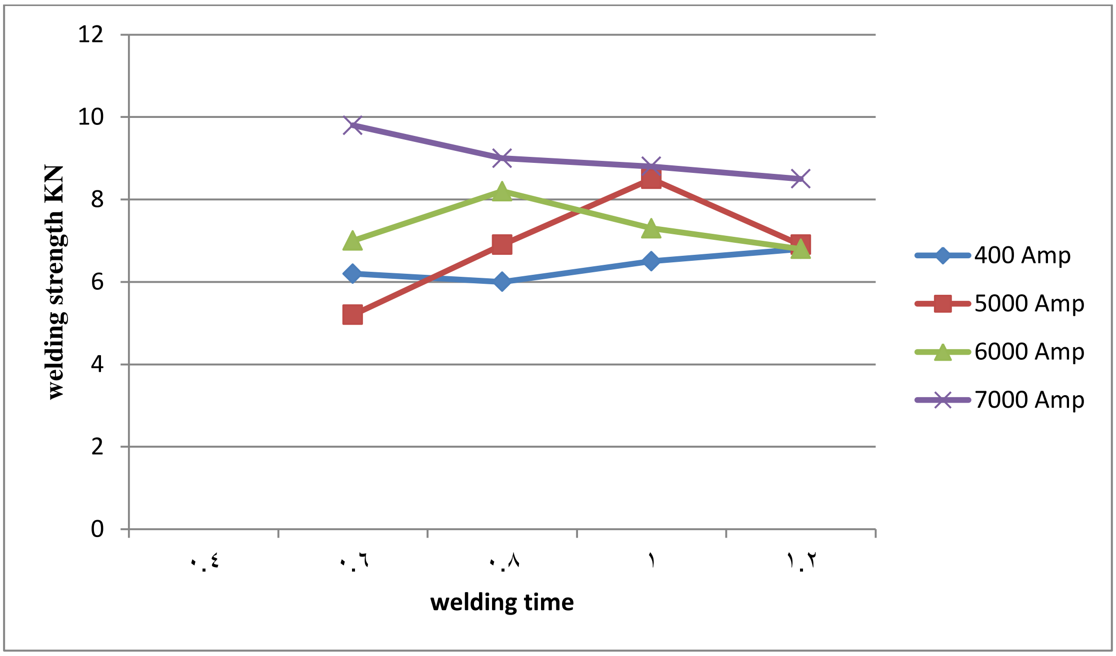


Fig. 18. Welding cycle time and welding strength of (2mm) thickness.

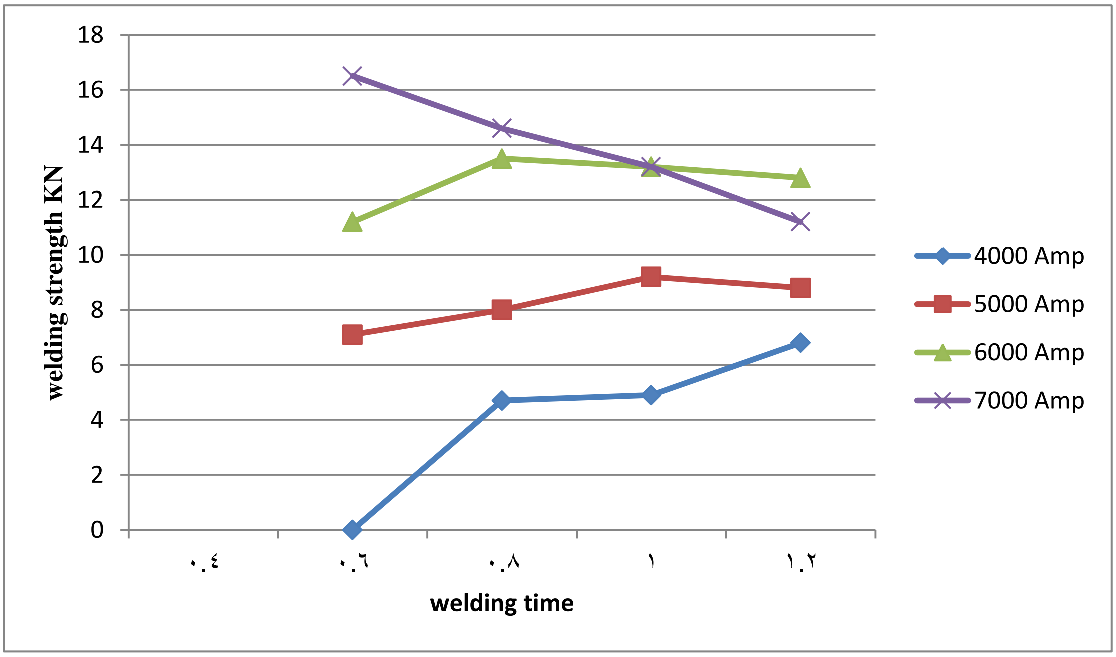


Fig. 19. Welding cycle time and welding strength of (3mm) thickness.

Chapter Five

Conclusions part

Chapter Five

"Conclusions Part"

5.1. Conclusions

1. In this project, the strength of welding joint for resistance spot welding type was evaluated with the tensile test of all three thickness (1, 2, 3)mm of similar plates and the welding was done with change the welding cycle time and welding current with all other parameters remaining constant. So the better welding strength joint can be gated when choosing the right welding parameters.
2. The effect of welding current on welding joint strength was more than welding cycle time.
3. Better value of welding strength was found at 7000Amp welding current and 0.6s welding cycle time.
4. Some of errors happened in this project which including that depending on the welder foot to represent the electrode force.
5. At low welding current the weld wasn't done especially at thick thickness (3mm).
6. The spot welding machine used in this project was simple in work and does not have gage to record pressure force of electrodes comparison with other spot welding machine.

5.2. Future Scope of Work.

1. Used another materials such as aluminum and different types of steel .
2. The welding process can do on dissimilar materials.
3. Change the welding conditions.
4. Using another various thickness.
5. We can used another types of electric resistance welding.
6. We can do more tests such as impact test, hardness test, torsion test and study the microstructure in the welding area.

7. We can do the weld by used another type of spot welding machine which have a gage to record the pressure force electrodes .

Chapter Six

References Part

Chapter Six

"References"

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