FACULTY OF ENGINEERING AND NATURAL SCIENCES

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FINAL PROJECT

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Absract

In this article, we will talk about the general lines of cold welding process and its many properties. The general purpose of the article, which will be examined in the chapters of introduction, research topic and literature, we will examine not only the theoretical datas about cold welding, but also the practical and experimental datas.First of all, in the introduction part, we will talk about definiton, history and industrial importance of cold welding. In the research topic, we will examine the advantages of cold welding, suitable metals and and applications of cold welding process. As we mentioned before, in the article we selected in the literature section, we will make many examinations of the cold welding process with experimental and numerical datas.

INTRODUCTION

Cold welding is a welding process obtained by forcing metal surfaces to each other under high pressure without fusion or heating. For the successful application of cold welding, cleaning the surfaces that will contact each other is the key point of the welding process.Because, according to the experimental datas obtained by researchers, the bond strength of the welded metals has been observed to be considerably reduced when the contact surfaces are not clean. This cleaning can be done by degreasing or wire brushing methods. In addition, since the welding process is based on pressure welding, at least one of the metals to be used must have a ductile propertie.As it known, ductility is the feature of flexing without losing the load capacity of substance. If we talk about it in more detail, it is an essential feature that the metal used is ductile and when pressure is applied, it can be flexibly joined to other metal.

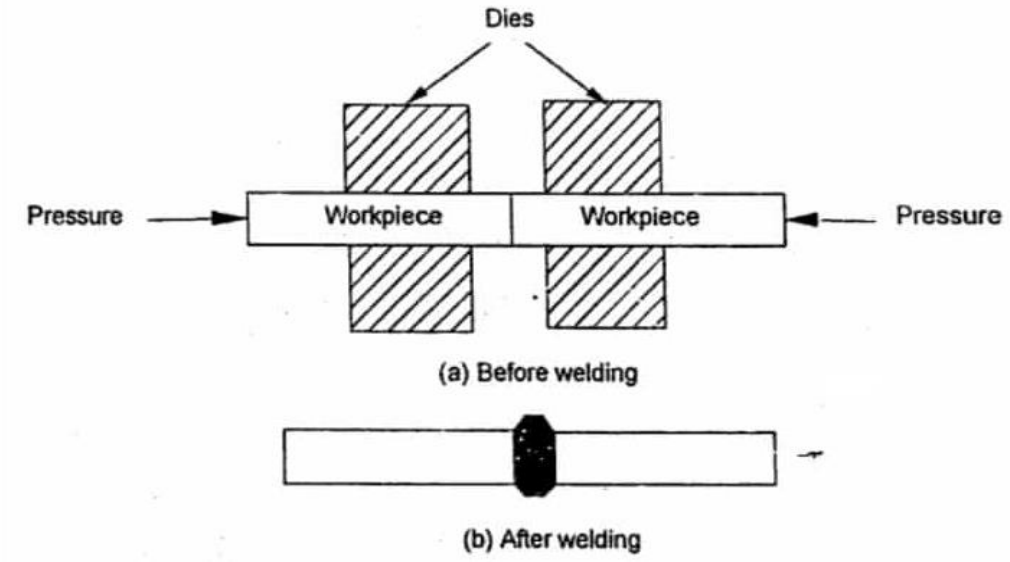

Fig.1.1 Cold Welding Process

The cold welding process was first carried out by John Theophilus Desaguliers in 1724. This man first observed the cold welding process by the merging of these two balls when he pressed the same two metal balls together.

From an industrial point of view, aluminum and aluminum alloys are used in many parts in order to save fuel by reducing the vehicle mass, especially in automotive applications. Reducing the vehicle mass is not only limited by lightening the body parts. It is also possible to reduce the mass of cable and cable systems. With the developing technology, the use of auxiliary motors and devices in cars has increased, so the weight of cable systems in cars has increased up to 45 kilograms, so this has come to the fore as a disadvantage for fuel consumption. When copper cable cross sections in cars are between 0.35 to 0.50 mm2,occupies 1650 m space in vehicle.So reducing the fuel consumption accordingly is to make cable systems with lower cross sections and to use aluminum together with copper in cable systems. But when it comes to thin cables, of course, the strength of the material used is also important. However, since the tensile strength of aluminum is low, aluminum is not used in structures smaller than 1.5 mm2 cross-section for security purposes. In addition, the cost of aluminum is 75% less than copper. That is, using aluminum-copper alloy in automobile body parts and cable systems will be a more profitable investment in the long run.There is a figure below with price comparison of copper and aluminum.

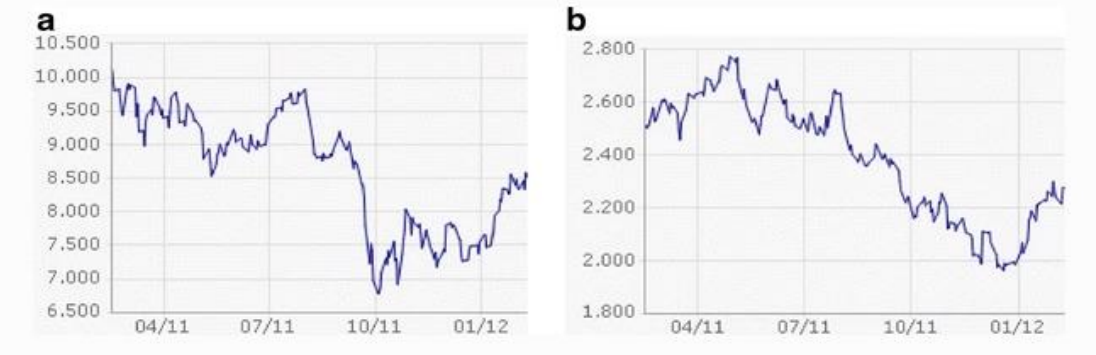

Fig. 1.2 Price development of copper(a) and alimium(b) in US dollar.

Also, from the industrial point of view again, the use of copper-aluminum alloy instead of copper will affect the conductivity of the cables. However, it has been observed that the combination of copper and aluminum does not affect the conductivity of the cables much. As is known, resistivity and conductivity are inversely proportional to each other. In the table below, resistivity of different elements and alloys are given.

Tab 1.1 Comparison of resistivity of intermetallic compounds

Intermetallic compound	**Resistivity [μΩ cm]**
Al_2Cu	8.0
AlCu	11.4
Al_4Cu_9	14.2
Al	2.9
Cu	1.75

As can be seen, a significant mass reduction of 40 percent has been observed in response to some reduction in the conductivity. As a result, the use of aluminum in the body parts and cable systems in the automotive industry seems to be quite profitable. And the cold welding method that makes it possible to use aluminum in these alloys is a profitable method for automotive companies.

2.RESEARCH TOPIC

2.1 Advantages of Cold Welding

Cold welding process has many advantages over other welding processes.First, as the welding process is done at room temperatures, no harmful thermal effects are observed at the joint or the metals being joined. Since the molds used to hold metals have simple structures, their cost is low. Generally, it does not require any other operation than pressure (such as heat), and the welding process is very fast and suitable for mass production. As mentioned before, the strength properties of the weld metal made by cleaning the surface to be welded with different processes are quite high.

2.2 Applications of Cold Welding

Cold welding is used cases made of different metals where heat should not be used containing explosives, foil coils and metal wires. Cold welding is used for rod coils for reliable use in smaller diameters. It is used for welding magnets that should not be exposed to heat and for joining semiconductor parts of electronic devices.

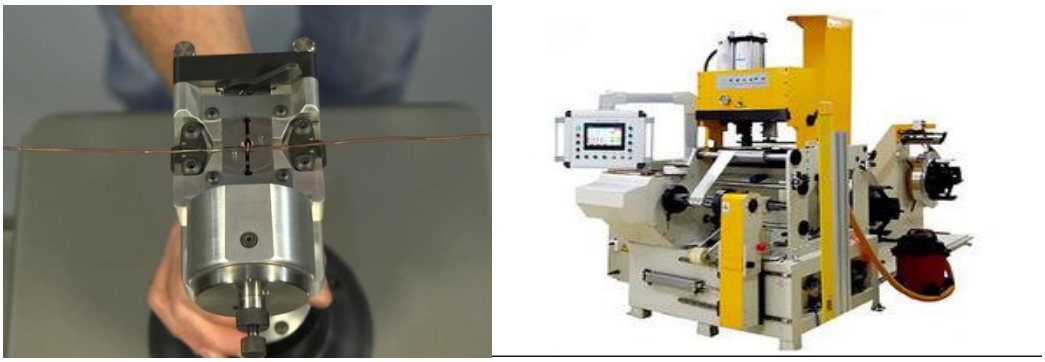

Fig 2.2.1 Small cold welding machine for high quality welds on wire and Automatic foil coil winding machine

2.3 Most Suitable Metals for Cold Welding

In order to determine the metals suitable for cold welding, it is first necessary to choose metals according to the advantages and properties of cold welding processes.

As it is known, in cold welding, there is usually a bond under high pressure without heat. At least one of the metals should be ductile to join metals under pressure. For this reason, metals such as iron, steel, titanium are not suitable for cold welding. But aluminum, copper, etc. Since metals are ductile, they are suitable for cold welding. Also, alloys such as brass, zinc nickel can be used in cold welding.

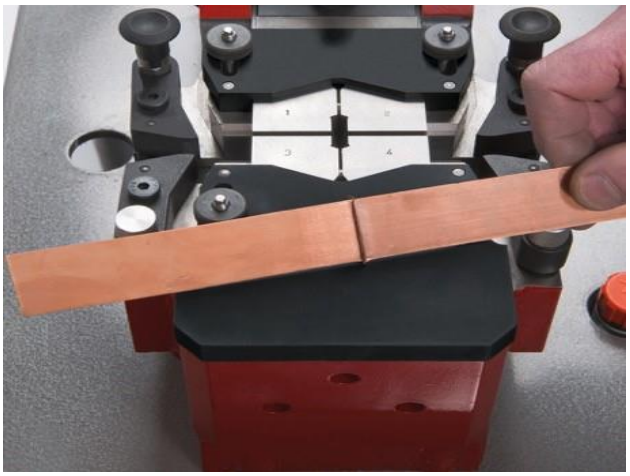

Fig.2.3.1 Cold welding of a power supply streamlines tube

In addition, it is more convenient to combine similar materials than other welding processes. The reason for this is that there are a few extra issues to consider when welding different metals: thermal expansions, conductivities, and a few properties of the materials that change after melting. In other words, cold welding allows different metals to be combined without any heat related problems.

3.LITERATURE

Mechanical and Metallurgical Properties of Aluminium and Copper Sheets Joined by Cold Pressure Welding, Kaan Ozel, Mumin Sahin, Aysegul Akdogan, 24.03.2008, Journal of Mechanical Engineering, Trakya University, Mechanical Engineering Department, Edirne, Turkey

3.1 Purpose

In the supporting article, the effects of surface roughness and welding deformation on the welding metal in cold welding process were investigated by experiments such as tensile, fatique and hardness tests. As it is known, the surface was cleaned with wire brushing processes and the effects of surface roughness to deformation were examined with different values. Microstructural investigation of the metal surface was made by changing the bond structures by wire brushing.

So the general purpose of the supporting article was to investigate the effects of surface roughness and pressure-induced welding deformation on the mechanical properties and strength of the joined metals.

3.2 Theory and Methods

As is known, the strength of the welding made in cold welding is directly proportional to deformation. However, too much plastic deformation occurs negatively affects welding strength.As we stated in the purpose section, in the supporting article, it was to examine the effects of surface roughness and deformation on weld strength with experiments and numerical datas. In this section, we will give information about these experiments with tables, figures and writings.

First, we will try to understand the mechanism of bound formations by examining the microstructure of the wire brushed surface. Wire brushing creates a hard and brittle surface on the surface of the cover layer.This hard and brittle surface eliminates adverse conditions such as unwanted oxidation that will reduce the rate of deformation. Then, by applying pressure at the cold welding stage, this hard and brittle bond is broken and new metallic bonds are formed. This microstructure is gradually shown in the figure below.

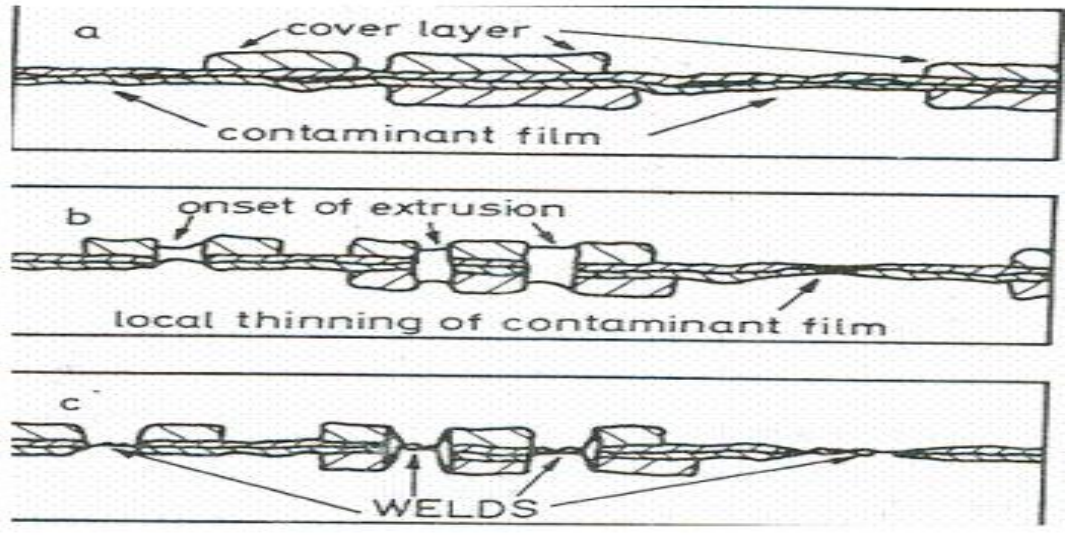

Fig 3.2.1 The bond formation mechanism in cold pressure welding

Secondly, the relationship between surface roughness and deformation was investigated in the dynamic tensile testing machine called INSTRON 8501. 30% welding deformation was observed when metal surfaces were first used. Cold welding is not possible with this deformation value. The relationship between weld deformation and roughness was investigated with deformation ratio %30 %45 %50 %60 and arithmetic average surface roughness Ra = 1, 3 ,5 µm values.In the figures below,shows the variation of weld strength with deformation for different surface roughness values and the variation of weld strength with surface roughness at different extents of deformations. As a result of these tests, the most suitable welding strength was found at 60% deformation rate and Ra = 5 µm.

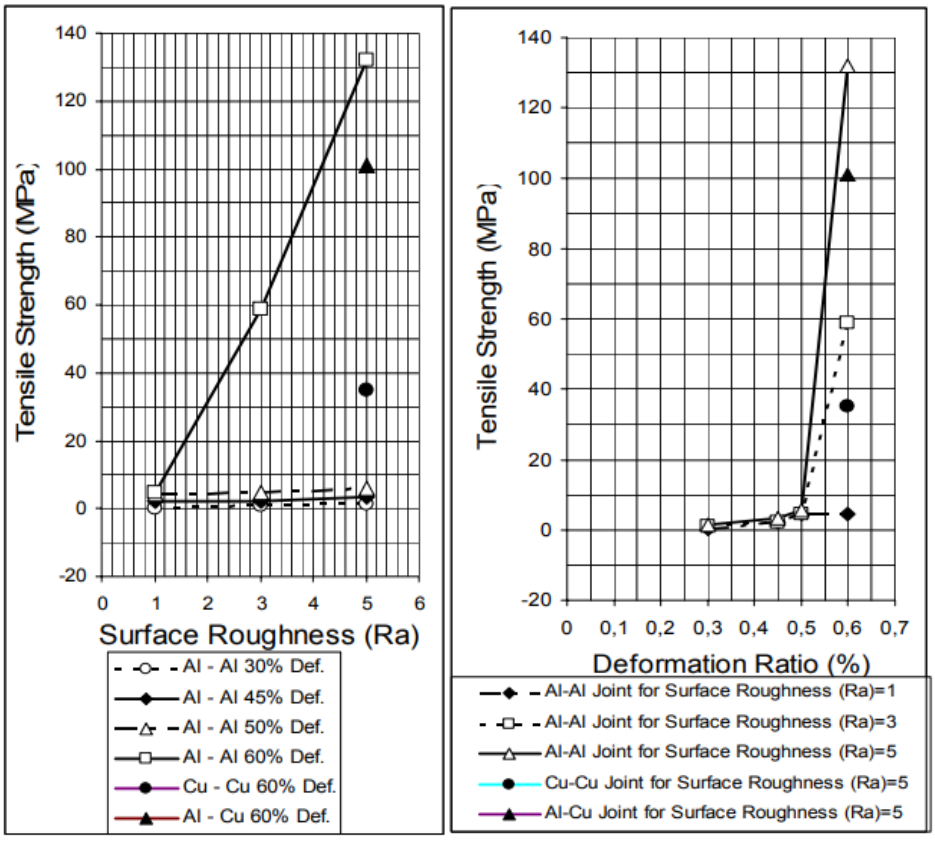

Fig. 3.2.2 Relationship between tensile strength and surface roughness at different weld deformations(left) and Relationship between tensile strength and weld deformation at different surface roughness(right).

The fatigue test was used as another test to measure the strength of the welded metals. This test was carried out in the INSTRON 8501 hydraulic fatigue machine. The strength of the metal was examined by sending overlapping waves at a constant tensile stress while welding was applied. While these tests were carried out, the metal had the highest strength properties with Ra = 5 and 60% deformation. While the magnitude of these waves was between 10 MPa and 20 MPa, the frequency of the waves was set as 10 Hz. The bonded metals have been broken. The most important point is that these breaks occurred at the welding point. The reason for this is due to factors that decrease the strength such as microcracks in the welding interface, surfaces that cannot joined with strong bonds. In the figure below we can see the visuals of the waves and tensile stresses for fracture of joined metals:

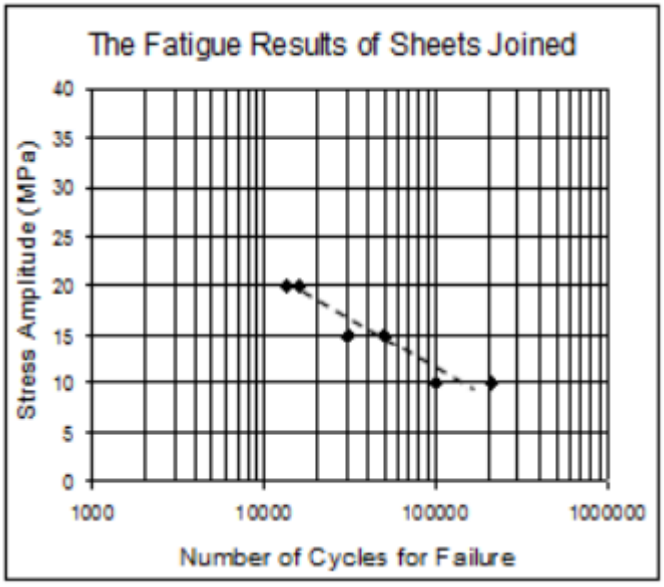

Fig.3.2.3 The Fatique Test Results

As another test, the hardness test will be applied. The purpose of this test will be to measure the hardness of the joined metals using different metals and different surface roughness values. In these tests, the effect of surface roughness on the hardness will be observed by using different surface roughness values. In addition, using different metals (Al-Cu combinations), Aluminum will be deformed more because it is a ductile material than Copper, although these metals have the same deformation value of 60% while welding.

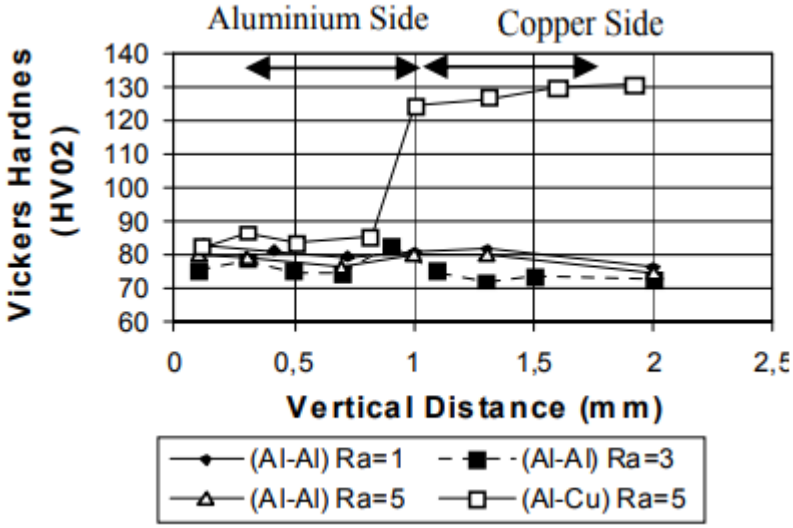

Fig. 3.2.4 Hardness variations along the vertical direction

3.3 Results

As a result, we can say that it is very important to clean the welding interface in order to make the new metallic bonds stronger when cold welding first. After the wire brushing, the hard and brittle bond structure plays a key role for the desired extent of deformation. In addition, we investigated which deformation and surface roughness value will have the highest strength value by tensile, fatigue and hardness tests.

3.4 Conclusions

We first measured how much load the bonded metals can withstand tensile stresses, but it is known that these metals will be exposed to different types of load in different areas of use. Thus, we measured the tensile strength of the bonded metal by sending the same tensile stress value continuously in waves.

Finally, the hardness test was done and the effect of the hardness-ductility relationship and surface roughness was examined. As can be seen from the graphic of test above, the effect of surface roughness on the hardness is very low. Also, considering that hardness and ductility are opposite concepts, it will be better when cold welding is made with aluminum-copper, since aluminum is a ductile material than copper.

4.CONCLUSIONS

We have talked about the stages, advantages, applications and industrial importance of the cold welding process throughout the article. As a result, the cold welding process does not include thermal defects in a cheap cost, unlike welding methods that use heat. We have determined how strong the metal bonded by the cold welding process and which deformation values and surface roughness values have.

It is the most important task of the engineer to use and determine a welding process more efficiently in the most suitable conditions and in the most suitable materials at a lower cost. In this article, we determined and interpreted how the cold welding process can be used in the most effective way and determined all the mechanical properties of the cold welding process that will be accepted in the commercial market.

Referances

Groover, MP., Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Wiley, 2014.

Bergmann J. P., Solid-state welding of aluminum to copper-case studies,***Welding in the World***, 57:541-550(2013)

Zhang W., Bay N., A Numerical Model for Cold Welding of Metals, ***CIRP Annals***, 45:215-220(1996)

Questions

1.Why is surface cleaning important in the cold welding process?

In the cold welding process, by applying pressure, the metals are deformed and bonded to each other. During this bonding, the surface is cleaned and stronger bonds are established.When the surface is cleaned by wire brushing, a brittle and hard layer is formed on the surface. This layer keeps undesirable situations such as oxidation away from the surface. When pressure is applied, this hard and brittle layer is easily broken and bonded to each other by strong metallic bonds of metals.

2. Why are aluminum and copper alloys frequently used in the cold welding process?

Since the welding is done by pressure in the cold welding process, the metals used must have some ductile property. Since the materials such as iron and titanium have very hard structures, they cannot be used in this process. Since aluminum and copper have ductile properties, they are easily deformed and change shape and joint with each other.

3. With which tests and purpose the strength of metals joined in cold welding be measured?

While determining the strength of the bonded metal, tensile, fatigue and hardness tests are used. The purpose of these tests is to find the highest tensile stress that the bonded metal can withstand. In the fatigue test, the strength of the bonded metal is measured by sending overlapping forces in waves instead of a stable force. The hardness test is used to determine which material will be more suitable for cold welding.