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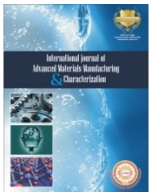

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Bonds Strength of St37 to SKF-Cu by Using Diffusion Welding

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A B S T R A C T

Different methods are used to produce bronze bearings with steel backing and bronze coatings. Technically, success of each method is dependent on the bonds strength and economically, production method is important. Temperature and pressure are two important variables in producing such bearings with appropriate bonds strength. This paper aims at studying temperature and pressure effects on the bonds strength of structural steel (St37) to pure commercial copper (SKF Cu), which has been produced using diffusion welding method. So, 18 sample pairs were used in 9 groups, each group containing 2 sample pairs. Diffusion was done in this way: 3 groups without any pressure, 3 groups with 1 MPa pressure, and 3 groups with 2 MPa pressure and 2 sample pairs of each group were diffused at boiling points 700, 850 and 920 C, respectively. Results show that there were no bonds in non-pressure condition at any temperature and also at 700C on all pressures conditions, while average bonds strength for 850C and 920C conditions were 2.2 and 5.4 MPa, respectively. So, for bonds between general structural steel and pure commercial copper, pressure is required with temperatures above 850 C.

Keywords: Bond's length; Bearing; Pressure; Temperature

1.Introduction

In engineering, efficiency of welded metals is associated with the quality of weld metal to achieve its useful life. The ability of welding metal to meet the above requirements is determined by its physical and mechanical properties.

Solid state welding methods are those in which two or more homogeneous or even heterogeneous materials at temperatures below the melting point are bonded by means of plastic deformation and penetration.

In diffusion welding (which is a type of solid-state welding), the high-temperature pressure creates a welding between two pieces through the penetration of the elements together and without microscopic deformation [1]. Therefore, welding will be stronger by increasing pressure or temperature.

Quality of contact surface is very important in diffusion welding. Smooth, parallel and flat surfaces reduce process time and optimize welding quality. The rough and non-parallel contact surfaces cause a lot of problems and prolong the process time because there is much porosity in welding point [1]. In this study, at first, surface is polished to minimize roughness and finally, using acid washing, surface is activated for better adhesion.

Bearings are pieces allowing a relative rotational or linear motion at least between two pieces. On the other hand, bearings are pieces that reduce the friction of involved surfaces. Two important tasks of bearing in devices with movable components are keeping axis in a way that prevents it from overloading, and preventing lateral movement so as to prevent collisions of moving and fixed parts. Another way of categorizing bearings is based on the type of force applied on it, which includes radial force, axial force and radial-axial force. Also, bearings are divided into three groups of sliding bearings, roller bearings and magnetic bearings regarding internal structure. If axial force is applied to the piece, radial bearing cannot prevent axis from moving, and therefore axial bearing should be used. Axial bearings are those that stand axial load during work [2, 3]. Therefore, the force applied to the interface of the layers is high and the quality of such bonds must be responsive to the force applied.

In this study, bonds strength is measured to ensure the performance of bearing layer. Axial bearing stands total weight of movable components (for example, in diesel engine, total weight of the crankshaft, connecting rod, piston, related screws, etc., as well as in the turbine of the axle, blades, etc.), and axial pressure. These pieces are placed on the elastic board and ultimately on the compression bracket. The oil required for lubricating and cooling bearings is provided by self-pumping (without pump) of radial

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holes of the block during the circulation of this part [2]. Therefore, the quality of bonds of these metals is of particular importance because if the bond of these metal layers is weak, they get separated.

Coating and welding are methods to coat pieces for intermediate layer. In this method, the parts are coated with filling metals having a melting point lower than the base metal. In the coating process used to coat components, fillers are used in the form of wires, belts, profiles, powders or even melt. A method for constructing axial steel-bronze bearings is coating and welding [4].

Welding method is used for making axial bearing with a bonded layer and bonds length of 6.6 µm [5] . In addition, welding method is used for making a CK15 steel axial bearing with a C93200 bronze layer. In that research, the bonds length is negligible (on a scale of one micrometer). Failure is due to low temperature and short time. For this reason, this research studies the effect of pressure and temperature on the bonds strength between construction steel and pure commercial copper.

A method for making steel-bronze radial bearings is horizontal centrifugal casting method. In this method, length of bonds was reported to be 2.4 microns [6]. In that research, bonds strength was not reported.

Another method for making steel-bronze axial bearings is using a pre-mold casting method. In this method, for the purpose of bonds, metals are first washed chemically. Then, the bronze melt is poured in pre-mold steel of general construction. In this method, the shear bonds strength is a minimum of 94.8 MPa and 0.45 µm bonds length [7].

In the present study, in order to ensure performance of bronze bearings, effect of temperature and pressure on the bonds strength between St37-SKF Cu (which is of particular importance in the production of bronze bearings) is determined.

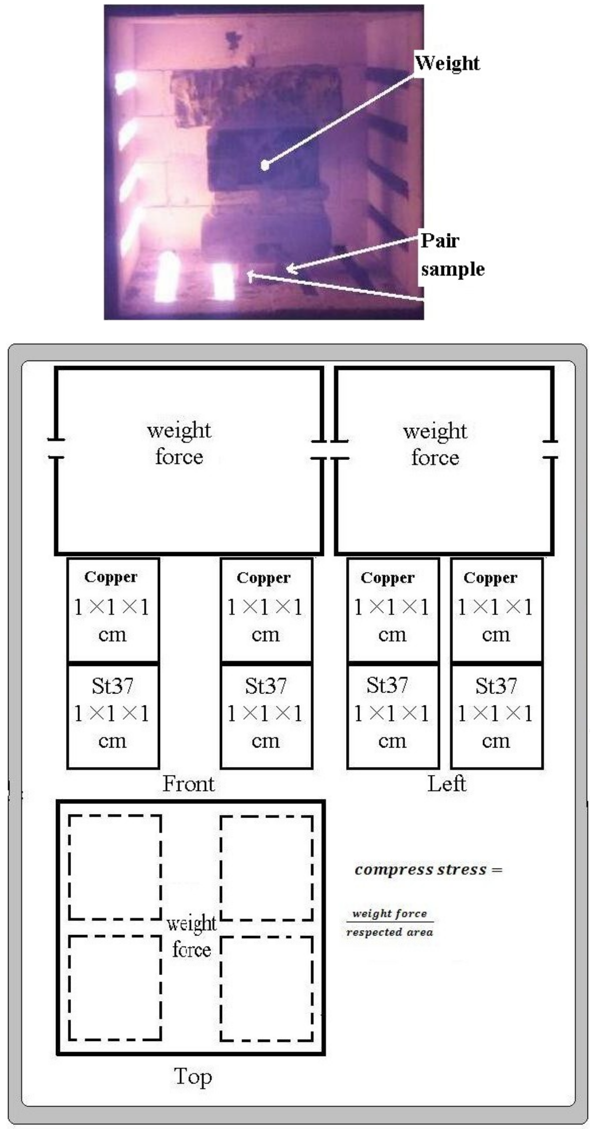
Materials and Method

In this study, 18 samples of 1×1×1 cm SKF Cu and 18 samples of 1×1×1 cm St37 were prepared. Their chemical composition is provided in Table 1.

Table 1: Chemical composition of SKF Cu copper and St37 steel

Element		Fe	C	Mn	Si	Cr	Cu	Co	Ni	S	P
St37	Wt%	Balance	0.09	0.50	0.24	0.02	0.01	0.007	0.01	0.022	0.030
Element		Cu	Others								
SKF Cu	Wt%	99.95	0.05								

The equipments used in this study were diffusion welding equipment, imaging equipment (electron microscopy) and measuring equipment (cutting machine test). In order to do diffusion welding at 750 to 920 ° C, a conventional resistance furnace was used according to Figure 1.



Commercial Electric Furnace

Figure 1: Resistance electric furnace for diffusion welding at Islamic Azad University Laboratory, Ayatollah Amoli Branch

Results of valid scientific and laboratory centres and calibrated machines were used to ensure accuracy. To evaluate the bonds length, a TESCAN MIRA III scanning electron microscopy was used which was available in a laboratory approved by Iranian Institute of Standardization. Cutting machine was used to measure the strength of bonds (shear test). To ensure the accuracy of the measurement results, the bonds strength of sample pairs was repeated twice.

Preparation of 36, 1×1×1 cm samples (eighteen of general construction steel and eighteen of pure commercial copper) was done by sand papers 100, 180, 400, 600, 800, 1000, 1200, 1500 and polishing (up to 0.13 µm roughness) and washing with 60% chloride acid. Then, eighteen sample pairs (each pair containing a general construction steel sample and pure commercial copper sample) were immediately placed inside the electric furnace.

Eighteen sample pairs were divided into 9 binary groups according to Table 2. Finally, all sample pairs were slowly cooled in the electric furnace.

Table 2: Diffusion welding properties of sample pairs

Specimen code	Time	Applied pressure	Applied temperature	Remarks
7000	4 h	0	700	1-Cooling and warming sample pairs in furnace. 2-Each group includes two sample pairs 3-Each sample pair includes St37 and SKF Cu.
7001		1	700	
7002		2	700	
8500		0	850	
8501		1	850	
8502		2	850	
9200		0	920	
9201		1	920	
9202		2	920	

As shown in Figure 2, having completed diffusion welding for measuring bonds strength, it is necessary to cut sides of sample pairs with wire cut to prepare them for cutting test. The remaining samples were used for studying the microstructure of bonds.

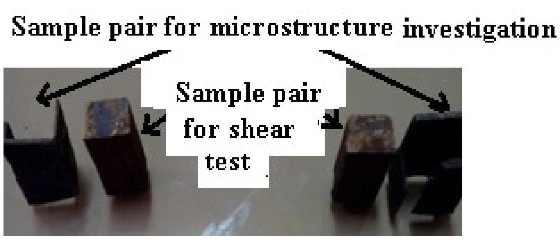


Figure 2: A pair of diffused welding samples was prepared for cutting test after wire cut

According to Figure 3, shear test is used for assessing the bonds strength between pure commercial copper and general construction steel. Steps are provided in Figure 4.

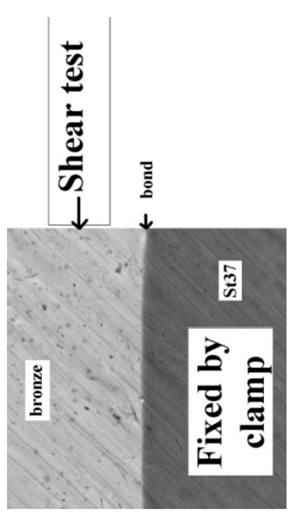


Figure 3: The way of doing cutting test

Raw material was purchased and its chemical composition was matched with standards.

↓

36, 1x1x1 cm samples polished with Sand paper 180, 400, 600, 800, 1000, 1200, 1500 and polishing up to 0.13 µm. Finally, it cleaned by acid wash.

↓

18 sample pairs (each pair including 1 general construction steel and 1 pure commercial copper) were divided into 9 pair groups. Then each 2 sample pairs (each group) were diffused transversally at pressures of 1 and 2 MPa and temperatures of 700, 850 and 920C. All sample pairs were cooled and warmed slowly in the electric furnace.

↓

Sides of sample pairs were cut with wire cut machine to be prepared for shear test. Remaining was used for studying microstructure.

↓

Microstructure was studied and its strength was measured.

Figure 4: Flow chart of research

Results and Discussion

Results of bonds strength and bonds length of St37-SKF Cu presented in Table 3. According to Table 3, samples which were not under pressure at diffusion welding time had no bonds. So, microstructures of such sample bonds were not studied. In sample 8501, bonds strength was 0.1 MP which can be neglected, so its microstructure was not studied. Pressure plays an important role in bonds of general construction steel to pure commercial copper.

According to Figure 5, the highest bonds strength belongs to samples with diffusion welding at 920 ℃. Their strength is twice as much as those with diffusion welding at 820C. So, at 920 ℃ pressure effect can be neglected. So, temperature is an effective factor in bonds of St37-SKF Cu.

Table 3: Results for diffusion welding of general construction steel to pure commercial copper

Specimen code	Average of bonds length	Average of bonds strength
7000	No bonds	
7001		
7002		
8500		
8501	60 µm	0.1 MPa
8502	60 µm	2.2 MPa
9200	No bond	
9201	100 µm	5.0 MPa
9202	100 µm	5.4 MPa

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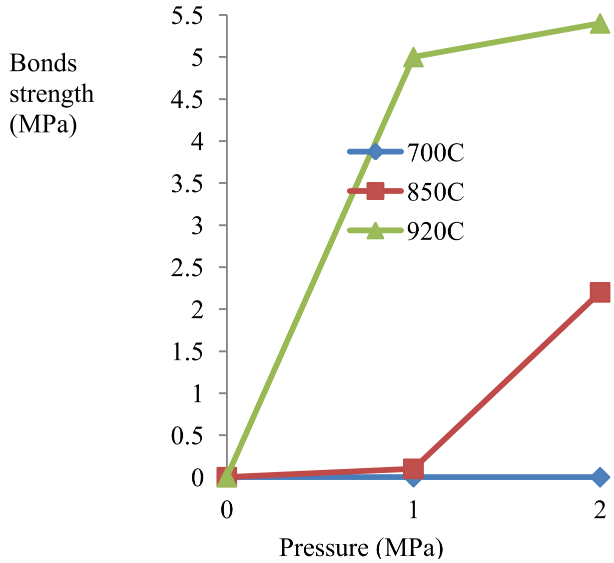


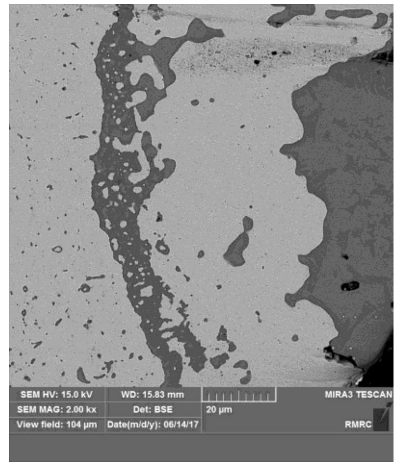
Figure 5: Relationship between pressure and temperature with St37-SKF Cu bonds strength

In Figure 6, light (heavier) phase is pure commercial copper (SKF Cu) and dark (lighter) phase is general construction steel (St37). Bonds is a mixture of dark and light phases meaning that such elements mixed but not dissolved or combined according to iron-copper phase diagram [8].

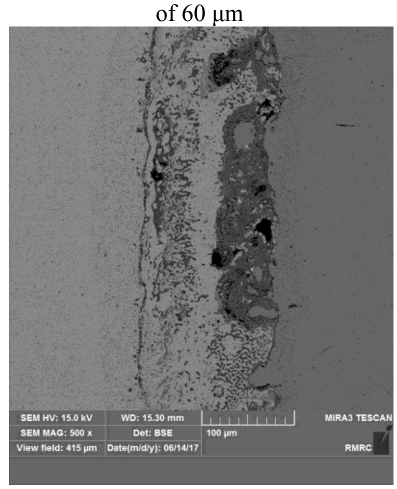
Bonds length in samples 8502, 9201 and 9202 are 60, 100 and 100 µm, respectively according to Figures 6a, 6b, and 6c. Higher bonds strength in samples 9201 and 9202 (about 5 MPa) than in sample 8502 (2.2 MP) is due to longer bonds in samples 9201 and 9202 (100 µm) than sample 8502 (60 µm). While bonds strength in samples 9201 (5 MP) and 9202 (5.4 MP) was almost equal, but sample 9201 has a few holes. As pressure 1 MPa was not enough for removing holes, so bonds strength in sample 9201 was a bit smaller than bonds length in sample 9202 (0.4 MP).

Soflaie and Vahdat [6] used centrifugal casting method to make steel-bronze radial bearings with a bonds length of 2.4 µm. In that study, there is a restriction in shape just for circular shape, while in present study, the effect of temperature and pressure on bonds strength was important, and mixing length in this study was up to 100 µm.

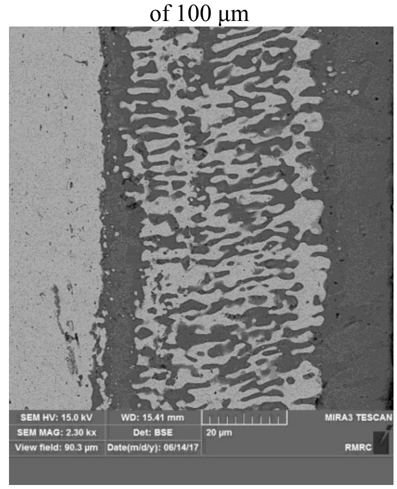
Zaheri and Vahdat [7] used pre-molding casting method to make steel-bronze axial bearings with bonds strength of 94.8 MPa and bonds length of 0.45 µm. Present study uses diffusion welding with mixing length of 100 µm and strength of 5.4 MPa.



(a)The image of welding metal of sample pair 8502, bonds length of 60 µm



(b)The image of welding metal of sample pair 9202, bonds length of 100 µm



(c)The image of welding metal of sample pair 9201, bonds length of 60 µm

Figure 6: Image of SEM TESCAN MIRA3 from the bonds of St37 (dark phase) - SKF Cu (light phase)

Conclusion

This study aims at investigating effects of temperature and pressure on the bonds between general construction steel and pure commercial copper. To have such a bonds, at first metals are polished mechanically and then washed chemically. And then applying weight forces of 0, 1, 2 MPa were placed in electric furnace and kept at 700, 850, and 900C for 4 hours. Results show that:

1. Copper and iron make a metal mixture at the bonds with pressure necessary for such a bonds and keeping in electric furnace should be at 850C.

2. Increasing temperature and pressure increases bonds length (up to 100 μm) and bonds strength (up to 5.4 MPa).

Although minimum temperature for bonds was 850C, even at 920C, bonds strength is not enough for engineering applications. So, diffusion welding should be at higher temperatures that will probably melt the copper.

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