# The Effect of Parameter of MIG Arc Brazing on Microstructure and Bonding Strength of Tin-based Babbitt Alloy ZChSnSb11-6 on ASTM 1045 Steel

**K Sun[1], P Y Wang[2], M Z Wei[1], J Zhou[1,3,\*] and F Xue[1,3]**

[1] Jiangsu Key Laboratory for Advanced Metallic Materials, Southeast University, Nanjing 211189, China
[2] Jiangsu Key Laboratory for Advanced Biologic Materials, Nanjing Normal University, Nanjing 211189, China
[3] Jiangsu Key Laboratory of Advanced Structural Materials and Application Technology, Nanjing Institute of Technology, Nanjing 211189, China

*jethro@seu.edu.cn.

**Abstract.** The effect of parameter of MIG arc brazing on the microstructure and the bonding strength of ZChSnSb11-6 and steel substrate has been studied. A cladding of ZChSnSb11-6 was obtained on the surface of medium carbon steel by MIG arc brazing. The microstructure of ZChSnSb11-6 and the microstructure of the interface between ZChSnSb11-6 and steel substrate have been systematically investigated. The highest bonding strength of ZChSnSb11-6 and the steel substrate is 66.42Mpa when welding voltage is 22V and welding current is 120A. The reason for the enhancement of the bonding strength was discussed. When the hard and brittle SnSb phase near the IMC layer is subjected to tensile stress at the interface between the Tin-based Babbitt alloy and the steel substrate, stress concentration occurs and the initiation and propagation of cracks are promoted. When the welding voltage is 20V, The number of the SnSb phase near the IMC layer decreases while the welding current increases, so the bonding strength increases. When the welding current is 120A, the distribution of SnSb phase changes while the welding voltage increases. When the welding voltage is 22V, the bonding strength is the highest.

## 1.  Introduction

As a support shaft transmission part, the bearing bush is very important, especially in large workpieces, the performance of the bearing bush affects the stability and reliability of the entire transmission system. The bearing bush mainly play the role of anti-friction, that is, to deal with the large impact, friction to ensure the integrity of the bearings [1-2]. Compared with other bearing alloys, Tin-based Babbitt alloys have been widely used in key components of bearings due to their unique excellent corrosion resistance, especially in steam turbines, high-speed engines and compressors [3-4]. Moreover, Tin-based Babbitt alloys even can remain soft after repeated cycles of loading because of its lower melting point [5-7].

At present, Tin-based Babbitt alloys on steel-base bearings are mainly produced by centrifugal casting [8]. However, Tin-based Babbitt alloys is easily separated due to the centrifugal force generated during the centrifugal casting process, resulting in non-uniform microstructure distribution

and unstable performance [9]. In this paper, MIG welding method was selected to bond Tin-based Babbitt alloys to steel substrate. The effects of different welding parameters on the microstructure and morphology of the interface IMC were investigated.

## 2.    Materials and Method

In this paper, Babbitt welding wires of ZChSnSb11-6 (named as BW11-6) was used. The chemical composition of Sn-based Babbitt Alloys ZChSnSb11-6 was shown in Table 1. The diameter of the welding wire was 1.6 mm. The ASTM 1045 steel was used as the steel substrate. Before welding test, the surface of substrate was polished to remove the oxidation layer. The surface of welding wires were cleaning to remove oil.

**Table 1.** Chemical composition of Sn-based Babbitt Alloys ZChSnSb11-6 (wt%).

| Brand | Sn | Pb | Cu | Zn | Al | Sb | Fe | Bi | As | others |
|---|---|---|---|---|---|---|---|---|---|---|
| BW11-6 | Bal. | 0.35 | 5.5-6.5 | 0.01 | 0.01 | 10.0-12.0 | 0.1 | 0.03 | 0.1 | 0.55 |

There were 5 sets of welding parameters for testing, numbers of samples and corresponding parameters were shown in Table 2. Protective gas was pure argon and welding speed was 40cm/min. The specimens were cut into squares, the specimens were polished in advance and then corroded by 4% nitric acid alcohol solution. The microstructures of the Babbitt and the interface were studied by the optical microscopy (OM) and scanning electron microscopy (SEM).

**Table 2.** Welding parameter of Sn-based Babbitt Alloys ZChSnSb11-6 (wt%).

| Sample | Welding voltage (V) | Welding current(A) |
|---|---|---|
| 1 | 20 | 115 |
| 2 | 20 | 120 |
| 3 | 20 | 125 |
| 4 | 22 | 120 |
| 5 | 24 | 120 |

In this experiment, the bonding strength of Babbitt alloy and ASTM1045 steel was tested according to the destructive testing method of the bimetallic bonding strength of sliding bearing which referred to the national standard GB/T12948-1991. The digital picture of sample was shown in Figure 1. The tensile speed was controlled by means of stress, and the applied value of stress was 10 N/(mm²s). Increase the stress until the alloy layer or the bond layer broke, or the alloy layer peeled off from the steel back. Five replicate tests were performed on each group of samples. The relative error of the value was less than 10% .



**Figure 1.** digital picture of the bonding strength test specimen

## 3.    Results

*3.1 Microstructures results of Sn-based Babbitt alloys*
The metallographic structure of the Sn-based Babbitt alloys BW11-6 studied in this paper was shown

in Figure 2(a)(b)(c)(d)(e). It can be seen from Figure 2 that BW11-6 is composed of a large number of square SnSb phases, acicular or star-shaped Cu6Sn5 phases in the α-Sn phases.

The microstructure of the Sn-based Babbitt alloys BW11-6 obtained from the five kinds of welding parameters was shown in Figure 2. When the welding voltage is 20V, the metallurgical structure is very sensitive to the changes in the welding current, with welding current increased from 115A to 125A, the crystal grains become coarser, especially the blocky SnSb phase. When the welding current is 120A, the grain size is relatively small when the welding voltage is 22V. At the same time, the microstructure is the most uniform at 22V.
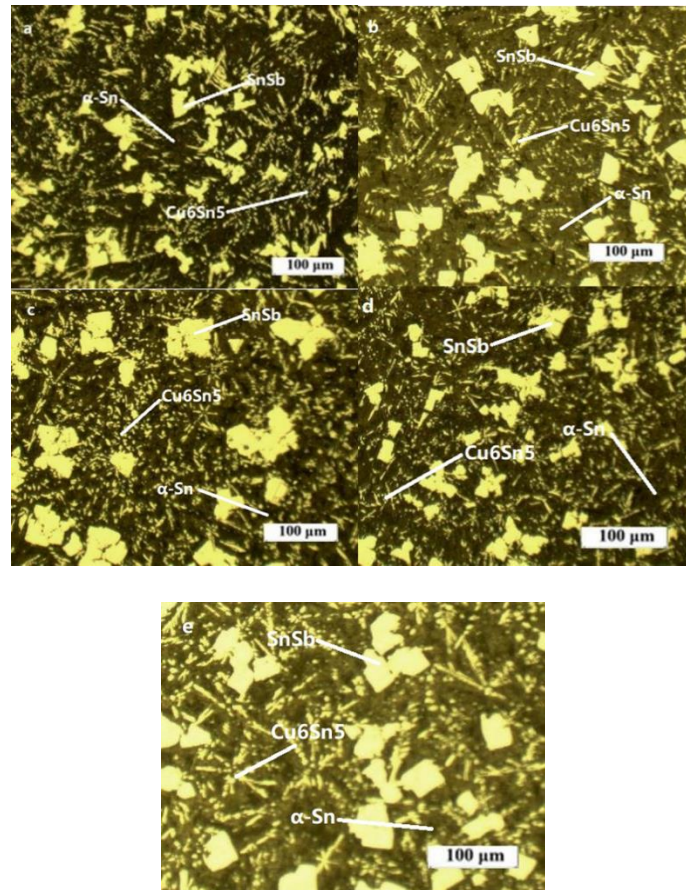


**Figure 2.** Microstructures of different welding parameter of Sn-based Babbitt alloys BW11-6:(a) sample 1(b) sample 2(c) sample 3(d) sample 4(e) sample 5

*3.2 Interfacial structure of the Sn-based Babbitt/ASTM 1045 steel interface*
The bonding strength of BW11-6 and the steel substrate depends on the microstructure of the interface. The interface microstructure of the five welded joints is shown in Figure 3(a)(b)(c)(d)(e). In Figure 3, there is an obvious transition layer between the substrate and the Babbitt alloy, and a large amount of bulk compound (SnSb) is accumulated near the transition layer.
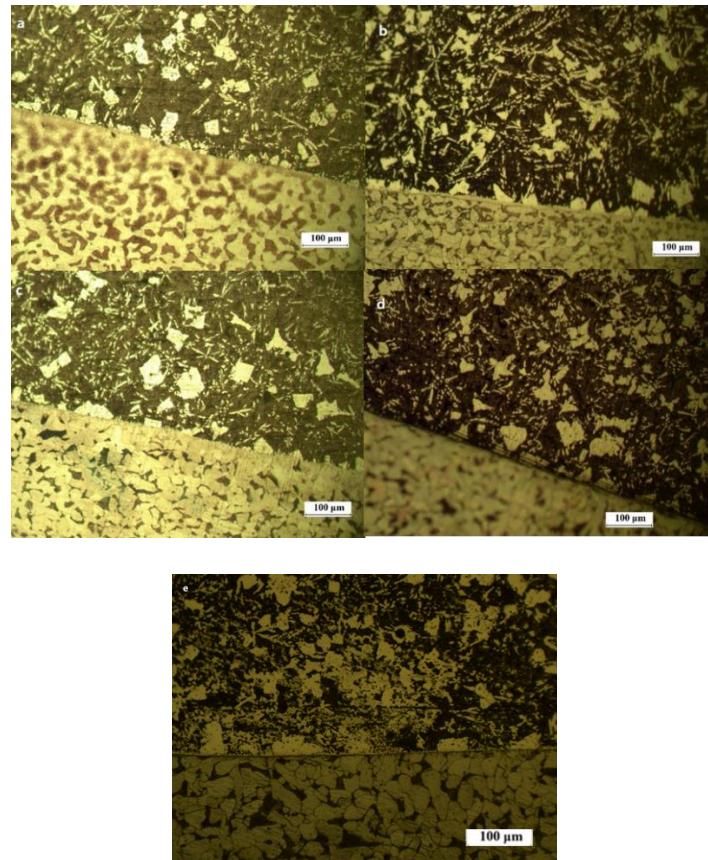
**Figure 3.** Interfacial structure of different experiment conditions: (a) sample 1 (b) sample 2 (c) sample 3 (d) sample 4 (e) sample 5

SEM and EDS were used to further analyze the interfacial microstructure and composition of the samples. It was found that the SEM images of the interfacial microstructure were similar, so one of the samples was selected for the study. The SEM image of the interface of is shown in the left column of Figure 4(a) and the right column of Figure 4 is the result of the line scanning. The results of EDS of points 1, 2 and 3 is shown in Table 3.According to Figure 4(b), the IMC layer at the interface of BW11-6 with the steel substrate is very thin (about 2 microns).
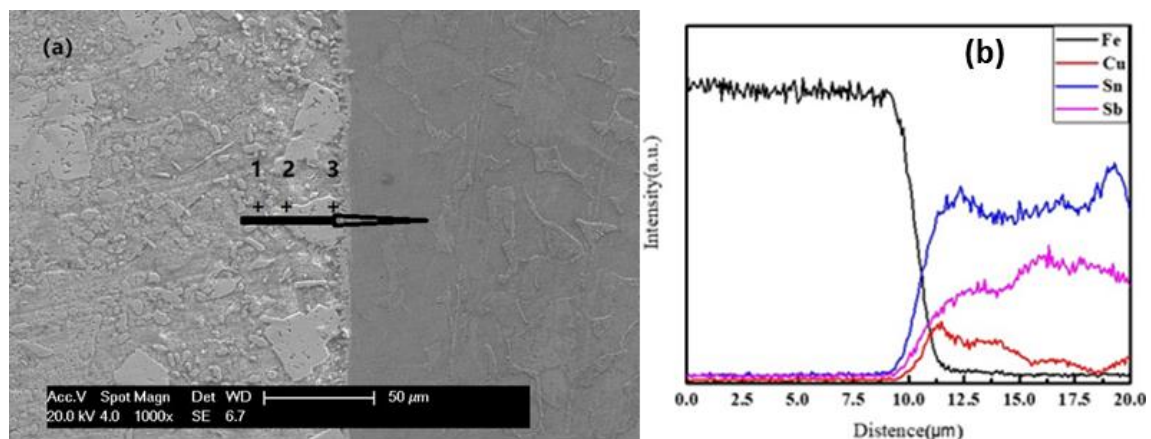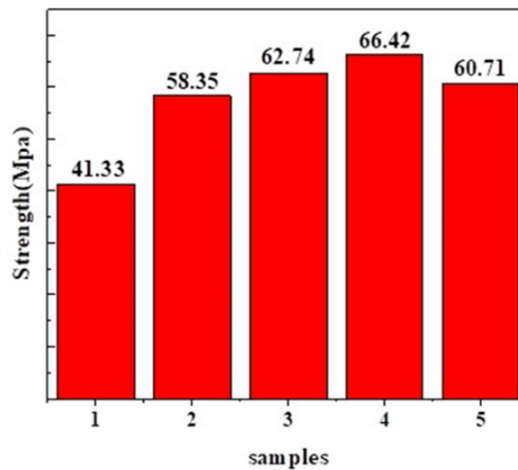


**Figure 4.** The SEM image of interfaces of Sn-based Babbitt alloys and steel substrate with EDS analysis and line scanning results

**Table 3.** The results of EDS at different positions in the IMC layer (at%).

| Position | Fe | Sn | Cu | Sb |
|---|---|---|---|---|
| 1 | 1.34 | 78.75 | 1.34 | 18.57 |
| 2 | 3.05 | 47.72 | 45.59 | 3.63 |
| 3 | 22.30 | 38.78 | 33.56 | 5.36 |

*3.3 The mechanical properties of MIG arc brazing Sn-based Babbitt*
The average test results of the bonding strengths of different samples in the test are shown in Figure 5. When welding voltage is 22V and welding current is 120A, the bonding strength of BW11-6 is the highest, which is 66.42MPa. According to the results of sample 1, 2 and 3, it can be seen that when the welding voltage is 20V, the bonding strength increases from 41.33 Mpa to 62 .74 Mpa as the welding current increases from 115 A to 125 A. According to the results of sample 2, 4, and 5. It can be seen that when the welding current is 120A, as the welding voltage increases from 20V to 24V, the bonding strength first increases from 58.35 Mpa to 66.42 Mpa and then decreases to 60.71 Mpa.



**Figure 5.** The bonding strength of Sn-based Babbitt and steel substrate

## 4. Discussion

*4.1 The effect of different welding parameter on microstructure of Sn-based Babbitt alloy*
From Figure 2, when the welding voltage is 20V, as the welding current increases, the square hard phase SnSb grain is larger. At the interface between BW11-6 and the steel substrate, the phase SnSb floats easily due to the low density and causes gravity segregation. The relatively large proportion of needle-like Cu6Sn5 itself has the ability to prevent the SnSb from floating, so even though the SnSb grains become larger, the larger Cu6Sn5 can better block the SnSb from floating, resulting in a reduction in the number of SnSb at the interface between BW11-6 and the steel substrate. The change of the welding voltage will affect the stability of the welding process. This affects the homogeneity of the microstructure of the Babbitt alloy. When the welding voltage is 22V, the crystal grains is the most uniform, and the distribution of SnSb phase at the interface between BW11-6 and the steel substrate is also the most uniform.

*4.2 The effect of different welding parameter on mechanical properties of Sn-based Babbitt alloy*
When welding current increases, the number of SnSb phases at the interface between BW11-6 and the steel substrate decreases. When the hard SnSb phase is subjected to tensile stress, stress concentration occurs. So the aggregation and growth of a large number of SnSb phases at the interface between BW11-6 and the steel substrate promote the initiation and propagation of cracks and reduce the

bonding strength.

The welding voltage mainly influences the stability of the welding process. Inhomogeneous microstructures results in the aggregation of SnSb phase at certain junctions, which reduce the bond strength. When welding current is 120 A, the welding voltage is 22V, the bonding strength of BW11-6 and steel substrate is the highest. This is because the microstructure of the joint is the most uniform when the welding voltage is 22V.

## 5.   Conclusion

Under different welding parameters, Tin-based Babbitt alloys BW11-6 has different microstructures, and the bonding strength between steel substrate is also different under MIG welding. When the welding voltage is 22V and the welding current is 120A, the bonding strength is the highest. It is 66.42Mpa.SnSb phase near the IMC layer reduces the bonding strength of the sample in the interface between the Tin-based Babbitt alloys and the steel substrate. Due to the existence of SnSb phase, when the specimen is subjected to tensile stress, stress concentration occurs, and the initiation and propagation of cracks are promoted.

## References
[1]   Goudarzi M M, Jahromi S A J and Nazarboland A 2009 Mater. Des **30** 2283-88
[2]   Zeren A, Feyzullahoglu E and Zeren M 2007 Mater. Des **28** 318-23
[3]   Valeeva A K, Valeev I S and Fazlyakhmetov R F 2014 J. Frict. Wear **35** 311-5
[4]   Sadykov F A, Barykin N P and Valeev I S 2003 J. Mater. Eng. Perform **12** 29-36
[5]   Khonsari M M, Booser E R 2002 J. Tribol **124** 428
[6]   Rigney D A 1997 Tribol. Int **30** 361-7
[7]   Bo J 2003 Tribol. Int **36** 781-9
[8]   He Y, Zhao Z and Luo T 2013 Mater. Des **52** 923-31
[9]   Kamal M, El-Bediwi A and Lashin A R 2011 Mater. Sci. Eng. A **530(24)** 327-32