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# Brazing of Different Metal Alloys with Highly-Silver Flux Addition and Microstructure Investigation

Bünyamin Çiçek[1*]

0000-0002-6603-7178

[1]*Machine and Metal Technologies Department, Technical Sciences Vocational School, Corum, Türkiye*

**Abstract**

In this study, it was investigated that two different metal alloys can be soldered with the help of industrial flux. Thus, the soldered state of two different metals used in areas such as defense, automotive, and battery was examined. A low-carbon steel alloy and a GBZ20-grade bronze material were used for brazing. An industrial flux was used as an intermediate material. Flux contains high levels of silver (Ag), as well as Cu, Zn, Pb, and Ni elements. A design is prepared between the two materials during soldering. With the flame heating method, the sample temperature was increased to approximately 800°C. After the experiment, rapid cooling was done in water. Inspection of the solder intermediate zone was examined with the help of a scanning electron microscope (SEM). Chemical analyzes of the materials were followed. Thus, two different metals are combined with a flux-assisted soldering process.

Keywords: Brazing, Steel, Bronze, Flux, Microstructure

**Research Article**

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* Corresponding author
Bünyamin Çiçek
cicekbunyamin78@gmail.com
Address: Machine and Metal Technologies Department, Technical Sciences Vocational School, Corum, Türkiye
Tel: +903122028653

## 1. Introduction

Soldering method is frequently used in many sectors. This process is applied in areas such as automotive, defense, electronics and batteries. The soldering process can be explained as the joining of two different metals at low temperature with the help of an additional structure (1-4).

The necessity of joining two different metals is an industrial need. For example, in an automotive industry, it may be necessary to combine copper and steel alloys in the field of energy and batteries. It is very difficult to manage these two metal-welded joining processes with very different expansion amounts with a fusion welding method (5-7). In addition, it is not possible to combine these metals with melting temperatures far from each other with classical welding methods. In this case, it is an important rule to solder the materials at low temperatures without melting. Thus, a process is performed away from expansion and distortion (8-10).

Solder can be applied by many different methods. The main purpose is to combine the main materials under the melting temperature. At this stage, a solder intermediate situation arises. Products such as an additional soldering wire can be used in the electronics field. A solder wire melted with a flame can be used for brazing metal pipes. However, no additional material can be applied without affecting the transition zone and design (11-14). Additional products may leave a layer or ridge on the materials. In this case, specially developed metal-based flux (paste) structures are used in industry. These technological flux structures, which do not affect the design, are involved in the brazing of alloys close to each other (11, 12, 15, 16).

Solders are generally formed by alloying metals that can melt at low temperatures. In this case, the primary elements can be Sn, Pb and Zn. In addition to these, the secondary elements Cu, Ag and Ni metals give properties to the solders (17, 18).

Brazing of different metallic alloys such as steel and bronze with flux structures is a method used in recent years. However, an academic view and examination has not been formed. The elements in the flux structure act as the intermediate material of the two metals. Thus, the solder area can meet the expected properties under dynamic and static loads (10, 11, 13, 14).

In this study, brazing of two different metals, steel and bronze, with an industrial flux was investigated. Elemental analyzes of the main materials steel and bronze metals were determined before the experiments. Flux was melted by heating the materials with the flame created by the natural gas + oxygen gas mixture. The flux structure, whose surface area increased as a result of melting, formed an interface between the two materials. The interface was followed by scanning electron microscopy (SEM) and reported. The states of the interface at the points of contact with the main materials were examined. Elemental ratios were analyzed after brazing. Thus, the general condition of the microstructure after brazing of two different metals was investigated.

## 2. Materials and methods

### *2.1 Materials*

In this study, S235JR quality low carbon steel (S235) and GBZ20 quality bronze were used as main materials. Castolin ActivaTec 1000 was used as solder flux material. The X-Ray Fluorescence (XRF) (Rigaku Primus II) results of the main materials are given in Table 1. Since the flux material is a commercial product, no elemental analysis was applied.

Table 1. Base materials of XRF analysis

| Elements | S235 | GBZ20 |
|---|---|---|
| Fe | balance | 0.10 |
| C | 0.18 | 0.01 |
| Mn | 1.35 | 0 |
| Sn | 0.01 | 21.25 |
| Cu | 0.45 | balance |
| N | 0.01 | 0 |
| S | 0.02 | 0.01 |
| P | 0.01 | 0 |

### *2.2 Brazing process*

The soldering process first started with a special design for tracking the interface. The designs of the base materials before soldering are shown in Figure 1. A real image of the test sample is also given in Figure 1.

A steel rod with a diameter of 15 mm and a square bronze of 15 mm were used as the main material. The design was completed by inserting the S235 material into the opening on the GBZ20. Before assembly, 5 g flux was plastered with a simple brush to the interior and the space. The test sample fixed on a ceramic base was heated with a flame created with natural gas + oxygen. Temperature was monitored with a laser thermometer (CEM DT836) during soldering. When the temperature reached 800°C, it was waited for 10 s and the sample was cooled instantly in 5 liters of water (25°C). The completely cooled sample was cleaned with a wire brush.

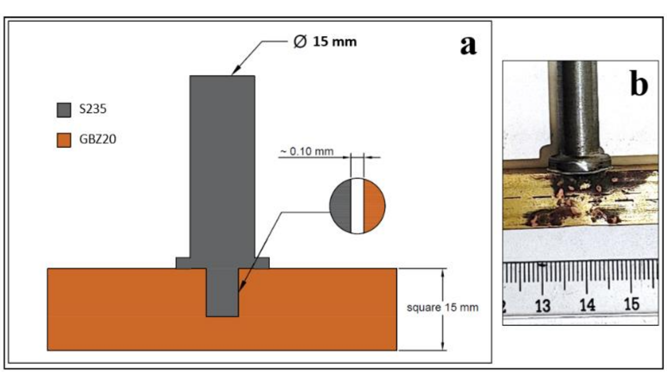



Fig. 1. (a) Design for base materials and (b) test specimen

### *2.3 Micro structure characterizations*

The test samples were cut precisely after soldering. Examination samples were taken into polymer (bakelite) and smoothed with 1200 mesh sandpaper with classical metallographic methods. Then, polishing was done with 1 μm alumina suspension. It was examined without etching. The macro image taken over bakelite is given in Figure 2.

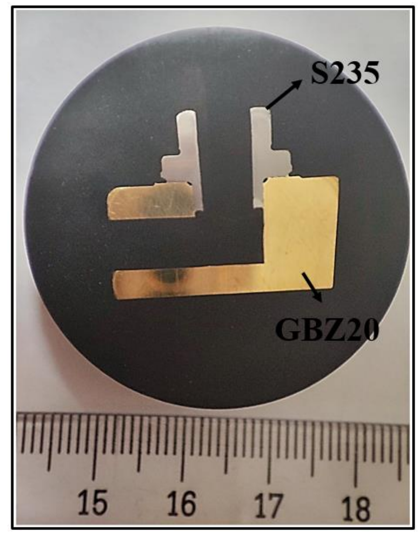



Fig. 2. Micro structure specimen

Microstructure analysis was carried out on Carl Zeiss Ultra Plus brand SEM device. Different regions detected in the microstructure were subjected to Energy Dispersive X-Ray (EDX) (Gemini Fesem) analysis.

## 3. Results and discussions

An acceptable level of joining was achieved as a result of brazing of steel and bronze material with a special flux structure. The basic microstructure image obtained as a result of SEM analysis is given in Figure 3.

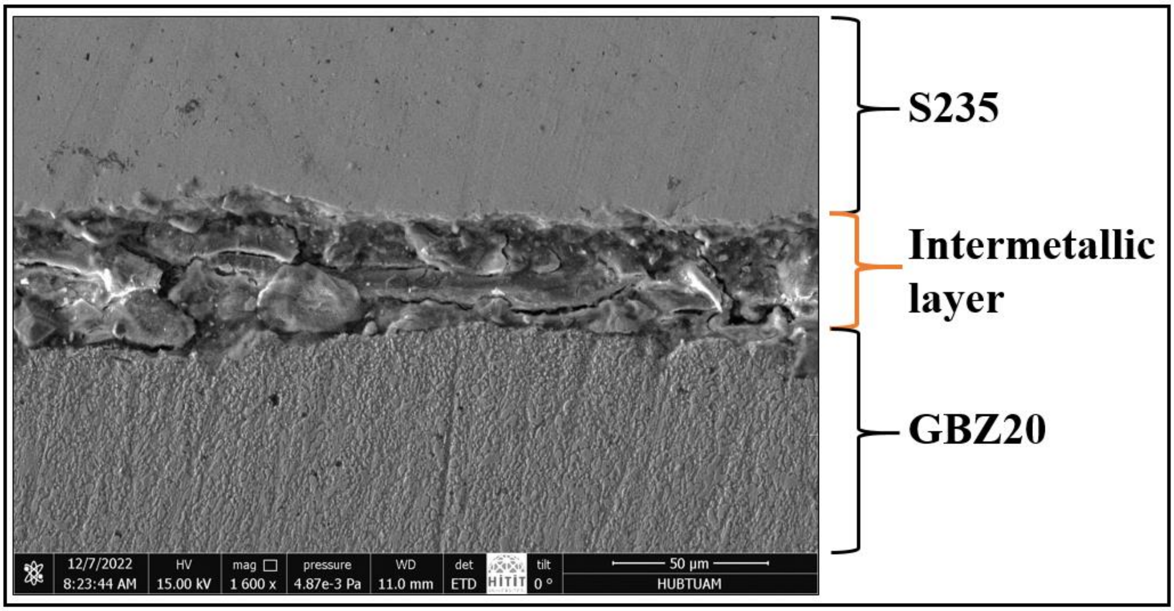



Fig. 3. Basic microstructure of brazing

When Figure 3 is examined, S235 and GBZ20 materials are observed. The remaining steel material on the upper part and the bronze on the lower part are marked. At the interface, as an intermetallic structure, an intermetallic layer formed by the effect of flux is seen.

In a study by Madeni et al., soldering was performed using a flux between Cu-Sn metals and a similar intermediate layer was observed (19). Thus, an intermediate layer consistent with the literature was formed. The microstructure showing the fusion regions formed in the S235 and GBZ20 interlayer is given in Figure 4.

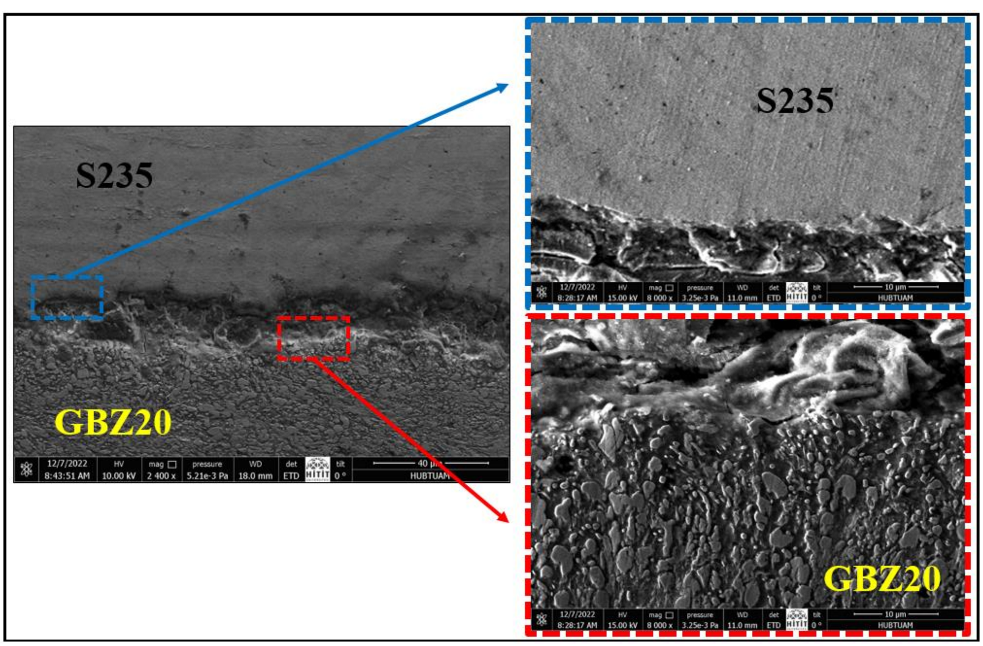
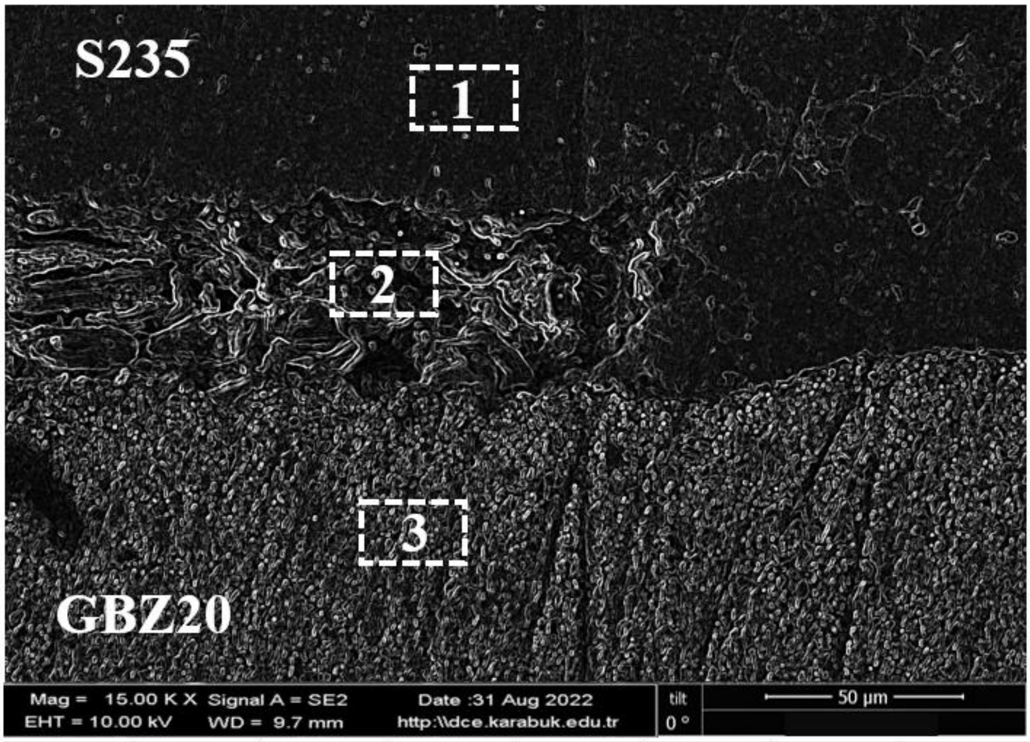



Fig. 4. Fusion zones of brazing

When Figure 4 is examined in detail, fusion points are observed between the solder layer and the base materials. Thus, the fusion semi-solid forms expected to form between the flux and the main materials were formed. In the study by Zhiwei Wang et al., a laser-assisted soldering experiment was performed.

At this stage, fusion zone zones formed between different metals were formed (20). Thus, the partial fusion regions formed in the transition region were supported by the literature. Finally, the EDX analysis results applied to the intermetallic layer are given in Figure 5.




| Zone | Fe | Cu | Sn | Ag | Mn | Pb | Ni |
|---|---|---|---|---|---|---|---|
| 1 | Balance | 0.21 | - | - | 1.18 | - | - |
| 2 | 1.01 | 11.41 | 7.85 | balance | - | 2.52 | 1.25 |
| 3 | 0.01 | balance | 18.25 | 0.01 | 0.18 | 0.52 | - |

Fig. 5. EDX analyzes of intermetallic layer and base materials

According to the EDX analyzes given in Figure 5, base materials are observed in the "1" and "3" zones. Elemental ratios for zones “1” and “3” support the XRF results given in Table 1. Ag, Fe, Cu, Sn, Pb and Ni elements were observed for the intermetallic layer given in the “2” zone. Elements detected in EDX analysis in the fusion zone (point) are in amounts likely to be present in the industrial product. In addition, Fe and Cu elements were found in the “2” zone and it can be said that these elements originate from the base materials. The determination of the elements of base materials in intermetallic structures formed in flux supported soldering processes is a well-known result in the literature.

In the soldering process between S235 quality steel material and GBZ20 quality bronze, the microstructure met the expected results. Partial fusion regions of base materials with solder are observed during soldering processes (21-23). As a result, two different metals were soldered with the help of flux. It can be said that the applied test method and the rapid cooling process after the test gave a successful result.

## 4. Conclusions

S235 quality steel and GBZ20 quality bronze material were brazed with the help of a flux in this study. The microstructure obtained after soldering was examined and the following general conclusions were reached.

1. The flux brazing process applied for steel and bronze materials and the rapid cooling process in water ensured the adhesion of the two structures to each other.

2. Fusion zones were clearly detected between the intermediate layer formed by the flux during soldering and the base materials.

3. In the intermetallic layer, the matrix elements Fe, Cu and Sn elements of the base materials were detected.

As a result, the soldering of metals with different melting points and atomic arrangements with the help of a flux was investigated. The resulting microstructure was supported by the literature. Thus, the idea of brazing steel and bronze alloys with such methods was obtained.

## Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

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