Mechanical and Micro structural Characterization of Al-Al/B4C Laminated Composites Depending on Manufacturing Parameters

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Abstract: In this study, it is aimed to produce a layered composite structure with Al sheath and Al / B4C cored by extrusion technique and to characterize the mechanical and micro structure of the products. In the production of composite billets, powder in tube (PIT) method was used. In this method, Al7075 (ø 30 mm) tube is filled with Al2124 / B4C powder mixtures. The semi-finished composite billets were sintered at 500 ° C for 1 hour and extruded at the extrusion ratios of R = 14 R = 9 and R = 6.25 at the same temperature to obtain circular cross-section rods. The density changes, hardness distributions and sheath-core section ratios of these bars were determined. The changes of these values depending on the extrusion rate and B4C ratio were investigated. It is also revealed in the micro structure changes depending on these ratios.

Keywords: Bimetal Composite, Laminated Metal Composite, Extrusion, Density, Micro structure, Hardness

1. Introduction

Machine elements in the form of hollow, hollow or hollow tubes with circular or special sections are widely used in the engineering field. These elements are now produced according to the needs of different materials, both inside and outside. This requirement can be in the form of requiring different features inside and outside of the machine element, or requiring a new feature. Layered metal composite materials, a type of material developed for such situations, are a different type of typical composite materials formed by joining the interfaces of two or more materials.

Aluminum has a heavy use in machinery, automotive and aeronautics due to reasons such as high strength / density feature, ease of workability. Along with this, the work of composite materials to improve the properties of aluminum or to use the superior properties of aluminum in different areas is also increasing. When we examine layered metal composites, it is seen that aluminum is used in the production of lighter and more economical conductive materials [1, 2, 3] together with copper. Or we can see that aluminum is used together with materials like steel to obtain structures with high strength-corrosion resistance [4]. Likewise, studies have been carried out in order to combine the superior properties of two different aluminum alloys [5].

2. Material and Method

In layered metal composites, the outer part of the material is called "sheath" and the inner part is called "core". For the layered metal composites produced in this study, 7xxx series aluminum alloy was used as sheath, 2xxx series aluminum powder with average size of 30 μm and B4C powder with average
size of 20 μm were used (Figure 1). The production was carried out by extruding the powder compacted tube into it.

Figure 1. Sheath dimensions (mm) and prepared billets for extrusion.

Al2124 / B4C powder mixtures containing 5%, 10% and 15% B4C in volumetric proportions were used in the sheaths which the oxides removed with the grinding operation. This powder mixture is compressed into sheaths at a pressure range of 400-500 kPa. The billets obtained in this way were sintered at 500 °C for 1 hour and then immediately subjected to extrusion. The billets were extruded at the extrusion ratios of R = 14, R = 9 and R = 6.25 by decreasing the diameters of 8, 10 and 12 mm. Table 1 shows the technical data of 12 different billets with extrusion process.

Table 1. Technical data of the tickets entering the extrusion process

| No   | Billet   | Sheath | Core             | D_out | D_in | Extrusion Ratio |
|------|----------|--------|------------------|-------|------|-----------------|
| 1    | No 1     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 14              |
| 2    | No 2     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 9               |
| 3    | No 3     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 6.25            |
| 4    | No 4     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 14              |
| 5    | No 5     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 9               |
| 6    | No 6     | Al7075 | % 5 B₄C-Al2124   | 30 mm | 20 mm| 6.25            |
| 7    | No 7     | Al7075 | % 10 B₄C-Al2124  | 30 mm | 20 mm| 14              |
| 8    | No 8     | Al7075 | % 10 B₄C-Al2124  | 30 mm | 20 mm| 9               |
| 9    | No 9     | Al7075 | % 10 B₄C-Al2124  | 30 mm | 20 mm| 6.25            |
| 10   | No 10    | Al7075 | % 15 B₄C-Al2124  | 30 mm | 20 mm| 14              |
| 11   | No 11    | Al7075 | % 15 B₄C-Al2124  | 30 mm | 20 mm| 9               |
| 12   | No 12    | Al7075 | % 15 B₄C-Al2124  | 30 mm | 20 mm| 6.25            |

Table 2 Some properties of materials used.

| Material | Density(gr/cm³) | Powder size |
|----------|-----------------|-------------|
| Al 7075  | 2.81            | -           |
| Al 2024  | 2.767           | 30 μm       |
| B₄C      | 2.52            | 20 μm       |
After 12 different billets were extruded under the same conditions, samples were taken from the obtained circular materials (Fig. 2) in suitable sizes for hardness and density examination. Hardness values were measured as micro vickers hardness measurements. The density measurements of the materials were made with Archimedes principle. The productions and tests were carried out at the Composite Laboratories of the Mechanical Engineering Department of Erciyes University.

Figure 2. a) Extrusion mold set and press b) Extrusion billet and product.

3. Results

3.1. Hardness Dispersion

The hardness values at the points shown in Fig. 3 were taken from the sections of the rods obtained from the extrusion end. The hardness test made on the cross section will show the behavior of compacting the material, especially the powdered core, after the extrusion process. For the extrusion process is carried out under warm conditions, it is not expected that the deformation hardens at high rates. When we look at the hardnesses of the Al 7075 bars (Figure 4), the hardness values are increased by at most 7-8% with increasing extrusion rate. However, in composite structures, the situation is somewhat different. The hardness value increases when going to the boundary of the sheath, it falls when it goes to the core region. It is believed that the rise in the sheath zone is due to the fact that the Al 7075 region is more deformed at the boundary, due to the different flow behaviors of the two separate material structures. The hardness in the core region is relatively lower than that of the powder structure.

Figure 3. The points taken hardness values
Figure 4. Cross-section hardness distributions depending on extrusion ratios a) R=14 b) R=9 c) R=6.25
When we examine the effect of varying the amount of B4C in the same extrusion ratios, the material has 5% B4C ratio is the highest intersection hardness. As the B4C ratio increases, the hardness distribution in the cross section becomes more stable. The hardness distribution in the core is increased by B4C but not by the extrusion rate (Fig. 5).

**Figure 5.** Hardness distributions on the cross section with the B4C ratios
3.2. Density and Cross Section Change

The sheath radius and the core radius of the composite material are proportioned and are defined as "β". And we looked at the change of β ratio by B4C amount and extrusion rate. It is important for the balancing of the flow characterization that the β ratio is as well as the billet. This ratio is the average β = 1.45 of the billet. β ratio does not change significantly with the extrusion rate. However, with the increase of B4C ratio, β ratio is seen to increase a little. This indicates that the B4C ratio reduces the plastic deformation capability of the core (Fig. 6).

The density of the composite material increases with the increase of B4C ratio as expected. However, there is no significant increase in the density with the increase of the extrusion rate (Fig. 7). It is believed that the reasons for this are the compression of the powder into the sheath with the minimum porosity and the hot extrusion process.

![R-β Change](image1.png)

**Figure 6.** Change of β ratio by B4C amount and extrusion ratio.

![ρ-R](image2.png)

**Figure 7.** Change of density by extrusion rate.
3.3 Micro structure

When we look at the microstructures of layered metal composites, it appears that the grain sizes of Al7075 are slightly larger than the Al2124 grain sizes (Figure 8). This difference is thought to be due to the fact that Al2124 is produced by sintering in the form of powder, even though the both materials pass the same process conditions. When the sheath-core regions of layered metal composites produced in the form of Al7075-Al2124 and Al7075-Al2124 / B4C are examined, it is seen that the joining is very well performed.

![Microstructural images taken from materials.](image)

**Figure 8.** Microstructural images taken from materials.

4. Conclusion

The mechanical and microstructural changes of the produced composite bars according to the production parameters were investigated. The results obtained can be summarized as follows:
1. Hardness values rise in the sheath areas close to the sheath-core boundary. This can be caused by the high rate of plastic deformation in these areas.
2. The hardness decreases from the core to the center. This is due to the flow characteristic of the extrusion.
3. The hardness does not increase with the increase of B4C ratio. The increased porosity caused by the increased B4C causes the hardness not to rise.
4. The hardness is increased by the increase of the extrusion rate. Because of this reason the porosity is decreasing.
5. Homogeneous distribution is observed in the core region.
6. As the extrusion ratio increases, the solid solutions precipitated on the grain boundaries become smaller and their dispersions become homogenous.
7. $\beta$ ratio shows a slight change. The reason for this is thought to be that oiling is not good and billets are not produced as standard.

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