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Research Article

# Recycling and Characterization of Metallic Chips Using Powder Metallurgy

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**Abstract:**

In this study, a new metal matrix composite material was produced by sintering from cast iron and bronze shavings made by recycling melting method. In the production of metal matrix composite material, 90% CuSn10 as a matrix material and 10% GGG40 cast iron as a reinforcement material were used. The chips having the same dimensions were mixed in a homogeneous mixture and pre-formed under a pressure of 1146 MPa and then sintered at 875 °C. The mechanical properties and porosity of the produced materials are characterized and the mechanical properties are compared with the mechanical properties of the bronze material in bulk state. According to the results, the mechanical properties of the material produced by the sintering method are very close to that of the bronze material in the bulk state.

## 1. Introduction

With the increasing world population and decreasing fossil resources, the need for alternative recycling resources has arisen in the industry. There has been increasing interest in other metal chip recycling methods besides the melting process in recent years. A few of them are recycling the chips with sintering and hot shaping [1-4]. Industrial recycling of metals is usually done by melting [5]. Another approach is to use 1 to 4 mm of chips. These dimensions are much more rough than the particle size used in conventional powder metallurgy [3-7]. According to another study, copper powders were combined with hot deformation of aluminum powders and a composite with improved mechanical properties was obtained [8]. In another study made with Fe, Cu and Co powders subjected to sintering after cold pressing, it was seen that the Cu powders increased the density by closing the pores of the material. According to these and similar works, cast iron and bronze shavings were recycled by sintering after pre-shaping [3-7].
In this work, cold pressed metal matrix composite material was sintered at 875 C with mixing of 90% Bronze and 10% GGG40. The mechanical properties and microstructures of the obtained metal matrix composite material were investigated.

## 2. Experimental Details
## 2.1.Material and Processing

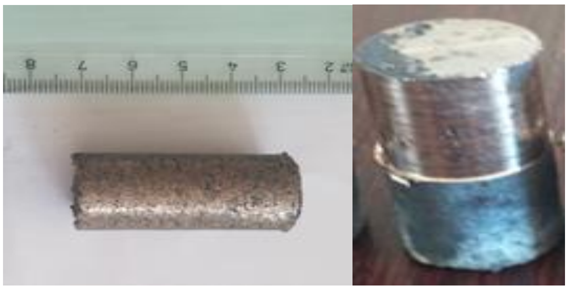
In the production of composite materials, CuSn10 was used as matrix material and GGG40 cast iron material was used as reinforcement material. The chemical contents of both components used are shown in Table 1. The materials were turned into chip under certain cutting conditions. The chips are then milled to a ball mill to achieve a more homogeneous structure.

***Table 1*** *Chemical content of CuSn10 and GGG40*

| Material | C | Si | Mn | S | Mg | P |
|---|---|---|---|---|---|---|
| GGG40 | 3,4 | 2,5 | 0,13 | 0,01 | 0,046 | 0,08 |
| **Material** | **Cu** | **Sn** | **Zn** | **Pb** | | |
| CuSn10 | 88,2 | 9,3 | 1,35 | 0,01 | | |

Grinded chips are sieved in 1-2 mm sieves to obtain chips in the same form and size. The chips are weighed at a ratio of 90% CuSn10 - 10% GGG40 by weight with a precision of 0.001 gr. The chips were mixed with a conical mixer to obtain a homogeneous structure.

The mixed chips were placed in the compression test specimen mold and pre-formed by a single effective press. Compression was applied in two stages. the pressure was first applied to 955 MPa at the same frequency, then the pressure was increased by 25% to 1146 MPa. Thus, compression samples having a diameter of 19 mm and a length of 42 mm were obtained (Figure 1-a).



**a)** **b)**

***Figure 1 a)*** *Compression sample* ***b)*** *Processed surface after sintering*

The material was sintered in the ash furnace after being pre-shaped (Figure 1-b). The sintering process was carried out by cladding the raw samples with a seamless steel pipe with clad steel. During this time, some powdered graphite was thrown into the pipe. The reason for doing this is to minimize the oxidation at high temperature. Powder graphite is used to inhibit oxidation by binding oxygen remaining inside. During the sintering process, the materials were left at 875 ° C for 1 hour and then allowed to cool to room temperature. Figure 2 shows the sintering temperature profile. The sintered material was processed to have a diameter of 16 mm and a length of 32 mm and subjected to porosity and compression test. All experimental studies were repeated three times and averaged.

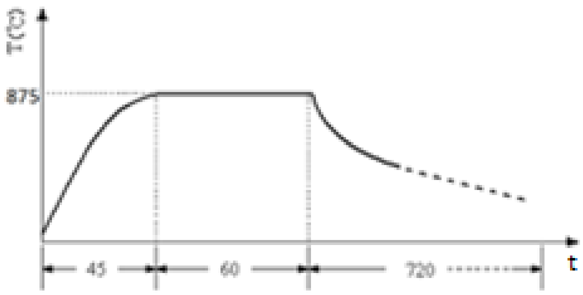
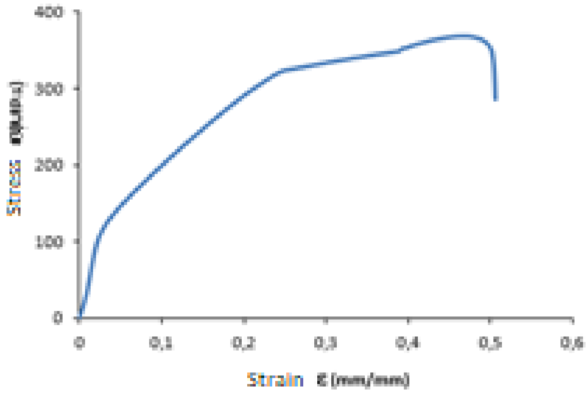



***Figure 2.*** *Sintering Temperature Profile*

## 3. Analysis Methods and Results

Compression tests were performed at room temperature in the Instron 8801 brand tensile testing machine. Compression test samples were broken by drawing at a feed rate of 2 mm / sec according to ASTM (E9-89a) standard. Figure 3a shows the graph obtained after the pressing test. Stress, strain, force and elongation data were obtained in the results of the experiments. Also shown in figure 3b is the material that breaks after the compression test.




a)

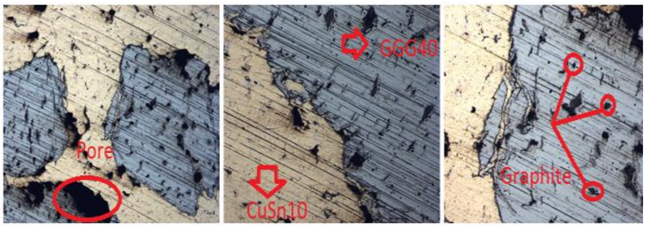
b)

***Figure 3****.a) Stress-Strain curve during the compression test b) broken sample after compression test*

The densities of metal matrix composites were measured in Archimedean scale. Also the mechanical test values are given in Table 2. The processed specimens were first subjected to surface polishing in order to obtain optical microscope images. Microstructure images were taken on a reverse-metal microscope (Figure 4).

***Table 2.****Compression test results*

| Material | Compressive Strenght (MPa) | Resilience ($J/m^3$) | Toughness ($J/m^3$) | Epsilon Final (mm/mm) | Relative Secant Mod (S/So) | Density ($g/cm^3$) | Porosity (%) |
|---|---|---|---|---|---|---|---|
| %90CuSn10-%10GGG40 | 346,25 ±23,15 | 0,53 ±0,01 | 230,15 ±29,65 | 0,5 ±0,02 | 0,447 ±0,17 | 7,163 | 16,222 |
| Bulk CuSn10 | 491 | 9,84 | 360 | 0,93 | 0,61 | | |




a) 875°C-50x b) 875°C-100x c)875°C-100x

***Figure.4*** *Microstructure images*

## 4. Conclusions

Cast iron and bronze metals can be recycled by sintering method after cold pressing instead of melting method. With this method, even though there is some attenuation in mechanical properties, this conversion can be achieved with a little material loss. The compression stress of the materials produced by this method could reach 70,5% of the compression stress of the bronze. This is an indication that the material has been recycled with this method. The toughness values of the produced materials reached 72% of the bronze toughness value in the mass state. This showed that the material could be recycled 72%.16% porosity of the produced composite materials will increase the oil absorption capacity. This feature makes the material available even when the bearing is not exposed to overpressure and the bearing is high speed.When the microstructure images of the composite material are examined, yellow parts show bronze and gray parts show cast iron. It is seen that the bronze shavings, which become semi-solid due to the effect of temperature, are joined together and become a whole by wrapping around the cast iron shavings. In addition, the pores and graphites in the structure draw attention.

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