DEFORMATION BEHAVIOR AND CHARACTERIZATION OF COPPER ALLOY IN EXTRUSION PROCESS

Shalini Kumari and Ajeet Kumar Rai
Mechanical Engineering Department, SSET, SHIATS
Allahabad-211004, UP, India

Devendra Kumar Sinha
Mechanical Engineering Department, IIT - BHU,
Varanasi, UP, India

Rahul Charles Francis
MED, SSET, SHIATS,
Allahabad-211004, UP, India

ABSTRACT

In the proposed work experimental studies have been performed on the extrusion of Copper rod. The commercial extrusion machine has been used for the extrusion of copper circular rod of diameter 12.5 mm. Microstructure analyses of the extruded products of Copper before and after deformation (extrusion) have been carried out. Material properties of Copper have been found using tensile and hardness test. It is observed that more uniform and homogeneous grains are obtained after extrusion. It is observed that the tensile strength of the extruded product increases by 6.8 % after extrusion of material and the braking load is increased by 22.9%.

Key words: Copper Alloy, Extrusion process and Hardness test

http://www.iaeme.com/IJMET/issues.asp?JTypeIJMET&VType=6&IType=7

1. INTRODUCTION

Extrusion is an important metal forming process having applicability in industrial as well as domestic sectors. Extrusion is the process by which a block of metal is reduced in cross section by forcing it through a die orifice under high pressure [11,
12]. Some of the important products of extrusion are rods of various cross sections, tubes, I-sections, channels etc. Extrusion is a hot-working process, which, like forging, rolling, etc., uses the good deformability of heated metallic materials for shaping them. The most important aspect of this process is that it enables considerable change of shape to be achievable in a single operation. Extrusion process is a means of dealing with metals and alloys whose metallurgical & mechanical properties renders them unsuitable for shaping by other manufacturing methods. With extrusion it is possible to form complex sections that cannot be produced by other methods of manufacturing.

One of the current challenges faced by the manufacturing industry is to produce component of high strength, resistance to fatigue, heat corrosion and low production cost. Forming is one of the process, which bears the additional advantage of greater utilization of raw materials and high productivity apart from above advantage. Among the common forming processes extrusion-forging is a process where difficult to produce shapes, can be formed with better mechanical properties and net shape production can be achieved. The experimental works on plastic deformation [12, 14] and metal forming starting in France by Colomb and Tresca. In the early 20th century the research on plastic deformation flourished in German. Towards the 2nd half of the 20th century analysis of the metal forming process was developed and efficiently used in all over the world. Many researchers contributed remarkable findings towards the field of extrusion [16].

2. EXPERIMENTAL STUDY AND CHARACTERIZATION

In the previous chapter literature review on Extrusion process has been carried out so that the probable conditions for the experiments could be made and experiments can be carried out successfully for different metals and alloys and formability knowledge could be generated to help industries involved in continuous extrusion process [2–4, 6–9]. The results so obtained would be required to be validated the process under study so as to ensure the correctness of the theory and practice. In the extrusion process, extrusion ratio, extrusion velocity and pressure by intensifier can be set and calculated and the best condition for extrusion of an alloy or metal is found. It is desired that a defect free part is produced. All the products of different alloys or metals out of the fabricated and commercial extrusion set up have been formed and presented in section 3.2. Material characterization of the product samples such as microstructure analysis, tensile test and hardness test before and after deformation has been carried out in this chapter to predict the material properties of feedstock before and after extrusion. The experiment is done for the Copper feedstock for several extrusion speed and extrusion ratio and formability of Copper has been found very well after the experiments. Figures 1–3 show the extruded product of Copper at different velocity and extrusion ratio. Figure 3 show the commercial setup used for carrying out the experimentation of Copper feedstock at different velocity and extrusion ratio.

<table>
<thead>
<tr>
<th>Elements</th>
<th>% Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>99.99</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.0005</td>
</tr>
</tbody>
</table>
3. CHARACTERIZATION

In this section three more studies are introduced such as Microstructure analysis of the extruded products like Copper, Tensile test and Hardness test of the extruded products to examine the material properties and microstructure prior and after the deformation of the feedstock material.

3.1. Microstructure analysis of the raw material and extruded product

In this section, the process of microstructure analysis of the extruded products through LOM (Light Optical Microscopy) method is explained. The Extrusion of Copper rod is carried out on the commercially available Extrusion setup TBJ 350.

Metallography (Sample Preparation) of Samples

The products of Copper extruded out using the commercially available setup are cut to a finite length using hacksaw as shown in Figure 3. Also samples of raw feedstock of Copper are prepared to study the microstructure of the material before and after deformation [13]. The aim of this section is to determine the probable extrusion speed and extrusion ratio at which the best microstructures are obtained.

For microstructure analysis of any material, the faces of prepared samples on which microstructures is to be obtained are initially rubbed on emery papers of coarse, medium and fine grades in longitudinal and lateral directions so as to avoid any
scratches and obtain mirror like faces before polishing of the samples. Polishing of the samples plays a vital role in the microstructure analysis of different materials. Some materials which are very soft such as Aluminum are very sensitive to pressure, therefore polishing of such kind of materials consumes much time as compared to other materials such as Copper and Brass. Polishing of the prepared samples are carried out till scratch free mirror like finish of the faces of the prepared samples are obtained. Velvet cloth, Brasso and Kerosene have been used while polishing of the prepared samples. During polishing of the prepared samples it has been found that polishing of Copper is easier as compared to the polishing of Aluminum samples. After polishing, the samples are etched using proper etchant. For Aluminum samples, Keller’s reagent (3 ml HCl, 5 ml HNO$_3$, 2 ml HF, 190 ml water) has been used as etchant whereas for Copper samples Ferric chloride in suspension of hydro fluoric acid and water has been used as etchant. Finally, the polished scratch free samples are mounted on the slide and are placed under the microscope with different magnifications for obtaining microstructures of the prepared samples.

3.2. Microstructure analysis of samples

Different samples of Aluminum and Copper at various extrusion wheel velocity and extrusion ratio have been taken to study the microstructure and deformation characteristics. Measurement of grain size and its comparison before and after deformation (extrusion) is possible by using standard length at different places in an image and the equation is given as:

$$d = \frac{(L_{\text{average}} \times \text{grain shape factor})}{M}$$

Where d: grain diameter, and

M: magnification

and grain shape factor is constant for every material. Therefore its value can be neglected for comparison before and after deformation (extrusion).

$$L_{\text{ave}} = \frac{1}{N} \sum L/n_i$$

N: number of data

L: Real visible and measured test length and

n: number of intercept.

For all images real magnification has been calculated from the ratio of visible or actual standard length over written length. All the samples are of circular shape cut out of raw feedstocks as well as of extruded products. The samples of Aluminum and Copper are prepared from the extruded product at various extrusion wheel velocity and extrusion ratio. Sample of raw feedstock is also prepared to examine its microstructure before deformation (extrusion) and comparison of microstructure and grain size can be studied at different extrusion wheel velocity and extrusion ratio. LOM (Light Optical Microscope) has been used for getting images of microstructure after proper polishing. Magnification of 50x, 100x and 200x has been used for all the samples. PL-Ink capture and Axiovision Rel 4.8 software have been used for obtaining the images under microscope and for measuring the grain size by making standard length respectively.

4. RESULTS AND DISCUSSION

4.1. Microstructure Analysis

In this section the microstructure images of all the samples of Copper alloy (C 101) has been carried out under different extrusion ratio. The microstructure of the
feedstock before extrusion and the final microstructure of the extruded product are shown in Figures 4 and 5. The microstructure images of all the samples show no considerable changes of grain size during before deformation (extrusion) but the shape of grains is changed as they are elongated after deformation (extrusion). The feedstock before extrusion has uniform grains. The average size of the extruded alloy after extrusion ranges from 80 µm to 200 µm.

**Figure 4** shows the microstructures of Copper samples of raw feedstock of 12.5 mm size at 50x, 100x and 200x respectively.

**Figure 5** Shows the microstructures of Copper samples of 8 mm size at 50x, 100x and 200x respectively

### 4.2. Tensile Test Result

It can be inferred from the table that maximum load bearing capacity of the extruded product increases by 8%. The tensile strength of the extruded product increases by 6.8% and the braking load is increased by 22.9% after extrusion of material.

**Table 2** Tensile Test result of Copper rod

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sample details</th>
<th>Max. Displacement (mm)</th>
<th>Max. Load (kN)</th>
<th>Max. Strength (MPa)</th>
<th>Breaking Displacement (mm)</th>
<th>Breaking Load (kN)</th>
<th>0.2% Yield Strength (MPa)</th>
<th>Energy Break (J)</th>
<th>% Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.5 mm</td>
<td>3.13</td>
<td>3.648</td>
<td>234</td>
<td>7.440</td>
<td>1.458</td>
<td>127.9</td>
<td>22.11</td>
<td>43</td>
</tr>
<tr>
<td>2</td>
<td>8 mm</td>
<td>6.300</td>
<td>3.941</td>
<td>250</td>
<td>9.168</td>
<td>1.793</td>
<td>53.2</td>
<td>30.23</td>
<td>52.46</td>
</tr>
</tbody>
</table>
Deformation Behavior and Characterization of Copper Alloy in Extrusion Process

4.3. Hardness Test Result

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sample detail</th>
<th>Average Hardness on Vickers Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.5 mm(Raw material)</td>
<td>70.6</td>
</tr>
<tr>
<td>2</td>
<td>8 mm(Extruded Product)</td>
<td>82.2</td>
</tr>
</tbody>
</table>

It can be inferred from the table that hardness of the extruded product increases and is more than the material before extrusion.

5. CONCLUSION

In the present experimental work commercial Extrusion machine [9] has been used for the extrusion of circular rod of diameter 12.5 mm and the product has been found satisfactory. Characterization of Continuous Extrusion process like microstructure analysis, tensile and hardness test of the copper sample before and after extrusion has been performed in the proposed work. Microstructure analysis of the extruded products of Copper before and after deformation (extrusion) has also been carried out. Material properties of Copper have been found using tensile and hardness test. It can be concluded from the proposed work that

- More uniform and homogeneous grains are obtained after extrusion.
- Material properties of the material can be enhanced after extrusion of raw material as it is clearly visible from tensile and hardness test result.

REFERENCES


http://www.iaeme.com/IJMET/index.asp  79  editor@iaeme.com


