The Superplasticity Behavior of Multiple Forged Al7075 Alloy

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Abstract - This work studies the effect of multiple forging (MF), on the superplastic behavior of Al7075 alloy. The raw material was received as a rod. The specimens were cut and annealed at 450°C for 30 minutes. The cylindrical specimens were subjected to MF at 250°C for three passes. Two different base materials were tested: raw material (as received then annealed), and MF material. Tensile tests at different elevated temperatures (450, 470, 490 and 510°C) were done with nearly constant strain rate. Hardness and tensile tests were performed to measure the mechanical properties (which are affected by the MF). It has been proven that the MF base specimen shows lower tensile strength and better maximum elongation when compared with the raw material. Other than these mechanical tests, some metallographic samples were performed to assist in obtaining rationale to this property’s change.

Key Words: 7075 aluminum alloy, multiple forging, superplasticity.

1. Introduction

The Al7075 alloy is a structural material of good quality, because of its various mechanical properties, which include: low density, high strength, moderate ductility, and toughness [1]. Due to these properties, this alloy is used for highly stressed structural parts. Applications include: aircraft fittings, gears & shafts, fuse parts, meter shafts & gears, missile parts, regulating valve parts, worm gears, keys, and various other commercial aircraft & aerospace applications [1,2]. MF is one of the severe plastic deformation (SPD) techniques, which is used to refine the grain size [3-7]. This grain refinement has a great effect on several material properties such as: strength, fatigue and superplasticity [4, 8].

The term superplasticity is defined as “the ability of a material to exhibit high tensile elongation before its failure [9]. This behavior is studied by much research across the world [10-12]. The reason for this interest in it came from its several advantages over the conventional forming operation, such as: the increase in productivity [13], the ability to form large and complex work pieces in one operation, the excellent precision of the finished product and the fine surface finish. Also, it does not suffer from residual stresses. Products can also be made larger to eliminate assemblies or reduce weight, which is critical in aerospace applications; the force required and the tooling costs are lower too [14].

2. Material and test methods

The considered material was produced at SWA (Southwest Aluminum group) Co. Ltd. The chemical composition is shown in Table-1:

<table>
<thead>
<tr>
<th>Material</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT%</td>
<td>0.12</td>
<td>0.37</td>
<td>1.76</td>
<td>0.06</td>
<td>2.66</td>
<td>0.23</td>
<td>5.66</td>
<td>0.02</td>
<td>balance</td>
</tr>
</tbody>
</table>

The raw material was received as extruded rod, 40 mm in diameter and 3m long. The received rod was annealed at 450°C for 30 minutes, then it was left to cool in the furnace in order to allow the precipitation process in the material to complete; this low cooling rate provides a stable base material for further tests.

2.1 Multiple forging (MF)

The principle of this technique is performing multiple repetitions of free forging operations by changing the axis of load by 90° each pass, as shows in Fig-1. The MF technique provides less homogeneity compared to other SPD techniques, however, it produces large specimen dimensions [8] and, because of the low force level and the open die forging needed, the tool cost is lower than that in other SPD techniques. There are some parameters that have to be determined before performing the MF process. One of the most important parameters is the forming temperature, since it has significant effect on forming ultrafine grain structure. The ultrafine grain structure development requires lower working temperatures than those commonly used in the conventional manufacture of semi-finished products [15]. In order to determine the forming temperature, several trial tests were done, and the results show that the lowest temperature which can be applied for all process steps is 250 °C.
The diameter-to-height ratio, which is another parameter that has to be taken into consideration, was found to be suitable at 0.54(D/H), according to the experimental results.

2.2 Tensile test and hardness measurements

It is widely used to investigate the strength and ductility of materials, and also as a main test for the superplasticity investigation of the materials [9, 16]. The test was done at different temperatures (450, 470, 490 and 510°C). The strain rate was not constant but changed within a very close range, when the strain rate decreased down to 70% of the starting value (0.01), the speed of the machine crosshead increased to raise the strain rate again.

Some other tests, such hardness measurements and optical microscopy photos, were carried out to check the properties and structure changes during the MF process.

3. Results and discussions

The results of all tests, which were done for both Raw and MF materials, show an improvement of material behavior after the MF process, as well as a microstructure development.

The results of the hardness measurements shown in Chart-1, describe the changes during the work processes. The raw material has the highest hardness of 118.25 HV, which then decreases to 81.6 HV after MF. The standard deviation decreases in the MF material, which can be seen clearly from the width of the natural distribution measurement curve. These results show an improvement in the structure homogeneity. It should be noted here that the number of hardness measurements was over 30 points distributed randomly on the material surface.
The optical microscope photos show the microstructure development during the MF process; both, the second phase particle size and the grain size decrease after the process fig-2. This grain refinement gives the material ability to behave as superplastic during tensile tests. The superplasticity can be further improved by modifying some of the process parameters, mainly the strain rate and forming temperature.

**Fig -2**: optical microscope photos of Raw material (left), and the 3-pass MF material (right)

The hot tensile test result shows quite good superplasticity for MF at 450°C; chart-2 shows the improvement in the aspect of superplasticity. The maximum elongation for raw material was 52%, while in the case of MF material was 142%.

![Chart 2: The stress-strain diagram for raw and MF materials](chart.png)

MF material shows less hardness and lower stress strain curve. This behavior can be explained by the dynamic recrystallization which is already noted after MF process [17, 18].

**3. CONCLUSIONS**

The MF process has high effect on the mechanical properties as well as the microstructure; some improvement in the properties can be seen from the stress strain curves in fig-4. The refining process does exist and the grain size decreases as seen in fig-3. Material homogeneity was also notably improved; this property’s improvement was due to two reasons: one is the grain refinement, and the other is the decrease in the second phase particle size.

The MF material shows good superplasticity compared to the raw material see fig-4; the maximum elongation increases up to 3 times more than that of the raw material, which means that the refining of the grains has significant effect on the superplastic behavior.

**REFERENCES**


BIOGRAPHIES

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