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INFLUENCE OF SUPERPLASTIC FORMING CONDITIONS OF 7475 ALLOY ON ITS MICROSTRUCTURE

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Abstract

This study concerns the superplastic forming process of 7475 aluminum alloy sheets. The objective is to define the interaction between the plastic strain and the evolution of the grain size of parts obtained by superplastic inflation. These parts are specially designed to show significant strain gradients. The rheological parameters of the sheet aluminum under conditions of superplastic forming are experimentally characterized by inflation tests on a conical die with a varying angle. The forming pressure for the standard part is determined by numerical simulation (Code FORGES 2®). The parts were formed at three different strain rates and a fixed temperature (510°C). The evolution of the grain size is measured along a radial section of each part. The numerically calculated plastic strain distribution is compared to the experimental results. The influence of the plastic strain and the strain rate on the evolution of the size and the morphology of the grains is analyzed and discussed.

Keywords :

Superplasticity, Microstructure, Aluminum Alloy, Grain size, Grain shape, Biaxial Tests

1 RHEOLOGICAL CHARACTERISATION OF THE MATERIAL

The material used for this study is the 7475 aluminum alloy from Pechiney with a sheets thickness of 2.5 mm.

Aluminum alloy 7475 T4

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb
0.03	0.06	1.64	87 *	2.25	0.23	15 *	5.79	0.02	24 *	16 *

Table 1: Chemical composition of the aluminum alloy 7475 (in %, * in ppm)

This material was used for the characterisation of its rheological parameters by biaxial forming tests, and for the analysis of friction between part and die.

The rheological characterisation:

Four conical parts were formed at a temperature of 510°C using the ENSAM ANGERS superplasticity forming machine (see figures 1 and 2). The forming pressure was controlled at all times, according to the height of the part, measured by a ceramic rod position sensor. The rheological parameters were identified, by the CEMEF [1], [2] by an inverse model obtained from the measured height-pressure-time and using the code FORGE2 ®.



Figure 1: Experimental superplasticity forming machine at ENSAM ANGERS

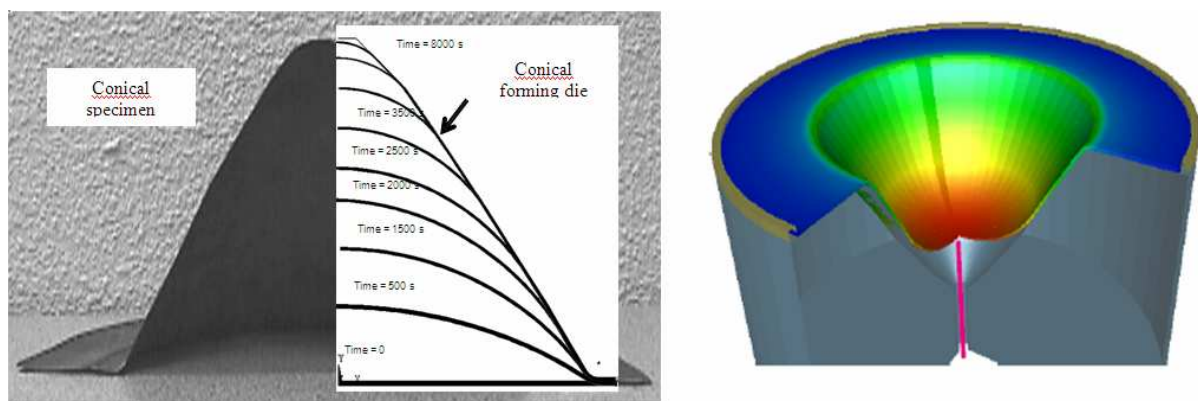


Figure 2: Conical forming test

2 FRICTION CHARACTERISATION

A standard part geometry showing a high gradient of plastic strain and significant slip between part and die was designed. See figure 3.

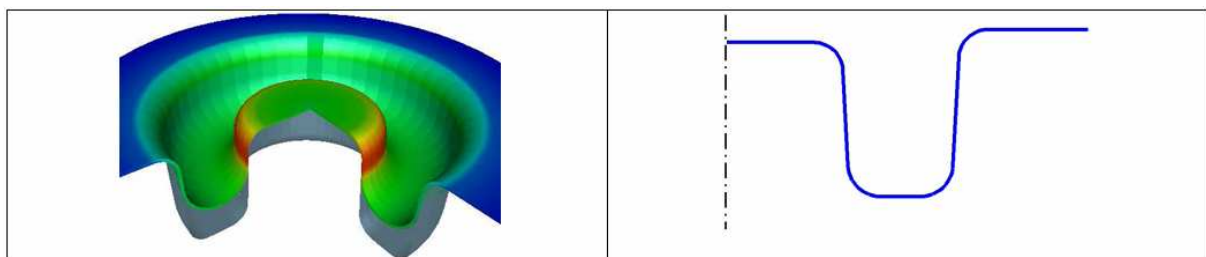


Figure 3: Axisymmetric geometry for friction identification

Three parts were formed at a temperature of 510° with different forming times (or strain rates).

Part reference	Forming time [s]
e3	22342
e1	7126
e5	3963

Table 2: summary of the tests carried out

The forming pressure was controlled in order to obtain a constant value of the maximum strain rate. The three different cases (pressure-time) were computed by numerical simulations carried out on the code FORGE2[®] by using the rheological parameters identified in the chapter A. The distribution of the sheet thickness along an axisymmetrical section of the part is strongly dependent on friction between part and die. The tribological model and its parameters were identified by the CEMEF [1] using an inverse method with the code FORGE2[®]. For each part, the sheet thickness was measured and compared to the corresponding simulation. See figure 4.

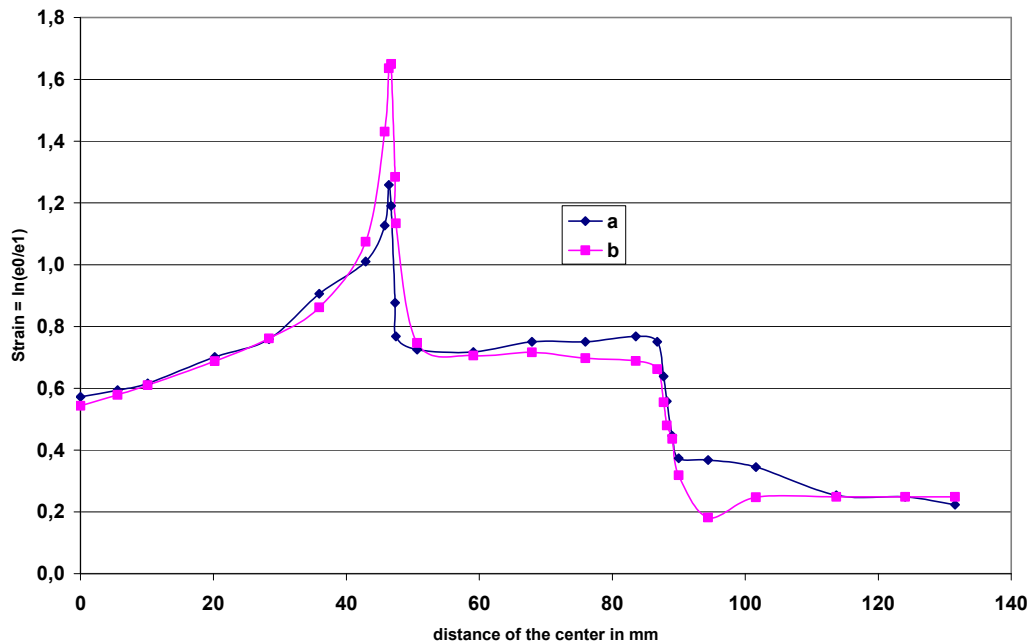


Figure 4: Strain distribution along an axisymmetrical section of the part for one of the forming parts
a: experimental specimen b: corresponding numerical simulation.

3 EXPERIMENTAL STUDY OF THE MICROSTRUCTURE

Analysis Procedure :

This study was carried out on the parts used to characterise friction in superplastic forming (parts references: e1, e2, e5 defined in section 2). The size and the shape of the grains were measured along the section of each part. The grain size was measured using a commercial image analysis software package “Visilog”.

The part shape has been chosen to obtain a complex strain path. Therefore the material has a different strain history depending on the position measured on the part. The objective is to evaluate the microstructural modifications due to the forming conditions and to analyze their influence. Seven points were selected on the section for the measurements (see Figure 5). For each point the analysis is carried out in the local coordinate system.

The X-axis is in the radial direction and is directed towards the part center. The N-axis is oriented normal to the part surface and the Z-axis is perpendicular to the section.

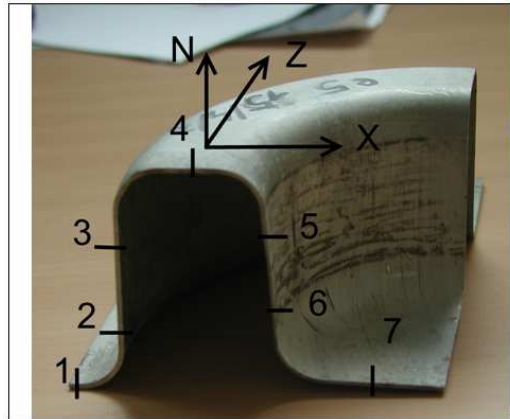


Figure 5: Reference points on the part section, coordinate system for point 4

The forming specimens underwent a heat treatment at 512°C after forming. This treatment makes it possible to avoid the precipitates from Mg Zn 2 which are not in the α phase [4]. They were coated, polished and then etched with the Keller reactive agent for 15 to 20 seconds before observations under the optical microscope.

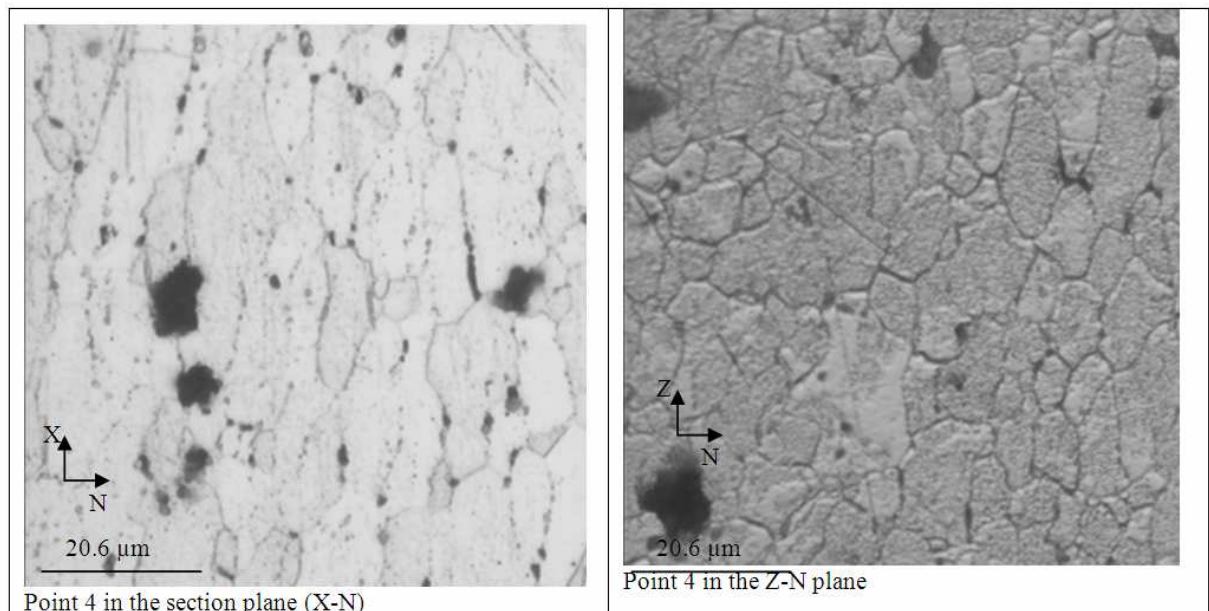


Figure 6: Microscope photos realized at point 4 according to planes X-N and Z-N

Results :

At all observation points on the section, the grains were stretched or elongated in the radial or X-axis direction. However the uniform grain shapes did not change in the Z-N plan.

The grains size seems to be sensitive to the forming time. It varies from 7 to 8.5 micrometers for the shortest time (4000 seconds) and from 7 to 10 microns for the longest time (22000 seconds). This forming time sensitivity is not however very significant.

The grain size distribution along the section shows two maxima corresponding to the vertical walls of the part (points 2-3 and 5-6). These points have a slow strain rate at the beginning of the test which quickly increases during the process.

Point 4 shows lower but more regular total strain during the total forming operation. At this point, the grain size was noted to increase less.

Figure 8 shows the distribution of the grain size with respect to the total strain at each corresponding point. We observe a linear tendency of the grain size evolution versus the total strain. This general tendency is strongly affected by significant strain rate variations for the points 2 and 3.

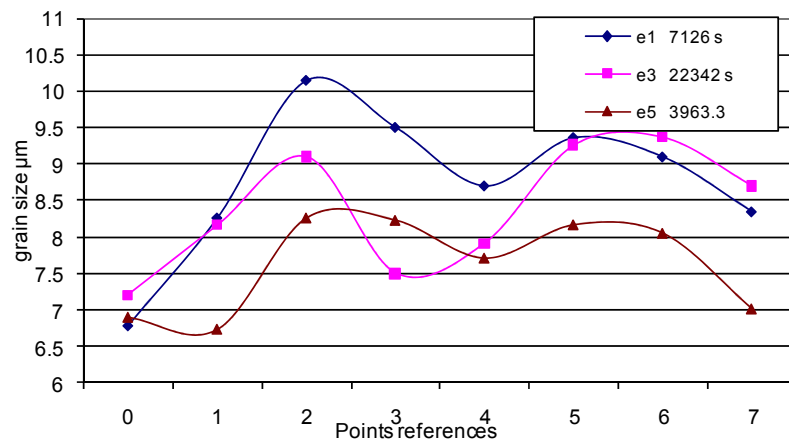


Figure 7: Grain size evolution (Z-N Plane) along the section for the three formed parts

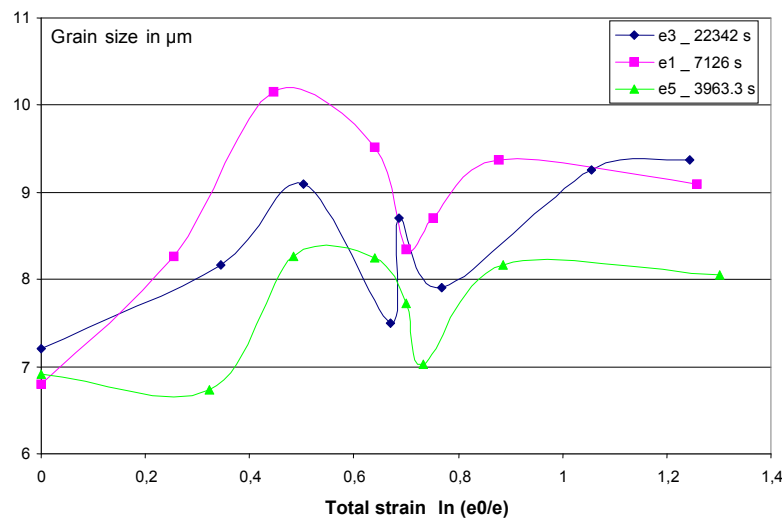


Figure 8: Grain size evolution (Z-N Plane) with respect to the total strain for the three formed parts

4 CONCLUSION

The superplastic forming of the 7475 aluminum alloy induces significant stretching of the grains in the direction of the greatest expansion. It causes also an increase in their size. These variations seem to be related by the strain level and the instantaneous strain rate. This increase in size remains small even for a total strain greater than 1. This small increase makes it very difficult to establish a precise correlation between the microstructure, the rheological parameters of material and the forming conditions.

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