ESRF	Experiment title: Strain induced damage during high temperature deformation of aluminium alloys under superplastic conditions and conventionnal plasticity	**Experiment number**: **HS895**
Beamline: **ID19**	**Date of experiment**: from: 07/05/99 to: 11/05/99	**Date of report**: 28/07/99
Shifts: 3	**Local contact(s)**: P. Cloetens	02 SEP. 1999 *Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

MARTIN Chantal Laboratoire GPM2-ENSPG-INPG
JOSSEROND Charles Laboratoire GPM2-ENSPG-INPG
BLANDIN Jean-Jacques Laboratoire GPM2-ENSPG-INPG
SALVO luc Laboratoire GPM2-ENSPG-INPG
BOLLER Elodie ESRF
CLOETENS Peter ESRF

The material investigated in this study was a 5083 aluminium alloy (Al-4.7wt% Mg) which was deformed at various strain rates (from 10-2 s to 10^{-4} s^{-1}) and for various strain (from ε=0.8 up to 1.65). The tensile testing were performed on an ADAMEL DY35 tensile machine at 525°C before ESRF experiments. The sample for Xray microtomography were obtained from the tensile specimen and the dimensions were 1mm x 1mm square and 5mm in height. The beam energy was 17.5 keV. The samples were set on a goniometer allowing a precise positioning of the sample. A scan of the samples consisting of the recording of 800 two-dimensional radiographs was performed during a 180° rotation around the vertical axis. Those radiographs were recorded on a 1024 x 1024 CCD camera developed at ESRF. The average exposure time for a radiograph was 0.3 s and the whole scan lasted about 10 minutes. The pixel size of the camera was 2 x 2 μm2. The detector was set 3 mm behind the sample. Well contrasted projections were obtained, resulting from the difference of X-ray attenuation by the features encountered by X-rays in the specimen. For each sample, the investigated volume was approximately 0.6 x 0.6 x 0.6 mm3, knowing that for large strains, the final thickness of the sheet may be less than 1 mm. In a first step of characterisation, only cavities with a volume larger than 10 voxels were taken into account. The two-dimensional radiographs were used to reconstruct the volume of the samples using a 3D extension of the conventional two-dimensional filtered back projection algorithm. From the reconstructed volumes, the populations of cavities were quantified and several parameters were defined like the cavity volume fraction, the number of cavities n_v per mm^3 and the volume of each cavity. Density measurements were also performed before ERSF experiments to obtain the volume fraction of cavity in each samples.

First results : Figure (1) compares the results deduced from X-ray tomography characterisation to those obtained by density variation measurements for the material deformed at $10^{-4}s^{-1}$. Volume fraction of cavities (C_V) is plotted versus strain. Very similar results are obtained with these two independent techniques. One can remark that a decrease of the sensitivity to cavitation is still detected at large strains, which indicates that it does not result from an artefact in relative density measurements. Figure (2) displays a 3D reconstructed image of the population of cavities through the alloy after a strain of 1.0. For these conditions of deformation, a mean cavity volume fraction of about 1 % was estimated (see figure (1)). A roughly homogeneous distribution of holes is observed and only moderate interlinkage between the cavities is detected. Figure (3) shows this variation with strain of the number of cavities n_V per mm^3 for the various strain rates. A continuous decrease of n_V is obtained and for a given strain, the number of cavities increases with the strain rate, which is associated to the mechanism of deformation (conventional plasticity at high strain rate and superplasticity at low strain rate). This confirms that significant interlinkage between the cavities takes place for large strain. This is illustrated in figure (4) which shows the biggest cavity for ε=1.65 at 10^{-4} s^{-1}. This suggests to define an interlinkage parameter as the ratio between the volume of the largest cavity in the investigated volume and the corresponding total volume of cavities. Details of the analysis of such a parameter have been presented in a conference of the Société Française de Physique [1] and a paper has been submitted [2] since these results are quite original.

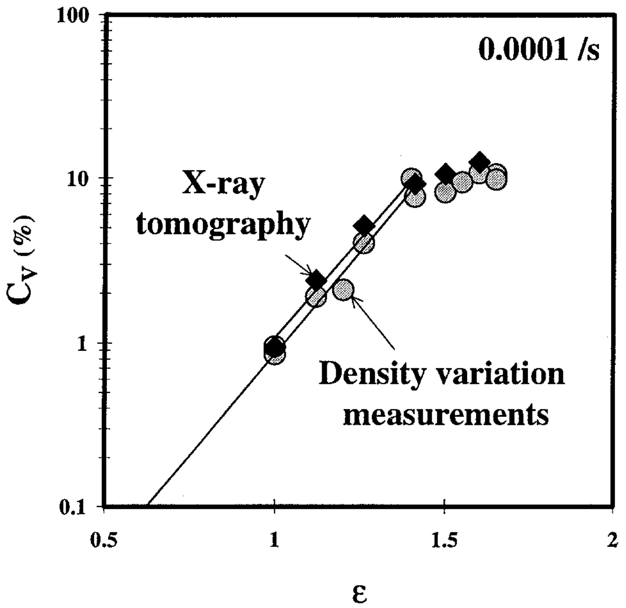

Figure (1) : Comparison of the variations of C_V between density variations measurements and X-ray tomography

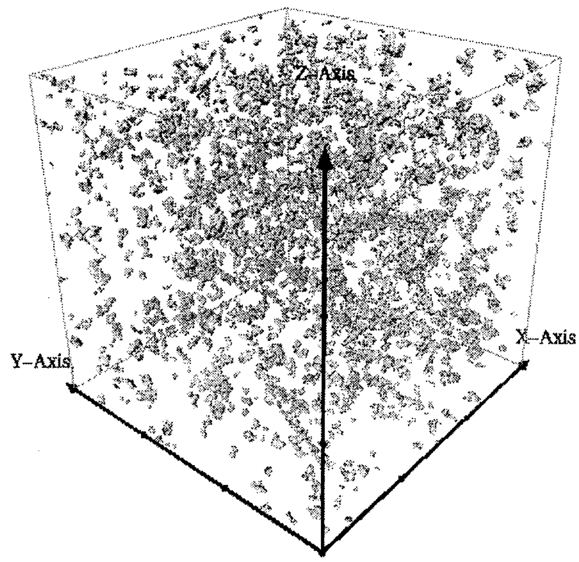

Figure (2) :
3D reconstructed image of the population of cavities ($\varepsilon = 1.0$, $C_V \approx 1$ %, $0.6x0.6x0.6mm^3$)

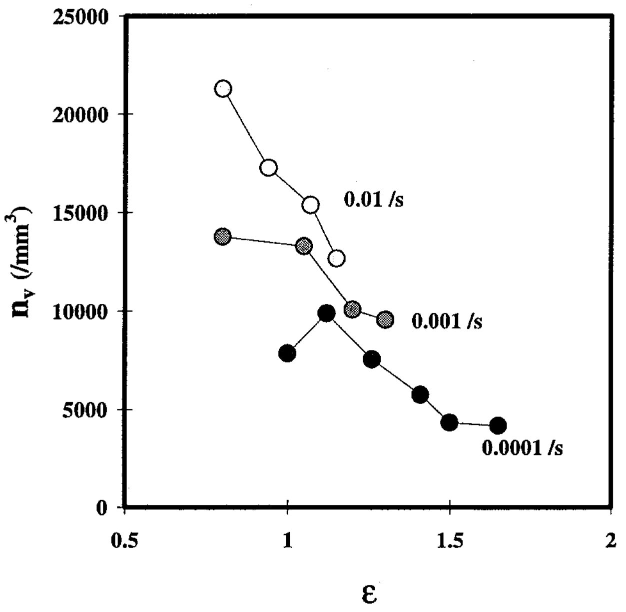

Figure (3) : Variations with strain of the number of cavities per mm^3

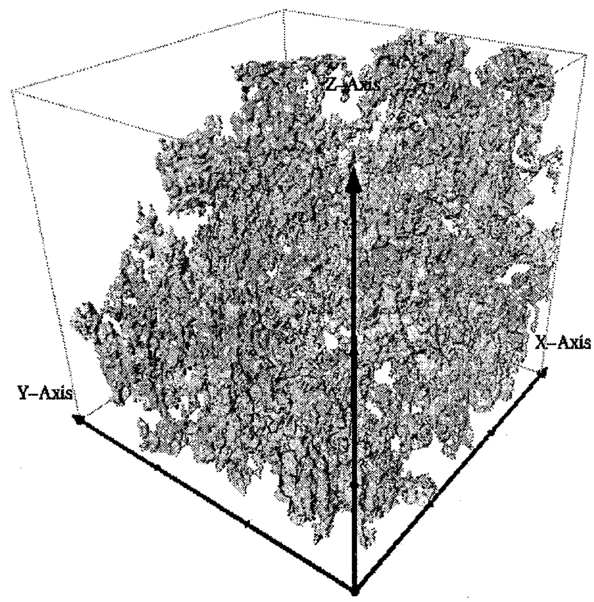

Figure (4) : 3D observation of the largest cavity in the investigated volume
($\varepsilon = 1.65$, $C_V \approx 14.5$ %, $0.6 \times 0.6 \times 0.6$ mm^3)

Conclusions : Xray micro-tomography is a very efficient tool to study the coalescence of cavities during superplastic deformation of aluminium alloys. This can only be done by this technique since it requires 3D information. Next step is to perform "in situ" measurements in order to follow the cavitation process on a unique sample.

[1] C.F. Martin, C. Josserond, L. Salvo, J.J. Blandin, W. Ludwig, P. Cloetens, J. Baruchel, "Etude par micro-tomographie X de l'endommagement généré durant la déformation superplastique d'un alliage d'aluminium", *Conférence Société Française de Physique (Colloque 8)* , Clermont-Ferrand (5-9 juillet 1999).

[2] C.F. Martin, C. Josserond, L. Salvo, J.J. Blandin, P. Cloetens, E. Boller "Characterisation by X-ray micro-tomography of cavity coalescence during superplastic deformation" submitted to *Scripta Materialia* (1999).