	Experiment title: Study of the microstructure of the heat affected zone of Al-Zn-Mg alloy weldments by means of Small-Angle X-ray Scattering	**Experiment number**: ME162
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Names and affiliations of applicants (* indicates experimentalists):

A. Deschamps*, M. Nicolas*, F. Perrard*, F. Livet*, F. Bley*

LTPCM-ENSEEG, DU, BP 75, 38402 St-Martin-d'Hères Cedex

Report:

ESRF Small-Angle X-ray Scattering was used in order to get results on the evolution of the microstructural state involved by welding in an Al-Zn-Mg alloy in terms of volume fraction and Guinier radius of particles. These alloys are particularly used in aerospace and automotive applications because of their high specific mechanical properties due to strengthening precipitation, which could become unstable in the so-called heat affected zone (HAZ).

In fact welding could be considered as a particular type of heat treatment with the schematic aspect shown on the Figure 1, where the peak temperature (Tp) and the rate of the initial heating part both depend on the distance from the weld (DFW):

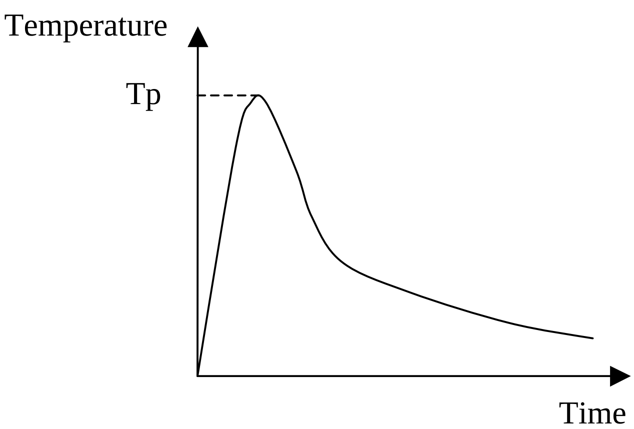

Figure 1 : Schematic showing the aspect of the thermal profile involved by the welding process.

The strengthening particles formed in an Al-Zn-Mg alloys arise from a complex sequence of precipitation :

$$\text{Solid solution} \rightarrow \text{GP} \rightarrow \eta' \rightarrow \eta,$$

where GP zones and η' are metastable phases and η is the stable $MgZn_2$ phase. These phases can become unstable during the welding treatment. Different phenomena could be observed depending on the initial state (type of precipitate initially present) and on the distance from the weld : dissolution, coarsening and transformation from metastable particles to stable ones.

This experiment is the continuation of one performed in May 2000 (experiment ME-6) on the BM02 beam line which provided us fruitful information about the precipitation state in the welded materials. The purpose of this new experiment was to investigate the influence of a post-weld heat treatment on the microstructure to determine the capacity of the material to recover its original properties.

Details of the experiments

Three different initial states of the alloy (Al-5.5wt%Zn-0.8wt%Mg) were investigated : T4 (containing GP zones), T6 (containing mainly η') and T7 (containing mainly η). Heat treatments performed by the base material are :

1. precipitation treatment (T4, T6 or T7)
2. instrumented arc welding (MIG)
3. post-welding heat treatments based on T6 or T7 type heat treatments.

A scan of the HAZ for each state was performed with a 100*300 μm^2 beam at 7.8 KeV. Thanks to the high spatial resolution of the ESRF beam mapping could be carried out on steps of 500 μm in the critical areas of the HAZ.

A small angle set-up was chosen to well characterise particles from 5Å to about 100Å, corresponding to scattering vectors from 10^{-2} to 0.3 $Å^{-1}$. For each measurement, volume fraction and Guinier radius of the particles were determined.

In-situ experiments were also carried out with a specially designed furnace. Initial states of the material were still T4, T6 and T7. Previous experiment in May 2000 allowed us to determine the temperature scale where competition between different behaviours is effective. Isothermal heat treatments were carried out every 20° around this critical region. Ramps from 10°/min up to 300°/min from room temperature were also performed to get information about the influence of the heating rate. Only a high flux source could allow us to get measurement with good counting statistics each 5 seconds.

Results

Numerous results were obtained, only a part of these are shown in the following.

Post-weld heat treatments

The influence of a T6-type post-weld heat treatment on an initial T6 is showed on Figure 2. Just after welding, three zones could be observed :

(I) a completly reverted zone where only GP zones are present which were formed either during cooling of the weld or during preparation of the sample,

(II) a transition zone where dissolution and coarsening are in competition,

(III) a unaffected zone corresponding to the initial state where the microstructure remains stable during the welding process.

During post-weld heat treatment, zone (I) recovered its initial properties and is now comparable to the T6 initial state, zone (III) was slightly overaged and coarsening of particles present in the transition zone (zone (II)) happened, which will result in a weakness of the structure in this part.

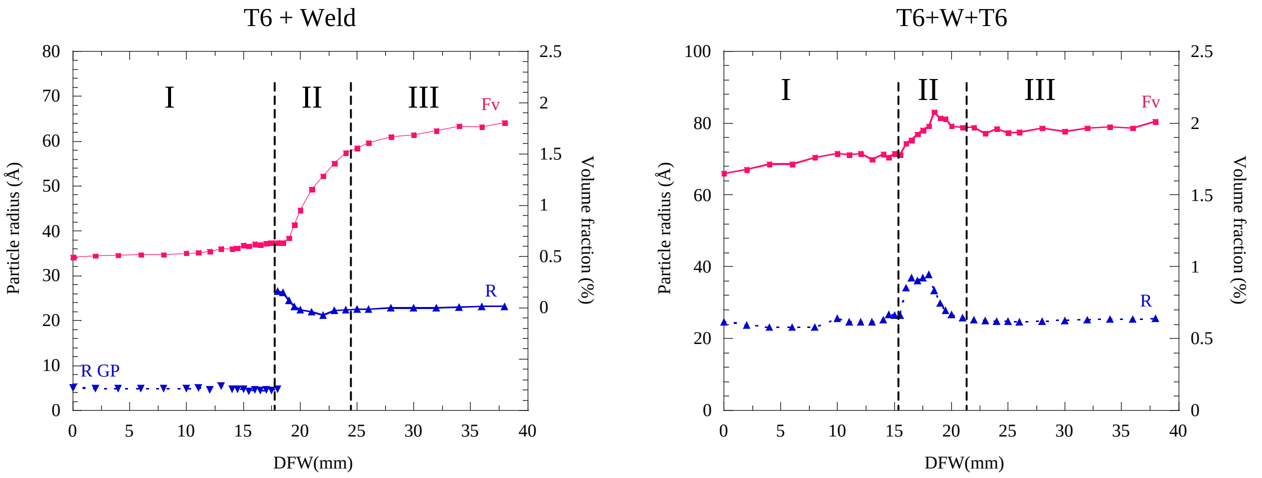

Figure 2 : Evolution of the volume fraction (Fv) and the radius (R) of particles versus the distance from the fusion zone (DFW) just after welding and after a subsequent T6 heat treatment in the case of a T6 initial state.

__In-situ experiments__

The results of a T6 and T7 samples submitted to a heating ramp at 10°/min are shown on Figure 3. What is characteristic on this figure is the presence of a bump in the case of the T6 initial state at a temperature around 250°C which is not present for the T7 initial state. This behaviour is believed to be the signature of the η’ to η transformation. The T7 state which already contains predominantly η particles is less subject to the phenomenon.

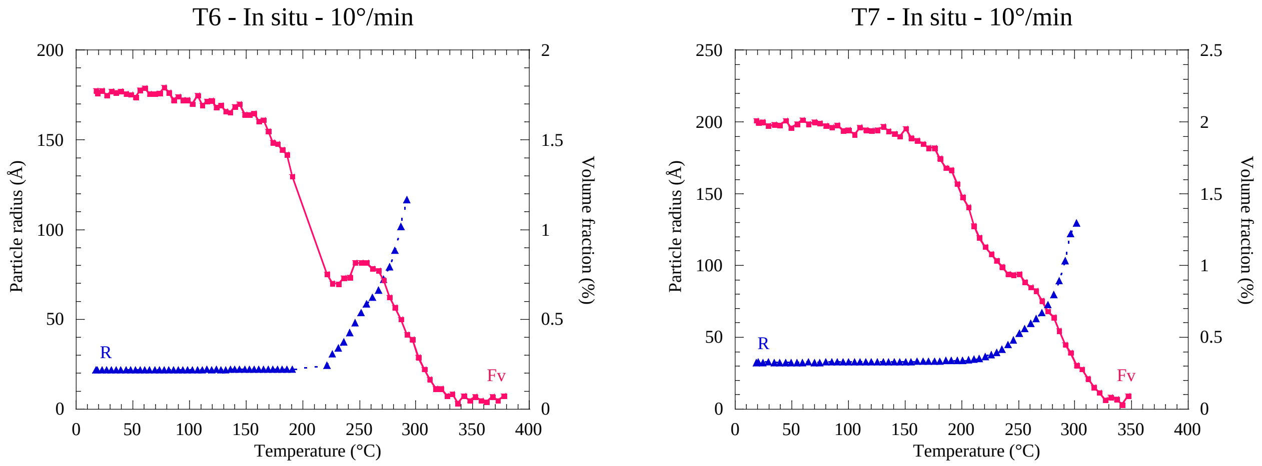

Figure 3 : Evolution of the particle radius (R) and volume fraction (Fv) with the temperature during an in-situ ramp heat treatment at 10°/min.

__Conclusions__

This experiment was a complete success : around 2400 CCD images have been recorded and could be interpreted. We are grateful to the ESRF staff, especially on the D2AM beam line for their help.