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THE BAUSCHINGER EFFECT IN THIN SHEET MAGNESIUM ALLOY USING ANTI-BUCKLING FIXTURE

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1. Introduction

Ultralight magnesium alloys with additions of other metals are already used in a variety of aerospace and automotive semi-products, and also in many other industrial applications requiring good properties and high values of the strength to weight ratio. Magnesium alloys have a special feature that is particularly visible during the forming of industrial parts. The basic tool to quantify the formability of metallic sheet which is Forming Limit Diagram (FLD) built with the in-plane principal strains in which a Forming Limit Curve (FLC) can distinguish between safe and necked points. However, during the forming of industrial parts made of magnesium alloy, instead of linear deformation path very complex strain paths are usually observed and can affect the formability of the sheet. Example of strain path change is shown in Fig.1 [1].

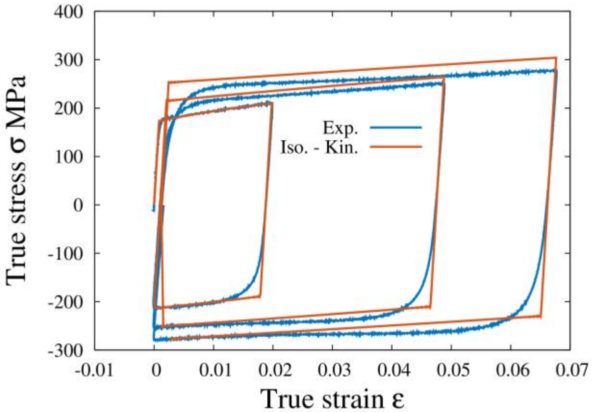

Fig. 1. Deformation process with strain path change; blue line - experimental results, red line - numerical results.

Among many important effects necessary to be taken into account one can indicate Bauschinger effect observed after change of the loading direction. It should be noted that material testing of flat specimens under compression within a large deformation range procures many difficulties, and the buckling phenomenon seems to be the most important. To avoid buckling problem a special device is necessary. In the last decade many new solutions were created [2]. Among them one can indicate the anti-buckling fixture proposed by IPPT PAN in 2012, which is illustrated in Fig.2.

a) b)

Fig. 2. Fixture mounted in loading frame (a) with attached extensometer (b).

The device is designed to carry out the compression or tension-compression tests in the standard testing machine. The most important feature of the device is its automatic alteration and adaptation of its length during tests, depending on loading type, which leads to specimen elongation under tension or shrinkage under compression. The next crucial feature of the device is the fact that it makes possible to measure the friction force which is generated due to movement of its parts. Therefore, fixture is equipped with four strain gauges cemented to surfaces of two measuring bars. These elements assembled into a full bridge system create the sensor of friction force measurement. This solution enables on-line measurement of the friction force and reduction of additional calculation errors.

The aim of this paper is to investigate the strain-hardening effect in thin sheet of ultralight magnesium alloys by application of the anti-buckling fixture.

2. Experimental procedure and results

All tension-compression tests were carried out on thin sheet specimens with nominal thickness equal to 1 mm. Cyclic loading was performed under displacement control with the rate of 0.025 mm/s. Boundary conditions were set into the loading controller to limit strain range during cycling. A special set up for the friction force measurements was applied. It consisted of two coupling bars with strain gauges calibrated in the range of ±2 kN.

In the first type of cyclic test, 15 cycles within a strain range ±0.04 were planned with the start in tension direction. In the second one, a similar program was arranged, however, with the start in compression direction. All tests were carried out using extensometer with a range of ±0.2. The loading cell was calibrated in the range of ±25 kN.

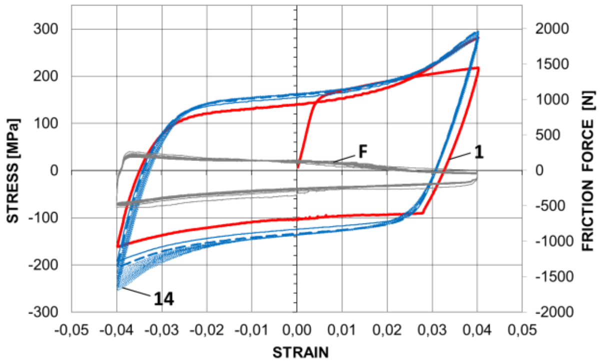

Fig. 3. Hysteresis loops of the AZ31B alloy and friction force variation - start in tensile direction.

The results of first type of test carried out on the AZ31B magnesium alloy under cyclic loading are presented in Fig. 3. The first cycle is illustrated by solid red line denoted as (1). In the next cycle represented by blue solid line, the magnesium alloy exhibited the highest level of tensile stress and for the rest of planned cycles it remained almost unchanged. A different behaviour may be observed for the compressive stress levels. In this case, a continuous hardening effect was obtained expressed by the gradual increase of the maximum compressive stress in the subsequent cycles denoted by blue dotted lines. Figure 3 also presents an evolution of the friction force (grey lines, denoted as (F)).

The results of second type of test are presented in Fig. 4. Here, the strain-hardening stagnation effect took place for the material in question. It is most remarkable for the first three cycles. During subsequent cycles the tensile stress value in the specimen tested remained at the same level, while for the opposite direction the alloy showed a continuous cyclic hardening.

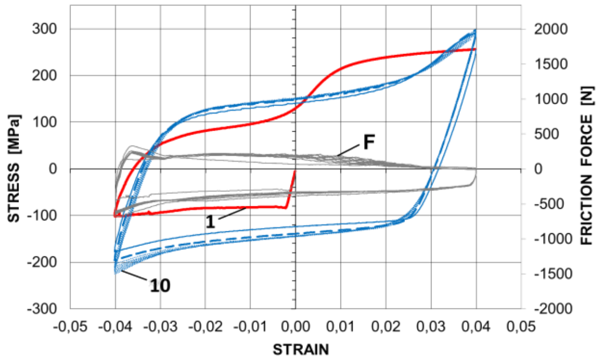

Fig. 4. Hysteresis loops of the AZ31B alloy - start in compressive direction.

3. Summary

The results shown in Figs. 3 and 4 exhibited the visible effect of strain-hardening stagnation observed after change of the loading direction, especially in the first cycle (1). Three dominant deformation mechanisms are presumably responsible for deformation behaviour of the AZ31B alloy: dislocation slip dominated deformation - Slip Mode, twinning-dominated deformation - Twinning Mode and detwinning-dominated deformation - Detwinning Mode [4]. The strain hardening stagnation may be atributted to the alternation between twinning and detwinning mechanisms.

Acknowledgements

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