STRAIN-HARDENING EFFECT IN THIN-SHEET MAGNESIUM ALLOY AZ31B UNDER LOW CYCLIC LOADING

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Abstract: Optimization of sheet metal forming processes requires a very good knowledge of material forming ability. During the forming of industrial parts, very complex strain paths are usually observed and can affect the formability of the sheet. Therefore, it is necessary to better understand and more accurately investigate deformation behaviour of sheet alloys. 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. This paper shows the results of tension-compression tests carried out on specimens made of ultralight magnesium alloys AZ31B with nominal thickness equal to 1 mm using the anti-buckling fixture to avoid buckling problem.

Key words: Bauschinger effect, cyclic loading, buckling, fixture, thin sheet

1. INTRODUCTION

Prediction of the fracture is one of the challenging issues which gains attention in sheet metal forming. The determination of Forming Limit Diagram which is the basic tool to quantify the formability of metallic sheet has always been the subject of extensive experimental, analytical or numerical works. A FLD is a strain diagram 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, 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.

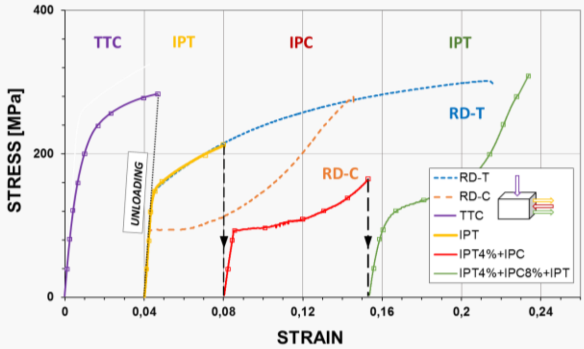

Fig. 1. Deformation processes of Mg alloy sheet with strain path change - experimental results (Kowalczyk-Gajewska, 2011)

Among many important effects necessary to be taken into account one can indicate strain-hardening stagnation observed after change of the loading direction. Therefore, tension-compression cyclic loading tests within large deformation should be carried out on specimens cut out in different directions with respect to geometry of the sheet forming process. The significant differences of the length to thickness ratio of the specimens procure a lot of problems during the test. One of them is the buckling phenomenon. To avoid buckling problem a special device is necessary. In the last decade many new solutions were created, (Libura et al., 2016). Among them one can indicate the fixture proposed by IPPT PAN, (Dietrich et al., 2016). The anti-buckling fixture is illustrated in Fig.2.

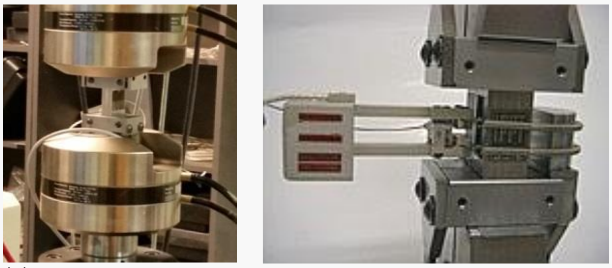

Fig. 2. Fixture mounted in loading frame (a) with attached extensometer (b)

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 the paper is to investigate the phenomena of the occurrence of strain-hardening effect in thin sheet of ultralight magnesium alloys used in the manufacturing process of industrial parts using anti-buckling fixture.

2. RESULTS

All tension-compression tests were carried out on thin sheet specimens with nominal thickness equal to 1 mm using the new anti-buckling fixture. 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. 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. 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.

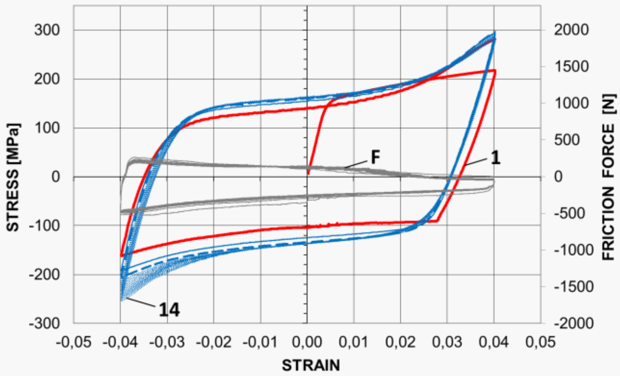

Fig. 3. Hysteresis loops of the AZ31B alloy and friction force variation during test - start in tensile direction.

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 third cycle represented by blue dashed 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 friction force is also shown as a function of time in Fig.4 as well as total force for all recorded cycles.

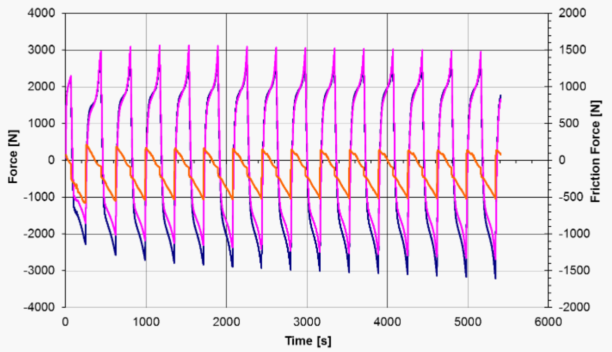

Fig. 4. Hysteresis loops of the AZ31B alloy and friction force variation during test - start in compressive direction.

The results of second type of test are presented in Fig. 5. 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.

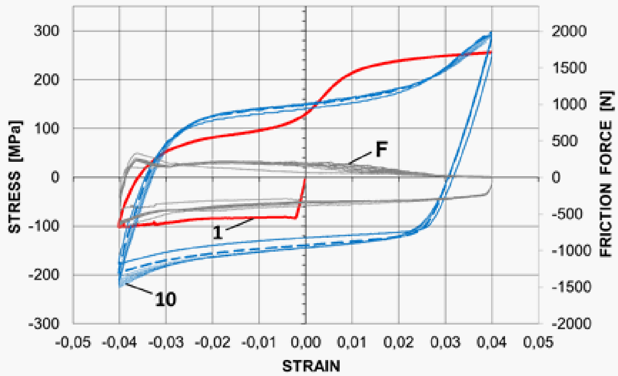

Fig. 5. Hysteresis loops of the AZ31B alloy and friction force variation during test - start in compressive direction.

The results shown in Figs. 3 and 5 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, (Wu et al., 2010) . The strain hardening stagnation may be related to the alternating achieving of twinning and detwinning.

3. SUMMARY

The strain controlled low-cycle fatigue behaviour of the rolled magnesium alloy (AZ31B) was investigated under the RD loading direction. The technique enabling buckling reduction during compression of specimens made of thin metal sheet was used. Experiments show an asymmetric behaviour of AZ31B magnesium alloy at room temperature. A large Bauschinger effect was observed during cyclic loading.

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