THE PORTEVIN-LE CHÂTELIER EFFECT IN AN AlZn10 ALLOY INVESTIGATED BY THE ACOUSTIC EMISSION TECHNIQUE

FRANTIŠEK CHMELÍK, JAROSLAV BALÍK, PAVEL LUKÁČ, ERWIN PINK

Deformation behaviour and acoustic emission (AE) of an Al-10.5%Zn alloy with different precipitation structure have been studied. The serrated flow activity decreases but the AE activity increases with increasing volume fraction of coherent precipitates. These results seem to contradict a recent model published by Bréchet and Estrin.

STUDIUM PORTEVINOVA-LE CHÂTELIEROVA JEVU VE SLITINĚ AlZn10 METODOU AKUSTICKÉ EMISE

V práci jsme studovali deformační chování a akustickou emisi (AE) slitiny Al-10,5% Zn s různými precipitačními strukturami. Bylo zjištěno, že s rostoucím objemovým podílem koherentních precipitátů roste aktivita AE, ale klesá aktivita Portevinova-Le Châtelierova jevu (pilovité deformace). Tyto výsledky patrně nejsou v souladu s modelovými představami publikovanými nedávno Bréchetem a Estrinem.

1. Introduction

The Portevin-Le Châtelier (PLC) effect (serrated flow) appears in many Al-based supersaturated alloys if they are deformed at suitable temperature and strain rate. It is well known that prior ageing treatment giving rise to changes in precipitation structure can affect the shape of serrations or determine whether serrations ever appear. Therefore, it is important to study the relation between the alloy precipitation structure and the deformation behaviour.

Pink and Król [1] investigated the A-type of serrations in an Al-10.5wt.%Zn alloy with different size and volume fractions of precipitates. By measuring a correlation between the load drop amplitudes (at a constant equipment compliance) and the precipitation structure they have found that coherent precipitates rather

RNDr. F. Chmelík, CSc., RNDr. J. Balík, CSc., Prof. RNDr. P. Lukáč, DrSc., Department of Metal Physics, Charles University, Ke Karlovu 5, 121 16 Praha 2, Czech Republic, e-mail: chmelik@met.mff.cuni.cz

Prof. Dr. E. Pink, Erich-Schmid-Institute for Solid State Physics, Austrian Academy of Sciences, Jahnstraße 12, 8700 Leoben, Austria.

prevent serrated flow provided that their amount exceeds a certain value. Large and incoherent precipitates have not been found to affect the A-type of the PLC effect. Nonetheless, the authors have stressed that their results are not fully unambiguous.

On the other hand, Bréchet and Estrin [2–4] have proposed (mainly theoretically) that an alloy hardened by fine shearable precipitates may exhibit serrated flow with all signs of the PLC effect (the pseudo-PLC effect), even if no dynamic strain ageing due to solute diffusion is present (simultaneous presence of the dynamic strain ageing should support the pseudo-PLC effect).

The influence of the precipitation structure on the plastic flow can well be studied by the acoustic emission (AE) technique, i.e. detection and processing of elastic waves generated due to collective dislocation processes (see e.g. an excellent review article by Heiple and Carpenter [5]). A distinct correlation between the PLC effect and AE has also been demonstrated by a number of authors [5–8].

The objective of this paper is an AE study on how the precipitation structure affects serrated flow in an AlZn10 alloy. This alloy exhibits the PLC effect in homogenized state and is prone to a rapid age hardening thereby matching the assumptions of Bréchet and Estrin [2–4]. Because of the identical material, this paper continues that by Pink and Król [1].

2. Experimental procedure

Identically to [1], an Al-10.5wt.%Zn alloy (solvus temperature at approximately 185 °C [9]) was melted, cast and rolled in one direction to sheets of 0.95 mm thickness. Tensile samples with a 75 mm nominal gauge length were cut parallel to the direction of rolling. The samples were first recrystallized at 270 °C for 30 min, then homogenized at 450 °C for 1 h, quenched in oil or water to be aged 6 h at 180 or 20 °C, respectively. The data on precipitation structure were taken from [1]. The material aged at the elevated temperature exhibits a low integral intensity of 100 obtained by small angle X-ray scattering that indicates a low amount of coherent precipitates. The material aged at the room temperature exhibits a high integral intensity of 2000 that indicates a high amount of coherent precipitates.

Immediately after the treatment, the samples were tested in an Instron 1195 testing machine at room temperature and at constant crosshead speed giving an initial strain rate of 4.4×10^{-6} s^{-1}. To determine the strain rate sensitivity of the flow stress, the crosshead speed was increased by certain factors during the tests.

A computer controlled DAKEL-LMS-16 AE analyzer was used to measure the AE count. A sensitive LB10A transducer (sensitivity 85 dB ref. 1 V/m s^{-1}) with flat response between 100 and 500 kHz and with a built-in preamplifier (gain of 30 dB) was mounted on the specimen surface by acoustic grease and a rubber band. The DAKEL AE-facility applies a two-threshold level system of detection and evaluation of AE, recently recommended by an ASTM-standard [10]. The AE signals are filtered, amplified and then evaluated at two threshold levels to get two

AE counts N_{C1} and N_{C2}. The total count N_{C1} from the lower level (corresponding to a gain of 110 dB) comprises all AE signals detected. The burst count N_{C2} obtained at the upper threshold (set difference 20 dB, i.e. total gain of about 90 dB) includes only the signals with amplitudes large enough to be detected (AE bursts). This procedure makes possible to determine the character of the AE signals, i.e. whether they have a small or large amplitude.

3. Experimental results and discussion

Fig. 1 presents the strain dependences of true stress and count rates at two threshold levels for the sample with the low amount of coherent precipitates. The offset yield stress of 26 MPa is consequently low. From the strain rate changes, a negative strain rate sensitivity is visible, giving evidence that the PLC effect is the controlling mechanism of the plastic deformation. The detailed analysis of load recordings reveals a jerky character of the plastic flow with sudden stress drops of 0.2 MPa. During the deformation, a more significant AE activity is observed at lower threshold level only, at higher threshold level few AE bursts are found. An increase of the strain rate by a factor of 10 produces a less distinct response in the count rates that tend to increase by a factor slightly less than 10, i.e. the AE count per unit strain decreases. Such a behaviour has also been observed in other alloys exhibiting the PLC effect [6, 8] and is referred to strain rate characteristics of the PLC effect, e.g. the amplitude of load drops often decreases with increasing strain rate.

Fig. 2 presents the strain dependences of true stress and count rates for the sample with the high amount of coherent precipitates. Let us note many differences to Fig. 1. The offset yield stress of 120 MPa is considerably higher showing a significant age hardening. The strain rate sensitivity is obviously positive indicating that the PLC effect leaves its flow controlling role to the precipitate shearing. A detailed analysis shows few stress drops with an amplitude of 0.03 MPa. The count rates are much higher than in the sample with the low amount of coherent precipitates, especially, many AE bursts appear. This increase can be explained by an intense precipitate shearing that is widely accepted as an effective source of AE [5]. The count rates respond distinctly to strain rate changes by a factor of 10 showing an increase by the same factor. This result supports the idea about the precipitate shearing as the main source of AE because one may assume that the number of the precipitates sheared per unit strain should be independent of strain rate.

4. Conclusion

Our results suggest that the model by Bréchet and Estrin [2–4] is probably not valid for the Al-10.5%Zn alloy because coherent precipitates seem rather to suppress the PLC effect. However, more detailed studies including alloys of different

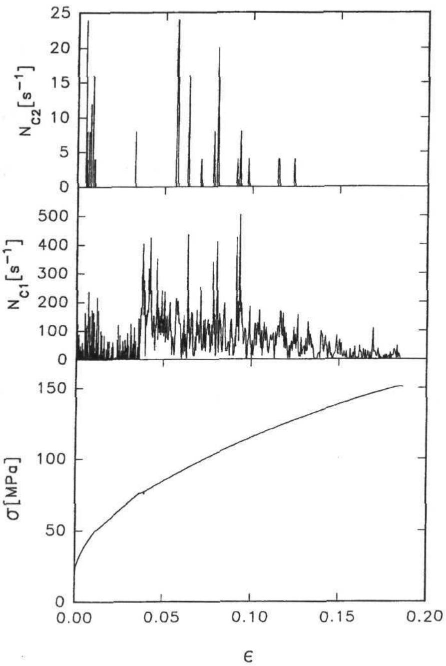

Fig. 1. The strain dependences of the true stress σ and the AE count rates N_{C1} and N_{C2} measured at the lower and at the higher threshold level, respectively, in the Al-10.5%Zn alloy containing mostly large incoherent precipitates. At strains of 0.01053 and 0.0361, the strain rate was increased by a factor of 10.

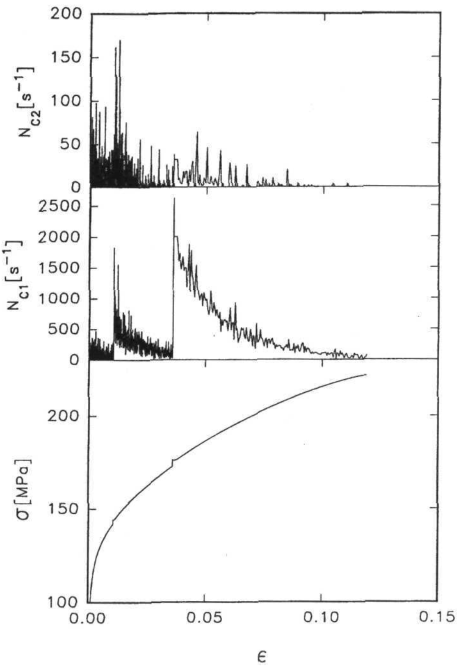

Fig. 2. The strain dependences of the true stress σ and the AE count rates N_{C1} and N_{C2} measured at the lower and at the higher threshold level, respectively, in the Al-10.5%Zn alloy containing a large amount of coherent precipitates. At strains of 0.01158 and 0.0363, the strain rate was increased by a factor of 10.

composition are needed to verify the Bréchet-Estrin model. Such studies are now in progress and will be published elsewhere.

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