

STRAIN RATE DEPENDENCE OF SERRATION BEHAVIOR FOR 5000 SERIES ALUMINUM ALLOY IN UNIAXIAL AND INDENTATION TESTS

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INTRODUCTION

The 5000 series Al-Mg alloy is known to show the serrated flow stress because the solute Mg atoms interact with the dislocations at a certain strain rate and temperature. At room temperature, the serrated flow stress is affected by the strain rate and Mg content. Thus, these factors should be investigated in detail. In this study, the strain rate effect of the serration behavior was investigated by the uniaxial and indentation tests.

EXPERIMENT

The annealed specimens were chosen as AA5005 (Mg: 0.8wt.%), AA5021 (Mg: 2.3wt.%) and AA5082 (Mg: 4.5wt.%). The tensile tests were conducted using the universal testing machine at strain rate from 10^{-4} to 10^{-1} s⁻¹. The indentation tests were performed at the constant loading rate from 0.7 to 350mN/s.

RESULTS AND DISCUSSION

In the uniaxial tests, the serration was appeared on the stress-strain curve. The observed serrations were summarized in Figure 1. The serration types were labelled according to previous study (Pink & Grinberg, 1982). It was confirmed that the serration behaviors were dependent on the strain rate and the Mg content.

In the indentation, the loading curvature (C), which was the loading part of the load-displacement curve, was serrated at a certain loading rates. The derivative of C (\dot{C}) was calculated as follows:

$$\frac{dC}{dt} = \frac{d}{dt} \left(\frac{P}{h^2} \right) \quad (1)$$

where P is the load, h is the displacement and t is the time.

In addition, the effective strain rate of the indentation ($\dot{\epsilon}_e$) was calculated. This strain rate can be related to the that of the uniaxial test ($\dot{\epsilon}$) through the equation below (Poisl, Oliver, & Fabes, 1994):

$$\dot{\epsilon}_e = b \left(\frac{\dot{P}}{2P} \right) \approx \dot{\epsilon} \quad (2)$$

where \dot{P} is the loading rate and b is the material constant.

The calculated \dot{C} and effective strain rates of investigated loading rates were overlapped. The \dot{C} and time relationships were shown in Figure 2 (only AA5005 and AA5082 results). The material constant b of equation (2) was taken as 0.1. It was found that the investigated loading rate covered the effective strain rate approximately from 10^{-5} to 10^0 s⁻¹. The \dot{C} began to fluctuate severely as the effective strain rate

decreased. Additionally, the degree of fluctuation was larger for the AA5082 than that of the AA5005, because AA5082 contained more Mg atoms than AA5005. It was surmised that the loading curvature of the indentation was affected by the effective strain rate and Mg content, which was the typical behavior of serration in the uniaxial tests.

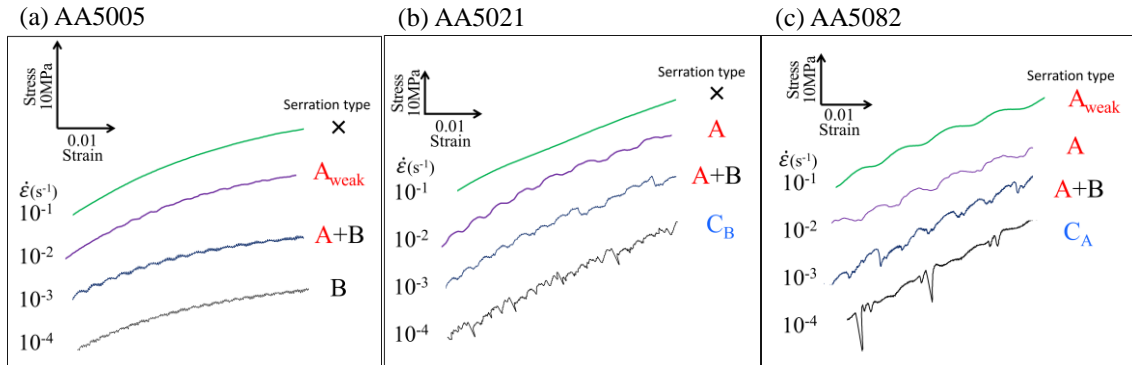


Figure 1. Observed serration behavior for investigated alloy in the tensile tests

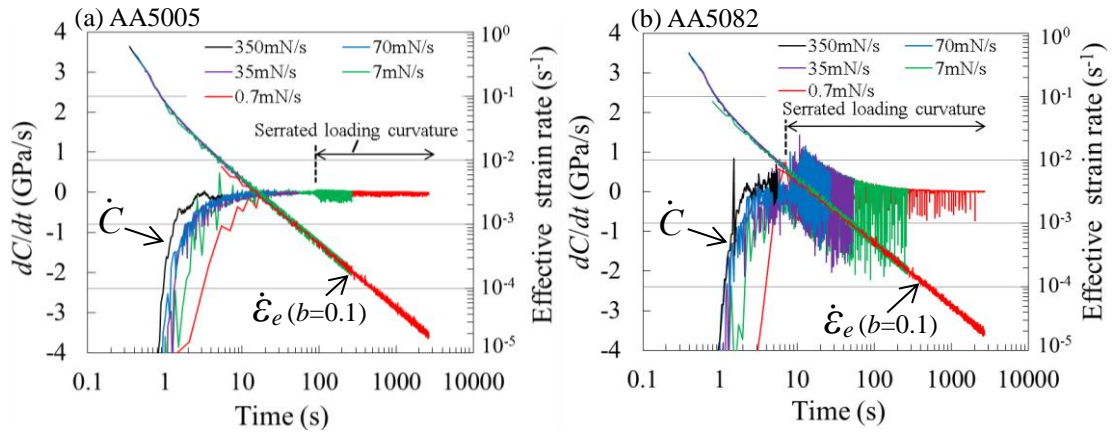


Figure 2. Derivative of loading curvature with respect to time (\dot{C}), indentation strain rate ($\dot{\epsilon}_e$) and time relationship obtained from constant loading rates 0.7mN/s to 350mN/s

CONCLUSIONS

In this study, the strain rate effect of the serration behavior was investigated by the uniaxial and indentation tests. It was found that the investigated loading rate approximately covered the effective strain rate from 10^{-5} to 10^0 s^{-1} . The severe fluctuation of \dot{C} was observed as the effective strain rate decreased. It was surmised that the loading curvatures were affected by the effective strain rate and Mg content.

REFERENCES

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KEYWORDS

Indentation, Effective strain rate, Serration, Al-Mg alloy, Constant loading rate, Loading curvature