MECHANICAL PROPERTIES OF SELECTED ALUMINIUM ALLOYS AT WIDE RANGE OF STRAIN RATES

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1. Introduction

Aluminium alloys (AA) are characterized by a very good ratio of strength to weight which enforces their application in structures where weight reduction is a key factor for operational parameters. Typical examples are lightweight construction alloys used for the purposes of automotive and aircraft industry, what in consequence leads to the overall vehicle weight lowering and finally to reduction of the fuel consumption. The vehicle structure must fulfill requirements of the occupants protection during vehicle crash. Therefore, mechanical behaviour of materials under dynamic loading conditions must be taken into account during designing stage. Moreover an intensive research has been done to improve ballistic protection by application of AA. In the case of armor also an influence of strain rate on the mechanical characteristic of a material must be considered.

The reliable constitutive model for the applied material should be developed and calibrated in order to provide an efficient finite element method (FEM) giving an opportunity to design process and simulate the results captured as close as possible. For this purpose the stress-strain curves should be determined for various strain rates and temperatures. The usual way of material characterization at higher strain rates is the Hopkinson bar method, which enables strain rate sensitivity evaluation of materials in the range up to $5x10^3s^{-1}$. However, this is insufficient in many cases, because local strain rates in the structure during extreme loading may overcame this value. En essential increase of the flow stress, which occurs in material at strain rates higher than $5x10^3s^{-1}$ is caused by appearance of the drag stress component. The discrepancy between predictions of constitutive model developed and the experimentally observed properties of the material may lead to significant errors in design procedure of the whole structure. Hence it is of great importance to provide the adequate testing methodology and reliable data of mechanical properties of materials tested at strain rates higher than 10^4s^{-1}.

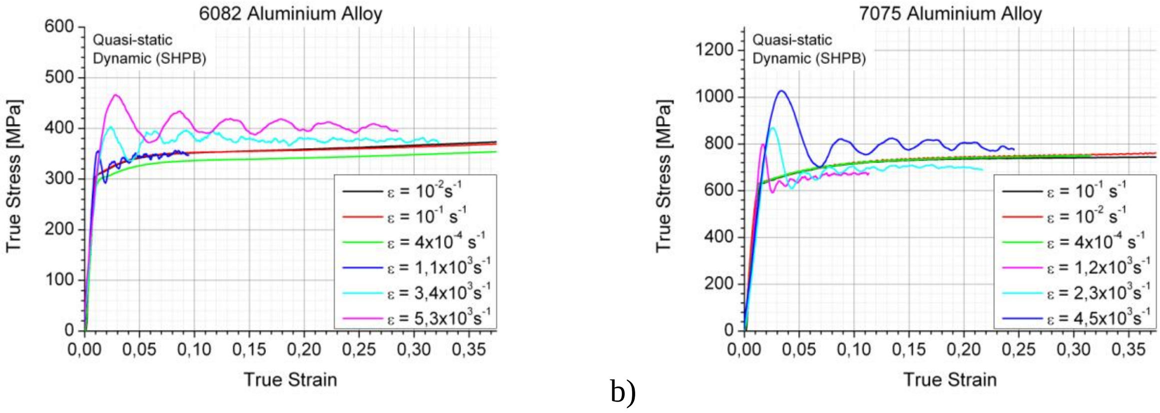
2. Experimental method

Quasi-static compression tests were performed on the standard servo-hydraulic testing machine (Instron), at room temperature. The dynamic compression experiments were carried out on both, the modified Hopkinson bar apparatus [1] at strain rate below $5x10^3$ s^{-1} and the miniaturized direct impact compression testing stand (MDICT) [2] at strain rates within a range from $3x10^4$ s^{-1} to $1,1x10^5$ s^{-1}. As a results a wide picture of AA mechanical behaviour at strain rates ranging from 10^{-4} s^{-1} to 10^5 s^{-1} was determined. The cylindrical specimens of 10mm diameter and 5 mm length were fabricated from extruded bars of 15 mm diameter using electro-discharging machine. The size of specimen for the purposes of miniaturized compression test was reduced to 1,5 mm of diameter and 0,5 mm of length.

3. Results

The stress-strain curves of tested materials are presented in Fig. 1(a) for 6082-T6 alloy and Fig. 1(b) for 7075-T6 alloy. Both materials shows very narrow strain hardening effects which occurs only at strain values lower than 0,05. Moreover, plastic strain hardening exponent doesn't change significantly with deformation rate.

Summarized results for all measurement techniques applied are show in Fig. 2 in the form of strain rate sensitivity chart. In could be seen that 6082-T6 AA doesn't shows any strain rate hardening effects below $5x10^3s^{-1}$, whilst 7075-T6 AA exhibits negative strain rate sensitivity value (dynamic strain ageing effect). At deformation rates higher than $5x10^3s^-1$ a significant increase of plastic flow rate, may be observed. The reason of such effect may be attributed to appearance of the viscous drag component of high magnitude [3] related to high velocity motion of dislocations.



a) b)

Fig.1 Stress-strain curves of AA obtained under quasi-static and dynamic loading conditions; a) – AA 6082-T6; b) – AA7076-T6

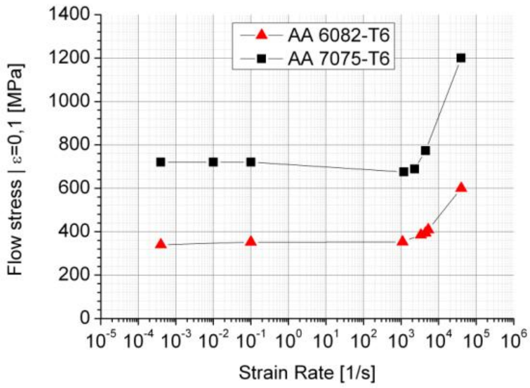


Fig.2 Strain rate sensitivity of tested AA

4. References

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