COMPRESSIVE BEHAVIOR OF 6082-T6 AND 7075-T6 ALUMINIUM ALLOYS AT VERY HIGH STRAIN RATES

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Abstract

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 $10^4 s^{-1}$.

Miniaturized direct impact compression method (MDICT) is one of the methodology which enables material testing at rates higher than those typically possible to attain on Hopkinson bar arrangement. The device for the MDICT testing with the upper strain rate limit equal to $10^5 s^{-1}$ was designed and developed at IFTR PAS [1]. Two different kinds of aluminium alloys were tested i.e. 6082-T6 (AA6082) and 7075-T6 (AA7075). The tested AA usually shows neutral or even negative strain rate sensitivity so called strain rate ageing under static and dynamic loading regime below strain rate of $5x10^3 s^{-1}$. The goal of the study was to investigate an influence of deformation rate on the flow stress at higher rates. The stress-strain curves of AA6082 and AA7075, obtained using the MDICT apparatus are presented in Fig. 1 and Fig. 2, respectively. The range of strain rates was within limits from $3x10^4 s^{-1}$ to $1,1x10^5 s^{-1}$ for AA6082 and from $4x10^4 s^{-1}$ to $9x10^4 s^{-1}$ for AA7075. The specimens of 1,5 mm diameter and 0,5 mm thickness were fabricated form extruded round bars using an electrodischarging machine. Comparison of the results obtained in this research for both tested alloys to those at strain rates below $5x10^3 s^{-1}$ achieved [2] identifies a significant increase of plastic flow rate, reaching a factor of 2. 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.

One of the basic assumptions to be introduced using the Hopkinson bar method is a force balance on the both specimen interfaces. According to the references the time required to establish forces equilibrium state is equal to three reverberation of elastic wave inside specimen. In the case considered the equilibration time is equal to 0,3μs. The result were confirmed by a FEM simulation.

The strong oscillations of the measured curves are one of the major problems during the MDICT experiments. The oscillations are generated by both mechanical wave dispersion in transmitter bar, reverberation of waves inside the specimen and testing stand elements. A complete elimination of the mentioned effects is impossible. However, they could be diminished by application of signal filtering and results interpolation using formulas established at static loading conditions. Applying this procedure enables reliable data to be collected.

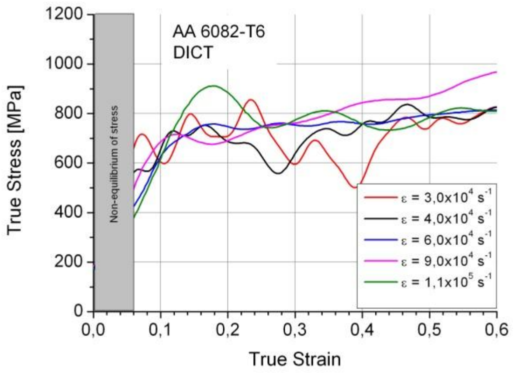

Fig.1 Stress-strain curves of AA 6082-T6 at very high deformation rates

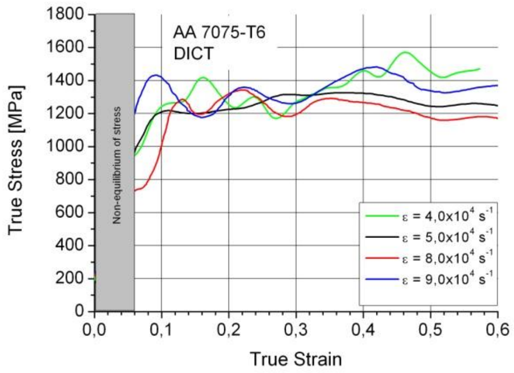

Fig.2 Stress-strain curves of AA 7075-T6 at very high deformation rates

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