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HIGH STRAIN RATE BEHAVIOUR OF AN AZ31 + 0.5 Ca MAGNESIUM ALLOY

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ABSTRACT

The paper reports behaviour of metal alloy AZ31 (nominal composition three the concerns Al - 1 Chronicles Zn – balance Mg) with AN addition of zero.5 wt. the concerns Ca at high strain rates. Samples were ready by the squeeze solid technology. Dynamic compression American Revolutionary leader tests were performed at temperature with impact velocities starting from eleven.2 to 21.9 m.s-1 . A fast increase of the flow stress and therefore the strain rate sensitivity was determined at high strain rates. Transmission microscopy showed extraordinarily high dislocation density and mechanical twins of 2 sorts. adiabatic shear stripe is mentioned because the reason for the determined behaviour at high strain rates.

1. INTRODUCTION

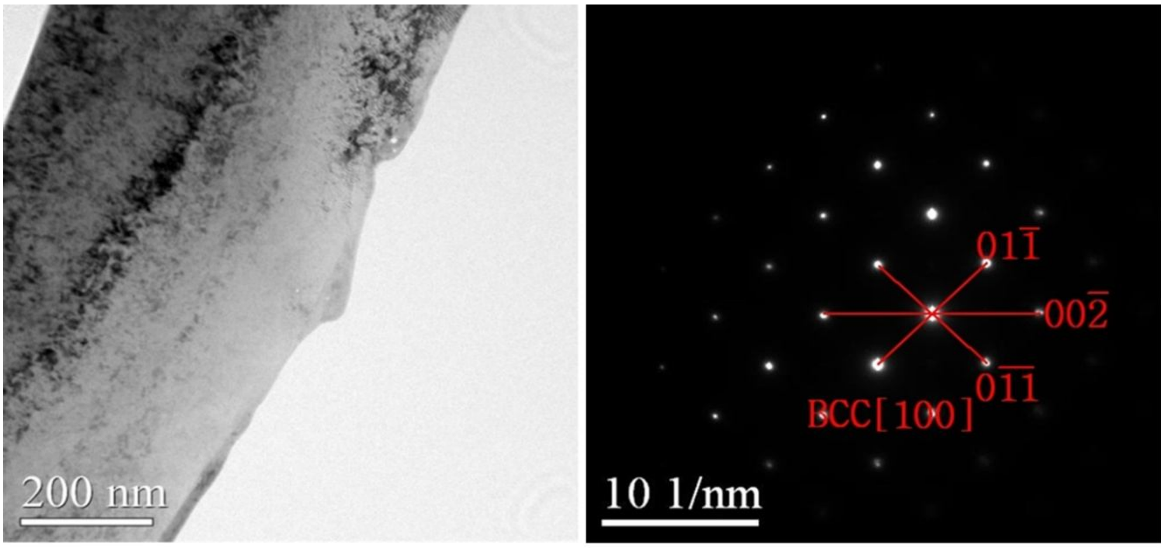
The strength of the many golden materials will increase with increasing strain rate and reduces with increasing temperature. This behaviour is explained by thermally activated dislocation motion and interaction between dislocations and matter atoms. once temperature will increase, there's a lot of thermal energy obtainable for dislocation motion, whereas once the strain rate will increase the time necessary for overcoming of native obstacles within the slip plane is shorter. At temperature and low and intermediate strain rates the deformation method is roughly equal. At higher strain rates, thermal conditions bit by bit amendment to adiabatic and therefore the internal temperature of the sample will increase. Then the deformation temperature is over close temperature. The strain hardening in metal alloys, i.e. increase of dislocation density throughout deformation, will be changed by mechanical biparous. Twins might contribute to straining however on the opposite hand, tiny twins area unit obstacles for dislocation motion; they contribute to the hardening. The high strain rate behaviour of golden materials has been according in numerous papers [1-4]. Recently, the critique of high strain rate properties was done by Armstrong and Walley [5]. At high strain rates some important strain rate exists at that the thermally activated rate dominant mechanism changes to viscous phonon drag [6]. Zerilli and Armstrong changed this concept as well as the dislocation drag into the model of thermal activation [7].

Operating at temperatures under four hundred K due to their fast strength reduction at higher temperatures. so as to beat this disadvantage, Ca - containing Mg alloys were developed with the aim to enhance mechanical properties at elevated temperature. Ca is reasonable and lightweight alloying part [9]. to boot, the Ca addition to metal alloys improves the creep resistance at elevated temperatures [10, 11]. The addition of Ca will refine the grain size, disperse the particle and break down the nerve fibre morphology of particle into spherical and well distributed tiny particles [8]. the target of this work is to ANalyze the deformation behaviour of an AZ31 alloy with Ca addition in dynamic experiments at numerous strain rates.
2. process 0.5 wt. take advantage of atomic number 20 was supplemental to the business Mg alloy AZ31 (nominal composition: three-dimensional, 1%Zn, balance Mg). the fabric was ready exploitation the squeeze casting technology. Cylindrical specimens of nine metric linear unit diameter and nine metric linear unit length were machined from the solid discs. The dynamic compression experiments were performed exploitation split American Revolutionary leader pressure bar (SHPB) technique. The SHPB take a look at is that the most ordinarily used methodology for determinant material properties at high strain rates. The split American Revolutionary leader bar equipment consists of 2 long slender bars that sandwich a brief cylindrical specimen between them. By putting the tip of a bar, a compressive stress wave is generated that straightaway begins to traverse towards the specimen. Upon arrival at the specimen, the wave partly reflects back towards the impact finish. the rest of the wave transmits through the specimen and into the second bar inflicting irreversible plastic deformation within the specimen. it's shown that the mirrored and transmitted waves area unit proportional to the specimen’s strain rate and stress, severally. Specimen strain will be determined by group action the strain rate.

In equation (3) E is that the modulus of bars, Sbar, Ssam area unit cross–sections of bar or sample, Lsam length of sample and C0 sound speed. HSBP tests were performed at temperature of twenty eight.5 °C. For comparison quasistatic compression experiments at a strain rate of eight.3x10-3 s -1 were performed. The activation volume was calculable within the stress relaxation take a look at. Transmission microscopy (TEM) investigations were performed with a Jeol two hundred0 FX microscope operated at 200 kV.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Transmission negatron micrograph of the as ready alloy is introduced . Relatively high dislocation density may be a characteristic feature of this state. Segments of the dislocation network area unit visible in Fig. 1. it's a consequence of the squeeze solid technique used for the preparation of the fabric. Engineering stress-strain curves obtained for numerous impact velocities area unit introduced in Fig. a pair of for numerous impact velocities.



(a) (b)

Fig:-1 TEM micrograph of the as prepared alloy

The strains dependences of the strain rate given in Fig. three were calculable for numerous impact velocities. The strain rate will increase with increasing strain approaching its most price at a strain of roughly zero.02. The strain rate dependence of the yield stress is introduced in Fig. 4. fast increase of the strain.

Rate sensitivity at high strain rates will be seen from Fig. 4. It ought to be note that every experiment at higher strain rates was performed many times. Values of the yield stress introduced in Fig. four area unit the mean values. the utmost strain rate dependence of the elongation to fracture εf is introduced in Fig. 5. equally as within the case of the yield stress the values of the fracture strain area unit the mean values calculable kind the many experiments. comparison with malleability calculable within the quasi–static experiment at temperature, the fracture strain decreases, however within the high strain rate region it will increase once more with a rise within the strain rate.

3.1 Thermal activation The strain rate, ε& , and temperature, T, dependence of the flow stress, σ, depends on the dislocation rate dominant deformation mechanism. sometimes this dependence is delineated by the chemist equation:
where zero ε& is that the pre-exponential term, ΔG the chemist free total heat counting on the thermal (effective) stress σ* = σ–σi (σi is that the internal stress). Kocks et al. [6] found the subsequent empirical relationship for this dependence
Model parameters p and alphabetic character describe the applied mathematics form of the native obstacle profile. ΔG0 is that the chemist free total heat necessary for overcoming a brief vary obstacle while not the strain and * σ0 is that the thermal stress at0 K.
Two sets of values area unit generally used [7]. The set p = alphabetic character = one corresponds to a “rectangular” obstacle profile and an everyday lattice arrangement of obstacles and results in a relentless activation volume V =

m.kT/σ*. The set p = l/2 and alphabetic character = 3/2 corresponds to a a lot of realistic obstacle form and distribution. Geometrically, the activation volume V = b.d.L, wherever d is that the obstacle breadth and L is that the mean length of dislocation segments between obstacles. The strain rate sensitivity parameter

Rapid increase of the strain rate sensitivity at higher strain rates is clear from Fig. 3. Similar dependence was determined conjointly in independent agency metals (see for instance [8]). The activation volume calculable at higher strain rates exhibits terribly tiny values, roughly V~b3 , wherever b is that the Burgers vector of dislocations. the worth of the activation volume calculable at temperature within the quasi–static experiment within the section of the yield stress was V~500b three . The limiting tiny price of the activation volume calculable at high strain rates and fast increase of the flow stress indicate a amendment in deformation mechanism. One risk the way to make a case for this behaviour is to contemplate the transition from thermal activation to drag controlled deformation that happens once a relentless structure is subjected to increasing stresses or strain rates. Zerilli and Armstrong [9] projected a replacement model introducing the dislocation drag into the model of the thermal activation. They calculable that the dislocation drag might considerably amendment the strain rate dependence of the flow stress. From the results by Zerilli and Armstrong, it should be over that the dislocation drag at the strain rates within the order 103 s-1 has solely marginal influence. The robust improvement determined for the flow stress isn't caused by the dislocation drag.

3.2. ADIABATIC SHEAR STRIPE

The mean speed of dislocations v is connected with the plastic strain rate by the Orowan equation.
Where ρm is that the density of mobile dislocations and ψ is Taylor orientation issue.
Constant in an exceedingly bound strain interval. At high strain rates the mobile dislocation density ρm changes and therefore the completely different equation should be used:
where dρ/dt is that the dislocation generation rate and x is that the average distance stirred by dislocations. Equation (9) is typically used at low or intermediate strain rates whereas the equation (10) is a lot of appropriate for top strain rates. The sample temperature is also influenced by the experimental conditions. an immediate conversion of mechanical work created throughout deformation to heat produces a mean rise in temperature, ΔT, inside a cloth volume while not loss of warmth from it. ΔT within the absence of any amendment in internal energy of the fabric (ΔE = 0) is obtained as [10]
where cv is that the heat per unit volume, σ is that the applied stress, and εp is plastic strain. The strain dependence of the heating is directly proportional to the worth of σ.
For the utmost strain rate of two.427x103 s-1 the corresponding stress is one hundred fifty MPa. With cv = one.85x106 Jm-3K -1 for AZ31 alloy a price of dT/dεp = eighty one K per unit strain is also calculated. an increase of temperature of many degrees is obtained for every % of strain that the fabric undergoes. This comparatively tiny increase of temperature is thanks to the averaging and presuming of continuity of the plastic flow method. On the opposite hand, Armstrong et al. [10] thought of solely localized rise of temperature which can be followed by the adiabatic shear stripe. Such adiabatic forming of shear bands was conjointly accustomed make a case for the discontinuous plastic deformation at terribly low temperatures [11].

The density of dislocations was calculable to be 7–8x 1014 m-2. At higher strain rates the waiting time of dislocations at the native obstacles is extremely tiny. this might contribute to the formation of dislocation pile–ups.

Existing within the material will be overcome by the fulminant unleash of pile–ups (or analogous deformation twins or cleavage cracks). intensive biparous was found nearly all told areas of the specimen. determined twins were of 2 sorts. Between huge twins bestowed in Fig. 7, micro-twins were determined (Fig. 8). The density of those micro-twins inflated with increasing strain rate. The adiabatic heating causes conjointly the determined increase of the fracture strain with increasing strain rate within the dynamic tests.

4. CONCLUSIONS

The experiments performed exploitation the split American Revolutionary leader pressure bar showed:

- fast rise of the flow stress at high strain rates;
- fast increase of the strain rate sensitivity at high strain rates;
- limiting low price of the activation volume (~b3);
- extraordinarily high dislocation density in malformed samples.

Experiments at high strain rates and therefore the TEM analysis enable North American country to conclude that the most deformation mechanism at high strain rates is that the adiabatic shear stripe with the high rates of dislocation and twins formation.

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