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Effect of Pre-straining on the Stress-Strain Properties of a Medium Carbon Steel at High Strain Rate

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Abstract

Effects of pre straining on the stress-strain properties of 0.41% carbon steel employing strain rate of about $7 \times 10^3/s$ at room temperature have been investigated in this study. As-received steel specimens were pre-strained quasi-statically at different strain levels and were then compressed dynamically. Results show that with the increase in percentage of pre-straining, the stress values of the material are increased.

Introduction

The theme of the present study was mainly confined to develop a suitable experimental technique described elswhere (1,2) to determine the stress-strain properties of metals and alloys at very high strain rates. In roder debet to establish and assess the various aspects of that technique, a number of preliminary tests (3,4) including the present one, were carried out. Results of these tests greatly helped to optimise the conditions used in the main investigations (1,5,6).

Experimental Procedure

Small samples of 15 mm diameter and 14 mm long were cut from as-received 15 mm round steel bar containing C-0. 41%, Mn-0. 78%, Si-0. 26, P—0. 018%, Ni-0. 13%, Mo-0. 02%, Al—0. 012% and the balance being iron. The samples were then compressed quasi-statically to 20% and 40% strain levels using a 50 Ton Universal Testing Machine and a sub-press fitted with a dial gauge. During pre-straining, graphite in grease was used as lubricant to minimise friction at the specimen platen interface and thus induce deformation more uniformly through out the specimen. After each 10% of strain. the test was interrupted and the interfaces were cleaned and relubricted. Dynamic tests specimens of 6.5 mm diameterand 6.0 mm long were then prepared out of these compressed samples.

Dynamic tests were conducted in a rig (Fig.1) specially designed and constructed to carry out the high strain rate experiments (1,5,6). The basic technique involved firing of a cylindrical projectile on to the small specimen placed on a comparatively rigid anvil. In order to facilitate recording of deformation-time history, a high speed image converter (IMACON) type camera was used. The camera is capable of recording the event at a rate of upto 10^6 events per second

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both in a framing mode and in a continuous streak mode. Details of the technique, recording of

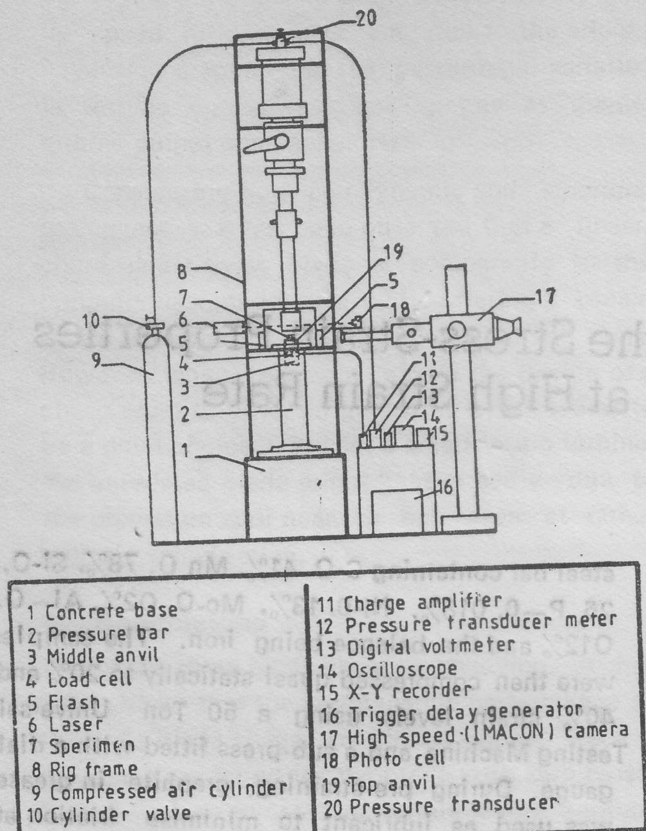


Fig. 1 Schematic diagram of the experimental rig.

the deformation-time history and processing of the experimental data have been described in earlier papers (1,2,6).

However, the impact speed of the projectile was 44.0 m/s and its mass was 16.4 gms. All the tests were performed using the same projectile and with same speed. The strain rate which is a function of the ratio of current velocity of the projectile to current height of the specimen (7), for instance was found to be about 7.3, X 10^3/s. In the resent study, the strain rate within 10% of initial strain rate was also considered as acceptable range. The material inertia and temperature rise during high strain rate deformation were found to have mutually cancelling effects (1). However. the effect of friction was found to be significant and accordingly appropriate corrections were made (1) in deducing the final results.

Results and Discussions

Fig.2 shows the displacement-time curves of the recording during high strain rate deformation of different pre-strained specimens. It can be

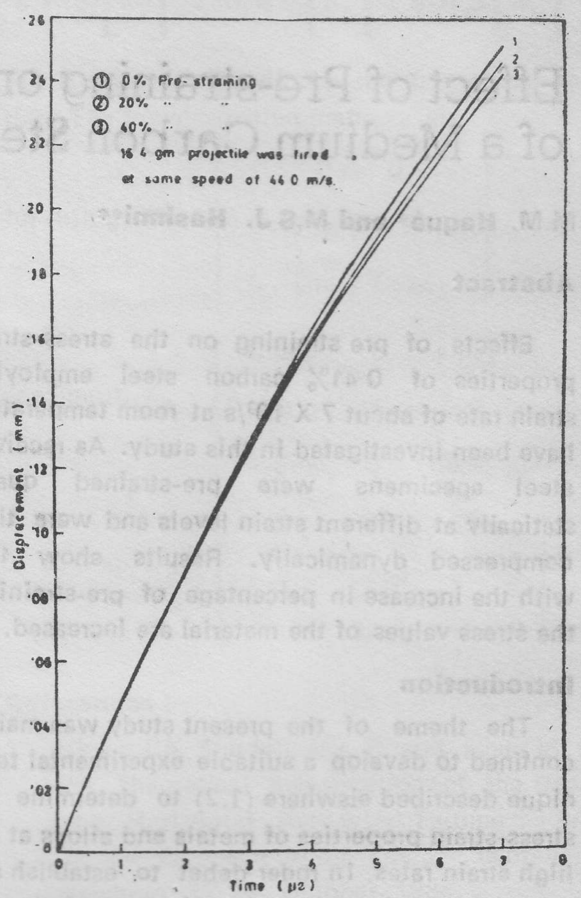
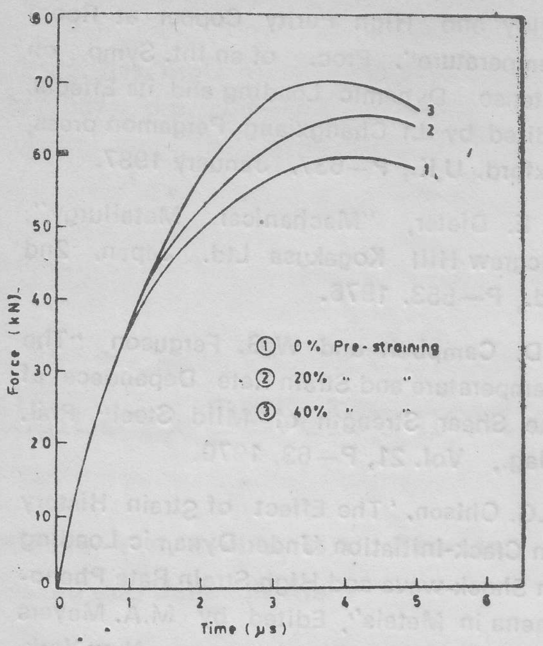


Fig. 2 Effect of pre-straining on the displacement-time curves during high strain rate deformation.

seen that the deformation for as-received specimen is more than the pre-strained specimen. This is because the material becomes work-hardened due to pre-straining. This work-hardening effect is also reflected on the force-time history during impact as shown in Fig.3. Obviously, the stresses



3. Force—time histories derived on the basis of the displacnment time curves of Fig 2.

obtained in the present study show greater value for pre-strained samples than for as-received samples. It can be seen from Fig.4 that the stress value for 0% pre-strained (i.e. as-received) steel is 1.18 kN/mm², whereas for 20% and 40%

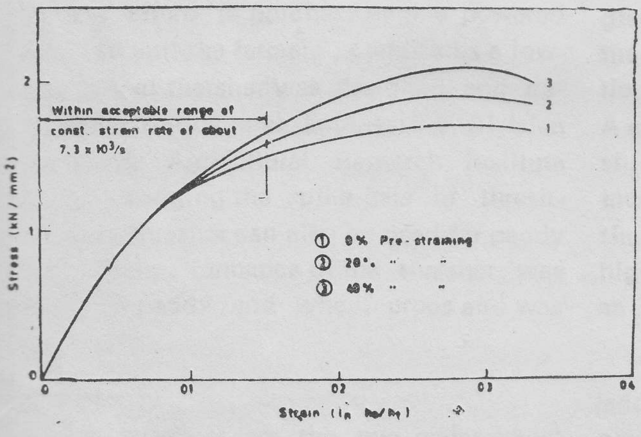


Fig. 4 Dynamic stress-strain curves of 'the steel samples pre strained at different strain levels.

pre-strained materials, stresses are found to be about 1.34 kN/mm² and 1.41 kN/mm², reepectively for almost the same strain increment of about 1.5 percent at initial strain rate of 7,3 x 10³/s, This is in accordance with the results obtained by campbell (8), who used 0%, 7. 5%, 21% and 28% pre-strained mild steel samples and found higher stress values for different levels of pre-straining. The effect of pre-strining was also investigated by Ohlson (9) on crack initiation under dynamic loading conditions who mentioned that work-hardening increased the yield stress of the material. Brown and Watson (10) have shown substantial increase in stress value due to torsional pre-straining (twisted to 1/8 revolution) on 0.51% carbon steel bar at same strain rate.

In the present investigation. It was also noticed that for 0% pre-strained specimen, the range of constant strain rate from the same test was longer compared to those of 20% and 40% pre-strained specimens. This finding suggests that the higher the pre-straining, i.e. harder the material, the shorter is the range of constant strain rate for a given speed of the projectile.

Conclusions

The following conclusions may be drawn from the present investigation :

(i) Pre-straining makes the medium carbon steel work-hardened,

(ii) The Higher the pre-straining, the greater is the stress values but shorter is the range of constant strain rate.

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