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IDENTIFICATION OF EFFECTS ASSOCIATED TO DYNAMIC TESTING USING SHPB OR DICT- EXPERIMENT AND NUMERICAL ANALYSIS

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Abstract:

Selected effects observed during dynamic testing of pure tantalum and VP159 high nitrogen austenitic steel are taken into account with particular emphasis to those of punching and strain rates. Tests were carried out using Split Hopkinson Pressure Bar (SHPB) and Direct Impact Compression Test (DICT) technique.

Phenomena related to the punching induce an error estimation concerning the macroscopic longitudinal strain imposed on the specimen [1]. As it is shown in Fig. 1, during dynamic loading the bar is deformed elastically inducing a local displacement U_2(r, t). It is necessary to include this additional displacement in the definition of the real length change of the specimen. However, it is not possible to measure this punching displacement in a precise way with a known experimental setup measurement. In this paper, the displacement induced by punching effect U_2(r, t) is analyzed to estimate how it may disturb the macroscopic average strain ε of the specimen using the displacement measurement of the DICT. Using numerical simulations, the displacement related to the punching effect was computed, Fig. 2. Simulations of the DICT were carried out for the different sizes of specimens. It is clear from this analysis that, the punching effect is larger for higher impact velocity. Therefore, the Young's modulus measured in experiment E_{measured} was lower in comparison to the theoretical value $E_{\text{theoretical}}$. However, it is possible to improve the measurement using the following formula for correction of the punching displacement:

$$\varepsilon_{corrected}(t) = \varepsilon_{measured}(t) - \sigma_{measured}(t)\left[\frac{E_{theoretical} - E_{measured}}{E_{theoretical}E_{measured}}\right] \quad (1)$$

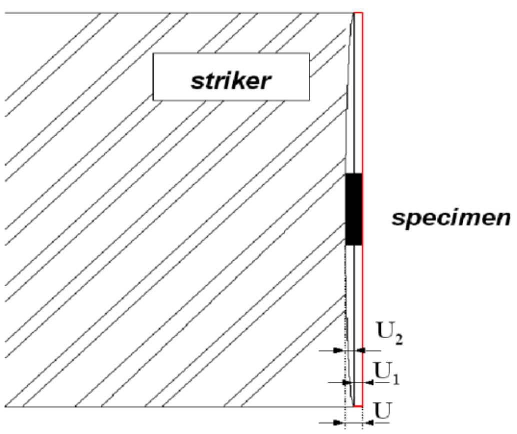

Fig. 1. Schematic description of the punching effect during dynamic compression using DICT

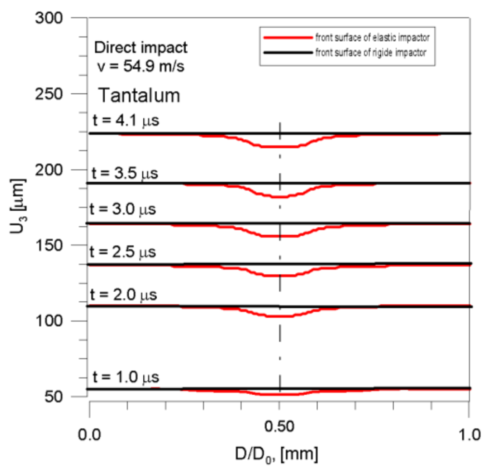

Fig. 2. The punching effect during dynamic compression using DICT with V_0 =54.95 m/s results for tantalum. Elastic displacement U_3 distribution on striker front surface in time t=1.0 - 4.1 μs.

The strain level $\varepsilon_{corrected}$ for an imposed stress intensity is changed. This effect is particularly important for brittle materials that fail at very small strain. In the case of ductile material the punching effect is of secondary importance since the failure strain level is larger than 10%. The results show that the measured Young's modulus $E_{measured}$ using elastic wave theory underestimates the theoretical values. Therefore, the modulus correction using Eq. (1) shifts the measured results closer to the theoretical one $E_{theoretical}$. However, Eq. (1) is not valid for visco-elastic materials, and as a consequence, a correction must be used.

Strain rate sensitivity of materials in question was investigated on the basis of the final set of quasi-static and dynamic curves for tantalum and steel. The range of strain rate values is nine decimal orders, that is from 10^{-4} s^{-1} to $2{,}2 \times 10^5$ s^{-1}. All curves were corrected to the isothermal conditions. The effect of strain rate on the flow stress is shown in Figs. 3 and 4 for three levels of strain for tantalum and steel, respectively. The rate sensitivity $\beta = (\partial\sigma / \partial \log\dot{\varepsilon})_{\varepsilon}$ for tantalum shows two ranges, at lower strains $\beta \approx 46$ MPa and $\beta \approx 260$ MPa above the strain rate threshold $\dot{\varepsilon}_C \approx 1000$ s^{-1}. Such result suggests existence of two thermally activated dislocation micro-mechanisms of plastic deformation in those two ranges of strain rate [2]. Similar result was obtained for steel, Fig.4. It can be seen that strain rate sensitivity for tantalum is much greater than that for VP159 steel obtained. For both materials it changes around $5 \times 10^3 s^{-1}$.

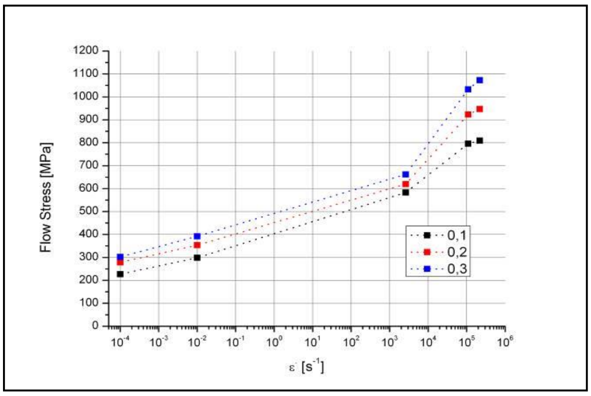

Fig. 3. Strain rate sensitivity of the tantalum at three levels of true strain

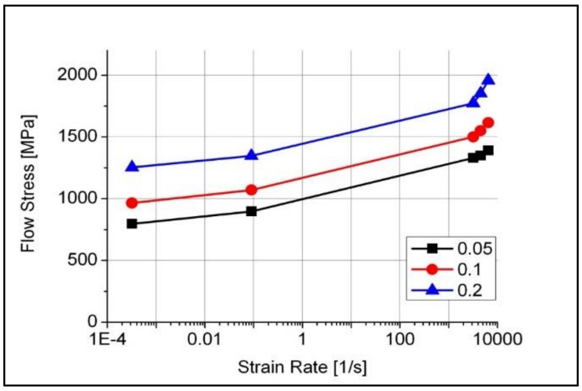

Fig. 4. Strain rate sensitivity of the steel at three levels of true strain

References

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[2] J.R. Klepaczko, J. Duffy, Strain Rate History Effects in Body-Center-Cubic Metals, ASTM-STP 765, 251 (1982).

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