STRAIN RATE AND LOADING COMPLEXITY EFFECTS ON THE CRUSHED STAINLESS STEEL TUBES BEHAVIOR

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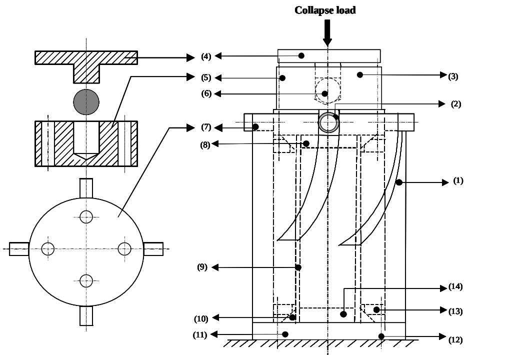
Summery A new experimental device (ACTP: *Absorption par Compression-Torsion Plastique*) for the complex dynamic plastic buckling of tubes is used generating a biaxial loading path (combined compression-torsion) from a uniaxial loading to improve the energy absorbed. Metallic tubes made form stainless steel 316 are investigated. The results show that the higher biaxial loading complexity provided by the ACTP is applied; the greater is the energy absorbed. Thus, the enhancement in the energy absorption under dynamic loading is higher than 186%, for the most complicated loading path compared to the uniaxial case.

INTRODUCTION

Recently, several research programs were interested in the uniaxial crush of metallic structures with various section shapes, mostly circular or square, using high strength steels in thin-walled [1]. Hence, the objective of numerous research programmes is to design optimized section shapes that should maintain almost the maximum stabilized allowable force throughout the greatest stroke length during a vehicle crush. Thus, motivated by a performance of high resistance to crush, the dynamic axial crushing of the cylindrical tubes has been largely used as a passive safety concept adopted since a few decades in structural crashworthiness design. The crushing process is strongly influenced by structural and material aspects, strain rate and inertia effects. The developed idea [2,3] focuses on the possibility of changing in the material strength properties under dynamic loading due to the loading path complexity concept given by the ACTP. Hence, the plastic buckling becomes more and more complicated (giving simultaneously three different strains of compression, bending, and torsion) since a shear component is added to these sequential phases of compression and bending under dynamic loading with more complicated load/unload condition.. Without intervening on the nature and on the geometry of the deformed tubes, additional energy absorption is demonstrated for these materials.

EXPERIMENTAL PROGRAM

The ACTP is employed for testing several stainless steel tubes (Fig.1). As a result of the loading path complexity, a change in the strength properties of the loaded materials is observed. Several degrees of complexity related to biaxial loading paths (referred to biaxial 30°, 37°, 45° and 60°) are created within the loaded tubes. The employed non-welded circular shells have the following dimensions: an internal diameters (d) 38 mm with 1 mm thickness (t) is used leading respectively to the following radial geometrical ratio η ($\eta = R_m/t$) of 19.5, where R_m is the mean shell radius. A longitudinal ratio ($\lambda = R_m/L = 0.15$) is chosen. Tests are conducted under initial impact velocity of about 9.5 m/s use either a masse of 45.5 kg. To ensure the experimental results accuracy, each test is repeated twice under the same experimental conditions. If the differences between the responses exceed 3%, then another test should to be performed.



(1) cylindrical body; (2) roller; (3) intermediate cylinder; (4) receiving disc; (5) higher tightening screw; (6) centering ball; (7) crosspiece; (8) higher disc; (9) specimen; (10) lower conical half-shells; (11) basic disc;(12) lower tightening screw; (13) lower conical clip; (14) lower disc.

Fig. 1 Brief view of the ACTP device

Fig. 2 Typical examples of the deformation modes for the specimens having η= 15.5 under different dynamic loading complexities.

EXPERIMENTAL RESULTS AND DISCUSSION

The deformation mode is almost of mixed mode (XM) type for these shells. As expected, the diamond part of the XM becomes more significant with the increase in the loading path complexity and substituting the axisymmetric mode (AM) systematically. It is found that the increase in the torsional component supports, in general, the appearance of the diamond mode (DM) quite systematically, particularly in the biaxial-45° case (Fig.2). The load-deflection curves of different quasi-static uniaxial and dynamic biaxial loading situations are demonstrated in Fig.3a. They are characterized primarily by a noticeable increase in the peak collapse load (F_{max}) particularly during the first plastic flow. In fact, depending proportionally on the loading path complexity, such loads undergo a considerable amplification. The specimens demonstrate a remarkable sensitivity not only to the strain rate, but also in more impressive manner, to the loading path complexity effect. Thus, the F_{av} for the three given loading situations are: 21.5 kN (free-ends (noted Ref): quasi-static uniaxial), 32.5 kN (free-ends: dynamic uniaxial) and 42.3 kN (dynamic biaxial-45°), giving a maximum increase of 186% in the biaxial-45°. This result is in a good accordance with those obtained in [3] in the aluminum case. Note that the dynamic velocity decreases naturally and gradually with crushing continuation up to join roughly the quasi-static state; and this affects obviously the materials response. The energy absorption is described in Fig.3b showing a significant enhancement in its value as a result of the loading path complexity. The estimated energies for the crushing distance of δ= 40 mm are: 0.86 kJ for the quasi-static uniaxial, 1.3 kJ in the case of dynamic uniaxial and 1.69 kJ for the dynamic biaxial-45°. Moreover, the maximum enhancement is higher than 185% in favor of the biaxial-45° load vis-à-vis a classical uniaxial case for an axial deflection of δ= 40 mm. In fact, one can interpret this behavior by the fact that such a material changes its local behavior at the dislocation level with respect to the strain rate coupled with loading path complexity factor as already demonstrated in [4] in which it is pointed out that the presence of high density tangled sessile dislocations explains the increase of 150% in the biaxially deformed aluminum (biaxial-45°).

CONCLUSIONS

As a conclusion, it is found that the higher is the inclination angle up to 45° of inclination angle, and the more complex loading is applied, the more severe the rates of change of torsional component, and the greater are consequently the mean collapse load and the corresponding absorbed energy. Therefore, the enhancement in the energy absorption for the stainless steel shells is higher than 185% in the biaxial-45° case.

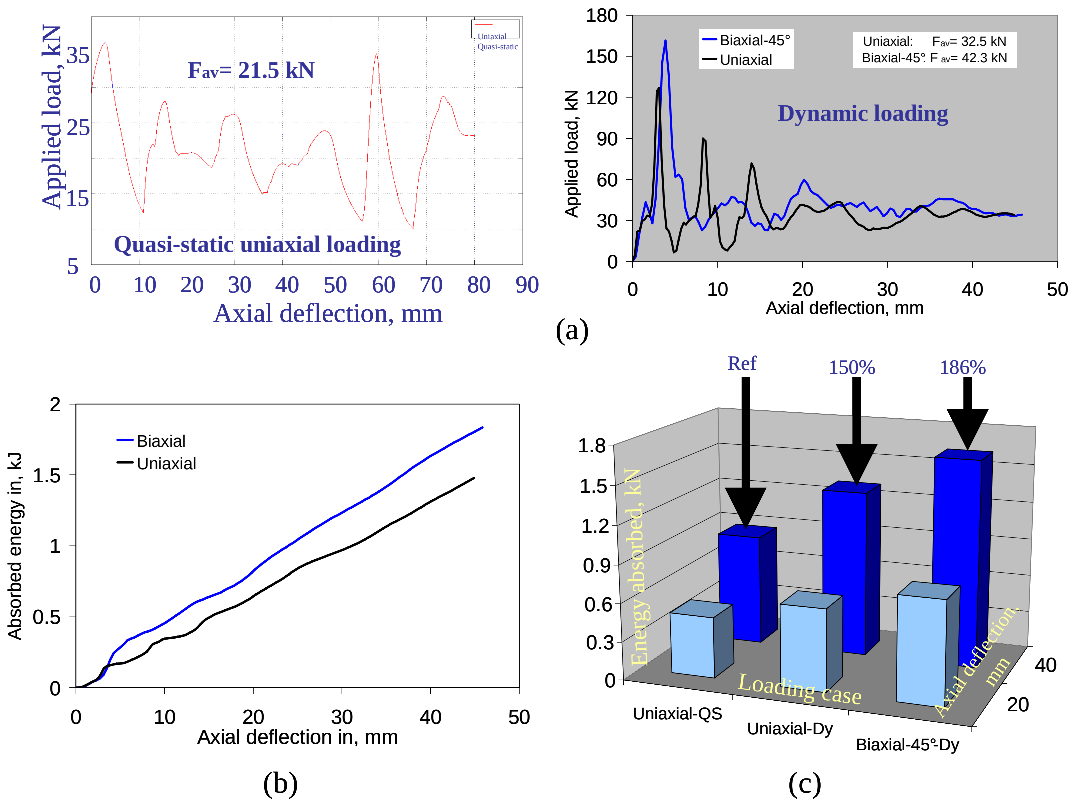


Fig. 2 Evolution of collapse loads (a) and energy absorption (b) evolutions versus axial deflection under different loading complexities for the stainless steel 316, showing a comparison in the absorbed energy and its affected be loading complexity and strain rate (c)

References

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