

APPLICATION OF PLASTIC DEFORMATION IN A NOVEL RE-USEABLE ENERGY DISSIPATION DEVICE

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ABSTRACT: The concept of a Universal Re-usable Energy Absorption Device ‘UREAD’, is introduced and shown to contain a passageway of a constant cross sectional area but with internal intersections where energy is dissipated through internal shearing of a plastically deformable material. Experiments were carried out under static and dynamic loading using different configurations in order to assess the usability of the technique in engineering structures. Both Experimental and theoretical results demonstrated the capability of the devices to absorb static and dynamic loads thus proving its suitability to dissipating excessive loading or undesirable energy.

INTRODUCTION: The use of energy in industry and transport in general has drastically increased during the last century. Thus, it has become desirable to develop devices that could dissipate energy at different levels and in such a way to prevent injuries and disasters. Nowadays, in the field of energy absorption considerable progress has been made and devices and techniques based upon metallic structures were developed to dissipate unwanted high levels of energies. Metallic plates were used by Darguh et al [1995] and inward inversion of metallic frusta by Aljawi et al [2005]. However, in most available techniques, especially impact events, energy is dissipated in the form of a force and a displacement where either the device is destroyed or a rebound force is generated in the opposite direction.

Almost all plastically deformable materials develop a pattern of internal shearing when subjected to loadings that exceed the material flow stress. Hence each deformable material exhibits resistance to stresses that is comparable or higher to its internal yield strength. This work introduces a universal re-useable energy absorption concept capable of dissipating impact energy by exploiting the principle of Equal Channel Angular Extrusion (ECAE). Historically, ECAE belongs to the severe plastic deformation group of processes where materials are extruded through an inclined channel. Its first mention was in 1977 and developed further by its inventor Segal [1995] to significantly improve the mechanical properties of metallic materials. This work develops and tests devices based on ECAE that are easy to integrate into structural designs while the technique itself should provide a new method for protection against disasters and also encourage research into the development of new deformable materials to suit the desired energy level.

'UREAD' ARRANGEMENTS, RESULTS AND DISCUSSION

The generalised form of UREAD has been described by Osman [2004] where the process of dissipating energy is carried out through the intense shearing of a deformable material at the interfaces of intersecting channels. Fig. 1 shows a section on an operational device and the basic configurations of intersecting channels; 90° , θ , where $180 > \theta > 0$ and the U-shape configuration. An energy absorption device will have two operating punches as shown in Fig. 1(a) and a deformable material in the channel section between the two punches. When one punch is activated by moving inward the material in the channel between the punches deforms while pushing the other punch outward. The energy expended by the material deformation defines the level of loading the device is capable of dissipating. The cross sectional area of the channel is of significance as larger volumes absorb higher energies. The intersection angle θ plays an important role in the severity of the deformation where 90° or less will give strains greater than 1, see Table 1.

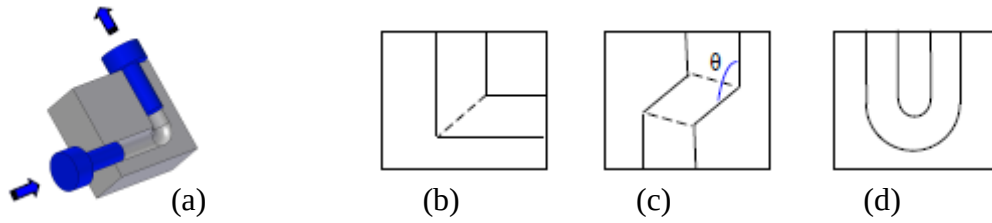


Figure 1: UREAD Basic Channels Configuration

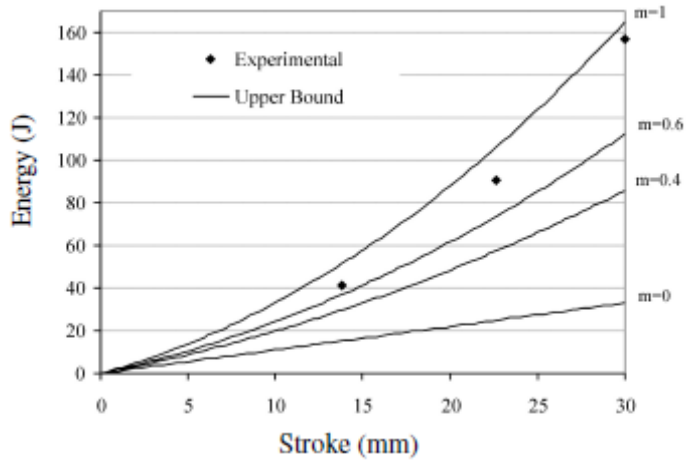


Figure 2: Theoretical and Experimental Energy Levels

Table 1: Deformation Strain

$\theta/\text{degrees}$	Strain
90	1.15
112.5	0.76
135	0.48

The Upper Bound technique has been applied to metal forming processes and provides an effective method for comparative analysis. Lupoi et al [2008] analysed the stresses applied on the tools and showed the significance of the frictional resistance at the

tool/material interface. Fig. 2 shows the experimental and the Upper Bound energy levels in a 10x10mm channel with lead as a working material, m is the friction factor. An U-shape unit was also tested on a beam type arrangement with impact energy of 8.05J, see Fig. 3 for the damping characteristics. The maximum force applied to the beam without the UREAD unit support was between 2-3 times the maximum load registered in Fig.3. Plasticine, wax, Lead, aluminium are among the materials tested under this technique, however deformable materials between lead and aluminium were not easy to find.

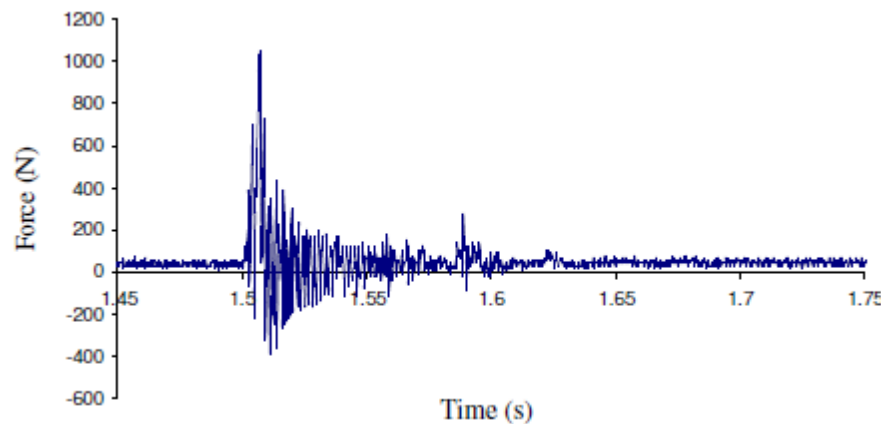


Figure 3: Dynamic test for a U-shape configuration

CONCLUSIONS: This investigation has shown that the UREAD concept can be used to absorb force and energy in a predictable manner under static and dynamic loading. Different deformable materials with yield strength that varies from 0.1MPa to 11MPa were successfully used in the experiments and results compared with theoretical predictions.

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