A FIBRE MATERIAL MODEL FOR MULTISCALE MODELLING OF HIGH PERFORMANCE COMPOSITES

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Summary: Multi-scale techniques are becoming commonplace in the analysis of complex structures. The current paper gives an overview of such a modelling approach in which a fibre based constitutive model is implemented in the ls-dyna commercial Finite Element code to simulate the behaviour of a high performance fibre, subject to a range of strain-rates. To validate the approach a comparison with experimental data is given.

1. INTRODUCTION

In the last 15 years a large number of new high performance polymer fibres with aligned carbon chains have been developed, which include Aramid fibres (Kevlar, Twaron, Technora), polyethylene fibres (Dyneema, Spectre), polypropylene fibres (Curv, Tegris) and PBO (Zylon). The main market for these low density fibres with high tenacity is lightweight body armour, such as vests and helmets. To fully utilise the benefit of using such fibres it is necessary to model the behaviour of the fibres at the micro-scale and the composite at the macroscale or continuum scale.

2. MODELLING APPROACH

The ballistic performance of flexible armour is generally considered to be controlled by the wave propagation along the fibres; the controlling material properties are the tensile wave velocity in the fibres and the specific energy absorbed at failure. A previous composite constitutive model [1] has been developed which incorporates these key features, but at a mesoscale. However, the approach can be applied at a fibre level with the individual fibres modelled rather than homogenised at the mesoscale level [2]. Figure 1 illustrates the key features which must be modelled to accurately predict the behaviour of a mesoscale composite, based on the micro-scale behaviour. Clearly the tensile behaviour with defibrillation at ultimate failure as well as the observed compression failure, which is similar to kinking failure observed in conventional carbon fibre based composites, are important. The
shear failure is dominated by the behaviour of the interface, which for such soft ballistic armours is very low [2]. The approach also allows rate effects which can be measured at the fibre level using Hopkinson bar techniques, to be modelled used in meso-scale modelling.

![Image](image.png)

Fig.1. Left: Tensile failure of Dyneema HB26 fibres, Right: Compression failure of Dyneema fibres

3. CONCLUSIONS

The development and implementation of a fibre based micro scale constitutive model will clearly allow the modelling of mesoscale tests, such as shear, tension and compression. Thus the behaviour of the high performance composite can be based on the fibre properties which can be substantially easier to measure than meso-scale properties.

The development of an approach based on fibre level properties does not require any enforcement of meso-scale plasticity arguments which are not well suited to such materials due to high porosity and very low resin fractions, also the very weak interfaces between the fibre and resin. The results presented using this novel approach is validated against documented static and high strain rate tests of high performance fibres.

4. REFERENCES