A computational study of the ballistic performance of UHMW-PE composites: looking beyond fibre properties

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Dyneema® fibres are a class of UHMW-PE fibres manufactured by DSM which are characterized by highly oriented molecular chains. Possessing such a molecular structure, these fibres exhibit high specific strength and modulus - making them ideal reinforcements for ballistic cross-ply composites. This rationale is also strongly corroborated in literature[1]. Recent experiments have indicated that in additional to fibre properties, other ply level properties can also contribute to ballistic performance. There are different failure mechanisms at play that can lead to different modes of onset of penetration[2, 3]. Insight into how these underlying mechanisms depend on ply level properties can help in developing better ballistic composites. Through this motivation a detailed computational study is carried out to mark out this dependence in the form of a mechanism map.

To construct this map, plane strain dynamic impact finite element simulations of a rigid cylindrical impactor onto an infinite UHMW-PE cross-ply beam were done in Abaqus Explicit. A homogenized ply level constitutive model with transversely isotropic elasticity and crystal plasticity was incorporated - in order to capture the anisotropic interaction between the fibre and the matrix within the ply. The results from each simulation were used to track the onset of tensile fibre failure within the plies and the mode of failure was identified. The overall parametric dependency was represented as an impact map. Fibre topology was incorporated into the model through modifications of the parameters in the ply constitutive model and its effect on failure modes was studied using two separate impact maps - one for the fibre system (circular fibres embedded in a matrix) and one for a corresponding equivalent tape system (continuous microstructure, with no individual fibres discernible).

The results of the simulations indicated an improvement in resistance against failure under ballistic loads in tape systems compared with the equivalent fibre systems. An additional operative failure mode was observed to be present for the tape systems which is absent in the fibre system.

References

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