Micro-mechanical modelling of UHMW-PE composites using crystal plasticity for ballistic performance evaluation

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ABSTRACT

Dyneema® fibres manufactured by DSM, are a class of Ultra High Molecular Weight Polyethylene (UHMW-PE) fibres which are characterized by highly oriented continuous molecular chains. Composites reinforced with these fibres exhibit superior resistance against ballistic impact loadings which is attributable to the fibres high specific strength and modulus emergent from the intra-fibre microstructure. Although superior fibre properties strongly correlate to superior ballistic performance, recent experiments have indicated that in addition to fibre properties, other ply level properties like matrix shear strength & fibre topology can also significantly contribute to ballistic performance [1, 2, 3]. During ballistic penetration, the interplay between different failure modes is uniquely influenced by a combination of composite properties and in order to tap into the full potential of these composites - a deeper understanding of the underlying penetration mechanics is sought. As a first step in this direction, an unclamped infinite UHMWPE beam under ballistic impact was analyzed using dynamic finite element simulations and the onset of different failure modes was identified. A micromechanically motivated homogenized ply level model using orthotropic elasticity and crystal plasticity was formulated to capture the anisotropic interactions between the fibers and the matrix. Fiber strength, matrix strength and fiber topology were varied by adjustments in the plastic constitutive law for each simulation and the corresponding dominant failure initiation mode was mapped as a function of these properties to construct impact maps. Two fiber topologies were studied based on manufacturing feasibility - a fiber system (with circular fibers embedded in matrix) and a strength equivalent tape system (an anisotropic continuous microstructure, with no individual fibers discernible). The impact map results indicate an improved ballistic resistance to failure in tape systems as compared to the equivalent fiber systems. Extending the study to capture failure mode propagation and switching, a viscous damage model is incorporated into the existing ply-level constitutive model in order to capture quasi-brittle fiber failure within plies at high strain rate impact loadings.

REFERENCES

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