Multiscale study of ballistic fabric mechanical properties over a wide strain rate range

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Abstract

Due to their high impact resistance, aramid fibres have been widely used to withstand high-velocity impacts in the form of flexible, lightweight yet hard-to-break garments. However, proper validation of such protection still involves expensive experimental ballistic testing. Therefore, numerical simulations are commonly used to reduce costly processes and to provide insightful information during impact. Numerical models require the introduction of material data relevant to the ballistic application. It has been widely demonstrated that the coefficient of friction, Young's modulus, failure stress and strain have an effect on ballistic performance. However, these observations haven't yet been coupled and compared on the same material with dynamic loading tests, weaving effect on weft and warp yarns, to assess the extent to which key parameters are critical for protection against projectile impact.
Moreover, proper validation of such protections still consists in expensive experimental ballistic tests. Therefore, in order to reduce costly processes and to have some insightful information during impact, numerical simulations are commonly used. This work is focused on a single fabric layer and examines the mechanical behaviour of two woven fabrics, a plain weave and a twill 2x2, respectively made with 215 and 1264 dtex of Kevlar multifilament yarns and with 13.4 and 6.7 weft and warp yarns/cm respectively (Figure 1). For this purpose, friction and tensile tests are conducted at different scales: fibre and yarn, for tensile behaviour investigation quasi-static tests are carried out by means of a universal press, intermediate regime of strain velocity is achieved via a drop tower and dynamic range is covered by split Hopkinson tensile bars. In addition, inter-fibres and inter-yarns friction coefficient are measured. Low velocity impacts are performed as preliminary impact tests to assess the energy absorbed by the two woven structures. Two kinds of indenters were used: a hemispheric and FSP so as to vary the stress state. The aim of those experiments is to understand the influence of the weave architecture on stress distribution and to identify the damage mechanisms induced by the round and sharp edge nose projectiles. The post-mortem specimens are observed to investigate the different profiles of yarn failure.
From this very rich experimental data set, an Abaqus Explicit numerical model is developed. An analysis of the influence of the woven fabric structure, strain rates and stress states on the impact performances of the fabrics is proposed either from an experimental and numerical point of view

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