ABSTRACT

In this study, shear thickening fluid (STF) encapsulated electrospun ultra-high molecular weight polyethylene (UHMWPE) mat was prepared and its ballistic performance was evaluated at high strain rates under dynamic compressive loading. Two different molecular weights of UHMWPE, M_w=2.21×10^6 g/mole (UM2.21) and 4.43×10^6 g/mole (UM4.43), were used to prepare the solutions at different concentrations in a binary mixture of decalin and cyclohexanone (70:30 ratio) solvent. Using de-Gennes's scaling theory, a correlation was established between rheological properties and electrospun morphology of the solutions to identify their critical entanglement concentrations, the concentrations at which polymer molecules started to entangle with each other. A smooth fibrous morphology was obtained when the concentration of the solution reached to 2-2.5 times the entanglement concentration. Further work was carried out by choosing higher molecular weight UHMWPE (UM4.43) at its optimum smooth fiber solution concentration (2 wt.%) due to its better properties. Other electrospinning process parameters such as applied voltage, solution conductivity, solvent type, etc were also optimized for UM4.43.

In the next step, the stretching of electrospun mat of UM4.43 was performed inside a hot air oven at different temperature range from 60-150°C. These stretched fibers, along with a single fiber of Spectra® lamina (as a control sample), were characterized for their mechanical performance and morphological analysis by SEM, XRD and tensile test under quasi-static condition.

Shear thickening fluid was synthesized with nano silica particles and characterized for its rheological behavior such as steady strain rate, dynamic strain rate and structural regeneration thixotropy test. The ballistic performance of nonwoven fabric with STF was first evaluated using a commercially available nonwoven felt of UHMWPE. This hypothesis of non-woven felt behavior was utilized in electrospun nonwoven fabric of UHMWPE.

Before STF impregnation in the electrospun mat, the surface properties such as the low coefficient of friction of UHMWPE fibers were altered by solution blending of high-density polyethylene (HDPE) with UHMWPE to increase the adhesion of silica particles on the fiber surface. Electrospinning of UHMWPE (UM4.43) and HDPE blended solution was performed at three different weight ratio compositions (100:0, 67:33 and 50:50) for obtaining miscible blend compositions. Mat prepared at miscible blends composition of UHMWPE and HDPE (67:33) was selected for shear thickening fluid impregnation study. Lastly, STF impregnated electrospun UHMWPE/HDPE fabric and UHMWPE felt (as a control sample) were encapsulated firmly by enclosing them using stretched UHMWPE fiber and tested for its high strain rate behavior. The high strain rate performance of STF encapsulated samples showed a significant improvement in peak stress in both samples enclosed by stretched UHMWPE fiber as compared to the unenclosed neat felt sample. From this study it was found that STF encapsulation after its impregnation in the fabric can improve the ballistic performance by helping STF to perform synergistically with lab synthesised electrospun fabric and can be a precursor for further technology development.