ABSTRACT

In the present scenario of technological advancement, the use of functional materials with special properties for various engineering and commercial applications is gaining importance. Textile being one of the most widely used material next to food; it is not only used mere for clothing applications but expands in its technical applications widely. Hence to contribute the development of technical applications of the textiles, in this work three functional materials such as the natural corn starch (CS) as shear thickening material for impact resistant textile structure development, phase change material (PCM, n-Octadecane) for the thermal regulation textile applications and the silver nanoparticles for the purpose of developing antimicrobial structure developments have been studied each with a specific emphasis as described below.

One of the important technical applications of the textile materials is the impact resistant textiles. Impact energy absorption of textile structures involves spreading of the energy over the large surface area. This requires the ability of the structure not only having the stress bearing capacity but also the ability to elongate in order to dissipate the energy. If the extension happens with high stress then the total energy absorption would be high. For the purpose many attempts have been made with various types of high performance fibre combinations such as ultra-high molecular weight polyethylene (UHMWPE), aromatic polyamide (Kevlar), aromatic polyester (Vectron), etc. In order to meet the end requirements, the layered form of fabrics made of these fibres are used. Attempts to use functional materials such as the nanoparticles and polymer combinations as the shear thickening fluids (STFs) for the increased stress build up while the structure is straining which have revealed good results. Similar to these studies, in this work also it is attempted to develop impact resistant structures with the combination of

high performance grade fibre such as the Kevlar and the regular grade polyester (PET) using the natural strain thickening material the corn starch (CS).

Therefore in the first part of the work, the Kevlar and Polyethylene terephthalate (PET) textile composite structures were developed through layering after impregnation with optimized corn starch shear thickening fluid (CS STF) using Corn Starch (CS) and polyethylene glycol (PEG). CS has been characterized for particle size and distribution through Dynamic Light Scattering (DLS). CS and PEG ratio was studied through fluidity and shear thickening studies using in-house funnel collector and electro-mechanical shearing stirrer through ampere measurement studies, respectively. In order to assess the shear thickening effect of the CS-STF and the composites with and without CS-STF, an in-house impact resistant tester as per the standard National Institute of Justice (NIJ) standard 0115.00. Using the tester, the impact energy calibration curve and the energy absorption calculations and methods are first established. Based on the impact energy calibration curve and energy calculations, the impact energy absorption of CS STF impregnated textiles have been studied. The order of layering of the STF impregnated textile structures have been systematically studied for effective impact energy absorption. Shearing studies revealed that at and above shearing time of 3000 µs, shear thickening was found to be prominent for the optimum CS & PEG ratio of 52:48. Similar trend was also observed in the impact energy absorption studies of textile structures impregnated with the CS STF. One layer of Kevlar woven fabric followed by one or more layers of PET nonwovens with CS STF showed good performance in impact energy absorption. Such trend was also observed in 6, 5 and 4 layering. Presence of more than one layer of Kevlar on the top of the nonwovens in the composite did not contribute; rather it decreased the energy absorption.

As the CS-STF is of natural origin, its incorporation inside the textile structure might facilitate the development of the microbe which might lead to structure degradation along with the unwanted smell development. Hence, in the CS-STF loaded structures, the incorporation of the antimicrobial were carried out. Antimicrobial agent treated structures showed 100 % activity by AATCC 100 method and they did not develop smell while the untreated samples developed microbes with intense smell.

The second part of the work involves the use of the phase change material (n-Octadecane) in microencapsulated form (µPCM) for developing thermo-regulating textile structures. Studies related to application of PCMs in textiles have been reported. In this study, a specific emphasis on mapping of the energy absorbing capacity of µPCM with the time of thermoregulations has been given which in general lacks in the research works so far reported. Hence, in the second part of the work, pure PCM and microencapsulated PCM (µPCM) were analysed for heat capacity and core content using DSC analysis and were tested for stability against heat and solvent. Energy release rate of human feet has been quantified through a novel in-house tester using water and air medium. Energy release rate by various experiments have been compared and ranges of quantity of µPCM have been recommended for a definite period of thermoregulation with and without a factor of safety. Based on theoretical predictions, socks were treated with µPCM for add-on values of 0.2 g to 5 g corresponding to 1 % and 25 % on the weight of socks, respectively. The treated socks were subjected to wear trials and evaluated as against the untreated one. It was found that the thermoregulation period of the µPCM treated socks were proportional to their weight add-on and were in close agreement with the proposed theoretical predictions. The presence of µPCM on the treated socks has been observed through scanning electron microscope.

The third part of the work exclusively on the development of effective antimicrobial agents due to two fold reasons first one being the area most widely explored in textiles for various sanitary, preservative and medical applications while the second one being focusing and strengthening the first two part of the research work. In the first two parts the use of antimicrobial agents becomes essential for preventing the microbial growth. The first part uses the natural corn starch as the shear thickening fluid (CS-STF) which is susceptible for the microbial growth and hence addition of the antimicrobial agent would prevent the microbial growth development and hence facilitate the performance. In the second part of the work, the use of μPCM supports the thermo-regulation of the socks in the feet, however, it does not address the microbial growth due to human skin contact and hence the smell development. Hence, the use of the antimicrobial agents along with the μPCM would again facilitate the performance of the μPCM preventing the smell development. Therefore, in the third part development of silver nanoparticle antimicrobial agent using natural reducing method has been studied and reported.

Hence, in the third part of the work, silver nanoparticles were synthesised from the $AgNO_3$ through reducing agents Lycopersicon leaves extracts. Silver nanoparticles have been characterized for particle size and distribution through Dynamic Light Scattering (DLS) and the crystalline and amorphous region in the silver nanoparticles were analysed through XRD. Silver nanoparticles treated socks showed 100 % activity by AATCC 100 method and well defined zone of inhibition was perceived in the case of *Staphylococcus aureus (S. aureus), Escherichia coli (E.coli) and Bacillus subtilis.*

In addition to the incorporation of antimicrobial agents in the socks for the purpose of preventing the unpleasant smell, attempt has also been made to incorporate the microencapsulated fragrance liquids so that the socks might just not develop any unwanted smell but has the ability to permeate the long lasting pleasant fragrance smell. Hence, in this work, additionally the study of microencapsulated fragrance (µFragrance), as another functional material, is also included. The materials in the micro encapsulated fragrance (µFragrance) were analysed by Fourier Transform Infrared (FTIR) spectroscopy (FTIR). The presence of silver nanoparticles and micro encapsulated fragrance (µFragrance) on the treated socks has been observed through scanning electron microscope. Wear trials of the socks with the µFragrance and µPCM revealed that it results in good thermal and psychological comfort compared to the counterpart socks without these functional materials.