ABSTRACT

After reviewing past work into the enzymatic treatment of cotton yarns and composites, an account is given of the cellulase treatment of cotton yarns produced from two different spinning technologies and hybrid fibre composites and nano composites which represent one of the major problems in finishing. The shortcomings of the knowledge are shown to be that, although a large number of papers have been published on the enzymatic treatments of cotton yarns, there have been no systematic studies on the response of regular and compact yarns and there have been virtually no attempt to characterise the substrates in terms of their structures.

Four yarns, which comprised of 60 Ne and 80 Ne regular and compact yarns, were subjected to cellulase treatment under the same condition and their tenacity, elongation, wickability, minimum twist of cohesion and bending rigidity were examined. Short staple natural fibres such as sisal, jute, banana reinforced thermoplastic composites are increasingly gaining attention for their emerging applications in the field of aerospace, automotives, construction, textiles, etc. For producing hybrid composites, mercerised cotton, cellulase treated cotton and sisal fibres were used. The mechanical, thermal and morphological characteristics of hybrid composites and nano composites were studied. PP composites were prepared by HAAKE Rheomixer followed by compression moulding. Cloisite 25A was used to improve the hybrid fibre composites. Mechanical tests showed considerable improvements. The morphology of hybrid composites and nanocomposites were examined by SEM (Scanning Electron Microscopy) and XRD (X-ray diffraction). Morphological findings revealed efficient
dispersion of nanoclay within the PP matrix. The crystallisation and melting behaviour and thermal stability of the hybrid and nanocomposites were studied using DSC (Differential Scanning Calorimetry) and TGA (Thermo Gravimetric Analysis).

Weight loss, which is an indication of hydrolysis, shows an increasing trend with increase in enzyme add on. The regular and compact yarns show an increase in strength following enzymatic treatment. The differences noticed between the 80s regular and compact yarns even after the treatments are maintained. The response of 80s yarn to enzymatic treatment in terms of bending rigidity seems to be better than those of 60s treated yarns. All the treated yarns show an decrease in bending rigidity which is an indication of decrease in stiffness. In the case of 60s scoured yarns, the compact yarn shows better wickability in comparison with regular yarn. Wickability is attributed to their lower twist. Wickability of 80s yarn is better as compared to 60s yarn. In the case of bleached, the same trend is being maintained. In the case scoured and enzyme treated, again the same trend is maintained. However the yarn seems to have better wickability. The mercerized treatment has led to an increase in shrinkage yarns. Minimum twist of cohesion following enzymatic treatment does not show any significant change.

As far as the effect of strain rate on the tenacity of yarns is concerned, it was found that at a higher strain rate, there was an improvement in tenacity. In other words, at higher extension rate levels, greater numbers of fibres contribute to the yarn tenacity. At higher rate of extension the higher percentage of fibre rupture causes an increase in yarn tenacity which is not offset by very small drop because of the less re-alignment of fibres in the duration of yarn failure. The net effect is that the increase in the extension
rate results in higher value of tenacity. Also the failure mechanisms are likely to be different at different strain rates. Fibres break at low strain rate due to the sliding and cascade like break due to mis-alignment at higher strain rate regime occurs. At low strain rate, individual fibres have enough time to relax through fibre sliding to re-distribute the strain before they break. At the same time, inter connections between fibres may partially be destroyed to realise the re-arrangement giving a large variability in tensile strength. Comparably at high strain rate, fibre relaxation through sliding is becoming a slow progress. Thus strain-distribution becomes more difficult, and eventually the local strain breaks some fibres and then the whole fibre which is in accordance with the link theory. At higher gauge length namely 254mm the percentage increase in strength is higher while at a gauge length of 12.7mm, the increase is less. In 80 Ne, the strength increase at higher strain rate is much higher than that of 60 Ne.

While there is a trend in the tensile strength of regular yarns at different gauge lengths in that at higher gauge length the strength shows a drop consistently at 5 mm/min, the strength values at 500mm/min are found to be erratic. Yarn tested at longer gauge length of 254 mm at 500 mm/min strain rate shows higher value in comparison with 5mm/min strain rate. Even in treated yarns this trend is noticeable. This may be due to several reasons such as realignment of fibres and increase in broken fibres.

The reduction in tenacity and the extension can be attributed to the well known weak-link effect, namely the probability of presence of weakest link is greater in a longer specimen. The longer specimen exhibits lower extension owing to delayed tension build up, perhaps caused by partial relaxation of the applied stress and thus registering a relatively higher modulus.
Another notable feature in 80 Ne yarns is that the strain is highest at a gauge length of 12.7mm irrespective of the treatments given. An increase in strain rate has led to a drop in extension. This is due to the fact that very little time is given for the yarn to break and thus extension is reduced. However the breaking load increases at higher strain rate.

The Weibull plots were plotted for all the cotton yarns and the effect of different estimators were studied on Weibull modulus and parameters. It is noticed that estimator 1(Hazen) gave the higher Weibull modulus values in comparison with others.

The performance characteristics of mercerised CFP composites mercerised CSFP and cell-CSFP hybrid composites have been investigated. The composites prepared at 30% fibre loading with 2% MAPP concentration showed optimum mechanical performance. Of all 30% mercerised CSFP showed optimum mechanical performance. Replacement of hydrophilic CF by little stronger sisal fibre not only increases the mechanical properties of the composites but also significantly decreases the water uptake of composites. On the other hand, cellulase treated CSFP showed decrease in the mechanical properties marginally with increment in water uptake. The improved interaction between cotton/sisal fibre and PP after MAPP treatment, which was also verified from the SEM micrographs of composites, indicated that MAPP can efficiently improve the fibre–matrix adhesion in the hybrid composites when used at an optimal concentration. DSC, HDT and TGA/DTG thermo grams also confirmed an increase in thermal stability and crystallization temperature of PP matrix in hybrid composites with the addition of MAPP.
PP-MAPP-hybrid fibre nanocomposites were successfully prepared by employing melt intercalation technique. The comparative performance of the nanocomposites was studied. The WAXD patterns showed that the addition of clay improved the clay dispersion in the CSFP matrix in the presence of compatibilizer. Among all composition of nanoclays used in this study, the one with 3% has shown better mechanical properties than others. Further good toughness and stiffness were coexistant in the CSFP/clay nanocomposites compatibilized with 2 wt% of PP-MAPP. All the composition of clay has demonstrated the apparent nucleating effect because of the crystallization that occurred at higher temperature upon cooling. The crystallization temperature (°C) temperature is also affected by the intercalants characteristics. TGA thermograms showed higher thermal stability in the case of nanocomposites. This is significant as most of the commercial applications of layered silicate nanocomposites will be commercially viable if they are cost competitive with Regular additive approaches to modify polymer properties.

The industrial implications of the study are fully discussed.