



Effect of Fibre Architecture on the Tensile and Thermal Properties of Virgin and Waste Acrylic Reinforced Epoxy Composites.

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ABSTRACT

Fibres, yarns and fabrics were produced from used fabrics and sets were then used in compounding composites using epoxy resin then woven into 6, 7, 8 and 9 picks per centimetre (ppcm) and 3 (epcm) plain weave fabrics. The waste and virgin fibres, yarns tensile strength, staple length, fineness and other important fabricate the composites. The hand lay-up technique was used, composites were analysed for tensile and thermal properties. Tensile strength of the yarn reinforced composites was higher reinforced (in both weft and warp directions). For the thermal decomposition, a residual weight loss of between 8 -10 % were observed generally that gradual weight loss started at 100 °C for

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INTRODUCTION

The performance of any textile material is dependent upon a combination of inherent fibre properties, as well as upon the geometrical arrangement of fibres in yarns and of yarns in fabrics. A textile fibre is the fundamental unit from which textile materials are made. According to Mukhopadhyay and Midha (2008), a fibre is a material that has a length at least 100 times its diameter or width. This high length-to-width ratio gives a fibre its peculiar properties, such as flexibility.

The fibre morphology affects the fibre physical properties such as strength and elongation; the higher the orientation in a fibre, the higher the strength and the lower the stretch. Fibre morphology can also affect melting temperature, moisture absorption, dyeing, and fibre density (Mukhopadhyay and Midha, 2008). Textile recycling is the method of reprocessing used clothing and clothing scraps from manufacturing process.

Recycling can also be defined as the reclamation of material and its reuse which could include repair, manufacture and conversion of materials, parts and products (Domina and Koch, 2009).

Textile industry is among the most essential consumer goods industry however; it is accused of being one of the most polluting industries. Not only production, but after use cycle, textiles also produce waste. To counter the problem, textile industry has taken many measures to reduce its negative contributions to the environment. One of such measures is textile recycling, that is, the re-use as well as reproduction of fibre from textile waste (Domina and Koch, 2009).

Almost half (48 %) of the post consumer's textile waste that is recovered is recycled as second hand clothing, which is typically sold to underdeveloped nations. 26 percent of these post consumers waste is converted into fibre to be used in product



similar in nature to those manufactured from pre-consumer textile waste (Lang *et al.*, 2013).

Separation of fibres from the original materials must be severe enough to cause fibre separation, but in such processing the materials, the fibres produced were damaged and broken. The result was very short fibres, typically of one-half metre or less which are too short to make into yarn and fabric using commercial processes. Therefore, the recycling or reclamation of cotton or cotton polyester fibres has been restricted to the production of low-end textile products such as non-woven materials (Lewis, 2015).

Composites structures combine materials which together result in a structure with properties not achievable with any of the constituents alone. Fibre-reinforced composites, specifically those based on ceramic and metal matrix materials, combine the best of both materials; inheriting the high stiffness and strength from the fibres while preserving the elevated temperature capabilities of the matrix material. In addition, the fibre-reinforced material tends to be more resistant to damage and defects than the homogeneous material. Composites materials are characterised by being multi-phase materials within which the phase distribution and geometry has been deliberately tailored to optimise one or more properties (Dauda, 2008). Significantly, constituents of the composites retain their individual, physical and chemical properties, yet together they exhibit a combination of qualities which individual constituents would be incapable of producing alone (Achukwu *et al.*, 2015).

Textile-reinforced composites materials (TRCM) are part of the general class of engineering materials called composites materials. It is usual to divide all

engineering materials into four classes: metals, polymers, ceramics and composites (Achukwu *et al.*, 2015).

Composites reinforced with fibres are increasingly being sort after for several uses where high performance is required. In recent years, composites materials have found numerous structural applications in the aircraft and aerospace industries. The technology using fibre reinforced polymer composites is commercially available and new types of composites are continuously being developed with high specific strength, tensile strength and toughness for use in the aviation industry. The corrosion resistance, potentially high overall durability, light weight, tailored ability and high specific performance attributes enable the use of composites materials in areas where conventional material might be constrained due to durability, weight or lack of design flexibility. Fibre reinforced polymeric matrix composites materials are now used in applications predominated by metals and ceramics where high mechanical properties are requested; such areas include the aerospace and automobile industries, civil infrastructure materials, among others. However, the definition of high-performance material is not restricted to materials that possess high mechanical behaviour, but also to material possessing high specific behaviour (Gomes *et al.*, 2006). Therefore, any kind of material with high durability, extreme light weight or corrosion resistance higher than the conventional materials, for example, can be considered as a high-performance material. Roof and wall panels, automobile interior materials, storage devices, thermal and acoustic insulation materials, furniture etc. are few examples of applications where materials with specific high behaviour are required and the mechanical behaviour is not the most important property.

MATERIALS AND METHODS

The work was carried out in three stages; in the first stage, waste fabrics were collected and shredded into fibres. The fibres obtained were characterized and spun into yarns and the yarns were woven into fabrics. Similarly, the virgin fibres were spun into yarns and the yarns were woven into fabric using the same processing conditions. In the second stage, molds were produced, and various composites were fabricated using fibres, yarns and fabrics (virgin and waste) as the reinforcing materials, epoxy resin was used as the matrix. The composites were fabricated by hand-lay-up method. The third stage involved analysis of the fabricated composites for tensile and thermal properties.

Composite tensile strength was carried out in accordance with ASTM D636 of 2003, while the thermal test was performed on an SDTQ 600 thermal instrument.

Composite Fabrication

The composites were fabricated using hand lay-up method. The reinforcing agents were fibres, yarns and fabrics of waste and virgin acrylic fibre. The matrix used was epoxy resin which comes in twin form (epoxy and hardener). In the fabrication process, the epoxy resin and the hardener, with a ratio of 2:1, was uniformly mixed using hand lay-up method and into the mould cavity and kept for curing at room temperature for 24 hours.



Figure 7: Randomly Picked Composite Sample

RESULTS AND DISCUSSION

Effect of Fibre Architecture on Composites Tensile Strength

From Figure 8, it was observed that the tensile strength of the yarn reinforced composites is higher than that of the fabric reinforced (in both weft and warp directions). This is because the reinforcing yarns are aligned in the direction of the applied load so that all the yarns are

contributing maximum resistance to the applied load. Secondly, because the yarns are uncrimped, they offer higher resistance to applied load compared to the case of the fabric reinforced composites where warp and weft yarns are crimped. In a paper publication on comparative study of tensile strength of different weaves, it was observed that twill fabrics with longer floats/repeat (hence less crimp) than their

plain woven equivalent exhibit higher tensile strength and the reason given this is that the twills had lower crimp value compared to plain woven fabrics. Thus yarn reinforced composites will have higher tensile strength than their woven equivalents as a result of zero crimp in the yarn reinforced composites.

The random fibre reinforced composites had the lowest tensile strength of the types of reinforcement as shown in Figure 8. This is most probable because the fibres are randomly arranged and do not

lead themselves to fully support the tensile load. Furthermore, fibres are not coherently arranged as in the case of yarn and fabric reinforced composites, therefore they do exhibit enough tensile strength. However, it must be noted that fibre reinforced composites are still very popular and several researches are still on-going on fibre composites due to their ease of production and cost. They are also useful in secondary load bearing structures where high mechanical properties are not important.

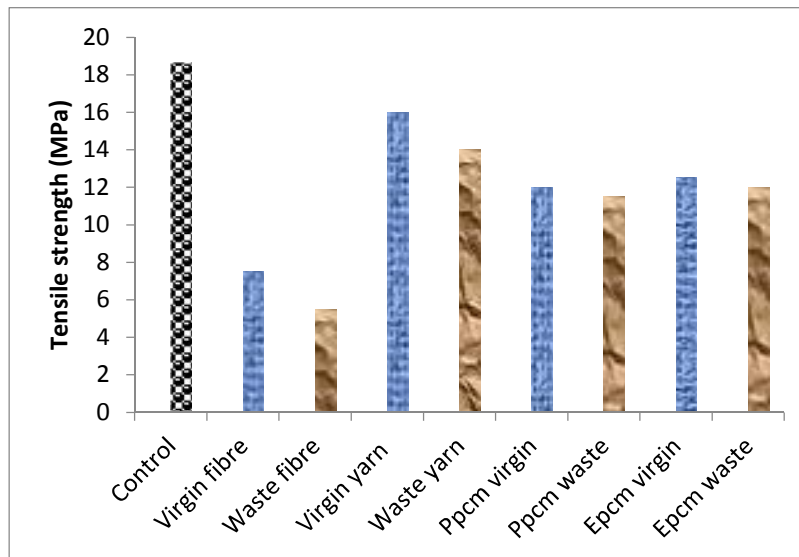


Figure 8: Effect of Fibre Architecture on Tensile Strength of Composites

Effect of Fibre Architecture on Composites Thermal properties

Thermogravimetric analysis (TGA) of fibre composites. Figure 9 shows the thermogravimetric (TGA) results generated

on virgin and waste fibre composites. The plot shows the percent mass as a function of sample temperature for virgin and waste fibre composites under a nitrogen purge.

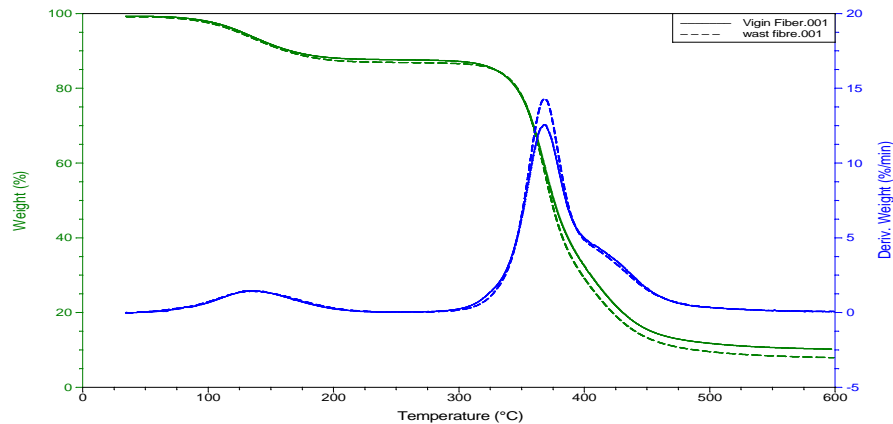


Figure 9: TGA of Virgin and Waste Fibre Composites

At about 100 °C a gradual loss in mass begins. This can be traced to loss of moisture content of the composites. The loss in mass continued above 100 °C at a slightly faster rate and at about 160 °C, a loss in weight of 15 % can be observed. Acrylic fibre is one of the very sensitive synthetic fibres that begins to degrade when heated near their melting point. Thus, the loss in weight is as a result of volatilisation of the acrylic fillers in the composites structure.

It is further observed in Figure 9 that the main onset of decomposition commenced at about 340 °C till the final decomposition at about 450 °C in which 83 % of the acrylic/epoxy fibre composites material have been lost. At 500 °C, 550 °C and 600 °C, the weight loss is 90 %, indicating that the composites material had experienced a total decomposition leaving 8 % residue (ashes).

A final observation from Figure 9 is that the waste fibre composites had a

slightly higher weight loss compared to the virgin fibre composites. At the initial decomposition stage where the acrylic component melted and volatilised, the loss in weight for virgin fibre composites is 15 % that of the waste composites is about 16 %. At the final decomposition stage at 600 °C, the virgin composites showed a weight loss of 90 % while the waste fibre composites showed a loss of 92 %. The probable reason for this is that the waste acrylic which has been depolymerised by UV radiation during use, volatilised more readily during the heating process compared to the virgin acrylic fibre component.

Thermogravimetric analysis (TGA) of yarn composites

Figure 10 shows the thermo gravimetric (TGA) results generated on virgin and waste yarn composites. The plot shows the percent mass loss as a function of sample temperature for virgin and waste yarn composites under a nitrogen purge.

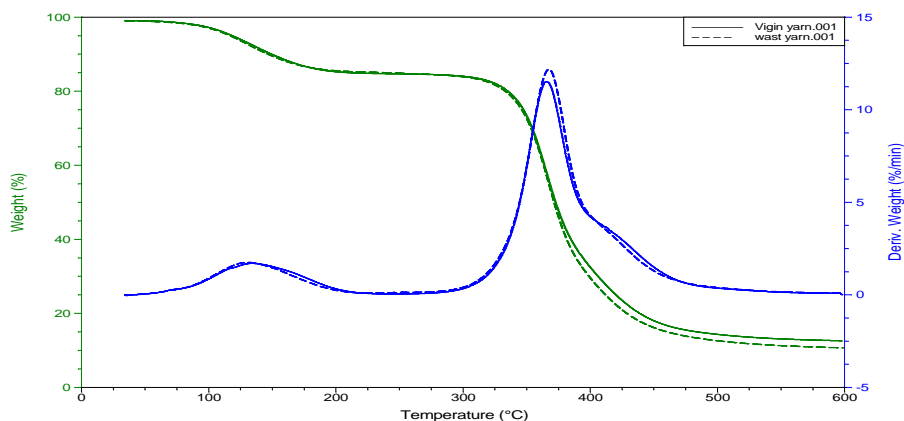


Figure 10: TGA of Virgin and Waste Yarn Composites

The experimental conditions were the same as the fibre composites sample. At about 100 °C, slight onset weight loss started and this can be ascribed to loss in moisture content in the composites. A relatively more rapid loss in weight is observed from 110 °C to about 170 °C during which the composites mass further reduced to 85 %. The loss in mass after water vaporisation, is due to melting and subsequent volatilisation of the acrylic component.

As was the case of fibre composites, here also the onset of main decomposition of the yarn composites is at around 340 °C till the final decomposition at around 440 °C. At this point, the weight loss is about 84 %, with further slight weight loss at 500 °C, 550

°C and 600 °C of 85 %. Finally, it can be observed that at about 375 °C, a slightly higher weight loss is observed and this trend continues till 600 °C where the weight loss for the waste yarn composites is 88 % compared to that of virgin yarn composites at 85 %.

Thermogravimetric analysis (TGA) of fabric composites

Figure 11 shows the thermogravimetry (TGA) results generated on virgin and waste fabric composites. The plot shows the percent mass as a function of sample temperature for virgin and waste fabric composites under a nitrogen purge.

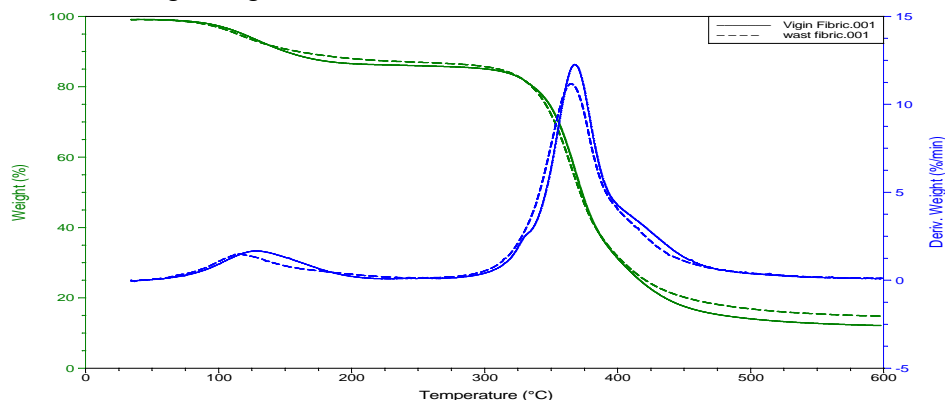


Figure 11: TGA of Virgin and Waste Fabric Composites



Figure 11 shows that as temperature increases, at approximately 100 °C, a slight reduction in weight is observed due to loss of moisture within the composites. Between 100 °C and 170 °C, a 15 % further loss in weight is observed, due to melting and vaporisation of the acrylic component of the composites. The onset of major decomposition of the composites is observed at around 330 °C and over the next 100°C rise in temperature, a total decomposition is observed at 450 °C, with a corresponding weight loss of 82 %. Over the next 150 °C rise in temperature, a further 8 % loss in weight is observed so that at 600 °C the residue weight remaining is 10%.

A careful observation of the weight loss profile shows that at the initial decomposition temperature range where the acrylic component is volatilised, the virgin fabric composites showed a slightly more rapid loss in weight. This trend is again noted at around 400 °C to 600 °C, so that at the end, while the virgin composites showed a residual weight of 12 %, the waste composites exhibited a residual weight loss of 10 %.

CONCLUSION

It can be concluded that mechanical properties of composites strongly depend on the orientation of the fibres, getting better when the yarns are woven and placed in the composites in an appropriate orientation. Woven fabrics have the advantage of enabling the orientation of the yarns, allowing control of the density of the fabric and its mechanical properties. Yarn reinforced composites offer the ability to place the yarn in the composites in exactly where it is required, and in the optimum quantity. Furthermore, the yarns straight and uncrimped, resulting in the highest possible contribution of the yarns to the ultimate composites strength. Generally, for

the TGA, it was observed that gradual weight loss started at 100 °C for all the composites. And after the decomposition, a residual weight loss of between 8 -10 % were left for all the composites at 600 °C.

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