Application of poly (lactic acid) fibres in automotive interior

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The application of poly (lactic acid) [PLA] based fabric for automotive interior application has been studied. It is observed that the PLA fabric meets almost all performance specifications formulated by an original equipment manufacturer, except for flammability and abrasion resistance. The performance of PLA fabric has also been compared with a polyester (PET) automotive fabric and it is found that the PLA fabric often perform equally or better in some properties than PET fabric in all performance parameters, except for abrasion resistance and flammability.

Keywords: Flammability, Flex, Poly (lactic acid), Polyester, Seam

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The growing importance of environmental issues in recent years led textile industry to explore new materials, modifications in manufacturing, and construction of fabrics. Textiles play a key role in the automotive industry. Approximately, 20.7 m² of fabric is used in the trunk and interior of an average automobile, and considering an average of 15 million cars produced each year, more than 375 million square yards of fabric is used for automobiles.1

New developments of textile fabrics, from natural fibres or fibres from renewable resources that are biodegradable, are very significant to the automotive industry. Polyethylene terephthalate (PET) meets the standards established by the automotive industry and is currently the preferred material for several applications, including seating. PET, however, is obtained from a non-renewable source (fossil fuel). Although some PET parts are recyclable, the presence of other polymers in composite materials often makes recycling difficult. Poly (lactic acid)[PLA], a polymer derived from corn, has received considerable interest recently. PLA can also be produced from natural renewable sources, such as whey, sweet sorghum, wheat, sugar beets, and barley.2 Earlier, Carothers produced PLA by removing water obtained during condensation polymerization using a solvent under high temperature and vacuum. This process produced polymers with low to intermediate molecular weight. A range of molecular weights was produced later by coupling with isocyanates, epoxides or peroxides.3 An alternative method is currently being used by Cargill Dow Polymers, where water is removed under milder conditions to produce a cyclic dimer (lactide), thus eliminating the need for solvent. The monomer is purified under vacuum distillation, and is followed by a ring opening polymerization of the dimer under heat activation without any solvent. PLA can be obtained in two optically active isomeric forms, e.g. L-isomer and D-isomer. L-isomer is crystallizable while D form does not crystallize. A wide range of molecular weights of the polymer is achieved by controlling the purity of the dimer, thus allowing a variety of products to be produced. A material flow chart of PLA production is shown in Fig. 1 (ref. 4).

This thermoplastic polymer can be produced from renewable crops and is compostable like other natural fibres, such as wool, and cotton or regenerated cellulose. At the same time, its thermoplasticity provides a great advantage in automotive interior products and parts as it conforms to various shapes. PLA is stable in natural conditions of temperature and humidity; however, composting begins at 60°C and 90% relative humidity. It is possible to degrade PLA into water and carbon dioxide by hydrolysis and this degradability is important for disposal, particularly in...
densely populated areas and in landfills. Hydrolysis can be carried out rapidly in the presence of catalysts at elevated temperatures; however, this vulnerability to hydrolysis can be a disadvantage to some products. The present paper reports a study on the application of PLA as an automotive seat fabric, using the specifications formulated by Ford Motor Company, an Original Equipment Manufacturer (OEM). The study also compares the performance of PLA fabric with a PET automotive seat fabric, since PET is the predominant material of choice for the current automotive fabrics.

Both PLA and PET fabrics were produced keeping fabric parameters very similar to each other. Hopsack Med DK Parchment PLA fabric was produced using 725/288 (denier/filaments) air textured PLA warp and 725/288 (denier/filaments) air textured PLA weft. The fabric construction was 945 ends/m × 906 picks/m that weighed 359.4 g.m⁻². The fabric was coated with 32.9 g. m⁻² water soluble PVC-based latex. The Hopsack Med DK Parchment polyester fabric was produced from 725/272 denier/filaments air textured PET warp and 725/272 air textured PET weft. The fabric was constructed with 945 ends/m and 945 picks /m that weighed 362.8 g.m⁻². The PET fabric was also coated with 32.9 g. m⁻² water soluble PVC-based latex. Both the fabrics (PLA and PET) were tested for various properties, as described below, that are usually required by the automotive companies to be accepted for automotive seating:

(i) Seam fatigue — To determine the ability of a seating fabric to resist tearing or needle-hole elongation of a sewn seam under cyclic loading [Ford laboratory test method (BN, 1995b: 106-02)];
(ii) Breaking strength — To evaluate breaking strength of automotive textile fabric [ASTM grab test (ASTM D5034, 1995)];
(iii) Flammability test — To measure burning rate of polymeric materials used in the operator or passenger compartment of a vehicle [Horizontal test method (SAE J 369, Jan 1994)];
(iv) Resistance to snagging — To determine the tendency of individual yarn or fibres to be pulled from the fabric surfaces by sharp objects [Ford mace test (BN 108-11, 1990)];
(v) Flex fold — To determine the durability of sewn and dielectrically bonded seams of trim assemblies and individual trim materials [Ford flex fold method (BN 102-04)];
(vi) Resistance to pilling — To determine pilling tendency of automotive fabric [Ford pilling test (BN 108-03, 1996)];
(vii) Resistance to abrasion and snagging of automotive fabrics and/or vinyl-coated fabrics, (SAE J 948, Aug 1994); and
(viii) Colour fastness to crocking — To measure colour transfer from surface of coloured textile materials to other surface by rubbing [AATCC Crockmeter test (M 8-2001, 2003)].

Analysis of variance (ANOVA) and hypothesis testing techniques were used to determine statistically significant differences at a 95% level of confidence between the test data of the two types (PLA and PET) of fabrics.

Various properties of the PLA and PET fabrics have been compared with each other and also checked using Ford Motor Company’s pass/ fail standards. A brief summary of results is given in Table 1. The PLA fabric appears more resistant to seam fatigue than PET fabric because the length of the hole of PLA fabric seam (1.05mm ) was found smaller than that of PET (1.95mm). This phenomenon may be attributed to the higher elastic recovery of PLA. Furthermore, seam fatigue resistance in the warp direction is found better than in the weft direction. However, both PLA and PET fabrics satisfy Ford’s specifications for seam fatigue test. Breaking strength of PLA fabric is lower than that of PET fabric (Table 2).

Toughness values of the PLA fabric are higher than that of PET fabric due to the higher elongation that may allow PLA fabric to absorb more energy. Both the fabrics fulfill Ford’s requirements for breaking strength.

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<th>Table 1 — Comparison of PLA and PET fabrics properties</th>
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<td>Property</td>
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<td>Seam fatigue</td>
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<tr>
<td>Breaking strength</td>
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<tr>
<td>Flammability (Not significant)</td>
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<td>Snagging</td>
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<td>Flex fold</td>
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<td>Pilling</td>
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<td>Abrasion (1000&amp;2000 cycles)</td>
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<td>Crocking (Dry)</td>
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PET fabric exhibits greater resistance to fire since it burns at a significantly slower rate (Table 2). Both fabrics were coated with PVC-based latex and its effect is not known. It is also not known if the PET yarns in this study contain fire retardant agent. The PLA fabric failed to satisfy Ford’s requirement for fire retardancy. It is obvious that PLA fibre or yarn requires fire retardant treatment to meet the automotive seating specifications.

The level of snag occurred on the fabrics during testing confirms that there is no difference in snagging tendency between the PLA and PET fabrics; both the fabrics passed Ford’s snag test. PLA fabric, however, exhibits lower resistance to abrasion and failed to satisfy Ford’s abrasion rating requirement. The abrasion resistance is related to fibre surface geometry, toughness and flexibility of molecular chains; hence, it is possible to increase abrasion resistance of PLA with modification. Fabric pilling and flex fold data of both the fabrics are bound to be similar and both of these satisfy Ford’s specifications for pilling and flex fold. Table 2 describes snag, abrasion, pilling, and flex fold test data.

PLA and PET fabrics were tested for colour fastness to crocking using an AATCC method for both wet and dry crocking conditions. Both fabrics passed the Ford’s requirements; however, PLA fabric exhibited less crocking than that of PET. Colour fastness to crocking results are reported in Table 3 where rating 1 indicates most severe colour transfer while a rating of 5 represents no colour transfer.

It is found that PLA fabrics are able to satisfy most of the Ford Motor Company’s fabric specifications and perform equally well compared to PET fabric; however, PLA fabrics failed Ford’s specifications in two properties, namely abrasion and flammability. Therefore, further study is needed to improve these two qualities of the PLA fibre. These findings are significant because PLA can be manufactured from abundant natural and renewable resources. The biodegradability of PLA makes it a very environment-friendly material.

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References