MECHANICAL, ADHESIVE, AND APPEARANCE PROPERTIES OF NONWOVENS ON LWRT COMPOSITE SHEETS

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Abstract

Light weight reinforced thermoplastic (LWRT) composite sheets are produced with surface layers on either one side or both sides for such reasons as appearance, adhesion, formability, and coverage. Some automotive parts formed from LWRT sheets have a backside that is critiqued for appearance due to the likelihood they can be seen by the end users. This report covers the evaluation of different nonwoven surface materials for the backside application to LWRT sheets. Each nonwoven is black, soft to the touch, and matted like felt. There are various types and amounts of adhesive applied to the nonwoven to improve the adhesion between the nonwoven and the LWRT substrate. The coverage and appearance of the nonwoven were evaluated by a colorimeter on the surface, and thermoformed parts were molded by a lab scale molding tool. The adhesion between the nonwoven and the substrate was tested by ASTM D903 with heat aging over a range of temperatures. The nonwoven was confirmed to have minimal to no impact on the flexural properties of the composite through ASTM D790, or on the flammability through FMVSS 302.

Background and Requirements

Light weight reinforced thermoplastic composites are well known in the automotive industry for thermoform-ability and their high strength to weight ratio. LWRT material has to meet general standards from the automotive OEMs depending on location and end construction. For interior trim materials, these properties can include flammability, trimability, color variation and aging [1].

Government regulations, such as the Corporate Average Fuel Economy (CAFÉ) standard and the Safer Affordable Fuel-Efficient (SAFE) Vehicle Rule, require auto manufacturers to make improvements on fuel economy and carbon dioxide emissions. A weight reduction on the vehicle increases fuel economy with all other factors the same. For this reason, OEMs request lighter components of their Tier 1 suppliers. This study explores lighter weight surface alternatives for the LWRT sheet that need to meet the interior part requirements.

This LWRT material is produced by a wet-laid method. The excess water is removed in the forming process and the substrate is dried in ovens. After the material is consolidated in the oven, the lamination step attaches the nonwoven material to either side of the composite core. The final steps of the process include cutting the sheet to size and stacking the sheets for shipment.

Materials and Experimentation

Test Methods

Areal density, thickness, ash (glass) percentage, and density were tested using internal procedures. Flammability tests followed the Federal Motor Vehicle Safety Standard (FMVSS) No. 302, “Flammability of Interior Materials.” ASTM D903 for conducting a 180° Peel was followed to evaluate adhesion of nonwoven to composite core. The flexural strength of the LWRT material was tested using ASTM D790 method. The coverage from the nonwoven was evaluated using a Hunter colorimeter with an internal procedure. Lastly, the molding performance was a visual evaluation based on magnitude of tearing in the nonwoven.

The existing scrim was approved by the customer for its composite core coverage and black color. To evaluate if the lower areal density scrim candidates meet the expectations of the customer, colorimetry on the surface of the LWRT was used. The colorimeter outputs the Hunter L, a, b color scale which is based on the Opponent-Color Theory [2]. Figure 1 shows how the L value is in the vertical with high numbers, 51-100, indicating light and low numbers, 0-50, indicating dark.

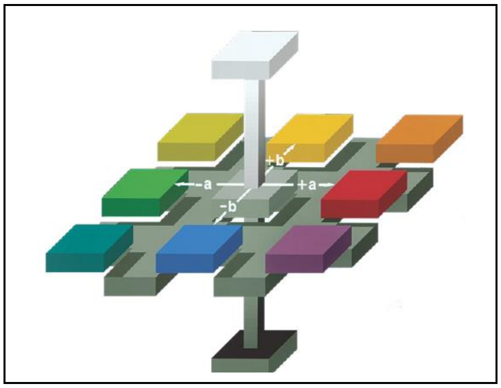

Figure 1: Opponent Color Scales of L, a, b [2]

Materials

Nonwoven

The nonwoven candidates came from three suppliers. All five nonwovens or scrims are black in color and have a felt like appearance. The nonwoven is a polymer based fiber with an adhesive added through the means of powder coating. Adhesive has been added historically to higher weight scrims, 70-90 g/m^2. Typically the adhesion issues are identified after molding and can be quantified through peel adhesion testing. Lighter and thinner scrims, 30 g/m^2, have passed peel adhesion without adhesive added. Each supplier has their own proprietary adhesive. To protect the suppliers confidentiality, only the target quantity of adhesive applied to the scrim will be discussed, nothing of its chemical nature.

The existing nonwoven has been in use for over 8 years at Hanwha Azdel. Prior to commercial use, this nonwoven was tested for its performance when laminated to the LWRT during manufacturing. The existing nonwoven is produced by supplier 1. Because of the historical success of this skin layer, the four candidates are compared against the existing nonwoven.

LWRT

This type of nonwoven has been applied to the LWRT on interior applications with a “B-side” that has the potential to be seen by the customer. The existing nonwoven has been laminated to LWRT sheets ranging in core areal densities of 600-2000 g/m^2. This study will focus on a core areal density of 1700 g/m^2 with a 98 g/m^2 polypropylene film on the opposite side of the sheet to the nonwoven in discussion.

Results

Material Characterization

Both the nonwoven and LWRT were tested for their basic characteristics. Table 1 lists the results of internal testing of areal density and thickness on the five nonwoven materials, with a description of their target fiber and adhesive areal density. Table 2 describes the material characterization of the LWRT with each scrim after production but prior to molding.

Table I: Material characterization of nonwoven candidates

Nonwoven Candidates					
	Existing Scrim	**Scrim A**	**Scrim B**	**Scrim C**	**Scrim D**
Supplier	Supplier 1	Supplier 1	Supplier 1	Supplier 2	Supplier 3
Target Construction (g/m^2)	70 fiber 20 adhesive	50 fiber 10 adhesive	50 fiber 0 adhesive	50 fiber 15 adhesive	44 fiber 16 adhesive
Areal Density (g/m^2)	89.5	70.1	55.7	83.7	55.8
Thickness (mm)	0.51	0.36	0.51	0.46	0.33

Table 2: Material Characterization of LWRT samples

LWRT Material with core weight of 1700gsm					
	Existing Scrim	**Scrim A**	**Scrim B**	**Scrim C**	**Scrim D**
Areal Density (g/m^2)	1881 ± 21	1861 ± 13	1823 ± 9	1886 ± 9	1836 ± 16
Ash Content (%)	49.2 ± 0.4	50.1 ± 0.2	50.1 ± 0.2	49.9 ± 0.3	50.2 ± 0.3
Density (g/cc)	0.34 ± 0.01	0.33 ± 0.01	0.33 ± 0.01	0.33 ± 0.01	0.33 ± 0.01
Thickness (mm)	5.60 ± 0.06	5.58 ± 0.06	5.58 ± 0.08	5.64 ± 0.10	5.56 ± 0.06

Flammability

Depending on the type of fiber and the external coatings, some nonwoven materials are flame retardant and self-extinguishing. To properly evaluate the scrim material in this study, the FMVSS 302 method was used on the scrim material alone. The existing scrim, scrim A, scrim B, and scrim D burned so rapidly that it was not feasible to characterize their burn rates (inches/minute) accurately, as shown in Table 3. Scrim C burned at a quantifiable rate of 18.3 inches/minute. When compared to the FMVSS 302 standard of 4 inches per minute, scrim C would fail this requirement if not combined with the LWRT composite.

Table 3: FMVSS 302 with developmental scrims

FMVSS 302 with scrims (in/min)					
	Existing Scrim	Scrim A	Scrim B	Scrim C	Scrim D
FMVSS 302 (in/min)	burned immediately and quickly	burned immediately and quickly	burned immediately and quickly	18.3 ± 1.4	burned immediately and quickly

The LWRT was tested both as produced and molded flat to a target thickness of 5.0 millimeters. The molded composite will have better consolidation between the resin and glass fiber and will have the same reheated expansion and subsequent pressure forming as the end product. All LWRT material, unmolded and molded, meet the four inches per minute burn rate requirement from FMVSS 302. Table 4 shows the results.

Table 4: FMVSS 302 with 1700g/m^2 core and developmental scrims, both molded and unmolded

FMVSS 302 with LWRT sheets (in/min)					
	Existing Scrim	Scrim A	Scrim B	Scrim C	Scrim D
Unmolded LWRT	1.61 ± 0.04	1.69 ± 0.05	1.72 ± 0.05	1.75 ± 0.06	1.92 ± 0.09
Molded LWRT	1.57 ± 0.04	1.85 ± 0.18	1.83 ± 0.11	1.76 ± 0.14	2.02 ± 0.23

Flexural Properties

The flexural strength can be used to evaluate the rigidity of a composite material. The ASTM D790 is a three-point loading system method that utilizes a specimen sized 25mm by 100mm. The LWRT composite with each scrim were molded to 5.0 millimeters prior to testing the flexural properties. The flexural peak load in the machine direction (MD) for the existing scrim, scrim A, scrim B, scrim C and scrim D were 50.8, 54.5, 53.1, 55.3, and 51.6N, respectively. The flexural peak load in the cross direction (CD) for the existing scrim, scrim A, scrim B, scrim C and scrim D were 33.5, 29.5, 31.1, 34.5, and 34.6N, respectively. These results with their variation are summarized in Figure 2 and has established that all the development scrims do not affect the flexural strength of the LWRT composite.

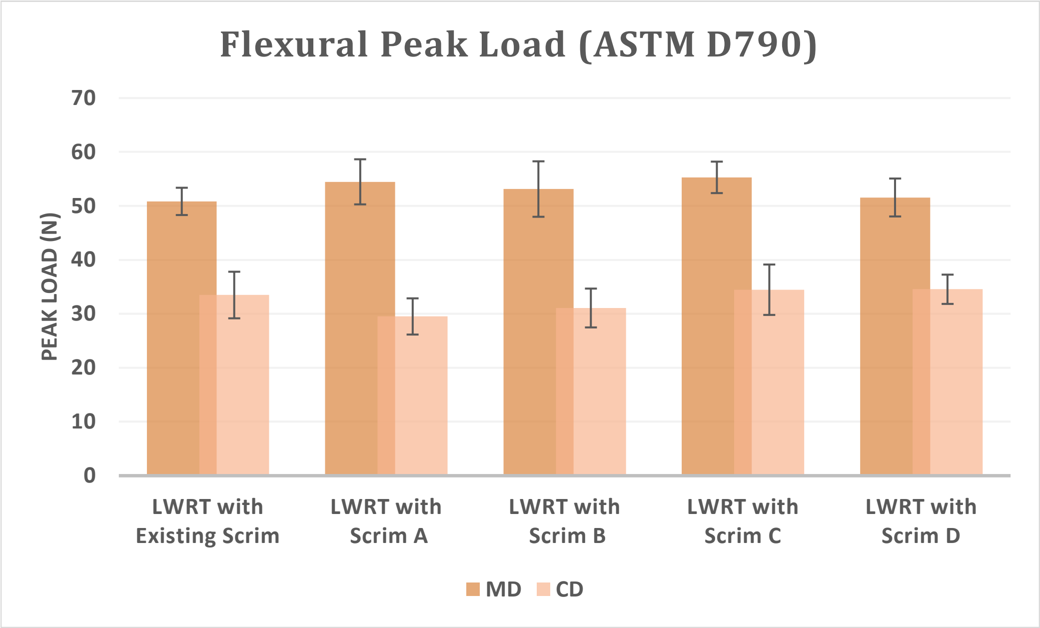

Figure 2: Flexural Peak Loads through ASTM D790 of molded LWRT with scrim candidates

Adhesion

The adhesion of the scrim to the composite core is critical to the automotive part performance. Historically, the delamination of the existing scrim does not occur at ambient temperatures. To compare which of these scrims can withstand heat aging, the LWRT was molded flat to a target of 5.0 millimeters then put in the environmental chamber for 24 hours at various high temperatures (80°C, 90°C, 100°C, and 110°C). After the heat aging, the specimens, 1 inch by 12 inches, in the machine direction (MD) and cross direction (CD) were peel tested using ASTM D903 which is conducted at 180 degrees. The adhesion between Scrim A and the composite core in the machine direction could not be peeled for all four temperatures, which is depicted in Figure 3 without bars on graph since it is not a numerical result. The Scrim A in the cross direction could not be peeled after heat aging at 110°C and the remaining temperatures were quantifiable and significantly higher than the other scrim candidates. The scrim D peel adhesion showed improvement over the existing scrim.

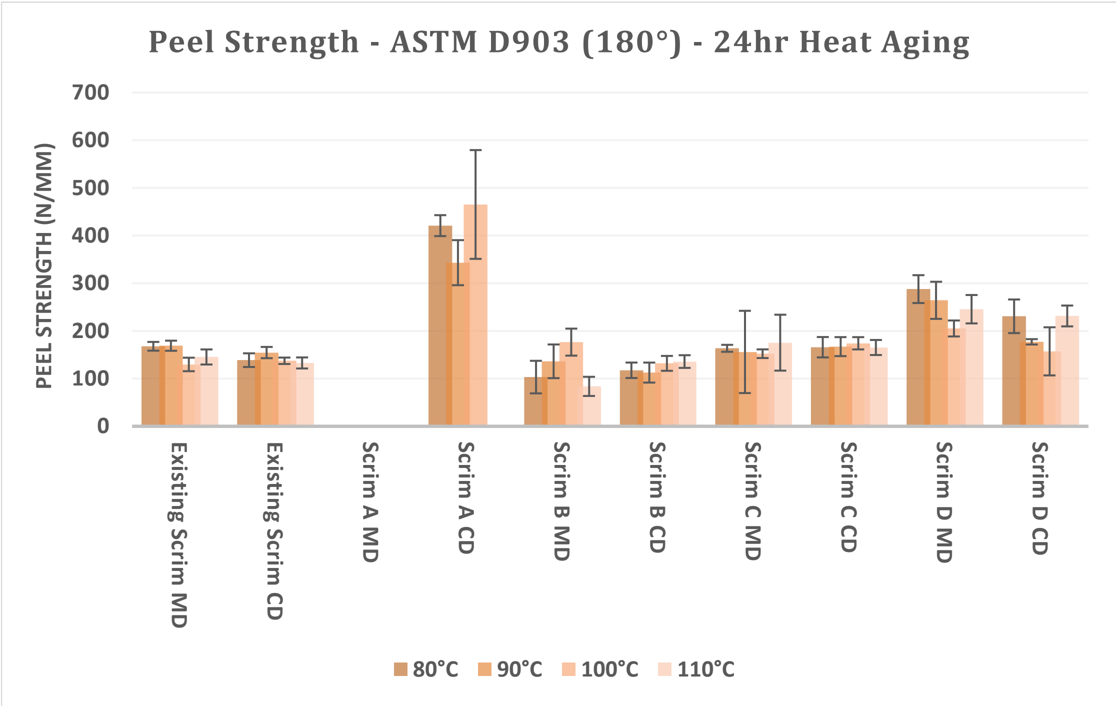

Figure 3: 180° Peel Adhesion of the LWRT with candidate scrims after 24hr heat aging at various temperatures (Scrim A MD all temperatures and CD at 110°C could not be peeled)

Coverage

The unmolded and molded LWRT composite with the candidate scrims were tested with the Hunter colorimeter to see if the molding heat would affect the fiber coverage. For unmolded coverage, scrim C was the only candidate that had a lighter result than the existing scrim. All four candidates showed darker surface coverage than the existing scrim when molded, which is accepted by current applications; Scrim A was the darkest with a 14.4 L value.

Table 5: Colorimeter L Values for the LWRT composite with scrim candidates

Colorimeter Color Scale L Value (0 is pure black, 100 is pure white)					
	Existing Scrim	Scrim A	Scrim B	Scrim C	Scrim D
Unmolded LWRT	16.6	15.8	16.0	17.8	16.6
Molded LWRT	16.5	14.4	15.0	15.8	14.6

Molding Performance

The molded composite testing for flammability, flexural strength, peel adhesion, and coverage were molded into flat plaques for ease of testing. The final part shape for typical interior applications has curves and depths which can be replicated by an internal molding tool, the wrinkle tool. All sample parts were molded at the same time with the same process settings. A visual evaluation of each molded part as a comparison against the other candidates was used. The deepest draw in the wrinkle tool is the upper left corner which is the focus of the comparison.

Figure 4 shows the existing scrim part with moderate scrim tearing in the upper left corner of the mold in the vertical section. In contrast, the wrinkle tool part molded with scrim A in Figure 5 has very minor scrim tearing in that same section of the part.

Figure 4: Existing Scrim molded in wrinkle tool

Figure 5: Scrim A molded in wrinkle tool

Both scrim B and scrim C, in Figure 6 and Figure 7 respectively, did not tear in the upper left corner of the wrinkle tool mold. Lastly, scrim D had the worst scrim tearing in the deepest draw in the upper left corner but also showed tearing along the top edge, shown in Figure 8.

Figure 6: Scrim B molded in wrinkle tool

Figure 7: Scrim C molded in wrinkle tool

Figure 8: Scrim D molded in wrinkle tool

Summary and Next Steps

The five nonwoven/scrim candidates were evaluated for flammability, flexural strength, adhesion, surface coverage, and molding properties. Scrim A held the best adhesion, passed flammability, maintained a consistent LWRT flexural strength, showed improvement on coverage and had better molding performance in the wrinkle tool than the existing scrim. The next steps will be to produce more LWRT with scrim A and conduct a molding trial at a customer to confirm performance in a specific application.

Acknowledgements

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