DEVELOPMENT OF A NOVEL LIGHT WEIGHT REINFORCED THERMOPLASTIC (LWRT) FOR AUTOMOTIVE APPLICATIONS

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Abstract

Light weight reinforced thermoplastic (LWRT) has emerged as a promising material for automotive applications due to its excellent mechanical properties, low density, and recyclability. LWRT can be used in various automotive components, such as head liners, underbody shields, trunk trim, and rear window trim. Reducing the overall weight of thermoplastic parts while maintaining mechanical properties has been a focus in the automotive industry over the past decades to improve fuel efficiency and reduce carbon emissions.

In this paper, a novel LWRT has been developed with a remarkable strength-to-weight ratio, and it can be molded into complex geometries with varying thicknesses. In order to achieve superior mechanical properties, a high consolidation level is applied during the manufacturing process. Compared to a standard LWRT counterpart, this new LWRT material can maintain the same level of mechanical properties with reduced basis weight. ASTM D790 method was used to benchmark the mechanical properties, including flexural peak load and stiffness, against a traditional LWRT. Physical properties such as basis weight and density can be adjusted to meet various requirements.

Introduction and Background

The development of light weight reinforced thermoplastic (LWRT) has been motivated by the need for lightweight materials in various industries such as aerospace, automotive, and consumer electronics. LWRT offers a unique combination of mechanical properties such as high strength, stiffness, and impact resistance, while maintaining low weight. This results in improved fuel efficiency and reduced emissions in transportation applications. In addition, LWRT is corrosion-resistant, has good thermal stability, and is recyclable, making it a sustainable alternative to traditional materials. The use of LWRT also enables the design of complex and innovative structures that are difficult to achieve with conventional materials. These advantages have led to the increased interest and research in the development of LWRT in recent years. LWRT materials manufactured in Hanwha Azdel Inc. (e.g., SuperLite®) are able to provide a high strength-to-weight ratio. In addition, LWRT has much better formability than other types of materials (e.g., polyurethane), which can provide OEMs with more room for manufacturability and design.

A novel LWRT (N-LWRT) is introduced in this paper to further improve the strength-to-weight ratio over the standard LWRT (S-LWRT). The manufacturing process for LWRT involves wet-laid techniques, which can be seen in Figure 1. Polypropylene (PP) and chopped glass fiber (GF) are mixed with city water to create an aqueous slurry suspension. This slurry is then transferred to a web-forming section where the excess water is removed from the PP-GF web. The resulting PP-GF web is then heated, pressed, and subjected to a high-consolidation process which enables better resin wet-out around the glass fibers. LWRT sheets can be thermoformed into various shapes and are commonly used for headliners, parcel shelves, door panels, underbody shields, truck trim, and rear window trim. To achieve the desired properties for specific applications, the LWRT material core substrate is usually sandwiched between two skin layers of adhesive film, barrier film, non-woven, fire-retardant scrim, or protective layer. The entire structure is further consolidated to produce a composite sheet. The resulting mechanical performance and formability of the LWRT sheet are determined by the core material formulation (e.g., PP/GF ratio), areal density (grams per square meter, gsm), functional/decorative skins attached to the core material, and corresponding thermo-forming thickness [1-4].

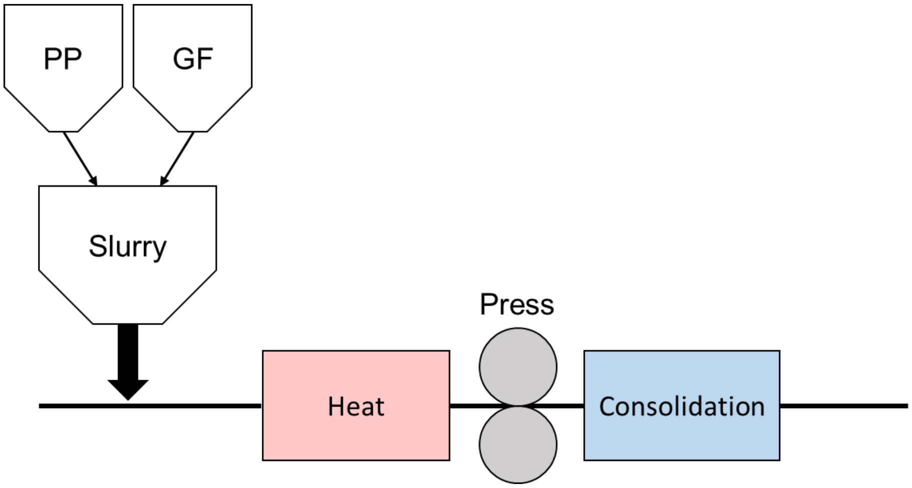

Figure 1. LWRT manufacturing process

The LWRT composite material mentioned in this paper consists of a core substrate with a protective scrim layer on each side of the core to form a composite substrate. A schematic illustration of the LWRT is shown in Figure 2. The physical properties (e.g., areal density, as-produced density, glass content, and lofted thickness) as well as the mechanical properties of S-LWRT and N-LWRT will be investigated later.

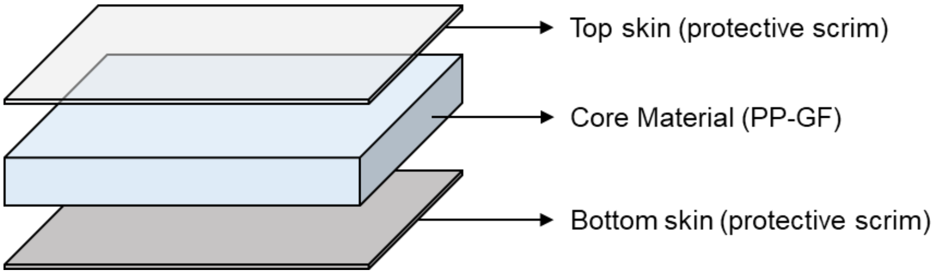

Figure 2. Schematic demonstration of LWRT composite material

Experimentation

Characterization

900gsm core S-LWRT was used as a control for 675gsm core N-LWRT, and 1000gsm core S-LWRT was considered as a control for 750gsm core N-LWRT. Basis weight, glass content, and as-produced thickness were measured following standard testing procedures in the internal lab. Each sample was tested by 5 replicates.

The flexural properties (3-point bending) of the molded specimens were evaluated using MTS mechanical testing system according to ASTM D790 standard. Rectangular specimens (100 mm × 25 mm) were cut from plaques in the machine direction (MD) as well as the cross-machine direction (CD). The cross-head speed, span, anvil diameter, and nose diameter were 15 mm/min, 64 mm, 6.4 mm, and 6.4 mm, respectively. For the flexural test, each dot in the following charts represents the average of 5 replicates, unless stated otherwise. After the mechanical test, the areal density and glass content were re-checked to ensure the consistency and repeatability of the molded specimens.

Results and Discussion

Physical properties

The areal density, as-produced density, glass content, and lofted thickness of standard S-LWRT and N-LWRT are listed in Table 1 below. The overall weight of each N-LWRT is around 25 % lighter than each of the control S-LWRT as shown in Table 1. The as-produced density of N-LWRT is higher than S-LWRT, which indicates a higher consolidation level for N-LWRT during the manufacturing process. It can be noticed that the lofted thickness of N-LWRT is around 40% higher than S-LWRT, which provides the capability of molding into a substrate with a higher desired thickness.

Table I: Physical properties of S-LWRT and N-LWRT

Materials	Areal density (g/m^2)	Density as-produced (g/cm^3)	Glass content (%)	Lofted thickness (mm)
900gsm core S-LWRT (Control)	960	0.27	50.2	6.1
1000gsm core S-LWRT (Control)	1057	0.33	52.1	6.5
675gsm core N-LWRT	755	0.47	36.0	8.7
750gsm core N-LWRT	830	0.43	35.4	9.3

Flexural properties

The flexural properties were evaluated on specimens molded into a variety of thicknesses. As shown in Figure 3 and Figure 4 for 900gsm core S-LWRT and 675gsm core N-LWRT, the S-LWRT could only be molded up to approximately 3.25 mm substrate thickness due to its limited lofting capability. However, it was practical to thermoform the N-LWRT into higher thicknesses without causing any surface cosmetic issues. In the automotive industry, a wider range of molding thickness gives the automotive design team much more room and flexibility. Overall, the general trend for both samples is better mechanical properties in the MD direction than in the CD direction, which can be ascribed to fiber alignment along the MD direction. Throughout the entire molding thickness range, the N-LWRT shows quite a comparable or slightly better flexural peak load and stiffness than the S-LWRT. Similar mechanical properties were observed from 1000gsm core S-LWRT and 750gsm core N-LWRT as shown in Figure 5 and Figure 6. It indicates that N-LWRT is capable of achieving around 25% (or 250 g/m^2 areal weight) weight reduction without significantly sacrificing the flexural properties compared to the control S-LWRT. With a higher PP content in S-LWRT and the higher consolidation process, the bonding between the fiberglass and PP resin may be stronger than the S-LWRT material, which can effectively prevent the PP-GF matrix from 'fiber pull-out' or 'fiber microbuckling' [5-7].

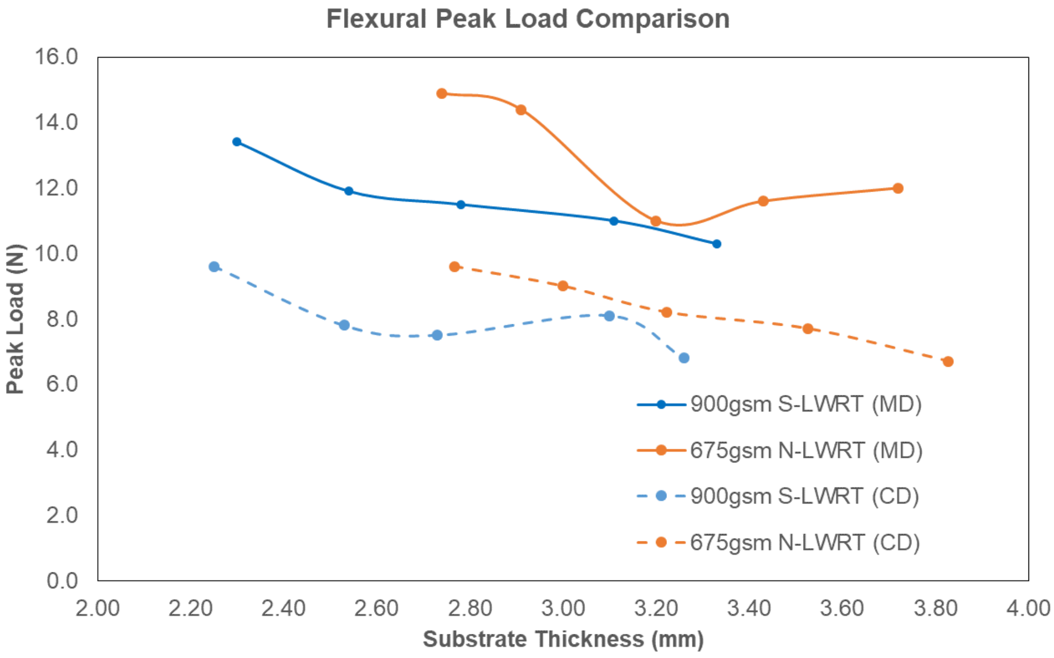

Figure 3. Flexural peak load (ASTM D790) comparison between 900gsm S-LWRT and 675gsm N-LWRT. The solid lines represent trend of the MD values and the dashed lines represent the trend of CD values.

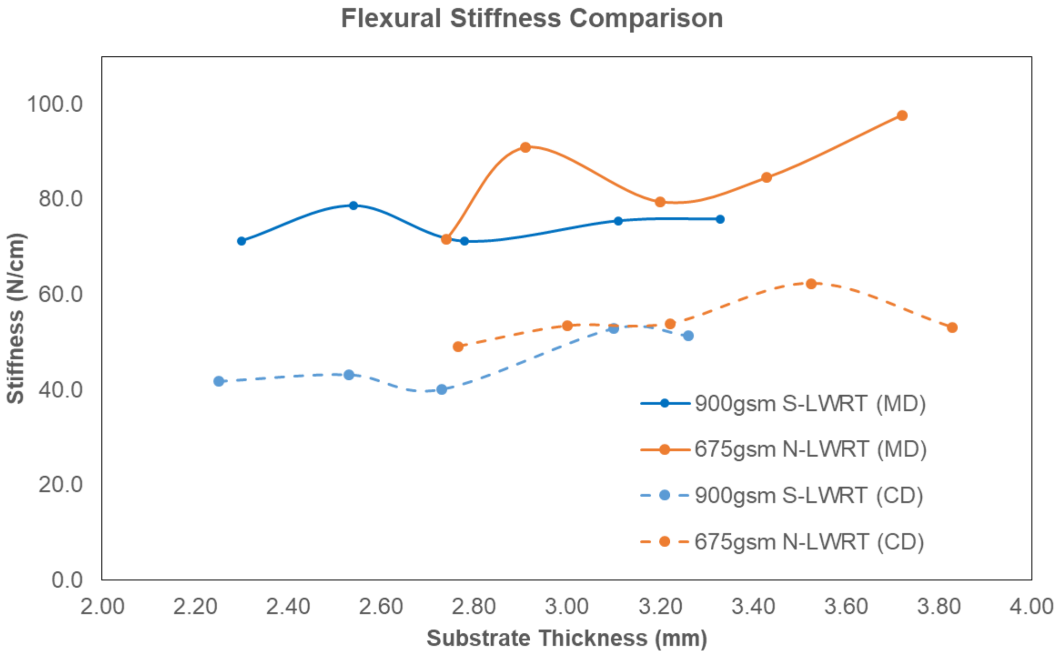

Figure 4. Flexural stiffness (ASTM D790) comparison between standard 900gsm S-LWRT and 675gsm N-LWRT. The solid lines represent trend of the MD values and the dashed lines represent the trend of CD values.

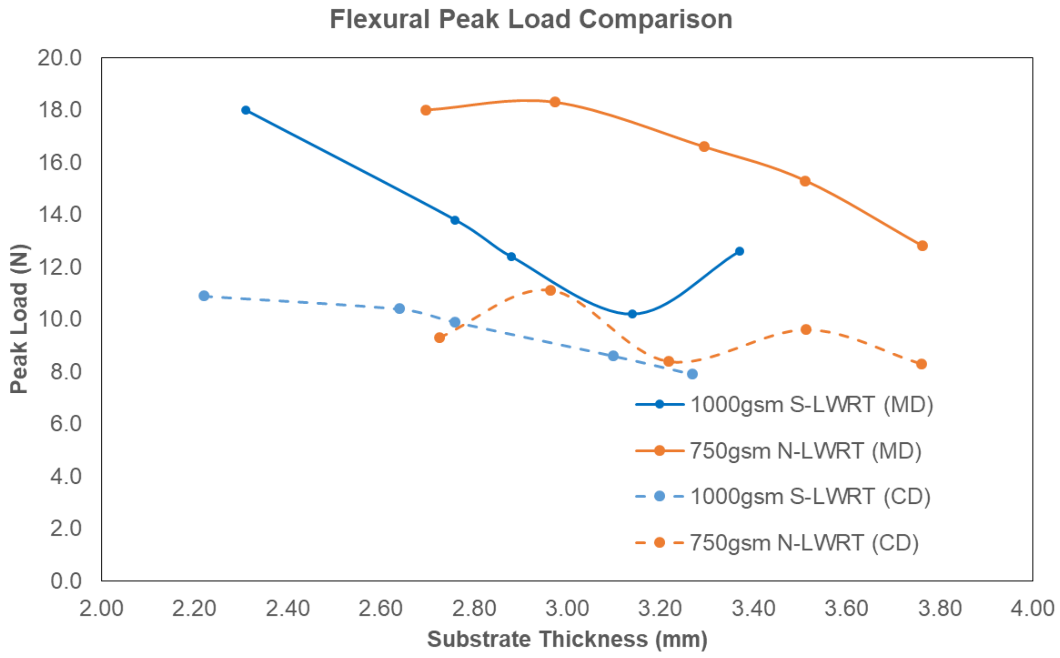

Figure 5. Flexural peak load (ASTM D790) comparison between 1000gsm S-LWRT and 750gsm N-LWRT. The solid lines represent trend of the MD values and the dashed lines represent the trend of CD values.

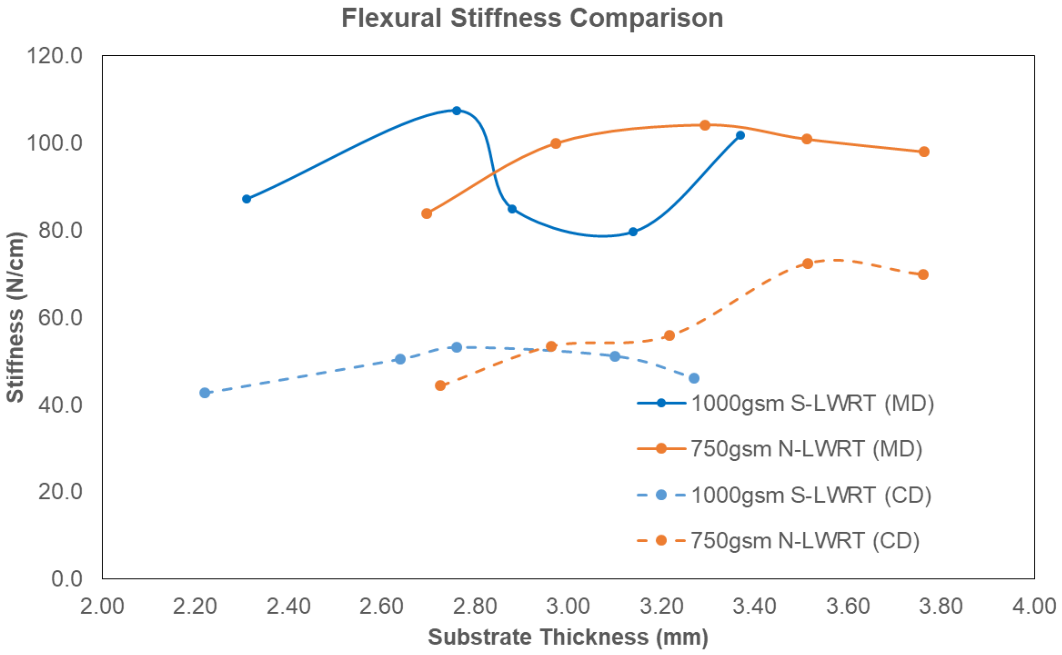

Figure 6. Flexural stiffness (ASTM D790) comparison between standard 1000gsm S-LWRT and 750gsm N-LWRT. The solid lines represent trend of the MD values and the dashed lines represent the trend of CD values.

Summary and Next Steps

A new grade of LWRT, has been developed by altering the PP-GF ratio and applying a higher consolidation level. This N-LWRT not only improves or at least maintains the mechanical properties of its S-LWRT counterpart with a 25% weight reduction but also enables a wider range of thermoforming thickness. In the future, we will look into the possibility of achieving further weight reduction without sacrificing any critical properties.

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