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Optimal design of Natural Fiber Composite Structure for Automobile

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Abstract : In this study, a optimal design on the hood automotive using eco-friendly natural fiber composites is performed. The hood of an automobile is determined by dividing the Inner panel shape through optimization phase to outer panel and inner panel. It was performed to optimize the size of the thickness of the inner panel and the outer panel by applying a flax/epoxy composite materials. The optimized shape was evaluated for weight-lightening, stability and the pedestrian collision safety. Through the resin flow analysis are confirmed to molding possibility judgment of product.

Key Words : Automobile Hood Component, Composite material, Light weight, Carbon Fiber, Resin Transfer Moulding

1. Introduction

Recently due to increasing interest in eco-friendly materials, studies on fiber obtained from nature have been actively performed to the area of composites. Although the natural fiber has less strength than the high strength fiber such as the carbon fiber, it has similar strength to glass fiber. Accordingly, it can be applied as very advantageous composite when an appropriate resin has been selected. [1],[2]

In this study, the design of eco-friendly structure using natural fiber was performed after investigation on mechanical properties of natural composite. The selected target structure is hood for compact automobile.

Optimization of structure design using the FEM can be divided largely into a size optimization, shape optimization, topology optimization, Size optimization is design parameters such as fixed geometry to repeat the finite element analysis for variable. There are only possible in a given shape, so the degree of freedom falling disadvantages. In the case of topology optimization, by changing the topology, which is a method with optimal model for the system within constraints.[3]

For manufacturing of the hood using flax fabric/vinyl-ester composites, the RIM(Resin Injection Method) was adopted. In order to finding the proper RIM conditions of the food, the resin flow analysis was performed. The flow analysis is to predict of resin flow filling time and to confirm no dry-patch. The resin flow analysis was performed using the Polyworx FEM flow simulation solver. The prototype hood was manufactured by applying the RIM based on the resin flow analysis results, it was confirmed that the measured resin infusion time agreed well with the analyzed resin infusion time.

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2. Structural Design

2.1. Load case

Hood according to design criteria are as follows: [4]

a. Bending stiffness

It compares the bending displacement of the loading point was added to a load of 100N on Hinge position latch portion as shown in Fig.1 (a).

b. Torsional rigidity test

Hinge and then secure the latch to a load of 100N on the right front portion as shown in Fig.1 (b).

Hood Torsional rigidity: more than 150Nm / deg

C. Outer panel Rigid

200N in the vertical displacement is less than 15mm, and confirms whether or not the damage as shown in Fig.1 (c).

2.2. Optimal Design

The load applied to the topology optimization was performed in the Inner panel via a commercial program Shape Optimization. It was applied to Steel for the convenience of the design, and minimize the mass of the 40% target. The results of the topology optimization of the coordinate value on the primary node was using the reverse modeling by CAD program. The initial design geometry, optimized design values, improved model produced results is shown in fig. 2.

Each thickness of the secured Inner panel and outer panel fixed shape was carried out by optimizing the size variable. The netting rule and the rule of mixture were used for composite initial structural designing. In order to confirm the structural safety of the initial structural design, structural analysis was performed by using FEM code. The structural design result is 3plies on outer panel, 16plies on inner panel of flax. The laminate sequence is $[\pm 45^{\circ}]_6$.

In order to evaluate the structural design results of hood, the structural analysis was performed by the finite element method. The element types used for the analysis are the composite shell element PCOMP. In this analysis, static stress analysis and safety factor at load cases were carried out.

In the case of bending stiffness analysis it was that the vertical displacement of the load caused the displacement of 2.87mm, structural safety factor of 11.4. torsional rigidity was meets the design requirements to 897.597 nm / deg, the safety factor confirmed that 15 or more. The vertical displacement of the rigid outer panel is 1.22mm, the safety factor is 2.758. Static structural analysis result of a bending, torsional rigidity, rigid outer panel structure analysis. Through the structural analyses, it is confirmed that the designed hood using natural flax composite is acceptable for structural safety.

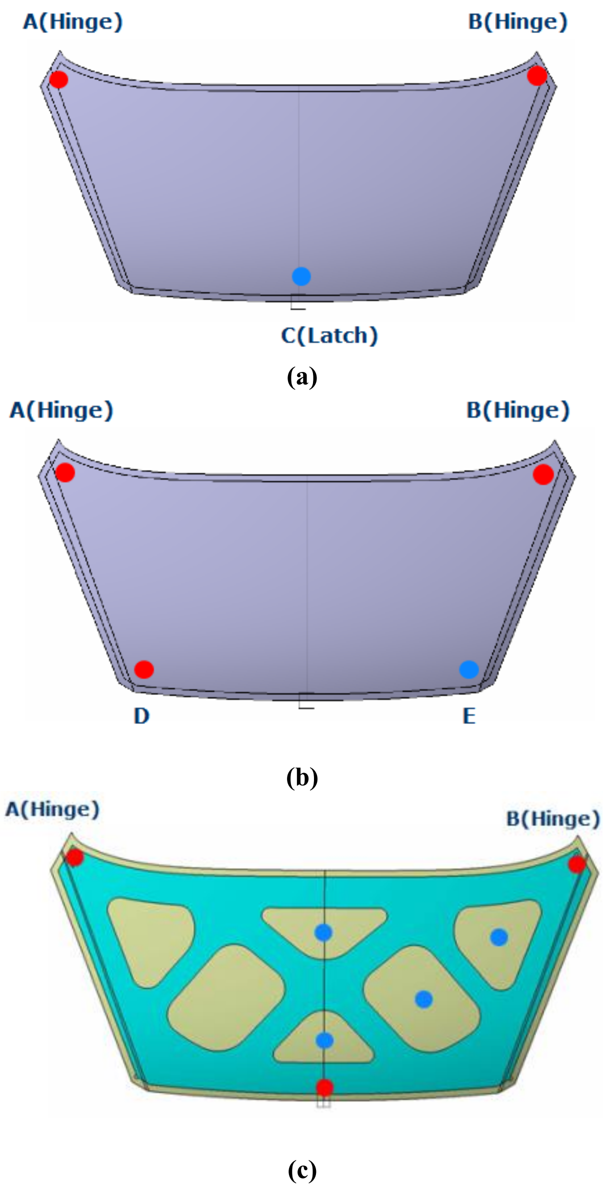

Fig. 1 Load Cases of Bending stiffness(a), Torsional rigidity test(b), Outer panel Rigid(c)

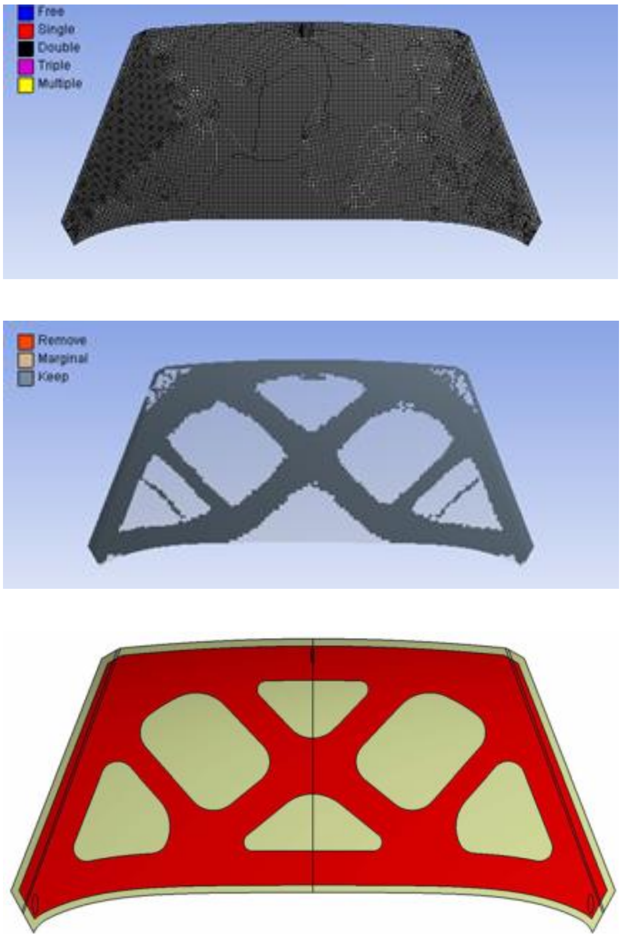

Fig. 2 Topology optimization and revers modeling

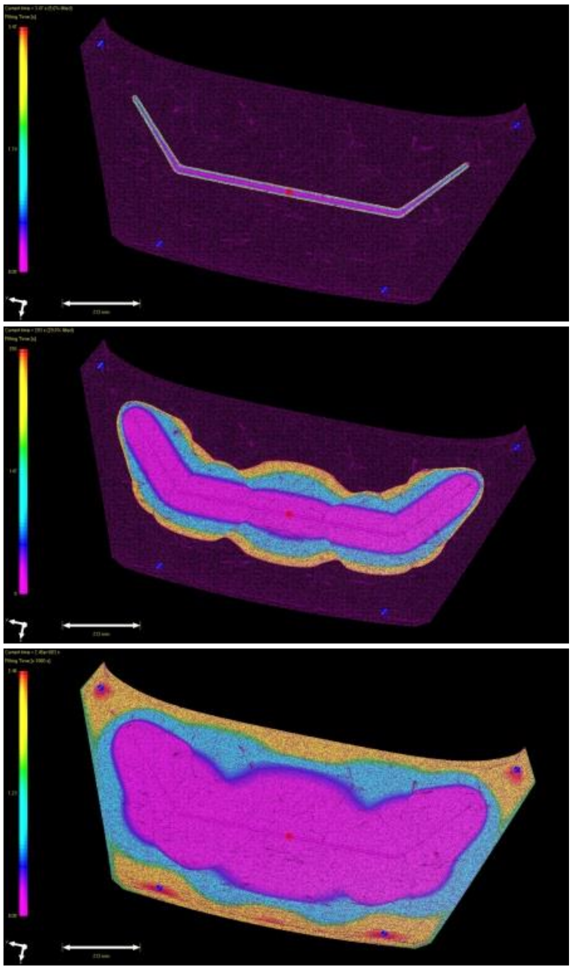

Fig. 3 Resin flow analysis result of hood

3. Resin Flow Simulation of RIM and Prototype Manufacturing

After structural design and analysis, the resin flow analysis of RIM manufacturing method was performed. The flow analysis of flax/vinyl ester automobile hood was performed to confirm the manufacturing possibility using RIM and to predict of resin flow filling time and confirm no dry-patch. The resin flow analysis was performed using the Polyworx RTM-Worx FEM flow simulation solver. The permeability coefficient data is important for resin flow analysis. The modeling using thin shell element was performed by RTM-Worx software. Vacuum pressure is -1bar and runner was applied to the center. According to flow analysis results, the resin filling time was 2460sec. Therefore, the filling time is lower than resin gel time 3000sec. Fig. 3 shows resin flow analysis result of hood.

In this work, after investigation on structural analysis and resin flow simulation results of hood, the prototype was manufactured using flax/vinyl ester. In order to manufacture the prototype hoof, the RIM method is adopted. Fig. 4 shows manufacturing process of hood. The manufactured hood is shown in Fig. 5.

The impact analysis carried out by modeling the adult head model to analyze the head impact safety.

Impact Analysis analyzed the stress and displacement of the hood during a crash in the hood central region at a rate of an adult male head 40km / h. The diameter of the head model is 165mm, weight is 4.9kg.[5]

Impact Analysis results from the panel central region displacement was 108.5mm. If the vertical deformation exceeding 120mm are interference engines directly crashes head and head injury occurs.

Fig. 4 Manufacturing process of hood

Fig. 5 Manufactured hood

As a result, since vertical deformation of the hood it does not exceed 120mm was confirmed to be safe. The stress analysis results applied to the pedestrian head was confirmed by 135.22MPa.

4. Conclusions

Optimal design on the hood automotive using eco-friendly natural fiber composites is performed. The hood of an automobile is determined by dividing the Inner panel shape through optimization phase to outer panel and inner panel applying a flax/epoxy composite materials. The optimized shape was evaluated for weight-lightening, stability and the pedestrian collision safety.

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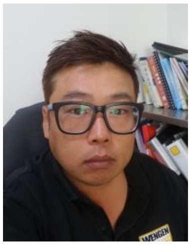

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