Research on the Forming Method of Lightweight Body and Parts

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Abstract. In recent years, with the diversified development of various scientific research competitions, undergraduate competitions such as the Formula Student Car Race have gradually become regular and high-level. The various parts of the car must be updated and optimized before each race. Among them, the change of the load-bearing frame and the lightweight of parts are particularly important. Therefore, how to reduce the weight of the car, improve the torsional stiffness and mechanical performance of the car by changing the body state, so that the car has better acceleration, braking and handling performance, has become an urgent problem that needs to be solved. Then started research on this.

Keywords: Racing car, bearing frame, lightweight.

1. Research background
Vehicle energy consumption and body safety have become social problems that need to be solved urgently in the world today. In order to solve the above problems, on the one hand, the use of carbon fiber sandwich structure load-bearing body to lighten the body and reduce the weight of the car is an effective means; on the other hand, it is necessary to realize the lightweight of the car body to save energy while ensuring the firmness and safety of the vehicle. Therefore, thermoformed parts are gradually getting attention and are more and more commonly used in car body design. Therefore, a good study of a mold forming method for a carbon fiber sandwich structure load-bearing car body or an application method for thermoformed parts can shorten the project development cycle and save development costs.

2. Research status at home and abroad
(1) Carbon fiber material
In recent years, carbon fiber composite materials have been widely used, not only in formula racing and aerospace, but also in the civil automobile industry. The concept of lightweight has also been paid more and more attention. The application of composite materials in automobiles is gradually expanding.

For the field of college students' Formula Racing, the origin of foreign FSC events is earlier than that of China. The mainstream foreign teams mainly produce carbon fiber load-bearing body molds:
① Divide the mold into upper and lower two-step method, and form the upper and lower parts separately and then bond with adhesive. The advantage of this method is that the foam female mold can be directly counted and milled. The upper and lower parts of the mold are open systems, which is convenient for prepreg. Paving, saving production time; the disadvantage is that the upper and lower parts of the mold require high precision, if the accuracy is not up to standard, it will have a very large impact.

② Through five-axis numerical milling of foam male mold, and set up the upper and lower parting surfaces, make the upper and lower parts of glass fiber reinforced plastic negative mold, and then close the upper and lower parts of the negative mold to form a closed system, and it is difficult to lay the prepreg. However, by this method, a carbon fiber sandwich structure load-bearing car body can be integrally formed without upper and lower bonding.

In China, the autoclave forming process is the current mainstream process for preparing composite car bodies. The parts formed by the autoclave forming process have low porosity, high fiber volume content, and good product performance. But its disadvantage is high cost and limited size. And need corresponding equipment.

(2) Thermoformed parts
Since the introduction of the new thermal technology by HardTech in Sweden in the 1980s, it has been used more and more widely, especially in joint venture models. Statistics on the application of thermoforming materials for SOP joint venture models in the past 3 years as shown in Table 1:

| Model   | XC90 | V90  | XC60 | POLO | Kodiaq | Astra | BMW 6 |
|---------|------|------|------|------|--------|-------|-------|
| Percentage (%) | 30   | 28.9 | 26.3 | 21   | 20.3   | 18.5  | 17    |

It can be seen from the table that the thermoforming application of Volvo models is the most, up to 30%, and the proportion of thermoforming applications of other models is also more than 15%. In recent years, more and more domestic autonomous vehicles have used thermoforming materials. The application of thermoforming materials for SOP autonomous vehicles in the last three years is shown in Table 2.

| Model   | Trumpchi | Saab X55 | Borui | MG Q8 | Tiggo7 | Yuexiang7 |
|---------|----------|----------|-------|-------|--------|-----------|
| Percentage (%) | 13.3 | 11       | 8     | 7.4   | 6      | 5         |

It can be seen from the table that the thermoforming application of self-owned brand models is 13.3% at most, which is about 16.7% less than that of joint venture brands.

3. The application principle of thermoformed parts
Intensity contrast
Take common car models, small and medium-sized cars as an example, the A-pillar outer panel, B-pillar outer panel, roof side beam, firewall crossbeam and front longitudinal beam reinforcement beam are 5 parts as thermoformed parts, which are non-thermoformed for basic car models. The parts are replaced.

The alternative formula for deformation resistance and other strength is as follows:

$$\sqrt{R_1 \times t_1^{1.75}} = \sqrt{R_2 \times t_2^{1.75}}$$

Among them: R1 is the yield strength of the replaced part; t1 is the material thickness of the replaced part; R2 is the yield strength of the replacement part; t2 is the material thickness of the
replacement part. The material thickness of the replacement part is derived according to the above formula:

\[ t_2 = \left( \frac{R_1}{R_2} \right)^{\frac{2}{3}} \times t_1 \]

Use strength substitution formulas such as deformation resistance to calculate the parts in the cab area to obtain the material thickness of the applied thermoformed parts. The above formula is also suitable for the conversion of material thickness of non-thermoformed parts, and combined with energy absorption and other strength substitution formulas for calculation.

The alternative formula for energy absorption and other strength is as follows:

\[ \sqrt{S_1} \times t_1^2 = \sqrt{S_2} \times t_2^2 \]

In the formula: S1 is the yield strength of the replaced part; t1 is the material thickness of the replaced part; S2 is the yield strength of the replacement part; t2 is the material thickness of the replacement part. The material thickness of the replacement part is derived according to the above formula:

\[ t_2 = \left( \frac{S_1}{S_2} \right)^{\frac{1}{4}} \times t_1 \]

Use energy absorption and other strength substitution formulas to calculate the parts in the collision energy absorption area to obtain the material thickness of the applied thermoformed parts. The above formula is also applicable to the conversion of material thickness of non-thermoformed parts.

For the defined thermoformed parts, use the above formula to calculate the material thickness of the thermoformed material, bring the material thickness and thermoformed material performance curve into the CAE model to calculate the stiffness, strength, collision and NVH performance, and calculate according to the analysis results fine-tune the material thickness of the thermoformed parts. CAE results show that the equal-strength substitution formula is accurate and reliable, which proves that thermoformed parts can reduce the weight of the vehicle while ensuring the safety of the vehicle.

4. The principle of load-bearing body improvement

The method for improving the load-bearing car body proposed in this article first improves the mold, not milling out in the machining center, but using the modeling software catia sheet metal module for modeling, and handing it over to the sheet metal factory for the synthesis of sheet metal (usually below 6mm) cold working process, including cutting, punching / cutting / compounding, folding, welding, riveting, splicing, forming, etc. to form molds. As shown below:

**Figure 1.** Sheet metal design drawing.
In the actual application process, the basic information of the method used in this article is as follows: two better plies:

1. [45F/02/0F/0/45F/Core]s
2. [45F/03/0F/02/45F/Core]s

Wherein F represents plain weave cloth, 02 subscript represents the number of layers, and s represents symmetrical plies.

When prototypes are trial-produced, the core material types and thicknesses selected are: aluminum honeycomb core 15, 20, 25mm three specifications, and PVC foam core material 15mm. A total of 6 sample pieces:

1. Honeycomb core 15mm, honeycomb core 20mm, honeycomb core 25mm, PVC foam 15mm
2. Honeycomb core 20mm, honeycomb core 25mm

After the production is completed, the vacuum bag molding process is used to prepare a simple laminate.

The following figure is a schematic diagram of the vacuum bag press molding process. A single-sided mold is used, and a fiber cloth and a flexible vacuum bag are laid on the mold, and the negative pressure of the sealed vacuum bag is used to pressurize the product. And use the vacuum negative pressure to inject the resin, so that the resin is impregnated with the reinforcing material, and then cured and formed.

The process is as follows: mold preparation, application of release agent, reinforcement material, release cloth, piping, rubber strip, vacuum bag sealing, vacuuming, resin suction, curing, and demolding. The process feature is low cost. The material utilization rate is high, the product porosity is small, and the resin penetration is good, but auxiliary molding equipment and auxiliary materials need to be added.

![Vacuum bag press forming process](image)

**Figure 2.** Vacuum bag press forming process.

5. Summary
This article preliminarily analyzes the application of thermoformed parts and the improvement of carbon fiber bodywork, and preliminarily determines the equivalent material thickness of thermoformed parts through the equal strength substitution formula. In addition, through the research of this article, a simple and novel mold manufacturing method is established to ensure that the project is carried out accurately and quickly. Through the research of this article, the development cycle of the vehicle project is shortened, and the project investment is reduced.

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