RTM technology of woven spacer fabric reinforced sandwich composite panels

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Abstract. The polyester fiber was utilized to fabricate the woven spacer fabric on the common loom, and the sandwich panels were produced by resin transfer molding process (RTM). The parameter of RTM molding process was determined. The correct ratio of resin, curing agent and accelerator in RTM process is 100:86:1. The injection temperature is 65°C. Injection time is shorter than 2 hours. Flexure and flatwise compression of composite panels were tested. The experiment result shows: flexure property and flatwise compression property of the RTM composite panels are better than that produced by handle paste shaping process.

1. Introduction
Composite material is a kind of solid material which is made of two or more than two kinds of single material, which is made by the physical or chemical method. RTM molding method, as a new type of fiber reinforced composite molding process has many advantages, such as low cost, environmental protection, good performance and fast molding speed.

RTM composite process can be traced to the 1940 Macro method [1], at that time, the filling and wetting of the resin were achieved by vacuum. Xiancheng He et al. used the resin transfer molding process to prepare the domestic T700 class carbon fiber composite laminates. The results show that the internal quality of the composite laminates is good [2]. Chongxin Yuan and others studied the feasibility of using the RTM process to make A-shaped reinforced frame, and finished the machining of complex structural parts. Finally, structural parts meeting the technology requirements were developed [3]. But so far, no one has applied the RTM process to the molding process of the sandwich panel.

2. Experimental Procedures

2.1. Experimental material
111dtx/192f technical polyester filaments were selected to manufacture woven spacer fabric as reinforcing material. Compared with brittle materials such as glass fiber, polyester filament has a higher bearing capacity and better fatigue resistance. At the same time, polyester has good weaving ability, which is of great importance and accords with the standard of this experiment.

2.1.1. Woven spacer fabric. Woven spacer fabric is a three layer structure, including the upper fabric, the lower fabric and the intermediate connection material [4]. In this study, all the woven spacer fabrics utilizing the plain weave as the face fabric weave to decrease the difficulties of design and manufacture to ensure the uniformity of the samples. Linking materials were a set of polyester
filament yarn [5][6]. Warp density of face fabric is 80 yarns per 10 centimeters. The thickness of panels is 1.2 centimeters.

2.1.2. Filled with foam. The purpose of this step is to fill the foam into the middle of the spacer fabric. First, open the spacer fabric with a mold. The two kinds of raw materials are evenly mixed in one to one proportion and then fill it in the middle of spacer fabric [4]. The raw material become polyurethane (PU) foam in the middle of spacer fabric, when the foam is fully filled the preform was obtained.

2.1.3. RTM molding process. After the processing of the preform, the RTM forming process of the composite panel is discussed. The main problems affecting the implementation of the process are discussed.

2.1.3.1. Dosage of curing agent and accelerator. Because the anhydride curing agent of epoxy resin and direct reaction, slow speed, high temperature, so often added the special accelerator, epoxy resin DMP-30. The dosage is generally 0.1%-3% through access to information. By calculation, the mass ratio of epoxy resin, curing agent and accelerator used in RTM composite process is 100:86:1.

2.1.3.2. Injection temperature. In the process of RTM composite molding, it is necessary to choose the resin with a lower viscosity to ensure the good invasive of the fiber. That is to say, by measuring the viscosity of epoxy resin in different temperatures, the temperature of resin at the lowest viscosity is chosen as the temperature of the resin injected. The experimental data are demonstrated that the viscosity decreased first and then increased with the increase of temperature. When the temperature is 65°C, the viscosity is the lowest. Therefore, the temperature of injection is 65°C.

2.1.3.3. Injection time. For the RTM process, injection time is generally 1/4–1/2 of curing time. After the resin was put into the oven and kept at 65°C, it was found that the viscosity of the resin was very low, when the temperature was up to 70°C and kept at 2h, the color of the resin was deepened and the viscosity was improved. When the temperature was up to 80°C and kept 1h, it was found that the color of the resin became darker and solidified. In view of this, this experiment selects 80°C as the starting temperature of resin curing. By looking at the literature, we can see that the curing temperature of RTM is 80°C~140°C. The resin injection process should be ensured to finish at least 2 hours to prevent resin from curing before completing the injection.

2.1.3.4. Molding process. The process of RTM molding process can be divided into three steps. The first step is preheating mold. Set the mold into the oven which is 65°C inside for 3 hours. The second step is vacuum assisted molding. The outlet of mold, the three gas drying bottle (acid, alkali, paraffin), the suction flask and the vacuum pump are connected with the rubber hose. Then vacuuming the mold. The last step is mold filling. Firstly put resin, curing agent and accelerator into the 60°C thermostat water bath and stir with a glass rod for 10 minutes. After that, put them into the reactor and start injection. The second and third injection is in the same way. Then keep the panels into oven for 10 hours to ensure solidify completely.

2.1.4. Handle paste shaping process. Epoxy resin and polyamide resin are mixed in one to one ratio. Then the preform was consolidated in a handle paste shaping process [2]. The samples were placed at room temperature for 24 hours until the resin was completely cured.

2.2. Testing of flatwise compression
According to the GB/T1453-2005, the sample was cut into 60mm long and 60mm wide. The test instrument model is CMT550. The velocity of testing is 2mm/min.
2.3. Testing of flexure
According to the GB/T1042-79, the sample was cut into 170mm long and 15mm wide. The test instrument model is CMT550. The velocity of testing is 30mm/min.

3. Results

3.1. Results of flatwise compression
Results of the flatwise compression test of RTM panels and handle paste panels are shown in the figure 1.

![Figure 1: Flatwise compression resistance](image)

Comparing the different panels, the results show that the panels obtained by RTM molding process are much better than those produced by handle paste shaping process. The failure load of RTM panels is about 8.5 times that of handle paste panels and the elastic modulus of RTM panels is about 10.7 times that of handle paste panels.

While the RTM panel is relatively stable and not easy to deform. The main reason is that the existence of injection pressure in the process of RTM molding let the resin infiltrated into the fabric structure to enhance the integrity of the panel. And the handle paste panel is only coated on the surface, so the integrity is not very well.

3.2. Results of flexure
The results of the flexure test of RTM panels and handle paste panels are shown in the figure 2.

![Figure 2: Flexure resistance](image)

Comparing different panels, the results show that the failure load and flexural elastic modulus of RTM panels are much larger than that of the handle paste panels. The failure load of RTM panels is...
about 3.0 times that of handle paste panels and the flexural elastic modulus of RTM panels is about 3.4 times that of handle paste panels.

The main reasons are: In the RTM molding process large amount of resin is used. Under the pressure, resin penetrate into the interior of surface fabric, enhances the integrity of the composite. However, in the handle paste shaping process, the resin is only on panel’s surface, so the integrity is not very well. In the RTM process, the mold is sealed, less gas in the panel, so the panel has better mechanical properties.

4. Conclusions
The RTM process was used to manufacture woven spacer fabric reinforced sandwich composite panels. The RTM process was explored and the main technological parameters of RTM were determined.

The flatwise compression and flexure of two kinds of sandwich panels were tested. The results show that the flatwise compression property and flexure property of the RTM composite panels are much better than that made by handle shaping process.

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