Study on preparation and mechanical performance of TPU/non-woven composites

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Abstract. In order to study the influence of resin content and layer sequence parameters on the mechanical properties of TPU/non-woven composite materials synthesized by moulding pressing technology. The effects of the resin content and layer sequence on composites were discussed. Through experiments and theoretical analysis, it was revealed how resin content, layer sequence impact on mechanical properties of composite. The mechanics properties of TPU/non-woven composite materials are improved. The process is pressure 0.5 MPa, temperature 110\(^\circ\)C and time 120s min. The melting of the TPU infiltrated into the fabric and filled the space between the fibers.

1. Introduction
Resin matrix composite materials have high strength ratio, excellent designability and corrosion resistance properties, etc [1, 2]. They have a wide range of applications in aerospace, automotive and marine industries. The design of the layer sequence can not only meet the thickness requirement of composite materials in practical applications, but also compensate the performance limitations of singularity element composites [3]. At present, domestic and foreign scholars have been studying the structure and performance of thermoplastic fiber reinforced composite materials, polymer matrix reinforced composites and the three-dimensional textile composite material, in which significant breakthroughs were achieved [4, 5]. However, the research on reinforced non-wovens for composite materials is relatively small. Based on previous literature, this paper uses thermoplastic polyurethanes (TPU) as matrix and hot pressing molding process development of resin matrix composites to observe and analyze the mechanical properties of TPU/non-woven composite.

2. Materials and instrumentations

2.1. Raw materials
TPU, with a surface area of 83.8 g/m\(^2\)and thickness 0.06 mm, was provided by Shanghai Anlao industrial co., LTD., China. It has a good hot melt, a strong stick relay and a high mechanical strength. Needle-punched non-wovens were purchased from Zhe Jiang Fusen spunlace non-woven co., LTD., China. The main specifications are shown in table 1.

2.2. Main equipments
The property of mechanic was studied by Electronic fabrics strength machine (YG065H, Shaoxing Yuanmao mechanical and electrical equipment co., LTD., china). The morphology of materials was characterized by Scanning electron microscope (SNG-3000, Korean SEC CO., LTD., Korea).
Table 1. Material specifications.

| Material | Composition | Surface area (g/m²) | Thickness (mm) | Breaking stress (MPa) | Elongation at break (%) |
|----------|-------------|---------------------|----------------|-----------------------|-------------------------|
|          |        |                    |                | Crosswise | Lengthways | Crosswise | Lengthways |
| Non-woven | PET      | 448.00              | 3.3            | 4.06       | 4.90       | 90.64     | 50.92      |

3. Layer lay-up design

In order to study the relationship between layer sequence and mechanical property of composite materials, the authors used non-wovens and TPU placed in layers of pure non-wovens in order to make resin matrix composite materials with 4 layers, according to 4 kinds of layer scheme shown in figure 1. 0° fiber as number B in longitudinal direction is defined as a composite material, and 90° fiber as number A latitudinal direction is defined as a composite material.

Figure 1. Non-woven layer sequence

4. Process of resin matrix composites molding

TPU is a kind of thermoplastic resin, so the fabrication of the composite material is made by a hot-pressing process. Reading reference literature of hot-pressing molding process parameters [5-7], the authors determined the optimum hot-pressing parameters as being: pressure 0.5 MPa, hot-pressing time 120s and hot-pressing temperature 110 °C. The non-woven was decorated in processing mould plate vulcanizing machine, when the temperature rose to 110 °C. Then the authors set the hot-pressing to 0.5MPa, normally keeping the composite materials for 120s in constant temperature hot pressing. The process is shown in figure 2 and figure 3.

Figure 2. Composite extrusion molding process.
5. Analysis

5.1. Impacts of resin on the mechanical properties of the composites

The mechanical properties of the composites were tested by the testing standard GB/T 1447-1447, which is used to characterize the tensile performance of fiber reinforced plastics [8-10]. The non-woven material was tested by the electronic fabrics strength machine, and mechanical properties of composite materials were determined for layer BBBB. Test results are shown in table 2.

Table 2. Tensile properties of the material data

| Name of fabric | Number of plies | Thickness (mm) | Breaking stress (MPa) | Elongation at break (%) |
|----------------|----------------|----------------|-----------------------|-------------------------|
| Non-woven      | 1              | 3.30           | 4.06                  | 4.90                    | 90.64                  | 50.92                  |
| Composite      | 1              | 2.70           | 5.90                  | 7.80                    | 16.70                  | 19.10                  |
| Composite      | 2              | 5.50           | 5.90                  | 7.80                    | 28.40                  | 31.10                  |
| Composite      | 4              | 10.80          | 5.70                  | 6.80                    | 105.1                  | 56.80                  |

According to table 2, it can be concluded that the fracture stress is higher than the pure resin reinforced composites non-wovens, and the longitudinal stress is greater than the transverse fracture, but with the increase of composite material layers, the fracture stress does not increase accordingly. This is because the molten resin infiltrates the internal structure, and the space between the fiber and the fiber form become tightly coated, causing the fiber bundle to form a continuous phase [11, 12]. If connected at the same time, the TPU on each layer, causes interlayer structure formation and consolidation, improving its mechanical properties, and with the increase of composite material layer, the fracture stress of composite material change is not large, showing that the resin can evenly permeate into the non-woven, indirect composite extrusion molding process parameters being reasonable [13, 14].

5.2. Impacts layer sequence on the mechanical properties of the composites

The longitudinal tensile properties of the tests performed on the composite materials are shown in table 3.

From table 3, it can be concluded that the mechanical properties of samples 1 and 2 are similar. The fracture stress of sample 3 is the worst, but the elongation at break is the best. The fracture stress of sample 4 is the best, but elongation at break is the worst. The main cause of this phenomenon is the positive correlation between the material fracture stress and the number of samples participating in longitudinal tensile, the larger the number, the greater the fracture stress. The elongation at break of
composite materials has an opposite trend, namely the mechanical properties of composite materials is not related with the layer order, but is related to the number of longitudinal tensile.

### Table 3. The tensile properties of the composite material test results

| Marking sample | Lay-up | Breaking stress (MPa) | Elongation at break (%) |
|----------------|--------|-----------------------|-------------------------|
| 1              | ABAB   | 5.00                  | 70.60                   |
| 2              | BAAB   | 5.10                  | 72.80                   |
| 3              | ABBB   | 4.70                  | 77.90                   |
| 4              | BBBB   | 6.80                  | 56.80                   |

5.3. Microstructure analysis of the composite materials

![SEM images of different materials](image)

Figure 4. SEM images of different materials.

Figure 4(a) and (b) show SEM images of pure non-wovens and composite materials, respectively. It can be seen from the diagram, that the pressure is 0.5 MPa, 120 s hot-pressing time, hot-pressing temperature is 110 °C, the melting of the TPU takes place under pressure, infiltrating into the fabric, filling the space between the fibers. Material deformation with pressure takes place at the same time, discharging gas inside the fabric, reducing the gap and improving the shape and structure of the composite materials [15, 16]. Thus, the resin reinforced composites determines the mechanical properties of fiber in a close extent, and contribute to the optimization of the important reference indicator of composite extrusion molding process.

6. Conclusions

We studied the preparation of resin matrix composites. The influence of resin content and layer order on the materials was further explored. Results show that the fracture stress of composite materials is proportional to the resin content, but has very little to do with the layer order. Further research shows that part of the resin infiltration of composite materials causes a major improvement on its mechanical properties.

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