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Discussion on the Tensile and Bending Properties of PAN-based Pre-oxidised Fibre Felt Composite Materials

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Abstract
The impact of the mass percentage of PAN-based pre-oxidised fibre felt in a composite material and of the curing temperature on the composite material's mechanical properties were studied in order to optimise the preparation method of epoxy resin composite material. The results showed that when the dosage of PAN-based pre-oxidised fibre felt was 15% of the mass of epoxy resin and the curing temperature was 170 °C, the tensile and bending properties of the composite materials produced were the best. This study has addressed the absence of reports on this type of composite material, and is expected to lead to the development of applications for this new type of composite material.

Key words: *tensile properties, bending properties, PAN-based pre-oxidised fibre felt; composite material.*

Introduction

Composite materials have gradually replaced wood and metal alloys because they are light- weight, strong, easy to process by moulding, and have good elasticity and resistance to chemical corrosion and the weather [1-5]. Globally, the production of composite materials has been mainly concentrated in Europe, the United States and East Asia, and the market of mainland China has developed rapidly in recent years.

Composite materials are mainly used in the aerospace and automobile industries at present [6-10]. The extent of research into composite materials and the scope of their applications, as well as the rate and scale of their production development, has become one of the important measures of the level of advancement of science and technology of a country. Pre-oxidised fibre felt is produced with PAN-based pre-oxidised short fibres treated by acupuncture or other processes [11-15]. Pre-oxidised fibre felt is an intermediate product of the process of making carbon fibre felt products, and its cost is lower than that of carbon fibre. It has other advantages too: it displays good heat insulation and resistance to acid-base corrosion, chemical environment, climate, etc., it has a low density and soft texture and is absorbent [16-19]. Morever, it has many applications , for example, as heat insulation and heat preservation material for buildings, high temperature furnaces and pipe insulation, as well as in fire insulation suits, flame retardant decorations and so on [20-22].

In this paper, we produced a PAN-based pre-oxidised fibre felt/epoxy resin composite material with good mechanical properties, utilising the significant effects of permeability, extensibility, ease of moulding, and so on, of PAN-based pre-oxidised fibre felt, on which was based its use as a reinforcing agent with epoxy resin as the matrix. The influence of the mass percentage of the PAN-based pre-oxidized fibre felt and of the curing temperature of the matrix on the mechanical properties of the composite materials is discussed.

Experiment

Main materials and reagents

The following materials and reagents were used: PAN-based pre-oxidised fibre felt (Nantong Toray Bond Carbon Fibre co., Ltd.), epoxy resin E-44 (Sinopec Baling Petrochemical Branch), low molecular 650 polyamide resin (Hangzhou Five Port Adhesive Co., Ltd.), anhydrous ethanol (Tianjin Wind Ship Chemical Technology Co., Ltd.), and remover (Texas's disinfection Technology Co., Ltd.), etc.

Preparation process for the composite material

A certain amount of epoxy resin was weighed, and then the relative quantity of epoxy resin, diluted with anhydrous ethanol, was added. The mixture was stirred with an electric mixer for 30 min until fully dissolved. Finally, to obtain a 1:1 ratio of the epoxy resin and curing agent, 650 ml of a polyamide curing agent was added, and the mixture was stirred to mix it uniformly.

In this procedure a Y/TD71-45 flat open mould was adopted to press the composite materials. PAN-based pre-oxidized fibre felt, produced by the acupuncture process as a material for the reinforcement of composites, was employed as it has a significant effect on permeability, extensibility, and ease of moulding. In view of these characteristics of PAN-based pre-oxidised fibre felt, PAN-based pre-oxidised fibre felt and resin composite can be made by the method of hand lay-up and infiltration using the simple technique of moulding into composite materials, at low cost. An appropriate epoxy resin was fully infiltrated by the hand lay-up method at ambient temperature, because at this temperature the epoxy resin was in an appropriate liquid state after the dilution. Then it was

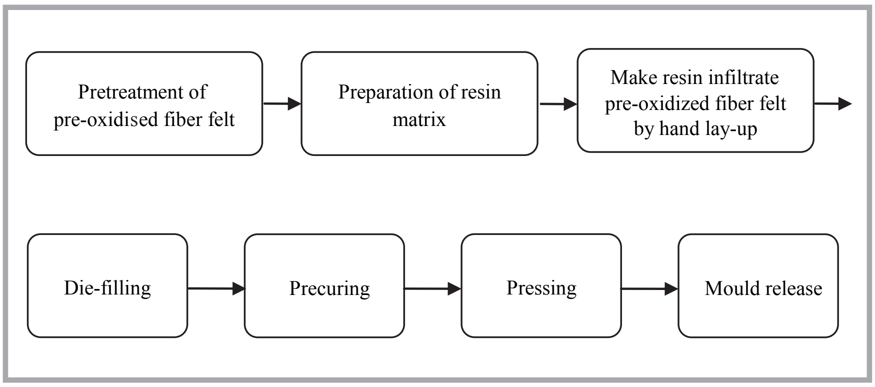

***Figure 1.** Preparation of composite material.*

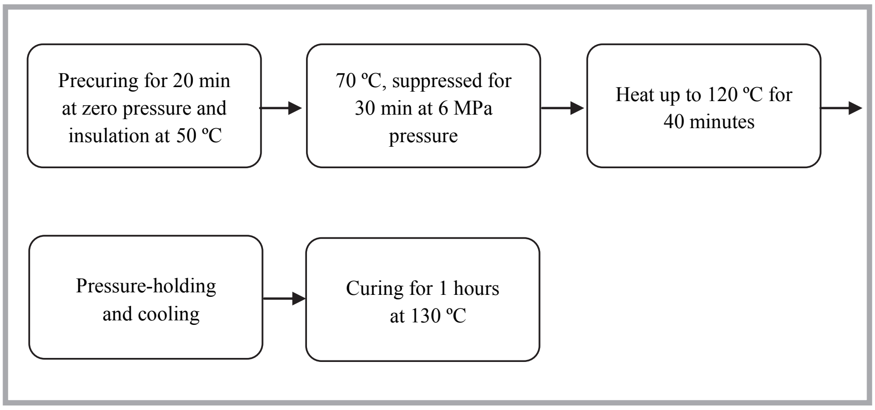

***Figure 2.** Mould pressing process for composite material.*

subjected to curing for some time before moulding at a certain temperature. The preparation process leading to the composite material is shown in ***Figure 1***. The mould pressing process for the composite materials is shown in ***Figure 2***.

Test parameters and methods for composite materials

Test of tensile properties

Testing of the tensile properties was conducted using an Instron universal material testing machine, following the test methods for GB1447-2005 fibre reinforced plastic tensile properties. The specifications of the samples were as follows: 250*25 mm, thickness 1.5-3.0 mm, clamping distance 170 mm, and the speed of loading 2 mm/min. For each group 20 samples were tested, with the average taken, and then displacement-load diagrams and tensile stress diagrams for the composite material were obtained from the test results.

Test of bending properties

Testing of the bending properties was conducted using an Instron universal material testing machine, following the test methods for GB1449-2005 fibre reinforced plastic bending properties. The test method involved the three point bending method. The specifications of the samples were as follows: width 15 ± 0.5 mm, thickness 1.5-3.0 mm, and the span was fixed according to the thickness of the sample, at a loading rate of 2 mm/min. For each group 20 samples were tested, with the average taken.

***Table 1.** Parameters of contrast experiment.*

Sample No.	Mass of PAN-based pre-oxidized fibre felt, %
1	30
2	25
3	20
4	15
5	10

***Table 2.** Parameters of contrasting experiments.*

Sample No.	Temperature of curing, °C
1	10
2	50
3	90
4	130
5	170

Results and discussion

The influence of the mass percentage of PAN-based pre-oxidised fibre felt on the mechanical properties of the composite material

To explore the influence of the mass percentage of PAN-based pre-oxidized fibre felt on the mechanical properties of the composite material, five experiments were designed, with the parameters of the contrasting experiments as shown in ***Table 1***. The results of testing the mechanical properties of composites with different contents of PAN-based pre-oxidized fibre felt are shown in ***Figures 3-4***.

Figures 3-4 showed that the mechanical properties of the composite materials are best when the mass of PAN-based pre-oxidised fibre felt is 15% of that of the epoxy resin, with the values of the longitudinal and transverse tensile breaking load peaks reaching the maximum. However, when the mass of PAN-based pre-oxidised fibre felt is more than 15% of that of epoxy resin, with an increase in the specific gravity of the PAN-based pre-oxidized fibre felt, the mechanical properties of the composite materials gradually diminish. When the composite materials are under the action of an external force, the reinforcement will shoulder the bulk of the load. A conclusion can be drawn from observation that when the mass percentage of PAN-based pre-oxidised fibre felt is too small, the quantity of reinforcing fibre is too low to support the main external load, which leads to poor mechanical properties of the composite material on the whole. When the mass percentage exceeds 15%, the content of resin decreases relatively, in which case the matrix cannot fully saturate into the fibre felt, which leads to poor bonding strength between the resin and reinforcing material, so that the resin detaches from the fibre easily under external force, which reduces the mechanical properties of the composite material.

Influence of the curing temperature on the mechanical properties

In order to explore the influence of the curing temperature on the mechanical properties of the composite materials, five experiments were designed to conduct curing at 10 °C, 50 °C, 90 °C, 130 °C, and 170 °C, respectively. The parameters of the contrasting experiment s were as shown in ***Table 2***.

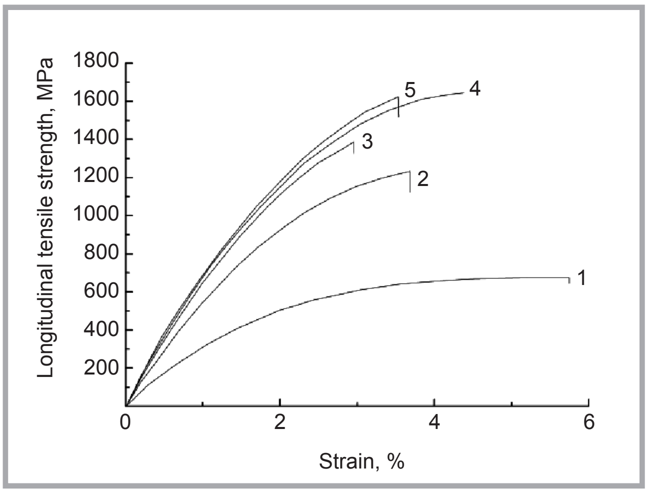

__Figure 3.__ Effect of mass percentage of PAN-based pre-oxidised fibre felt on the tensile strength of the composite material. 1, 2, 3, 4, 5 – see __Tables 1__ and __2__.

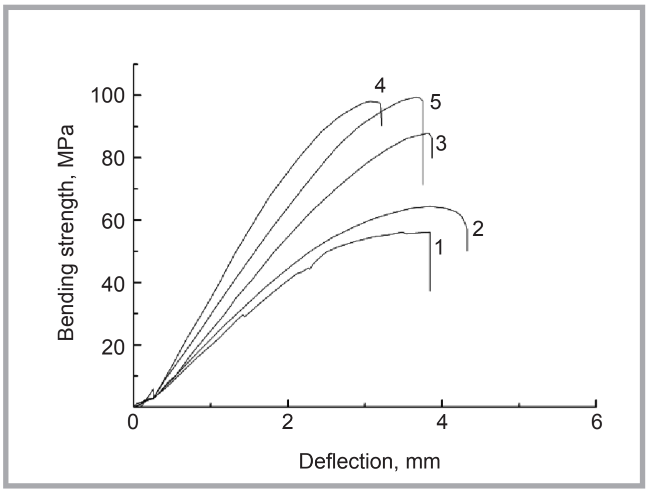

__Figure 4.__ Effect of the mass percentage of PAN-based pre-oxidised fibre felt on the bending strength of the composite material. 1, 2, 3, 4, 5 – see __Tables 1__ and __2__.

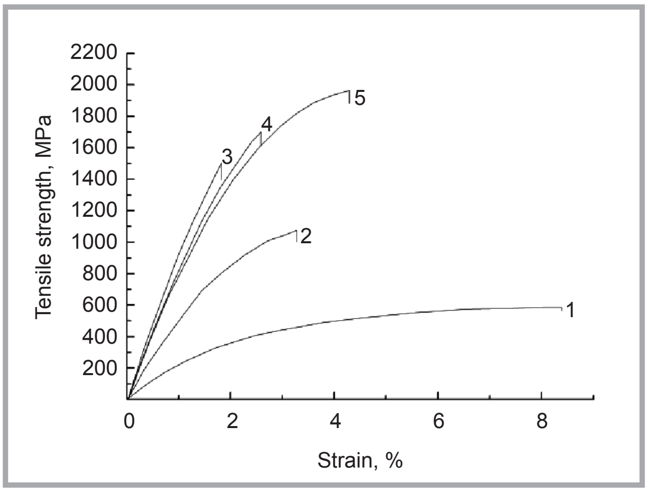

__Figure 5.__ Effect of curing temperature on the tensile strength of the composite material. 1, 2, 3, 4, 5 – see __Tables 1__ and __2__.

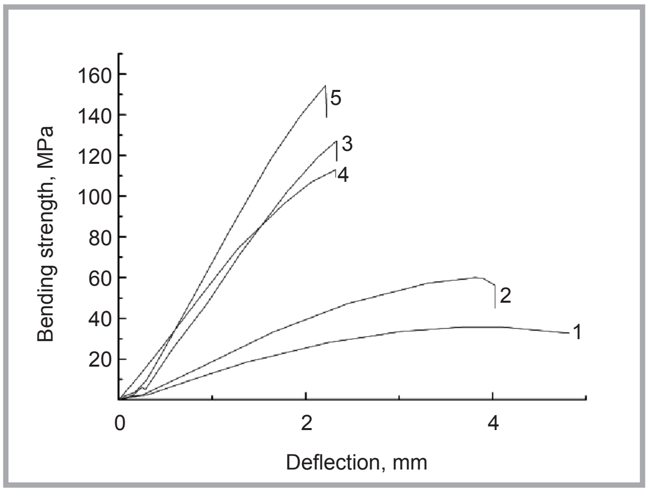

__Figure 6.__ Effect of curing temperature on the transverse bending strength of the composite material. 1, 2, 3, 4, 5 – see __Tables 1__ and __2__.

The outcomes of the mechanical property tests of the composite material for each group of experiments are illustrated graphically in ***Figures 5-6***.

As can be seen from ***Figures 5-6***, the mechanical properties of the composite materials are improved with an increase in the curing temperature. When the temperature is below 90 °C, the change in the mechanical properties of the composite materials with temperature is more pronounced than when the temperature is above 90 °C. For the same curing time, the higher the curing temperature within a certain range, the more fully cured the samples and the better the mechanical properties are.

Conclusions

The article describes the use of PAN-based pre-oxidised fibre felt as a reinforcement and epoxy resin as the matrix to produce PAN-based pre-oxidised fibre felt/epoxy resin composite materials with good mechanical properties. When the dosage of PAN-based pre-oxidised fibre felt was 15% of the mass of the epoxy resin, and the curing temperature was 170 °C, the tensile and bending properties of the composite materials produced were best. This study addressed the absence of reports of this type of composite material, and is expected to lead to the development of applications for this new type of composite material.

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