PREPARATION OF A SIMPLE HEAT-RESISTANT COATING OF THE OPTICAL FIBER EMBEDDED IN COMPOSTIES

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1 Background

Composites were widely used in aircraft load-carrying structure materials because of its excellent strength, stiffness, anti-fatigue performance and durability. However, composite materials are very sensitive to damage because of no reinforcement materials in thickness direction. Effective Non Destructive Testing (NDT) technology for the composite structure damage inspection with continuous monitoring has important significance. The optical fiber sensor has many unique advantages, for example, small, material compatibility, distribution measurement, and so on; thereby optical fiber intelligent materials and structures are developing very quickly in recent years [1-5].

To enhance the mechanical strength of optical fibers, the glass fibers are coated by polymeric coatings during the fabrication process [6-11]. The molding temperature of composites used in large aircraft is above 180℃, therefore the optical fiber coating requires a high temperature resistant performance to ensure to not influence the optical fiber's transmission abilities. In this paper, the resistant high temperature abilities of three ordinary optical fiber coatings including uncoated optical fiber, double-coated fiber and polyimide coating optical fiber, were researched, and a kind of optical fiber coating filled with TiO_2 was prepared. This kind of coating did not need ultraviolet light or heating. The effects of PVC (pigment volume concentration) on the properties of coating were investigated, and an optimal formula was obtained. The best coating was painted on the optical fiber. The relationships of the coating diameter and the distances of the centers of the coating layer and optical fiber were studied.

2 Experiments

2.1 Preparation of coatings

The samples were prepared by steps as follows:
1) Mixed selected TiO_2 power, acrylic resins and the corresponding solvents in a certain ratio;
2) Be grinded three times by high-speed mill;
3) Be distributed for 12 hours by high-speed emulsion machine;
4) According the testing requirements, the coatings were on painted the board with various thin samples.

2.2 Performance test methods

The properties of coatings were tested by the following criterions:
Determination of impact resistance of film GB/T 1732-93.
Determination of flexibility of film GB/T 1731-93
Paints and varnishes-Cross cut test for film GB/T 9286-1998.
Specifications for optical fibre test methods--Part 21: Measurement methods and test procedures for dimensions--Coating geometry GB/T 15972.21-2008.

From above methods, the effects of PVC on the properties of coatings were acquired as shown in Table 1.

Tab.1. the effects of PVC on the properties of coatings

sample code	PVC	Impact resistant properties (cm)	Flexibility (mm)	Cross cut test(degree)	Thickness ratio
1#	0	50	1	1	0
2#	10%	50	1	1	0
3#	20%	50	1	1	0.05
4#	30%	50	1	1	83.3
5#	40%	50	1	2	90.5
6#	50%	45	2	2	97.7
7#	60%	40	3	3	97.4
8#	70%	30	5	3	97.8

3 Results and Discussions

From table 1, impact resistant properties, flexibility and cross cut test of coating decreased with PVC increasing, and the thickness ratio (the ratio of the minimum thickness of coatings to the maximum thickness of coatings) increased with PVC increasing. Therefore the comprehensive performances of sample 4#, the PVC of which was 30%, were better. So this formula was collected as the best formula to continue the subsequent experiments.

Optical fibre coated with 4# formula coating was pulled with different speeds. We can see that the speed was slower, the coat is thicker, that is the diameter of coatings was bigger. For knowing the relationship between the diameter of coating and the concentricity of the optical fibres, the distance of center of coating and center of optical fiber was represented as concentricity. Observed under the microscope, the relationship between diameter and distance of centers of circles was obtained, as shown schematically in Figure 1.

As can be seen in Fig.1 that the smaller diameter coating, the better roundness and center degrees of coating. To obtain better roundness and center degree, the diameter should be the smallest. But the coating of optical fibers could protect the optical fiber by enhancing mechanical strength, the diameter of the coating should not too thin[12-13]. The optimal diameter was selected as 200±5μm.

Optical fiber with commercial double-coated (fig.2), optical fiber without coatings (fig.3), polyimide coating optical fiber (fig.4) and 4# coating (fig.5) were embedded in vinyl resin casting body respectively, and their cross sections were observed under optical microscope.

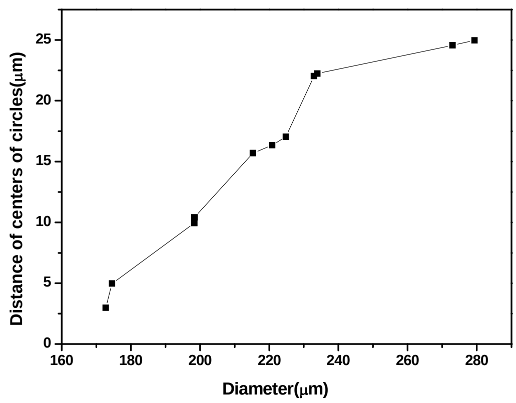
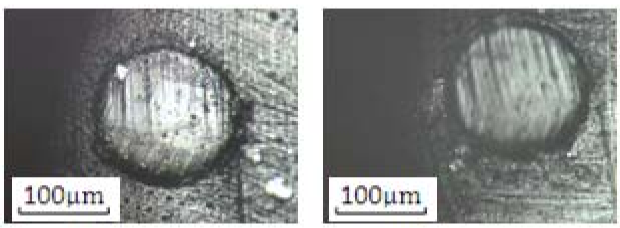


Fig.1. Relationship of diameter and distance of centers of coating and optical fibers.

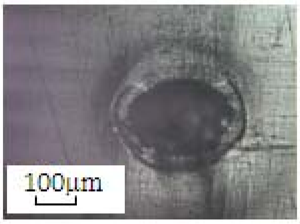
Then they were heated at 90℃ for 2 hours, at 130℃ for 1.5 hours 180℃ for 3 hours which simulate the temperature variations during composite materials molding process. The cross sections were observed under optical microscope again after heated.



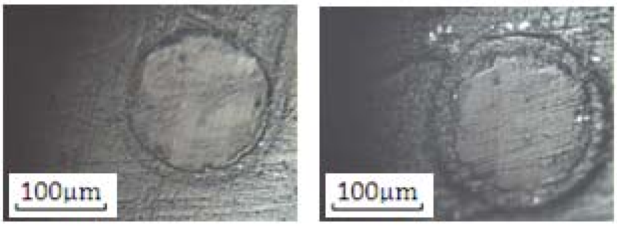
(a) Unheated (b) heated

Fig.2. Optical fiber without coating

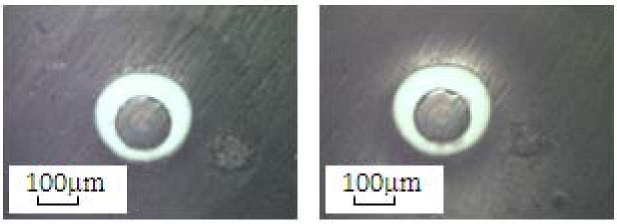
(a) Unheated (b) heated



(c)Section after removing coating in fig.3(b)
Fig.3. Double coatings optical fiber



(a) Unheated (b) heated
Fig.4. Polyimide coating optical fiber



(a) Unheated (b) heated
Fig.5. TiO_2 coating optical fiber

It was found that after heated, naked optical fibers moved obviously. At first, naked fiber and resin in the same plane. After heated, relative displacement between fiber and resin has occurred. The reason is thermal expansion coefficients of optical fiber and resins are different, the deformation of the resins was happened induce to remove the resin from fiber. The inner coating of ordinary commercial double-coated optical fiber has completely melt and leak out because of gravity and pressure from resin extrusion, and polyimide coating was separated apparently from resin because that the expansion coefficients were different between polyimide and optical fiber. The TiO_2 coatings embedded in composites used in large aircraft had no change when it was heated. As shown schematically in Figure 5.

4 Conclusions

The formula and preparation of a new kind of resistant high temperature optical fiber coating were investigated. Some important results are summarized as follows:

1) When PVC is 30%, comprehensive performances of coating were the best;
2) This new kind of optical fiber coating can be rapidly solidified without under ultraviolet light and heating source. It can reduce energy applications;
3) This new kind of coating has good heat-resistant performance;
4) It’s easy to control the thickness and roundness of the coating by controlling the speed of pulling out the optical fibers.

5 Outlooks

In future work, a kind of heat-resistant optical fiber coating with SiO_2 would be researched, and a method of quantitative determination to measure the heat-resistant properties of coating.

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