RESEARCH ON STRUCTURAL INTEGRITY OF CFRTP AFTER THUNDER ATTACK

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1 Introduction

The purpose of this research is to examine the thunder resistance (Fig.1) of carbon fiber reinforced thermoplastics (CFRTP) in order to apply them to mass production automobiles. Damage area when spark occurs are measured first for several combinations of fiber volume fractions (V_f) and thermoplastics. Then, CFRTP is found to be easily damaged by electric charge, but the electric charge never penetrates CFRTP plate by the existence of carbon fiber. The first feature is not good for primary structure of airplane from a viewpoint of structural integrity, but this is a not so severe problem in the case of automotive application. On the other hand, the second feature is very good information since protection of passenger is the most important function of automobile [1].

In this research, we aimed to investigate the damage of not only car body but also passenger when the CFRTP car has a lightning strike. We evaluated an influence of a type of resin and carbon fiber volume fraction on the conductivity, critical distance and damage area when spark occurs.

2 Experimental methods

Test items and specimens used in this study are summarized in Table 1. First, we measured the resistance of samples, and calculated electrical conductivity by width, length, and thickness. Then, we used voltage generator made by Green Techno Inc. in order to measure a critical distance when spark occurs. We measured voltage when spark occurs by changing the distance between specimen and spark point by 10, 20, 30, 40, 50 and 80 mm.

Next, we used spot welder and contacted it with the sample by changing the electrical capacity by 500, 1000, 1500, 2000 μF under 400 volt, and observed a characteristics of the damage.

Additionally, we made a hole of 10 mm diameter in the specimens, and observed whether the electrical discharge pass the hole or not. If the electrical discharge can't pass the hole, it can be said that passenger is safety even if the roof of car is damaged by the previous lightning.

3 Experimental results

3.1 Conductivity

Fig.2 shows conductivity of each sample. For metals, we quoted the value of the metal handbook [2]. Higher fiber volume fraction causes higher electrical conductivity.

3.2 Critical distance when spark occurs

Figs.3 to 6 show a critical distance when spark occurs. We did not see much difference by V_f. In airplane CFRP with copper mesh is used, so that the effect of the copper mesh as shown in Fig.11 are measured, but obvious difference can't be confirmed. From these results, the critical distance is not so influenced by the conductivity of the specimens when the specimens have a certain amount of electrical conductivity. And CFRP and CFRTP can be classified as a good conductive material as metals even if the V_f is not so high.

3.3 Damage area by electrical discharge

As shown in Fig.7, the larger electrical capacity induces the bigger damage area, and the damage area of CF/EP are larger than that of CF/EP. Another difference between UD-CFRP and short fiber reinforced CFRP is the depth of damage. In the case of UD-CFRP, depth of damage were relatively shallow and did not change by changing of the electrical capacity.

As shown in Figs.8 to 10, UD-CFRPs show a large crack running in the direction of the fibers, which indicates that the electrical charge can escape more

efficiently. On the contrary, short fiber reinforced ones show deeper damage. It is because that the fiber contact induces higher conductivity in out of plane direction.

3.4 Behavior of the spark at the damaged area

Fig.12 shows that the spark runs to avoid PP, although the spark is absorbed by CFRP as shown in Fig.11. Figs.13 and 14 show the behavior of the spark when the specimens have a hole. In the case of PP (Fig.14), the spark is passing through a whole. But in the case of CFRTP (Fig.13), the spark is absorbed by CFRP form the hole edge and the spark can't reach the another conductor. This result shows a very good feature of CFRP because electrical discharge by thunder can't reach to a human head by the existence of carbon fiber mesh shielding.

4 Conclusion

In this research we measured critical distance and damage area when spark occurs first for several combinations of thermoplastics and carbon fiber volume fractions. Then CFRP and CFRTP are shown to be highly conductive to protect the passengers. And damage form of CFRP and CFRTP is different by matrix resin so we can say that structural integrity of the car body depends on the matrix resin.

In the future, we are going to extend this research into larger electric discharge as an actual thunder. Then we have to consider the best material for car body from a comprehensive viewpoints of structural integrity, passenger safety, pedestrian safety, cost and environmental impact.

References

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[2] "Metal data book (4th ed.)", ISBN4-621-07367-2, Maruzen, (2004).

[3] "Functional Polymers & Plastics Encyclopedia", ISBN-10-4882825643, (2004).

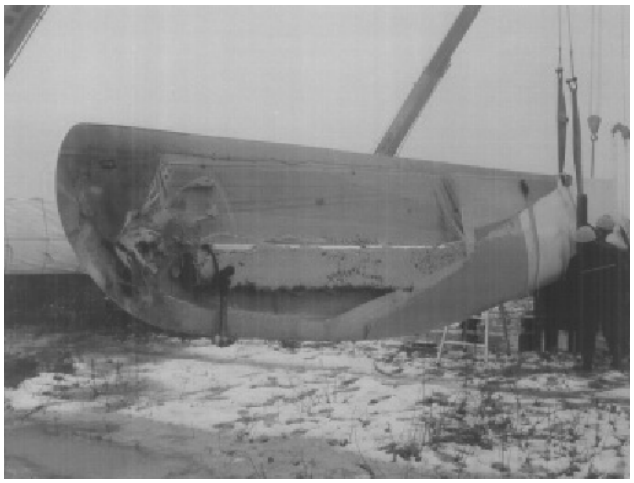

Fig.1 Wind power generation blade damaged by thunder.

Table 1 Test items and specimens used in this study.

	A	B	C	D
Cu		○		
Fe		○		
Al		○		
CF/PP(Vf5%)	○	○	○	
CF/PP(Vf15%)	○	○	○	
CF/PP(Vf25%)	○	○	○	○
CF/PP(Vf25%,UD)				
CF/EP(Vf5%)	○	○	○	
CF/EP(Vf15%)	○	○		
CF/EP(Vf25%)	○	○		
CF/EP(Vf60%)	○	○	○	
PP(Maleic acid)				○

A: evaluation of conductivity
B: critical distance when spark occurs
C: damage area to CFRTP when spark occurs
D: behavior of spark to CFRTP damaged by electric charge

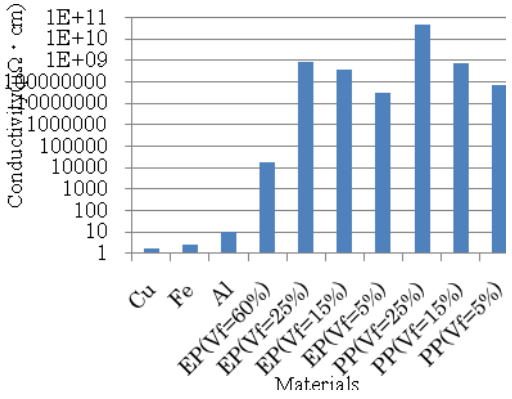

Fig.2 Conductivity of metal, CFRP and CFRTP.

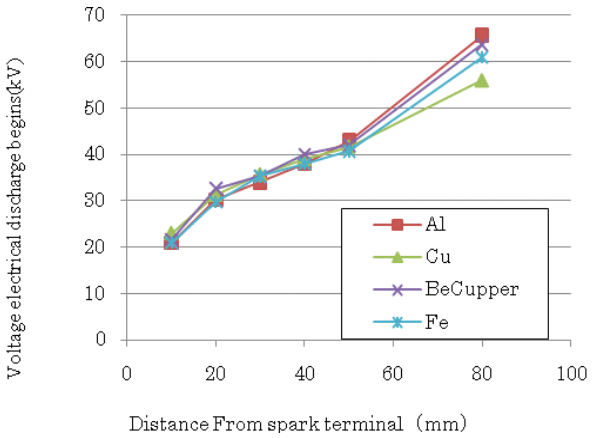

Fig.3 Voltage electrical discharge begins (metal).

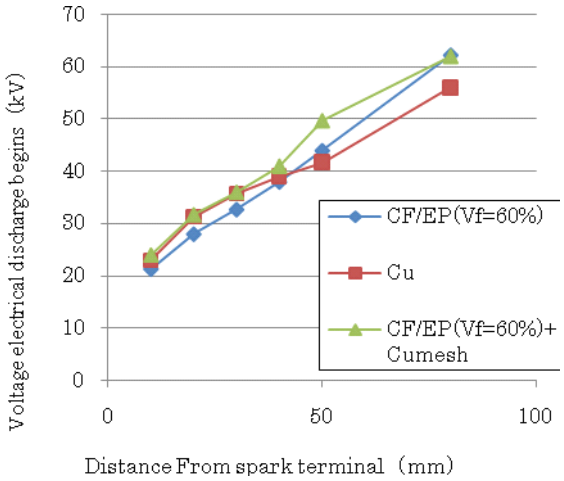

Fig.4 Voltage electrical discharge begins (CF/EP).

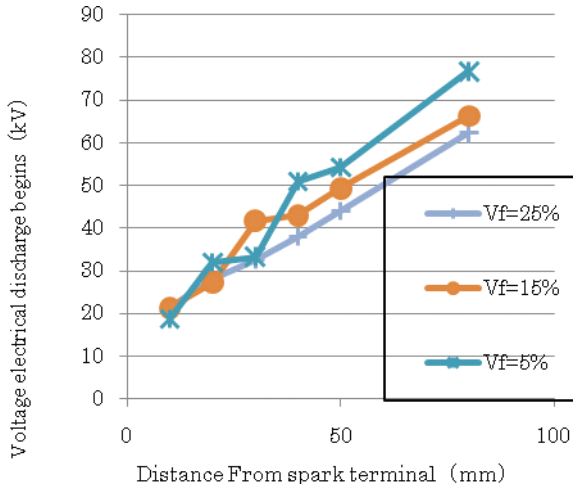

Fig.5 Voltage electrical discharge begins (CF/PP).

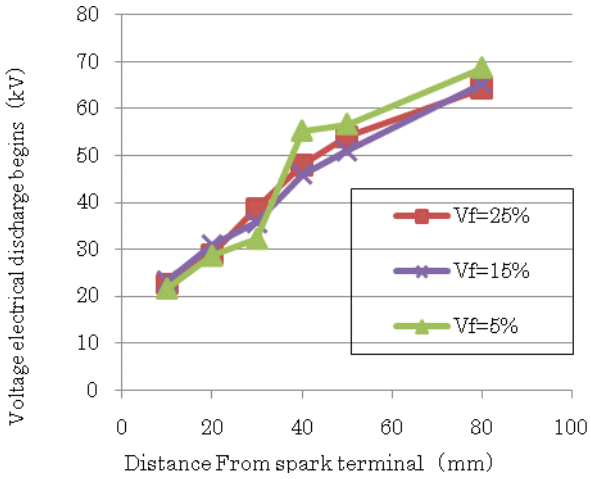

Fig.6 Voltage electrical discharge begins (CF/EP).

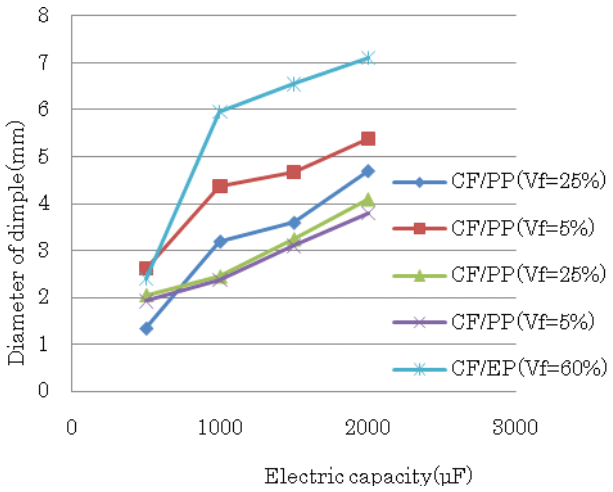

Fig.7 Diameter of dimple generated by spark.

Fig.8 Damage surface of unidirectional CF/PP.

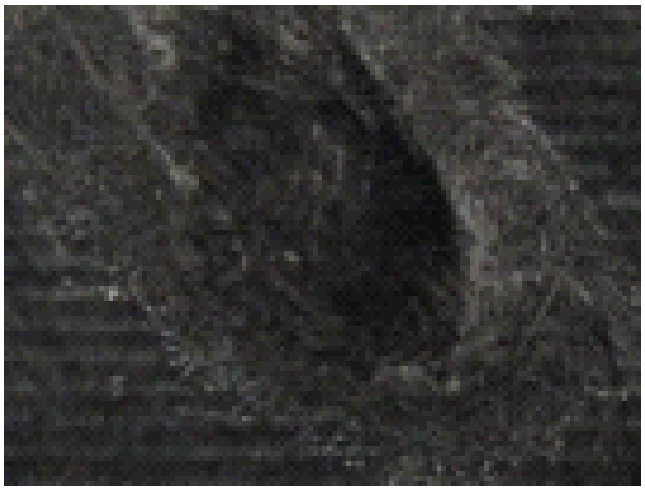

Fig.9 Damage surface of short fiber reinforced CF/PP.

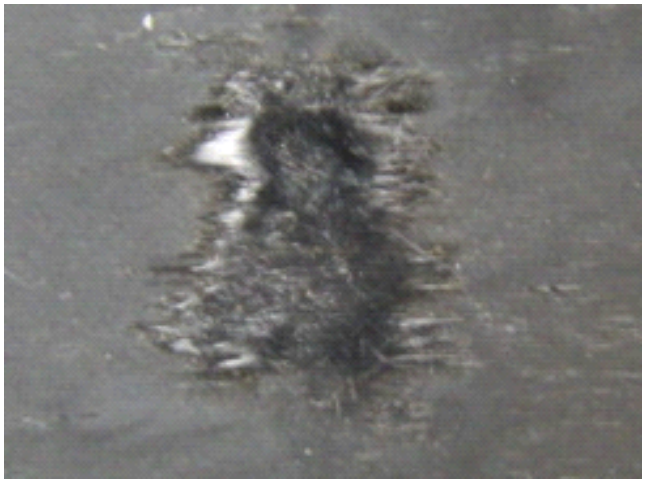

Fig.10 Damage surface of unidirectional CF/EP.

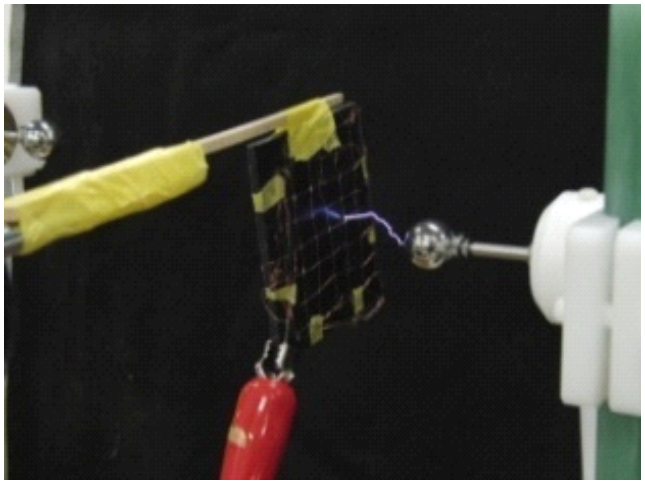

Fig.11 Spark to CFRTP covered with copper mesh.

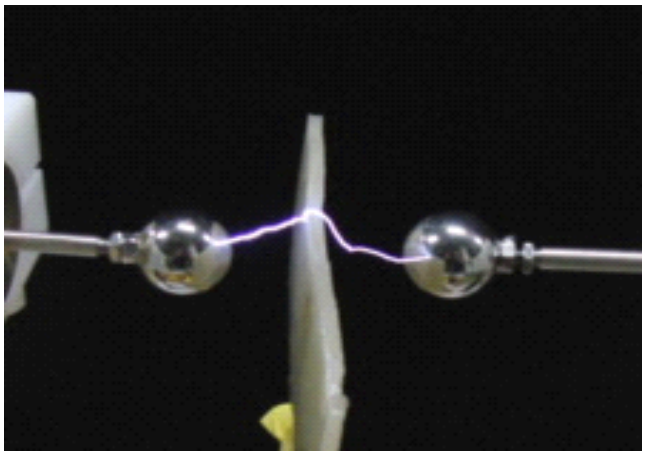

Fig.12 Spark aside from PP.

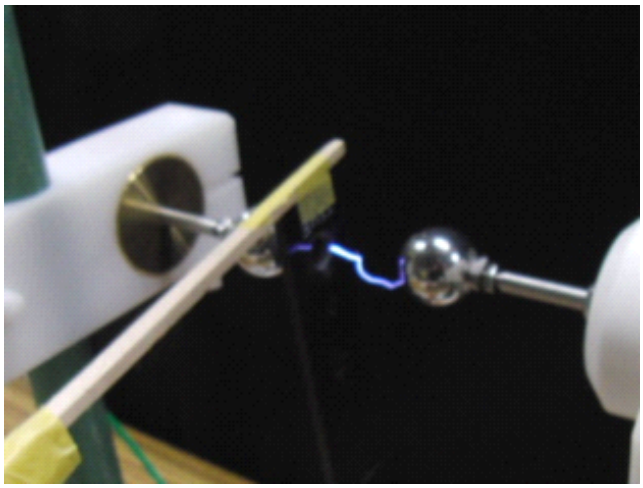

Fig.13 Spark behavior to CFRTP with hole.

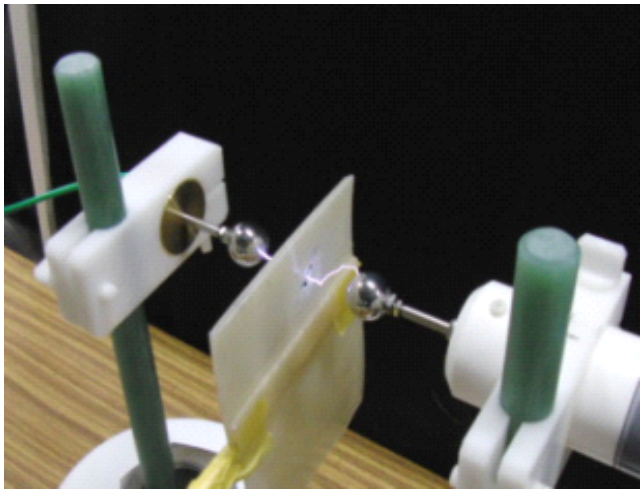

Fig.14 Spark behavior to PP with hole.