Impact Damage and CAI Strength of MR50K/PETI5 Carbon/Tough-Polyimide Composite at Room and High Temperatures

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Introduction

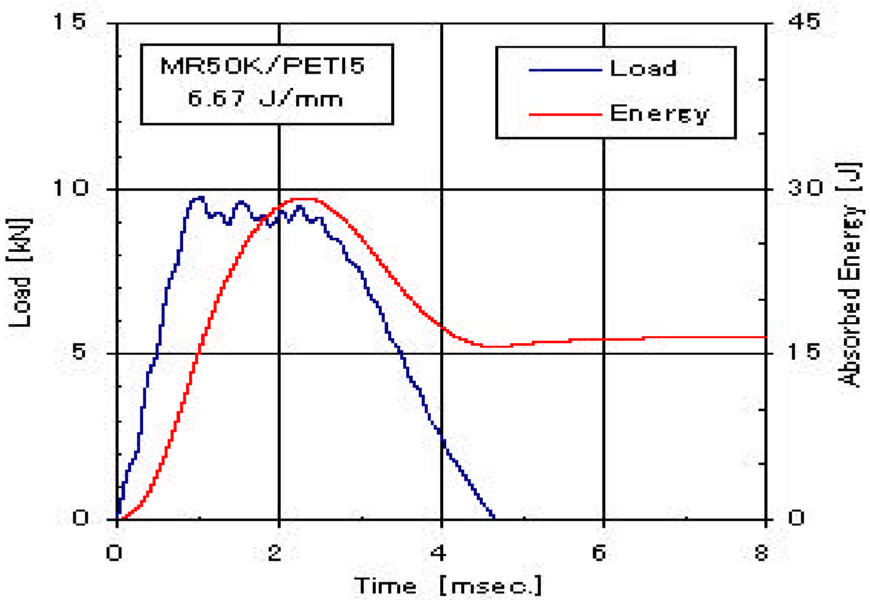
PETI5 was recently developed at NASA as a high heat-resistant and tough polyimide-resin for use in the second generation supersonic transport, HSCT, structures. CAI strength is frequently used for the structural design criteria because of the low CAI strength of general laminated CFRP's. A tough resin CFRP is practically attractive and scientifically interesting, because such a resin is expected to show improved mechanical properties and different behavior from those seen in common epoxy CFRP's. However, there is no report on the CAI behavior of a CFRP of PETI5, a typical tough resin.

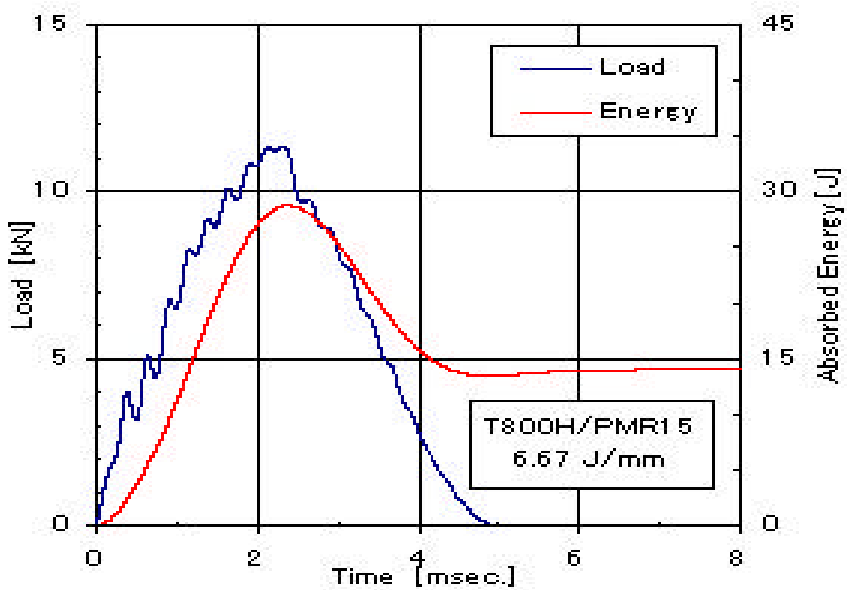
The objective of this study is to experimentally investigate the impact damage and CAI strength of MR50K/PETI5 composite material, with a stacking sequence $[-45/0/45/90]_{4S}$. MR50K is a carbon fiber having medium-elastic modulus and high strength produced by Mitsubishi Rayon Co.

Research contents:

(1) MR50K/PETI5 specimens were impact-tested at room temperature. Load and absorbed energy were measured.
(2) The impacted specimens were observed by an ultra sonic C-scanner and a 3-D ultra sonic inspection system.
(3) The CAI strength at room and high temperatures was obtained.
(4) The cross-sectional area cut from the CAI failure specimens was observed to study the failure mode.
(5) A part of test results were compared with those of T800H/PMR-15, a typical carbon/ brittle-polyimide composite material.

Impact Test Results





MR50K/PETI5

- Trapezoidal load response curve

T800H/PMR-15

- Parabolic or triangular load response curve

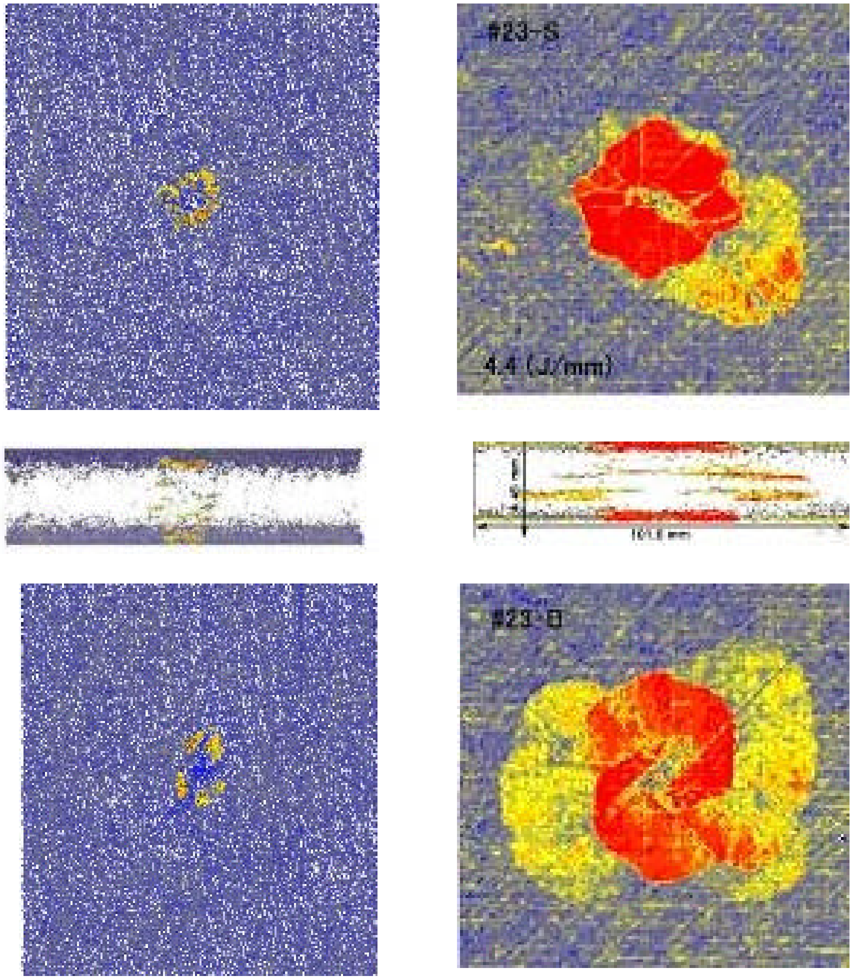
Fig. 1 Load and absorbed energy during an impact test for MR50K/PETI5 and T800H/PMR-15 at IE = 6.67 J/mm.

Delamination of MR50K/PETI5 and T800H/PMR-15

C-Scope
(Upper Surface)

B-Scope

C-Scope
(Lower Surface)



MR50K/PETI5 T800H/PMR-15

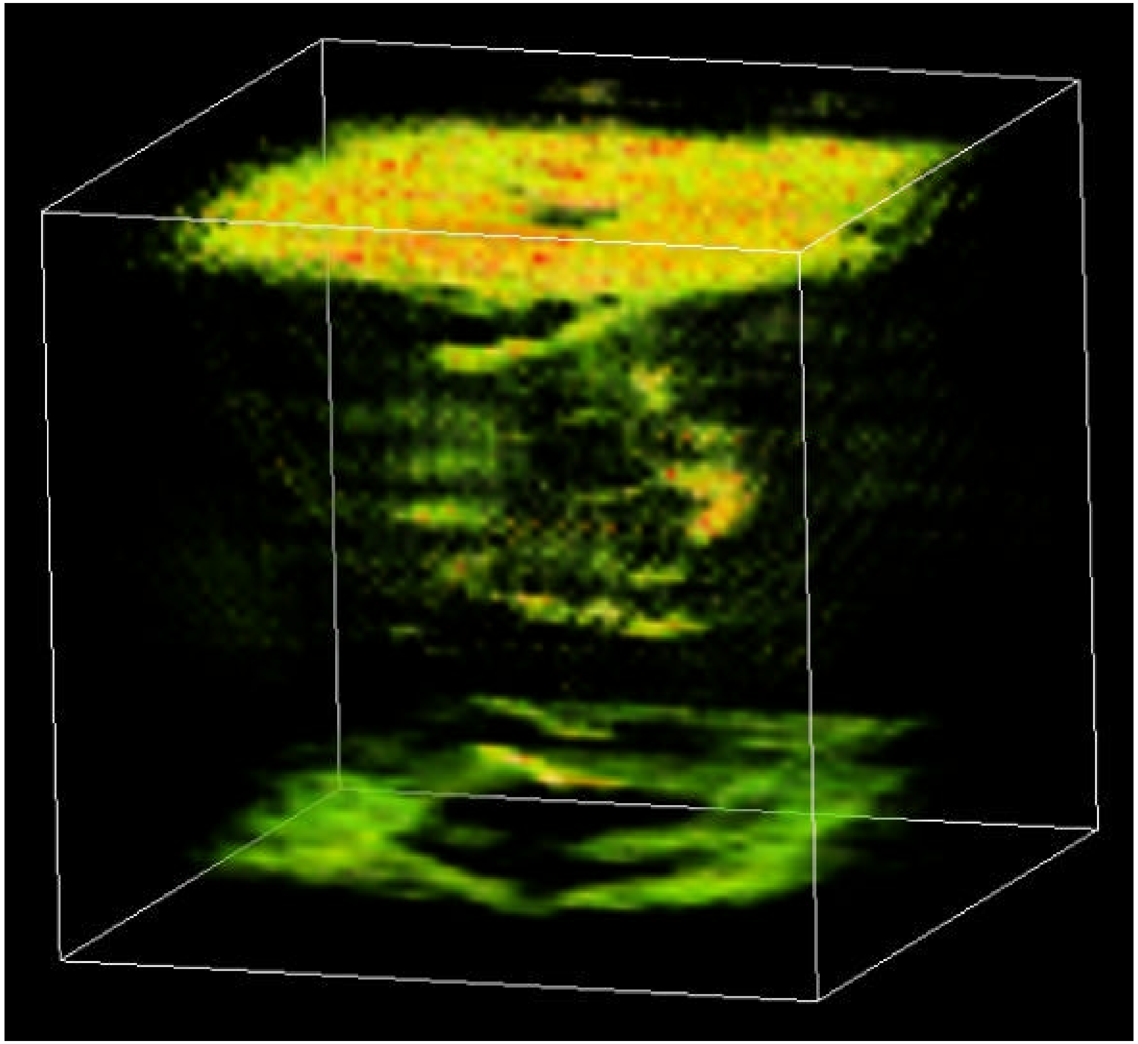
MR50K/PETI5

- Small delamination area.
- Cylindrical damage volume.

T800H/PMR-15

- Large delamination area.
- Frustum damage volume.

Fig. 2 Delamination observed by an ultrasonic C-scanner at IE=4.45 J/mm.



3-D Photo of Impact Damage

- Significant surface damage.
- Helical progress of delamination, clockwise turn from the top to the center, then counterclockwise turn from the center to the bottom. Due to the stacking sequence.
- Small damage volume.

Fig. 3 A three-dimensional view of the impact damage in MR50K/PETI5 from an impact energy of 4.45 J/mm, obtained with a 3-D ultrasonic inspection system.

Delamination Area and CAI Strength

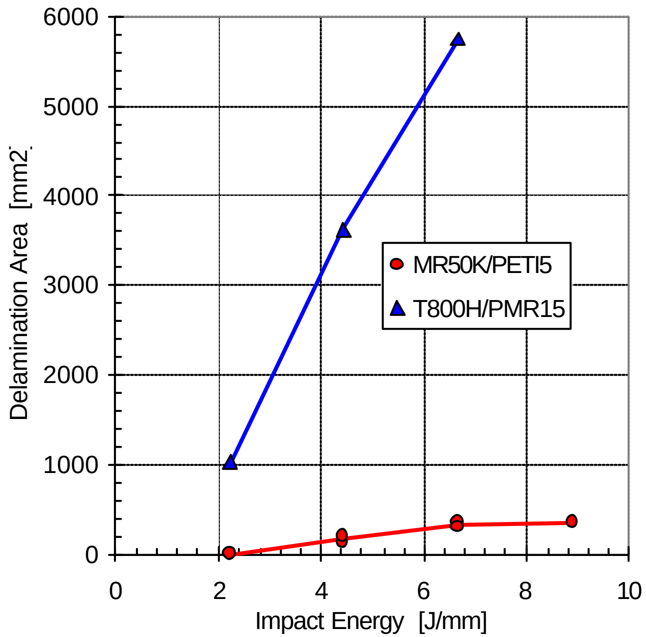


Fig. 4 Delamination area vs. impact energy.

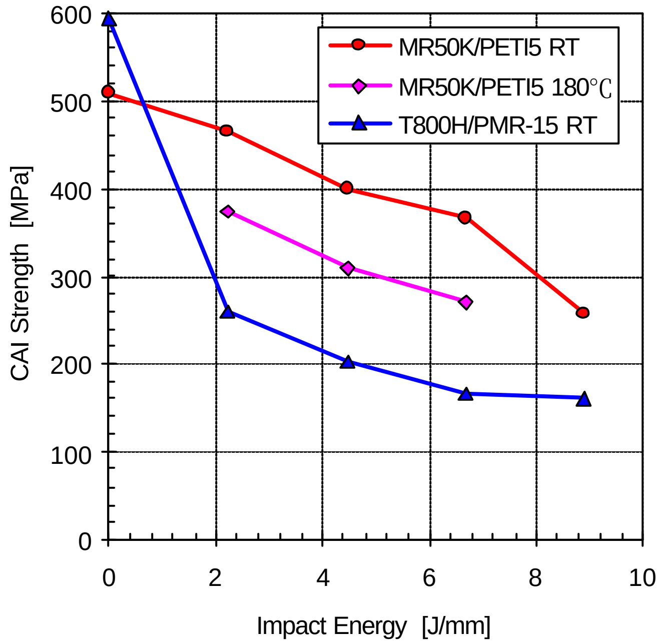


Fig. 5 CAI strength vs. impact energy.

MR50K/PETI5

- Small delamination area.

T800H/PMR-15

- Very large delamination area.

MR50K/PETI5

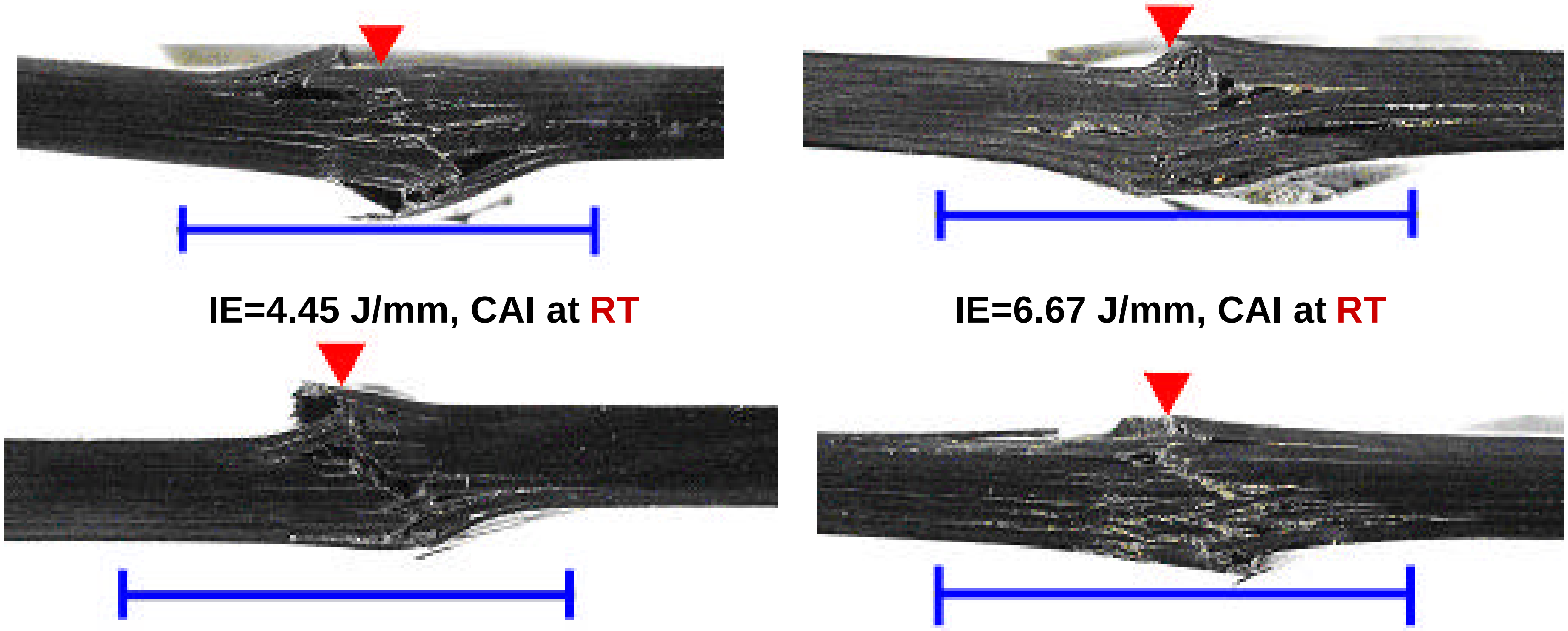
- Static strength is lower than that of T800H/PMR-15.
- CAI strength is much higher than that of T800H/PMR-15, even at 180℃.

T800H/PMR-15

- Higher static strength.
- Significantly lower CAI strength.

Impact Damage and Compressive Failure Aspects of MR50K/PETI5

- Triangle marks indicate impact points.
- The range of a blue line is the delamination length after an impact test and before a compression test.
- Macroscopically shear fracture both at RT and 180℃.



IE=4.45 J/mm, CAI at RT

IE=6.67 J/mm, CAI at RT

IE=4.45 J/mm, CAI at 180℃

IE=6.67 J/mm, CAI at 180℃

Fig. 6 Impact damage and compressive failure observed on the cut section of the specimen after CAI tests at RT and 180℃.

Conclusions

The CAI behavior of a MR50K/PETI5 is as follows:

(1) When a MR50K/PETI5 specimen was impacted, visible damage appeared on the surface, though the delamination area was quite small. The surface damage area was the same size as the delamination area inside of the specimen, when impacted at 4.45 J/mm.

(2) The delamination progressed spirally clockwise from the top surface to the center and then counterclockwise from the center to the bottom surface. Delamination occurred with a rotation from one layer to the next following small lamination angle differences.

(4) The unnotched compressive strength of MR50K/PETI5 at RT was lower than that of T800H/PMR-15. The CAI strength of MR50K/PETI5 at room temperature was much higher than that of T800H/PMR-15. This is due to the high toughness of PETI5, including the different failure modes.

(5) The compressive failure mode of an unnotched MR50K/PETI5 specimen at RT was macroscopic shear fracture. Similarly, for CAI tests the shear failure mode was macroscopically dominant both at RT and 180℃. This failure was accompanied by additional delaminations.

(6) In MR50K/PETI5, the delamination length in the load-axis direction observed for a specimen failed by the CAI test was only a small amount longer than before the CAI test and after the impact test.

(7) Typical and fundamental CAI behavior of a CFRP using PETI5, a highly tough resin, was clarified.

(8) This study demonstrated that the weak out-of-plane strength of CFRP structures can be greatly improved, if a highly tough resin is introduced into CFRP structures.