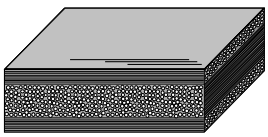
High-cycle fatigue characteristics of quasi-isotropic CFRP laminates

Atsushi Hosoi [1] and Hiroyuki Kawada [2]

[1]Graduate School of Waseda University, [2]Waseda University

Background & Motivation



Carbon Fiber Reinforced Plastic (CFRP) Laminates

Characterization of CFRP

- Light, with high strength
- Good moldability
- Reduction of working line

Energy-Saving, Improvement of efficiency and Lower Costs

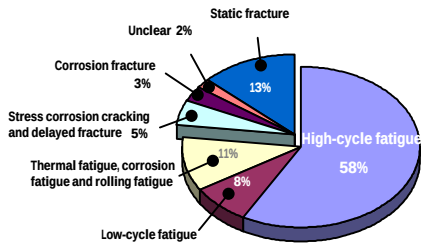
Materials for structure substituted metal

Examples of application with CFRP laminates

CFRP is expected to replace for metal materials and aid the expansion of applications in various fields in the future since it has excellent mechanical properties, such as light, high strength and good moldability.

However, machines under serviced load suffer from the fatigue failures, and it's noted that the high-cycle fatigue fractures are the main factors of the destruction of the machines. Especially, high-speed train, a car used in long-term and the surroundings of a turbine are applied cyclic loadings over 10^8 cycles. Therefore, it's demanded that the long-term reliability of CFRP laminates is established.

Moreover, in many applications of CFRP, they are used in the form of multidirectional laminates. Hence, it's important to investigate high-cycle fatigue characteristics of quasi-isotropic CFRP laminates.



Causes of failure accident

Establishment of long-term durability in CFRP laminates is demanded.

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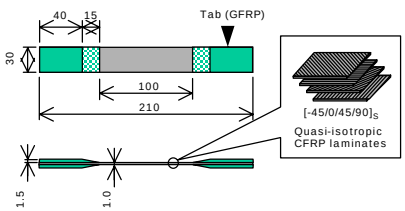
Method & Research

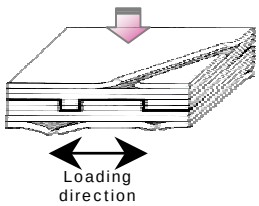
Specimen & Test Condition

The tensile fatigue tests were conducted at the room temperature with a sine waveform under load control conditions using a hydraulic driven testing machine. All tests were run at a stress ratio of R=0.1 and the selected maximum stress levels were 20~60% of the static tensile strength.



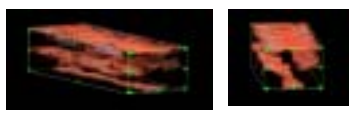
Observation of Damage Growth

3D Ultrasonic Inspection System

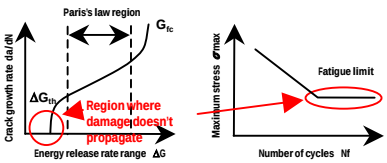


Loading direction

Delamination growth



Evaluation of Damage Growth



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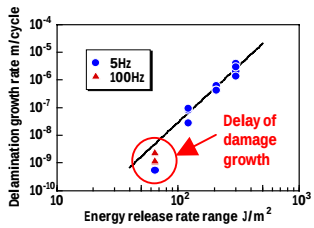
To evaluate damage growth, the energy analysis is used as follows.

1. Energy consumed damage growth is calculated.
2. The relationship between the damage growth rate and the energy consumed damage propagation is investigated as shown in left figures.
3. It is investigated whether there is the regime where damage doesn't grow.

Results & Discussion



It was found that the some plots deviated from a straight line of the modified Paris's law under the test condition of the low applied stress level. Two points are thought to be the reason that the delamination growth rate was delayed.

1. The implication of threshold of the delamination growth.
2. The suppression of the delamination growth due to the delay of the transverse crack propagation.

These results indicate the long-term reliability of CFRP laminates.

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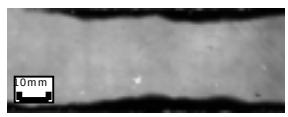
(a) σ_{max}/σ_b=0.5, f=5Hz, N=1.0×10⁴



(b) σ_{max}/σ_b=0.3, f=100Hz, N=1.0×10⁶

The internal damage observed with a soft X-ray photography

Fatigue Test Under Low Applied Stress Level → Extreme Delay of the Damage Growth → Sign of Long-term Durability in CFRP

Conclusion

Conclusion 1 It was found that the damage growth behavior was different according to applied stress level.

Conclusion 2 It was observed that the damage growth delayed extremely when CFRP was subjected to low applied cyclic loading.

Future work Long-term durability of CFRP laminates with initial damage, such as impact is researched for the damage tolerant design.

Internal condition of CFRP damaged due to impact

Acknowledgments: This study is conducting with the support of TORAY and TOSHIBA .

Waseda University