論文 / 著書情報
Article / Book Information

題目(和文)	連続体損傷力学モデルに基づく繊維-樹脂界面はく離現象の特性評価
Title(English)	Characterization of fiber-matrix interfacial debonding based on a continuum damage model
著者(和文)	BudimanBentang Arief
Author(English)	Bentang Arief Budiman
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10139号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:岸本 喜久雄,轟 章,天谷 賢治,水谷 義弘,因幡 和晃,Hwa-Teng Lee
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10139号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Mechanical sciences and engineering	専攻
学生氏名： Student's Name	Bentang Arief Budiman	

申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
指導教員（主）： Academic Advisor(main)	Prof. Kikuo Kishimoto	
指導教員（副）： Academic Advisor(sub)	Asc. Prof. Kazuaki Inaba	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Fiber-matrix interface has been known to give a significant effect on the performance of composite materials as load-bearing structures. Its complexity due to inhomogeneity and micro defects causes difficulty in characterizing the interfacial properties. In an effort to conduct it, single fiber fragmentation test (SFFT) has been widely used. However, the conventional analysis of SFFT finds uncertainty because it neglects interfacial debonding for simplification. In this dissertation, a debonding process is considered to characterize the interface, which can be realized by analyzing matrix stress contours near the interface. A continuum damage model which is based on phenomenological model is implemented to represent the debonding. The importance of debonding appearance to the interfacial properties is intensively discussed.

This dissertation consists of five chapters. In chapter 1, *introduction*, applications and failure mechanisms of fiber-matrix composite are summarized. A comprehensive discussion about interfacial region between fiber and matrix is then given which emphasize on the remaining problems that must be solved in interfacial debonding characterization. The effects of a debonding process at fiber-matrix interface under longitudinal and transverse loadings are also revealed by using a commercial finite element analysis (FEA) software, ABAQUS 6.11. Debonding is found to cause ineffective stress transfer from matrix to fiber and vice versa. Recent relevant studies on debonding process at the interface are also highlighted. These previous studies indicate that overestimated result might be obtained if the debonding on interface characterization is neglected.

In chapter 2, *new parameters for interfacial characterization*, the analysis of conventional SFFT to evaluate interfacial strength (t_o) is briefly explained. An axisymmetric model representing SFFT condition is then developed by using FEA software. The boundary conditions of the model are selected carefully because fiber fraction is very low in actual SFFT condition. To achieve that, parametric studies are conducted for geometrical parameters and mechanical properties of fiber and matrix. The FEA results show that the model is representative to SFFT condition if radius ratio of matrix and fiber is more than equal 20 and a longitudinal length of the model is longer than ineffective length previously defined by Rosen. After obtaining appropriate boundary conditions, simulations with many different values of interfacial properties are conducted. The results show that characteristic lengths in matrix stress contours which relate to interfacial properties i.e. t_o and interfacial fracture toughness (G_c^i) are found. These lengths are potentially used for evaluating interfacial properties.

In chapter 3, *relationship between characteristic lengths and interfacial properties*, the relationship between matrix stress distribution and the interfacial properties on SFFT is comprehensively discussed. t_o as a function of its characteristic length is derived by using stress-based approach. Moreover, non-dimensional analysis to generalize the function is also demonstrated. In order hand, G_c^i as a function of its characteristic length is also derived by using energy-based approach. One-dimensional analysis is demonstrated in this derivation. Those functions are then compared to FEA model provided in chapter 2 in order to assure that applied assumptions are sufficient to model SFFT. The comparison of results shows good agreement between derived functions and FEA results.

In chapter 4, *experimental realization for observing matrix stress contours*, an apparatus consists of a mini tensile test, high resolution of microscope camera, and photoelastic tools are designed. The image of matrix stress distribution captured by using this apparatus is analyzed. An image processing technique

for the captured image is introduced in this chapter. The technique uses hue parameter rather than red, green, and blue (RGB) parameters in order to capture a matrix micro stress contour near the interface. By using this method, characteristic lengths in matrix stress contours can be measured properly. Interfacial properties are finally evaluated by using derived functions in chapter 3. In the experiment, two different fiber surface treatments are examined and it shows that developed method can differentiate the interfacial properties. It is also found that the results with debonding consideration are correcting the conventional results of SFFT. Discussion about the appearance of debonding phenomenon in the interface is also demonstrated here.

In chapter 5, *conclusions and future works*, the conclusion of this dissertation is summarized with potential future works. This dissertation concludes that a novel analysis for SFFT method is introduced by considering debonding phenomenon. Overestimating values of interfacial properties from conventional methods are confirmed and quantified. The analysis considering the debonding process increases the accuracy of interfacial properties evaluation which can make reliable composite failure prediction and determine reliable fiber-matrix interface design.