PMC-23: Bias in the Weibull Strength Estimation of a SiC Fiber for the Small Gauge Length Case
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It is known that the single-modal Weibull model describes well the size effect of brittle fiber tensile strength. However, some ceramic fibers have been reported that single-modal Weibull model provided biased estimation on the gauge length dependence. A hypothesis on the bias is that the density of critical defects is very small, thus, fracture probability of small gauge length samples distributes in discrete manner, which makes the Weibull parameters dependent on the gauge length. Tyranno ZMI Si-Zr-C-O fiber has been selected as an example fiber. The tensile tests have been done on several gauge lengths. The derived Weibull parameters have shown a dependence on the gauge length for the case of small gauge length samples. Fracture surfaces were observed with SEM. Then we categorized the fracture surfaces by the characteristic fracture patterns. Percentage of each fracture pattern was found dependent on the gauge length, too.

PMC-24: Stress Analysis of Single Fiber Composites using Elastoplastic Shear-lag Approach
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An elastoplastic shear-lag analysis is developed to analyze the stress distribution around a fiber break in a composite to consider the plastic deformation in the matrix. One-dimensional shear-lag analysis which considers the fiber, the matrix and the interphase shear layer is conducted. It is assumed that the fiber consists of an elastic material and the matrix and the interphase layer elastoplastic materials. The method of successive elastic solutions is used to determine the plastic strain distribution in the elastoplastic materials.

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Fiber-matrix interfacial adhesion in composites is traditionally evaluated by means of a stress-based parameter. Recently, an interfacial energy parameter is suggested to be a valid alternative. However, the energy-based approaches overestimated the energy release rate to initiate the interfacial debonding (interfacial energy), since the plastic deformation in the vicinity of the debonding was neglected for simplicity. An effect of the plastic deformation on the interfacial energy of a fiber-reinforced polymer matrix composite is studied to evaluate the initiation of the interfacial debonding. The fragmentation tests with a model of glass fiber-reinforced vinyl ester matrix composite were performed, and the interfacial energy with the energy balance method taking into account an energy dissipation of the plastic deformation was calculated. The following results are confirmed: the plastic deformation has a significant influence on the interfacial energy, and the energy balance scheme taking into account the plastic energy dissipation leads to the constant interfacial energy without reference to the amount of the released potential energy. The differences between our model and the previous one are discussed.

PMC-26: Relationship Between Delayed Failure of Glass Fiber and Surface Condition Under Water Environment
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Tests for evaluating delayed fracture of an E-glass fiber were conducted under water environment. Loaded E-glass fibers were immersed in purified water, and time-to-fracture was measured. As a result, the moisture was an environmental factor for the delayed fracture, since the delayed fracture was confirmed under the water. The relationship between the chemical reaction and the fiber strength was evaluated for estimating moisture-absorption effect on the delayed fracture. The E-glass fiber surface was observed using XPS and AFM. Those observations showed that roughness on the glass surface increased due to the moisture-absorption. Furthermore the fiber-bundle strength decreased with increasing immersion time. Results of observation indicated that microscopic cracks accelerated the delayed fracture under the water. We concluded that the delayed fracture of the E-glass fiber occurred by microscopic crack growth due to moisture-absorption on the glass surface with the coupling agent.

PMC-27: Experimental Evaluation of Thermal Conductivity of Carbon Fiber Reinforced Plastics
S. OGIHARA, M. OKITA, Tokyo University of Science; J. SHIMIZU, M. HAYASHIDA, Nippon Steel Corporation; Y. OKABE, N. TAKEDA, The University of Tokyo, E-mail: oghi@rs.noda.tus.ac.jp, ms.area51@yahoo.co.jp

Thermal conductivity of a CFRP unidirectional composite is evaluated experimentally. Effect of fiber volume fraction on the thermal conductivity is discussed both experimentally and analytically. To enhance the thermal conductivity of CFRP, a hybrid matrix material is employed. In the hybrid matrix, alumina particles are embedded in the epoxy resin. Effect of amount of alumina particles is also discussed. a function of applied laminate stress. To discuss the experimental results, a stress analysis procedure considering the material nonlinearity is employed.

PMC-28: Numerical Simulation for Interlaminar Damage Growth of Composite Laminate under Transverse Loading with Cohesive Zone Model
M. NISHIKAWA, N. TAKEDA, The University of Tokyo; T. OKABE, Tohoku University, E-mail: nishikawa@smart.k.u-tokyo.ac.jp

Fiber reinforced plastic (FRP) laminate has a low interlaminar toughness. Interlaminar delaminations tend to occur due to transverse forces, and reduce the compressive strength of the laminate. Numerical approaches have been previously focused on understanding the mechanisms and mechanics of these damages with empirical modeling or experimental information. Instead, a simulating method to predict the damages in the laminate is highly demanded in the design of composite structures. This research proposes a numerical method to simulate the interlaminar damage growth automatically in fiber reinforced composite laminate under transverse loading, using finite element method (FEM). Convolution finite element method is not suited to represent the stress field near the crack tip. Thus, cohesive zone model (CZM) is applied to representing damage-processing zone between volumetric finite elements near the crack tip. Our proposed model assumes a mode-independent traction-COD (crack opening displacement) relation to describe the cohesive law. The cohesive traction of each fracture mode declines irreversibly along a linear dissipative path or elastic-unloading path. The proposed model can consider both stress and energy criteria for damage initiation and propagation. In implementing the model, we devise a simulating method to chase the multiple damages in arbitrary locations individually. This enables us to consider the mutual effects of multiple damages accurately. We also examine various aspects of the proposed method, such as dam-
The efficiency pattern, mesh sensitivity, numerical strategy and computational efficiency. The simulated results for damage growth will be shown in the presentation as well.

Lunch

13:30 p.m. - 15:00 p.m.  
Room A  

SMS-V: SMART MATERIALS AND STRUCTURES, NDE

SMS-27: Environmental Tests on a Reinforced Concrete with Embedded FBG Sensors  
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FBG sensors are optical strain gages that offer many advantages over the conventional ones such as a long term stability. This long term stability of the sensor has to be accompanied by durable contact with the structure. For instance when the sensors are used for monitoring a bridge of a highway the glue used to attach the sensor on the metallic reinforcement may be spoiled by the severity of the environment. In this paper a specimen of a reinforced concrete with an FBG sensor glued on the metallic reinforcement has been subjected to thermal cycles. Tensile tests have been performed on the specimen while reading the FBG response. The wavelength shifts of the sensors compared with the readings of the pulling machine has given information on the quality of the adhesion of the sensor to the specimen and consequently on the effect that the environment had on the glue.

SMS-29: Coupling Deformation Properties of Various Anti-Symmetrical Laminate Composites

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Anti-symmetrical laminate composites have the coupling effect between tensile stress and twisting deformation, and are very attractive as blade materials of aircraft engines. Blades made by anti-symmetrical laminate composites can automatically adjust a stagger angle to better aerodynamic condition with change of rotational speed. Thus, aerodynamic efficiency and stability of aircraft engines can be greatly improved. In this paper, the coupling deformation properties of anti-symmetrical laminate composites were evaluated by tensile tests. Two kinds of tensile-test specimens fabricated by carbon/epoxy laminate composites with difference in anti-symmetrical stacking sequence were tested. On the basis of the tensile-test results, the anti-symmetrical laminate composites were applied for blade materials. The coupling deformation properties of the test blades at high-speed rotating conditions were evaluated by spin tests and FEM. It was demonstrated that test blades twist about 4 deg at 10,000 rpm.

SMS-30: Fabrication of Highly Reliable Advanced Grid Structure

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There is a growing demand for weight reduction of aircraft structure to achieve energy and cost saving. Composite materials such as CFRP are promising candidates to meet this demand. Composite materials, however, have not been fully applied to the aircraft structures especially in commercial area, because extremely high level of reliability is required. A structural health monitoring system is the most effective technology to solve such problem. The authors have been developing new lightweight grid structures with health monitoring systems using FBG sensors for future aircraft applications. The strain data of the rib in a grid structure are to be easily obtained by the embedded FBG sensors since the grid structure has very simple load path. In the present report, A fabrication technique to embed FBG sensors into the grid structure was studied, first. A new apparatus to laminate CFRP prepregs and optical fibers was