# 【事前申込不要】東北大学大学院工学研究科次世代航空機研究センターからのお知らせ

TU Next Seminar in Applied Mechanics and Computational Engineering

## 2017 年 12 月 21 日（木）15：00-17：15 東北大学流体科学研究所 2 号館 5 階大講義室

December 21st 2017 15：00-17：15　5th floor Building2 institute of Fluid Science

## 15：00-16：00 Prof. Tomonaga OKABE

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### Continuum damage mechanics modeling of composite laminates including transverse cracks

In this study, the continuum damage mechanics model for predicting the stiffness reduction of composite laminates including transverse cracks is formulated as a function of crack density. To formulate the model, first the damage variable in the direction normal to the fiber of a ply including transverse cracks is derived. The damage variable is derived by the model assuming a plane strain field in the isotropic plane and using the Gudmundson–Zang model for comparison. The effective compliance based on the strain equivalent principle proposed by Murakami et al. and classical laminate theory are then used to formulate the elastic moduli of laminates of arbitrary lay-up configurations as a function of the damage variable. Finally, the results obtained from this model are compared to the finite-element analysis reported in previous studies. The model proposed in this paper can predict the stiffness of laminates containing damage due to transverse cracks (or surface crack) from just the mechanical properties of a ply and the lay-up configurations. Furthermore, this model can precisely predict the finite-element analysis results and experiment results for the elastic moduli of the laminate of arbitrary lay-up configuration, such as cross-ply, angle ply, and quasi-isotropic, including transverse cracks. This model only considers the damage of the transverse crack; it does not consider damage such as delamination. However, this model seems to be effective in the early stage of damage formation when transverse cracking mainly occurs. The model assuming plane strain field in the isotropic plane which is proposed in this paper can calculate the local stress distribution in a ply including transverse cracks as a function of crack density. The damage evolution of transverse cracks can thus be simulated by determining the fracture criterion. Moreover, we would like to introduce the continuum damage mechanics modeling for composite laminates under high-velocity impact in this presentation. First, we conducted high-velocity impact tests on CFRP laminates and investigated the penetration and damage behaviors. Three kinds of internal damage were observed: fiber breakage, matrix cracking, and delamination. The observed matrix cracks were classified into two categories: multiple (diffuse) cracks around the impact point and large (dominant) cracks on the bottom ply. A continuum damage mechanics modeling was then developed based on these experiment observations. In the present model, both continuous and discrete damage models were implemented for modeling two crack configurations. To validate the presented model, high-velocity impact simulations were performed, and the predicted results were compared with experiment and conventional models in terms of the damage area and distribution.

## 16：15-17：15　Dr. Yoshiaki Abe

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### Petascale simulation with a Python based flow solver PyFR

Many industrial problems, such as design optimization of jet engine turbines, often exhibit high-Reynolds-number flows, involving small turbulent structures. Large-eddy simulation (LES) is one of the most promising methodologies for predicting these flows, which would become feasible due to the recent progress in modern hardware and high-order unstructured schemes for fluid dynamics (e.g., Flux-Reconstruction (FR) methods).　In this talk, I will present application of PyFR, a high-order accurate Python based computational flow solver, to petascale simulation of flow over low-pressure turbine linear cascades. PyFR offers a single Python implementation for efficient computation on multiple / heterogeneous platforms, which is achieved by new software technologies including runtime code generation. The simulation has been performed by over 5,000 K20X GPUs on Titan at Oak Ridge National Laboratory, achieving a peak performance of 13.7DP-FLOPS/s. Another application of PyFR is the development of an a priori resolution estimator for turbulent boundary layer simulations, where an extensive parametric study has been performed for various grid configurations on turbulent channel flows. These insights will be utilized to generate a grid so that both the high accuracy and low computational cost are realized in the framework of implicit LES with high-order unstructured schemes.