論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Characterization of Functionally Graded Material on Dynamics and Fluid Structure Interaction and Its Fabrication by 3D Printing
著者(和文)	SUZIYI
Author(English)	Ziyi Su
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12076号, 授与年月日:2021年9月24日, 学位の種別:課程博士, 審査員:因幡 和晃,轟 章,伏信 一慶,齊藤 卓志,阪口 基己
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12076号, Conferred date:2021/9/24, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Thesis Outline

This thesis is entitled "Characterization of Functionally Graded Material on Dynamics and Fluid Structure Interaction and Its Fabrication by 3D Printing". The outline of this thesis is described as follows.

In Chapter 1, "Introduction," the characteristics and fabrication methods of functionally graded material (FGM), whose composition varies continuously are described. The use of FGM, which was invented as a heat-resistant material for space planes, is expected to be used in various industrial fields due to its potential to reduce thermal stress. For example, the use of FGM in T-junction pipes of power plants where high and low temperature fluids mix is expected to improve the thermal fatigue life from thermal striping. However, the method to deal with this problem by numerical simulation has not been sufficiently established. The purpose of this study is to propose a method for numerical simulation of FGM by comparing it with the theoretical solution of FGM pipe. Then, the validity of the proposed method is validated by experiments using FGM fabricated by a 3D printer. Finally, thermal fatigue life of functionally graded T-junction pipe is evaluated by one-way fluid structure interaction simulation.

In Chapter 2, "A Multi-layer Model for Simulating FGM and Its Validation," a multi-layer model for handling FGM by numerical simulation is proposed and validated by comparing it with the theoretical solution of natural frequency and transient heat conduction of FGM pipe. First, the continuous compositional change of the FGM can be defined by the power law index, and by dividing it into finite layers the continuous compositional change can be reproduced. Then, when the power law index is varied from 0.2 to 5, the natural frequencies of the theoretical solution of the FGM pipe derived from the three-dimensional elastic theory are compared with the results of the numerical simulation in which the compositional change in the thickness direction is reproduced by using 4, 8, and 16 layers model. Then, the transient heat conduction of the FGM pipe is discussed. By comparing the results of the numerical simulation using multi-layer model with the theoretical solution of the transient heat conduction of the FGM pipe, it is shown that the temperature distribution agrees well with the theoretical solution when there are 8 or more layers used in multi-layer model. And when the power law index is 5, the time to reach the steady state solution is longer, which may reduce the effect of temperature fluctuation.

In Chapter 3, "Fabrication of FGM Through a Fused Filament Fabrication 3D Printer," a method of fabricating FGM using a 3D printer by the fused filament fabrication method is investigated, and the validity of the multi-layer model in numerical simulation is experimentally confirmed. First, two-layer specimens made of shape memory polymer and elastomer are fabricated using a 3D printer with two extruders. By measuring the strains from two sides in a thermal tensile test, we have confirmed that it is possible to fabricate specimens with two different material properties in the thickness direction using a 3D printer. Next, FGM specimens made of PLA and ABS are fabricated using a 3D printer with a single extruder, and it is confirmed that the density and equivalent Young's modulus of the FGM specimens varied depending on the feed speed of each filament. In order to verify the multi-layer model, a cantilever beam made of FGM with composition varying in the thickness direction is fabricated, and the natural frequencies are measured. The natural frequencies from the simulation results of 8 layers model agree well with the experimental results, confirming the validity of the multi-layer model.

In Chapter 4, "Fluid Structure Interaction Simulation of Thermal Striping in a Functionally Graded T-Junction Pipe," multi-layer model is used to investigate the fluid structure interaction of a T-junction pipe subjected to thermal striping. Thermal fatigue life of a functionally graded T pipe made of steel and ceramics is evaluated. First, the mixing simulation of high and low temperature fluids considering the heat conduction to the steel pipe is carried out, and the results are confirmed to be consistent with the experimental and

numerical results of other researchers, and the distribution of flow velocity and temperature is clarified for the case of FGM with composition varying in the thickness direction of the pipe. The 6 Hz component in the temperature fluctuation caused by thermal striping has the largest fluctuation power, and the 30° direction in the pipe has the highest fluctuation intensity is confirmed. Furthermore, the thermal fatigue life of the piping is evaluated by the rainflow method, and the FGM shows that the ratio of stress amplitude to mean stress is smaller than that of pipe made of steel or composite steel-ceramic. By calculating the fatigue safety factor based on the Gerber method, the functionally graded T pipe with power law index 5 is shown to have a longer thermal fatigue life.