UNIVERSITI PUTRA MALAYSIA

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By

MOHAMMADMEHDI SHAHZAMANIAN SICHANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2010

DEDICATION

It is my honor to dedicate this thesis to my dearest parents due to their support, encouragement and motivation. I am indebted to them, so I hope I can make up their kindness by this dedication.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of requirement for the degree of Master of Science

THERMOMECHANICAL BEHAVIOR OF FUNCTIONALLY GRADED DISK SUBJECTED TO CONTACT CONDITIONS

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MOHAMMADMEHDI SHAHZAMANIAN SICHANI

December 2010

Chairman: Professor Barkawi Bin Sahari, Ir. PhD

Faculty: Engineering

An analysis of thermoelastic contact problem of functionally graded (FG) rotating disk with heat source due to contact friction is presented in this thesis. Finite element method (FEM) is employed. The material properties of disk are assumed to be represented by power-law distributions in the radial direction. The inner and outer surfaces considered are metal and ceramic respectively for FG disk. Pure material is considered for the pad disk. Coulomb contact friction is assumed as the heat source. Heat source is divided into two equal parts between pad and disk which leads to thermal stresses. ANSYS parametric design language (APDL) is used to simulate the FG disk. FG disk is divided into several layers. To validate the method of division of FGM into several layers, the steady state temperature distribution of FG rotating disk has been obtained by two methods; one using APDL and the other using own developed finite element program. For own developed finite element program, triangular axisymmetric element in which the material properties vary through it is used and weighted residual method is employed. The two results compared very well. Contact status between FG disk and

pure pad disk is investigated for different volume fractions. The appropriate thickness of FG disk for a full-contact status is obtained. It was found that all the areas between pad and disk are in full-contact status when the ratio of pad thickness to disk thickness is 0.66. In addition, the effect of layer number on thermoelastic results of FG disk is studied. It is seen that the thermoelastic behavior of FG disk are similar if the number of layers are bigger than 25. In addition, the influence of contact stiffness factor ($(G)_J$ on contact results is studied. The results show that by increasing $(G_J$, the contact penetration decreases and contact pressure increases. The effect of $(G_J$ on contact total stress, contact friction stress, contact heat flux and temperature distribution are presented as well. It is observed from the thermoelastic results that the total strain due to thermomechanical load is negative for some parts of the disks, whereas the thermal strains are always positive, but by increasing the volume fraction ( ) both of total strain and thermal strain increase. Moreover, it is seen that the radial stress for FG disk and full-ceramic disk are almost always positive, but for some parts of full-metal disk the radial stresses are negative. By and large, by increasing the volume fraction the value of temperature, radial displacement and absolute value of vertical displacement increase. It can be concluded from thermoelastic and contact results that volume fraction of the metal-ceramic has significant effect on the thermomechanical and contact responses of FG disks. The suitable value of for the design of FG disk is 0.5, from the consideration of stress, temperature and contact status.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

KELAKUAN TERMOMEKANIKAL BAGI CAKERA BAHAN FUGSIAN BERGRED DIKENAKAN KEADAAN SENTUHAN

Oleh

MOHAMMADMEHDI SHAHZAMANIAN SICHANI

Disember 2010

Pengerusi: Profesor Barkawi Bin Sahari, Ir. PhD

Fakulti: Kejuruteraan

Analisis masalah sentuhan termoelastik antara cakera berputar yang diperbuat daripada Bahan Fungsian Bergred (BFB) dengan sumber haba akibat dari geseran sentuhan dibentangkan dalam tesis ini. Kaedah unsur terhingga digunakan bagi analisis ini. Andaiannya, sifat bahan ceper di wakili oleh taburan hukum-kuasa mengikut arah jejari. Permukaan dalaman dan luaran yang di ambilkira ialah masing-masing logam dan seramik untuk ceper BFB. Bahan tulen di ambil kira bagi ped cakera. Geseran sentuhan Coulomb di anggap sebagai sumber haba. Sumber haba dibahagikan kepada dua bahagian yang sama antara ped dan ceper yang menyebabkan berlakunya tegasan terma. Bahasa reka bentuk parametrik ANSYS (APDL) digunakan untuk mengsimulasikan cakera BFB. Cakera BFB dibahagikan kepada beberapa lapisan. Untuk mengesahkan kaedah, ceper BFB kepada beberapa lapisan, pengedaran haba yang stabil bagi ceper BFB berputar dilaksanakan dengan dua kaedah, iaitu pertama dengan menggunakan APDL, dan kedua menggunakan program unsur terhingga yang dibina sendiri. Untuk program unsur terhingga yang dibina sendiri, unsur segi tiga dengan paksi simetri yang

mengandungi sifat bahan yang rencam digunakan, dan kaedah sisa bertimbang dimanfaatkan. Kedua-dua hasilnya dibandingkan dengan teliti. Status sentuhan antara cakera BFB dengan ped ceper tulen dikaji berdasarkan ruang geseran yang berbeza. Ketebalan yang sesuai bagi cakera BFB untuk sentuhan lengkap telah diperoleh. Di dapati bahawa semua ruang antara ped dengan cakera berada pada status sentuhan lengkap sekiranya nisbah ketebalan ped dengan ketebalan cakera adalah 0.66. Di samping itu, kesan jumlah lapisan terhadap hasil termoelastik cakera BFB turut dikaji. Di dapati bahawa perilaku termoelastik cakera BFB adalah sama sekiranya jumlah lapisan lebih daripada 25. Selain itu, pengaruh faktor kekakuan sentuhan ($(_G)_J$ pada hasil sentuhan turut dikaji. Hasil kajian menunjukkan bahawa dengan meningkatkan faktor kekakuan sentuhan maka penetrasi sentuhan akan berkurangan dan tegasan sentuhan meningkat. Pengaruh faktor kekakuan sentuhan terhadap tegasan lengkap sentuhan, tegasan geseran sentuhan, fluks haba sentuhan dan taburan haba turut dikaji. Dengan berdasarkan hasil termoelastik, di dapati bahawa terikan lengkap akibat bebanan termomekanikal adalah negatif untuk beberapa bahagian ceper, padahal terikan terma sentiasa positif, namun dengan meningkatkan pecahan isipadu ( ) , terikan lengkap dan terikan terma meningkat. Selain itu, di dapati bahawa tegasan jejari terhadap cakera BFB dan cakera seramik tulen hampir kesemuanya positif, tetapi untuk beberapa bahagian cakera logam tulen, tegasan jejari adalah negatif. Pada umumnya, dengan meningkatkan pecehan isipadu, nilai haba, sesaran jejari dan nilai mutlak sesaran menegak akan meningkat. Dengan berdasarkan hasil termoelastik dan sentuhan, dapat di simpulkan bahawa pecahan isipadu logam-seramik mempunyai kesan yang signifikan terhadap respon termamekanikal dan sentuhan bagi cakera BFB.

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At last, I would like to take this opportunity to express a very warm and immerse gratitude to my dearest parents and family for endless supports and motivations.

I certify that an Thesis Examination Committee has met on 30 December 2010 to conduct the final examination of Mohammadmehdi Shahzamanian Sichani on his thesis entitled "Thermomechanical Behavior of Functionally Graded Disk Subjected to Contact Conditions**"** in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The ommittee recommends that the student be awarded the degree of Master of Science.

Members of the Thesis Examination Committee were as follows:

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Date: 24 March 2011

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement of the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

MOHAMMADMEHDI SHAHZAMANIAN SICHANI

Date: 30 December 2010

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