FREE FLEXURAL (OR BENDING) VIBRATIONS ANALYSIS OF CERTAIN GROUPS OF STIFFENED COMPOSITE PLATES OR PANELS

- - IN FLIGHT VEHICLE STRUCTURES- -

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF

THE MIDDLE EAST TECHNICAL UNIVERSITY

By
Jaber JAVANSHIR HASBESTAN

IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE DEGREE OF
MASTER OF SCINECE
IN
THE DEPARTMENT OF AEROSPACE ENGINEERING

December 2009

Approval of the Thesis

"Free Flexural (or Bending) Vibrations Analysis of Certain Groups of Stiffened Composite Plates or Panels" - - In Flight Vehicle Structures- -

Submitted by Jaber Javanshir Hasbestan in partial fulfillment for the degree of Master of Science in the Department of Aerospace Engineering, Middle East Technical University by,

Prof. Dr. Canan ÖZGEN ______________________
Dean, Graduate School of Natural and Applied Sciences

Prof. D. Ozan TEKİNALP ______________________
Head, Department of Aerospace Engineering, METU

Prof. Dr. Umur YÜCEOĞLU ______________________
Advisor, Department of Aerospace Engineering, METU

Assoc. Prof. Dr. Sinan EYİ ______________________
Co-Advisor, Department of Aerospace Engineering, METU

Examining Committee Members

Prof. Dr. Ozan TEKİNALP ______________________
Department of Aerospace Engineering, METU

Prof. Dr. Umur YÜCEOĞLU ______________________
Department of Aerospace Engineering, METU

Assoc. Prof. Dr. Sinan EYİ ______________________
Department of Aerospace Engineering, METU

Prof. Dr. Rüşen GEÇİT ______________________
Department of Engineering Sciences, METU

Prof. Dr. Murat DİCLELİ ______________________
Department of Engineering Sciences, METU

Date: 9 Dec. 2009

I hereby declare that all information in this document has been obtained presented in accordance with academic rules and ethical conduct. I also confirm that as required by these rules, I have fully cited and referenced all material and results that are not original to this work

Name, Last Name: Jaber JAVANSHIR

Signature: ____________________

ABSTRACT

"FREE FLEXURAL (OR BENDING) VIBRATIONS ANALYSIS OF CERTAIN GROUPS OF STIFFENED COMPOSITE PLATES OR PANELS"

--In Flight Vehicle Structures--

JAVANSHIR HASBESTAN, Jaber

M.S., Department of Aerospace Engineering

Advisor: Prof. Dr. Umur YÜCEOĞLU

Co-Advisor: Assoc. Prof. Dr. Sinan EYİ

December 2009, 385 Pages

In this study, the "Free Flexural (or Bending) Vibrations of Stiffened Plates or Panels" are investigated in detail. Two different Groups of "Stiffened Plates" will be considered. In the first group, the "Type 4" and the "Type 6" of "Group I" of the "Integrally-Stiffened and/or Stepped-Thickness Plate or Panel Systems" are theoretically analyzed and numerically solved by making use of the "Mindlin Plate Theory". Here, the natural frequencies and the corresponding mode shapes, up to the sixth mode, are obtained for each "Dynamic System". Some important parametric studies are also presented for each case. In the second group, the "Class 2" and the "Class 3" of the "Bonded and Stiffened Plate or Panel Systems" are also analyzed and solved in terms of the natural frequencies with their corresponding mode shapes. In this case, the "Plate Assembly" is constructed by bonding "Stiffening Plate Strips" to a "Base Plate or Panel" by dissimilar relatively thin adhesive layers. This is done with the purpose of reinforcing the "Base Plate or Panel" by these "Stiffening Strips" in the appropriate locations, so that the "Base Plate or Panel" will exhibit satisfactory dynamic response. The aforementioned "Bonded and Stiffened Systems" may also be used to repair a damaged (or rather cracked) “Base Plate or Panel”. Here in the analysis, the “Base Plate or Panel”, the “Stiffening Plate Strips” as well as the in-between “adhesive layers” are assumed to be linearly elastic continua. They are assumed to be dissimilar “Orthotropic Mindlin Plates”. Therefore, the effects of shear deformations and rotary moments of inertia are considered in the theoretical formulation. In each case of the “Group I” and “Group II” problems, the “Governing System of Dynamic Equations” for every problem is reduced to the “First Order Ordinary Differential Equations”. In other words the “Free Vibrations Problem”, in both cases, is an “Initial and Boundary Value Problem” is reduced to a “Two-Point or Multi-Point Boundary Value Problem” by using the present “Solution Technique”. For this purpose, these “Governing Equations” are expressed in “compact forms” or “state vector” forms. These equations are numerically integrated by the so-called “Modified Transfer Matrix Method (MTMM) (with Interpolation Polynomials)”. In the numerical results, the mode shapes together with their corresponding non-dimensional natural frequencies are presented up to the sixth mode and for various sets of “Boundary Conditions” for each structural “System”. The effects of several important parameters on the natural frequencies of the aforementioned “Systems” are also investigated and are graphically presented for each “Stiffened and Stiffened and Bonded Plate or Panel System”. Additionally, in the case of the “Bonded and Stiffened System”, the significant effects of the “adhesive material properties” (i.e. the “Hard” adhesive and the “Soft” adhesive cases) on the dynamic response of the “plate assembly” are also presented.

Keywords: Free Vibrations, “Integrally-Stiffened and/or Stepped-Thickness Plates”, “Bonded and Stiffened Plates”, “Plates Reinforced by Bonded Stiffening Plate Strips”, “Modified Transfer Matrix Method (MTMM)”,

Özet

“KUVVETLENDIRILMIŞ KOMPOZİT PLAKA VE PANELLERIN BAZI GRUPLARININ SERBEST TİTREŞİMLERI”

--Hava Araçları Yapılarında**--**

JAVANSHIR HASBESTAN, Jaber

Yüksek Lisans, Havacılık ve Uzay Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Umur YÜCEOĞLU

Ortak Tez Yöneticisi: Doç. Dr. Sinan EYİ

Aralık , 2009, 385 Sayfa

Bu çalışmada, kuvvetlendirilmiş “Plaka ve Panel Sistemlerin Serbest Titreşimleri” incelenmiştir. Bu bağlamda, ilk önce, “Kendinden-Kuvvetlendirilmiş Plaka ve Panel Sistemlerinden”, “Tip 4”, “Tip 6” teorik olarak analiz edilip ve numerik olarak, “Mindlin Plaka Teorisini” kullanarak, çözülmüştür. Burada doğal frekanslar ve onlarla ilgili mod şekilleri, 6 ıncı moda kadar, her “Dinamik Sistemi”ne elde edilmiştir ve her “Problem” için önemli parametrik çalışmalar gösterilmiştir. İkinci aşamada, “Grup II” nin “Klas 2” ve “Klas 3” “Yapıştırılmış Kuvvetlendiricili Sistemi” çözülmüştür. Bu “Plaka Sistemi” bir kaç plakadan ölușmaktadır, kuvvetlendirici plakalari, ayrı çok ince adhesive tabakası ile taban plakaya yapıştırılmaktadır. Bu suretle, taban plakanı, uygun yerlerde daha güçlü hale getirip, ve istenen dinamik özellikleri elde edilecektir. Daha önce adı geçen yapıştırılmış kuvvetlendiriciler onarım için de kullanilabilir. Bu çalışmada, yapıştırılmış kuvvetlendiriciler va taban plaka aralarında bağlantı kuran yapıştırıcı tabakası bir linear continous media dan oluşmaktadır. Ayrıca, bu plakalar, bir "Minlin " plakası olarak analiz edilmiştir. Bu suretle, kesme deformasyonlar teorik formulasyon da göz önüne alınmıştır. Her "Problem" de "Yöneten Denklemler", birinci derece adi diferansyel denklemlerine dönüştürülmüştür. Bir başka ifade ile, "Serbest Titreşim" problem, ki bir başlangiç ve sınır değeri problemidir, adı geçen çözüm metodunu kullanarak, "İki Nokta ve Çok Nokta Sınır Değeri Problemine" dönuştürülmüştür. Bir sonraki kademede, "Yöneten Adi Diferansyel Denklemler" "State Vector" şeklidne düzenlenmiştir. Bu denklemler, numerik çözüm metodu yani "Modified Transfer Matrix Method (MTMM)" kullanarak integre edilmiştir. Numerik sonuçlarda mod şekilleri ve onlarla ilgili frekanslar 6 ıncı moda kadar değişik sınır şartlarina göre sunulmuştur. Bazı önemli parametrelerin etkisi doğal frekanlar üzerine incelenmiş ve sunulmuştur. "Yapıştırılmış kuvvetlendiricili Plaka ve Panel Sistem"inde yapıştırıcının material özellikleri nin etkisi bu sistemin titreşim üzerinde de gösterilmiştir.

Anahtar kelimeler: "Serbest Titreşim", "Kendinden Kuvvetlendiricili Plaka ve Panel Sistemi", "Yapıstırılmiş Kuvvetlendiricili ile Kuvvetlendirilmiş olan Plaka ve Panel Sistemi", "Modified Transfer Matris Metodu (MTMM)"

Dedicated to Gazi Mustafa Kemal ATATÜRK

ACKNOWLEGEMENTS

I would like to thank Prof. Dr. Umur Yüceoğlu for his great support from the begining of my enterance to METU upto the end of preparation of the present thesis, also I would like to express my gratitude to the Department of Aerospace Engineering, METU , for providing me with the great opportunity of pursuing graduate studies. I also thank my family for their kind support.

Table of Contents

TABLES

FIGURES

b) “Soft” Adhesive Case