UNIVERSITI PUTRA MALAYSIA

EXPERIMENTAL DERIVATION OF STIFFNESS MATRIX OF SHEET METAL JOINT

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

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Chair: Associate Professor Rizal Zahari, PhD
Faculty: Engineering

The thesis presents the study on the three-dimensional experimental derivation stiffness matrix of sheet metal joint substructure based on the basic principle of finite element method (FEM). Normally in FEM, the material properties of a complete structural system can be represented by Young's modulus, Poisson's ratio, density, surface area and etc but if the structure deflection influence coefficients or stiffness matrix are known, the behavior of complete structural system can be defined. One of user defined element existed in NASTRAN that rarely used is general (GENEL) element, the GENEL entry is used to define general elements whose material properties are defined in terms of deflection influence coefficients or stiffness matrix which can be connected between any number of grid points. A systematic approach of stiffness matrix extraction of a sheet metal joint has been successfully studied and developed. The experimental

stiffness matrix which represents the actual behavior of the substructure is then entered into NASTRAN as a new element, GENEL. Comparison of results between the experimental and the finite element analysis is carried to validate the method employed. Excellent agreement with the experimental results has been observed which confirms the accuracy of the approached employed. The methodology of extraction stiffness coefficients experimentally has also been successfully developed on the basis of the direct stiffness method.

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

UJIKAJI PENERBITAN MATRIKS KEKAKUAN UNTUK PENYAMBUNG KEPINGAN LOGAM

Oleh

ABDUL HAFIEZ YUSOFF

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Pengerusi: Profesor Madya Rizal Zahari, PhD
Fakulti: Kejuruteraan

Tesis ini menerangkan ujikaji penerbitan matriks kekakuan untuk penyambung kepingan logam berdasarkan prinsip-prinsip asas dalam analisis unsur terhingga (FEA). Kebiasaannya dalam FEA, sifat bahan untuk sesuatu sistem struktur diwakili oleh modulus Young, nisbah Poisson, ketumpatan, luas permukaan, dan lain-lain tetapi sekiranya nilai pekali pesongan atau matriks kekakuan diketahui, kelakuan sesebuah sistem struktur dapat diramalkan. Salah satu unsur yang dapat diatur cara oleh pengguna dalam NASTRAN ialah GENEL. GENEL merupakan unsur yang amat jarang sekali digunakan oleh pengguna dalam NASTRAN kerana pengguna perlu memasukkan sendiri nilai pekali pesongan atau matriks kekakuan ke dalam NASTRAN. Satu kaedah sistematik telah dibangunkan untuk mendapatkan matriks kekakuan secara ujikaji dan terbukti telah berjaya. Matriks kekakuan yang diperoleh secara ujikaji kemudiannya

akan dimasukkan ke dalam NASTRAN sebagai unsur baru yang dikenali sebagai GENEL. Hasil perbandingan keputusan analisis antara ujikaji dan analisis unsur terhingga menunjukkan tidak banyak perbezaan antara keduanya dan ini mengesahkan ketepatan kaedah yang telah dibangunkan.

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APPROVAL SHEET 1

I certify that a Thesis Examination Committee has met on 7 March 2013 to conduct the final examination of Abdul Hafiez Yusoff on his thesis entitled **"Experimental Derivation of the Stiffness Matrix of Welded Tube Joint"** 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 Committee recommends that the student be awarded the Master of Science.

Member of the Thesis Examination Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotation 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.

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ABDUL HAFIEZ YUSOFF

Date: 7 March 2013

TABLE OF CONTENTS

LIST OF TABLE

Page

LIST OF FIGURES

LIST OF ABBREVIATION

DSM	direct stiffness method
FEA	finite element analysis
FEM	finite element method
GENEL	general element

CHAPTER 1 : INTRODUCTION

1.1 : Background of Study

The development of the finite element method (FEM) owes much to the early work of individuals involved in aerospace structural design, and it is not surprising that this field continues to lead in the practical application of the method. Today FEM has been used in wide range of field other than aerospace engineering and expanded in many ways of application.

Mathematical model is essential to solve the geometrical model of a problem in FEM. The mathematical model may have degree of freedom as much as possible, but it should be identical as much as possible to the real structure. Displacement method is a method often used in solving problems in the FEM because it is the basis.

When computers came into use for structural analysis, it was soon recognized that the displacement method could be easily formulated for computer programming, and it has become the dominating approach in FEM (Holland, 1974).

In design stage, FEM is used to analyze structure behavior and predict what would happen under certain loads. One of the methods used to analyze statically indeterminate complex structure is direct stiffness method. As one of the methods of structural analysis, the direct stiffness method, also known as the displacement method or matrix stiffness method, is particularly suited for computer-automated analysis of complex structures including the statically indeterminate type. This is a matrix method that makes use of the members' stiffness relations for computing member forces and displacements in structures. The direct stiffness method is the most common implementation of the FEM ("Direct Stiffness Method," 2010).

Most engineering structure would be a single solid unit of the same material involving one manufacturing operation. However, there is engineering structure to be fabricated as separate components that should subsequently joined aim to facilitate movement from one place to another. Methods used today for joining metallic structural components to others include welding and mechanical fastening (Ankara & Dara, 1994).

Joints in structural system have important role because they represent potential weak points in the structure, the design of the joint can have a large influence over the structural integrity and load-carrying capacity of the overall structure (McCarthy, McCarthy, & V.P. Lawlor, 2005).

This study shall also investigate the application of MSC NASTRAN general (GENEL) elements on a sheet metal joint. The method present in this thesis shall provide a different way of modeling engineering substructure in FEM code NASTRAN.

1.2 : Problem statement

NASTRAN has a wide variety of elements to help user define the physical characteristic of the model. One of the elements that rarely used but has variety application in structural analysis is GENEL. Although the stiffness matrix of most structures can be readily obtained via numerical or computational methods, there are cases where due to the complexity of the material properties or geometry of structure, it is difficult and time consuming to model using numerical techniques accurately. One of the ways to overcome this problem is to obtain the structure's stiffness coefficients experimentally and enter the stiffness matrix in NASTRAN as GENEL. Another advantage of using GENEL is that they can provide means of protecting confidential designs features or secret while allowing only a stiffness matrix representative model to be passed on to a subcontractor. Previously, no works have been done to generate stiffness coefficients experimentally, with the technique provided it will advance our knowledge in experimental design technique. This study would add knowledge in NASTRAN GENEL that has a wide variety of applications.

1.3 : Justification for the study

The finite element approach simulates the structural properties with mathematical equation written in matrix format in FEM code. The GENEL is used to define general elements whose properties are stated in terms of stiffness matrices which can be connected between any numbers of nodes. The part of a structure could be represented by GENEL in term of stiffness matrix of experimentally or simulation measured data.

For confidential design features; GENEL could be used as stiffness coefficients representative model to be passed on to subcontractor. This means that confidential material and design features used by main contractor can be prevented from falling into the hands of subcontractors if the whole structure with components strategically shared between several companies.

The same concept could be applied to a substructure with unknown mechanical property. Stiffness matrix of relevant substructure could be analyzed in NASTRAN by entering experimental stiffness matrix code. In this method, more accurate representation of a substructure behavior could be obtained.

1.4 : Objectives

The main objective of this study is to develop an experimental technique to extract three dimensional stiffness coefficient of a structure. The following research objectives are formulated:

I. To develop a test rig and procedures for obtaining stiffness matrix of a sheet metal joint experimentally.
II. To include the experimentally measured stiffness matrix into NASTRAN new element (GENEL).
III. To integrate GENEL into a complex engineering structure and perform validation against FEA results.

1.5 : Scope of study

The scope of this study is to obtain the stiffness coefficients of a welded sheet metal joint in linear static region experimentally. Experimental work should be limited to linear analysis and statics motions only. Welded sheet metal joint used in the study is welded at both ends and considered homogeneous material. Comparison of results between the experimental and the finite element analysis is carried out via three test cases to validate the method employed.

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