"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor Mechanical Engineering (Thermal – Fluids)"

Signature : ....
Name of supervisor : ...Lee Yuk Choi...
Date : ....9/12/2005........

NUMERICAL SIMULATION OF TWO – DIMENSIONAL TRANSIENT HEAT CONDUCTION USING FINITE ELEMENT METHOD

OOI HOOI WOON

A project report submitted in partial
fulfillment of the requirements for the award of
the Degree of Bachelor Mechanical Engineering (Thermal & Fluid)

Faculty of Mechanical Engineering
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December 2005

"I hereby declared that this thesis is my own work except the ideas and summaries which I have clarified their sources"

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Specially dedicated to my family, friends and companion

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It is my pleasure and gratitude to thank my fellow project mate Mr. Wong Sau Keong where we have been gone through a lot of discussion and testing before we can actually start the our project's simulation. Although sometime argument happens due to different simulation tools been used, but it will not terminate my determination to complete this thesis. His valuable and wise inputs had made my simulation analysis proceed smoothly.

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ABSTRACT

A simulation study is undertaken by using MSC/NASTRAN to analyze the transient heat transfer analysis which has embedded with finite element method in order to run the numerical simulation in a two dimensional slab materials. This study investigates the temperature changes with time for a given boundary condition using different delta time for 32 and 200 elements. Comparison between MSC/NASTRAN and Mathlab was also performing in this analysis. An attempt was made to analyze the transient heat conduction for different materials namely aluminium, glass and building brick. Quadrilateral and triangular elements are being used in the analysis. From the simulation results it was showed that 200 elements with combination of delta time 0.4 seconds yield a better result and achieve steady state faster by providing more accurate analysis. Not much significant difference was observed between MSC NASTRAN and Mathlab with an error less than 1%, which is deemed satisfactory. The results also showed that delta time 10 seconds achieve steady state slightly faster due to the time spacing. Quadrilateral elements is suitable in two-dimensional because it provide sufficient flexibility as comparing to triangular mesh. Aluminium was found is the best material to release heat to surrounding faster comparing with building brick and glass. For more temperature difference applied on the both side of the materials, we can have a better cooling conditions.

ABSTRAK

Kajian simulasi ini adalah dengan menggunakan MSC/NASTRAN untuk menjalankan analisis permindahan haba fana yang telah terkandung dengan kaedah unsur terhingga bagi menjalankan analisis secara simulasi berangka dua dimensi dalam bahan papak. Keutamaan analisis ini adalah berasaskan perubahan suhu melintasi masa bagi graf suhu lawan masa dengan menggunakan unsur 32 dan 200..Perbandingan antara MSC/NASTRAN dengan Matlab juga merupakan sebahagian dalam anlisis Bahan yang berbeza seperti aluuminium, kaca dan bata bangunan akan dianalisis untuk menentukan fana konduksi haba. Unsur segiempat dan unsur segitiga juga dipilih dalam analisis ini. Daripada keputusan analisis, ia menunjukkan kombinasi unsur 200 dan delta t = 0.4s mencapai keadaan mantap lebih cepat dengan meberikan analisis yang lebih tepat. Tiada perbezaan yang munasabah antara MSC NASTRAN dan Matlab dengan ralat yang kurang daripada 1%. Delta masa 10 saat mencapai keadaan mantap lebih pantas disebabkan selang masa yang diambilkira adalah lebih besar. Dalam analisis 2-D, unsur segiempat adalah lebih sesuai di mana ia adalah lebih mantap kerana memberikan kefleksibelan yang memadai dengan berbanding dengan unsur segitiga. Aluminium merupakan bahan yang dapat membebaskankan haba ke alam dengan kadar yang cepat berbanding dengan bata bangunan dan akhir sekali ialah kaca. Dengan perbezaan suhu yang lebih diaplikasikan ke tepi kedua dua belah kepingan, kita boleh mendapat keadaan penyejukkan yang lebih baik.

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CHAPTER I

INTRODUCTION

This chapter discussed about the overview of the heat conduction treatment which had been applied into various different field from engineering to building constructions. It also provides dynamics of heat intensity and flow within objects knowledge of the temperature and its transient distribution for heat energy analysis. Objective and scopes of the simulations analysis based on MSC/Nastran in compliance with finite element method was discussed.

1.1 Overview

In our treatment of heat conduction we have gradually considered more complicated conditions. We began with the simple case of one dimensional, steady state condition with no internal generation, and we subsequently considered complications due to multidimensional and generation effects. However, we have not yet considered situations for which conditions change with time.

We now recognize that many heat transfer problems are time dependent. Such unsteady, or transient, problem typically arises when the boundary conditions of a system are changed. For example if the surface temperature of a system is altered, the temperature at each point in the system will also begin to change.

Although many simple steady-state and transient heat conduction problems can be solved analytically, solution for more complex problems are the best obtained numerically. Numerical solution methods are particularly useful when the shape of the solid is irregular, when thermal properties are temperature or position-dependent, and when boundary conditions are nonlinear.

Several of the detailed energy analysis programs use a time series solution for transient heat conduction. One of the main advantages of time series solutions over other numerical techniques such as finite difference and finite element methods is a substantial increase in the simulation speed. Other numerical techniques require the calculation and storage of every single nodal temperature at every time step. This increases the number of calculations required and the amount of storage necessary. In most cases, the temperature distribution inside a building element is of no intrinsic value to the overall simulation. Moreover, the time steps required to provide accurate simulation results tend to be shorter than with time series solutions.

Many engineering applications today only on the dynamics of heat intensity and flow within objects knowledge of the temperature and its transient distribution are vital in design and implementation. Therefore, in this study we would like to predict the temperature of an object given a set of initial and boundary conditions.

Finite element methods (FEM) are widely used in structural mechanics and also applicable to heat conduction problems. An object is divided into discrete spatial regions called finite elements. The most commonly used is the triangular element for two-dimensions and for three-dimensional element tetrahedron. The finite-element method allows the heat conduction equation to be satisfied in an average sense over the finite element; thus, the elements can be much larger than the control volumes used in finite-difference methods. The used of triangles or tetrahedrons for elements allows the approximation of complex and irregularly shape object.

Application of the methods leads to a set of algebraic equations, which are solved by matrix inversion and iteration. Compared to finite-difference methods, the formulation of these equations is considerably more involved and required more effort, as does writing a computer program to implement the procedure. However, once written, finite-element computers programs tend to be more versatile than their finite-difference counterparts. Choice of which method to use is perhaps dictated by the objective rather than by the intrinsic virtues of the method. For example, calculation of temperature variations in solids is often required for the purpose of determining thermal stresses. Since the finite-element method is preeminent for stress calculations, many standard computer codes use the finite-element method to calculate both temperatures and stresses in one package.

This study presents the uses of MSC/NASTRAN and advantages of using this software for Heat Transfer Analysis. Finite element method is a powerful numerical technique for analyzing structures/continua. Several commercial software is available for FE analyses MSC/NASTRAN is the most widely used general purpose software of FE analysis. It has versatile applications in the filed of static, dynamic, heat transfer. MSC/NASTRAN also offers linear and non-linear (material, geometric, and boundary conditions exchange in enclosures, specified temperatures, surface and volumetric heat loads, and elements of thermal control systems) analysis.

1.2 Objectives of the Project

The project is concerned with the two dimensional transient heat conduction in a slab to evaluate how successful the simulation by using the MSC/NASTRAN. The objectives are as follows:

1) To perform a numerical simulation of the heat flow.

2) To determine the temperature distribution as a function of time.

1.3 Scopes of the Project

The scopes of project are as follows:

1) Literature review specifically on numerical simulation of two-dimensional transient heat conduction.

2) Familiarize the use of MSC Nastran package as a tool.

3) Comparison with available analytical solution of previous work.

1.4 Gantt Chart

The progress of the project was shown in Chart 1.1 and Chart 1.2

Project Activities	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Topic discussion															
Gathering information															
Literature review															
Familiarize with MSC Nastran software															
First draft															
Power point															
First presentation															

Chart 1.1: Progress of the 1st Project

Project Activities	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Running MSC/N4W															
Data collection															
Data analysis & Discussion															
Second draft															
Power point															
Second presentation															
Writing of project report															

Chart 1.2: Progress of the 2nd Project.

CHAPTER II

LITERATURE REVIEW

This chapter reviewed various study and analysis's results and findings from previous researcher's researches. Most the review was based on finite element methods. Different condition of steady state and boundary conditions either for 1-D, 2-D or 3-D also been discussed. Other method such as Boundary Element Method (BEM), Laplace Transform Boundary Element Method (LTBEM), Modified Boundary Element Method (MBEM) and other methods also been taken for reviewed and analyzed.

2.1 Literature Review

In year 1993, Moncef Krarti presented a general solution for the steady state heat conduction problem under a slab-on-grade floor with horizontal insulation contributed thermal performance of the above-grade portion of buildings has been significantly improved after the energy crisis of the 1970s. The soil temperature field, the heat flux along the slab and the total slab heat loss are obtained and analyzed using the Inter zone Temperature Profile Estimation (ITPE) technique. In particular, it is shown that outer insulation is effective in reducing heat loss from slab edge and the thermally is better extend the length of outer edge insulation rather than increase the insulation thermal resistance over a short distance from the slab edge. Finally, the total heat loss was found to be significantly affected by the water table level.

Bomberg, et.al (1978) investigated the moisture redistribution process in an insulation slab that was sprayed with water before placing it in a heat flow meter apparatus which emphasized on the influence of moisture on the heat transfer through building materials. Vafai and co-workers (1986) have performed detailed numerical studies of the moisture transfer in insulations for several different boundary conditions.

In year 1994, N.E.Wijeysundera and S.J.Wilson investigated accuracy of three models for the interpretation of moisture redistribution experiments with fiber glass slabs, although each parameterisation arguably has its weaknesses. They predict the Quasi-steady model agreed well with the results of the transient numerical model in the heat flux and temperature distribution during the final drying-redistribution process. However, the semi- empirical model which incorporates the 'falling rate' evaporation period gives more accurate predictions of the experimental data and it used to obtain additional physical information on the moisture redistribution and drying process in the slab. The overall trend of physical behavior predicted by the above models agrees with the experimental trends of variation. Thus, the predicted changes in the heat flux and the temperature distribution occur at a much faster rate than is observed experimentally.

Sreekanta Das and Muhammad.N.S.Hadi (1996) developed a non-linear finite element (FE) analysis of reinforced concrete (RC) members like beams, slabs etc. using the majority of available commercial finite element software poses many numerical difficulties. Major difficulty is faced because of strain-softening behavior of concrete once it is yielded. This commercial finite element software of FE analysis remains totally inadequate in handling strain-softening behavior of concrete.

This is because this software offers only the traditional non-linear solution techniques like Newton-Raphson (N-R), modified Newton-Raphson (mN-R) methods etc. which can not handle the non-linear post-yielding analyses of members made of materials like concrete, soil, rock etc. which exhibit strain-softening behaviors after their yielding. MSC/Nastran, however, offers many advanced solution techniques like Crisfield's arc-length (CA) method, Riks' arc-length (RA) method, and modified Riks' arc-length (mRA) method. These methods can handle the strain softening behavior adequately.