UNIVERSITI PUTRA MALAYSIA

A PROTOTYPE KNOWLEDGE-BASED SYSTEM FOR CERAMIC MATRIX COMPOSITES MATERIAL SELECTION OF AUTOMOTIVE ENGINE COMPONENTS

M. SURESH DEVANESAN JACOB

ITMA 2002 5

A PROTOTYPE KNOWLEDGE-BASED SYSTEM FOR CERAMIC MATRIX COMPOSITES MATERIAL SELECTION OF AUTOMOTIVE ENGINE COMPONENTS

By

M. SURESH DEVANESAN JACOB

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

June 2002

DEDICATION

TO MY BELOVED FAMILY

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

A PROTOTYPE KNOWLEDGE-BASED SYSTEM FOR CERAMIC MATRIX COMPOSITES MATERIAL SELECTION OF AUTOMOTIVE ENGINE COMPONENTS

By

M.SURESH DEVANESAN JACOB

June 2002

Chairman: **Ir. Dr. Mohd Sapuan Salit**

Faculty : **ANDVANCED INSTITUTE OF TECHNOLOGY**

The aim of this research project is to develop prototype knowledge based system for ceramic matrix composites of automotive engine components. The materials are selected from ceramic matrix composites. The selected materials will be able to increase the efficiency of an engine and reduce weight. The designed knowledge based system consists of a knowledge based, material database and product design parameters. The development of such expert system for ceramic matrix composites leads to further increase in their application in high temperature field.

The proposed system helps to select the suitable materials for automobile engine components. The materials chosen for the research are ceramic matrix composites. For selecting materials to engine components, few specifications are laid out as constraints in terms of rule conditions. The materials, which satisfy the conditions, are selected as

suitable materials. The rules based reasoning are used to select the materials. For different range of constraint values, the selected materials will vary.

As for as constraint values are concerned, the values are selected from the product design specifications. The product design specifications are chosen from the past design and are calculated from the design procedures. The selected materials are ranked according to the properties and stored as result. The most suitable material is labeled as best material and the next level of materials are ranked according to the properties.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains.

SISTEM BERASASKAN PENGETAHUAN PROTOTAIP UNTUK PEMILIHAN BAHAN BAGI KOMPOSIT MATRIKS SERAMIK UNTUK KOMPONEN-KOMPONEN ENJIN AUTOMOTIF

By

M. SURESH DEVANESAN JACOB

Jun 2002

Pengerusi: **Ir. Dr. Mohd Sapuan Salit**

Fakulti : **INSTITUT TEKNOLOGI MAJU**

Objektif projek penyelidikan ini ialah untuk memilih bahan-bahan yang paling sesuai untuk komponen enjin kenderaan dengan menggunakan sistem berasaskan pengetahuan. Bahan-bahan tersebut dipilih daripada komposit matriks seramik. Bahan-bahan yang dipilih mestilah boleh meningkatkan keberkesanan bahanapi, mengurangkan kos pembuatan dan ringan apabila digunakan dalam komponen enjin kenderaan. Sistem ini terdiri daripada sistem berasaskan pengetahuan, sistem pengkalan bahan dan parameter-parameter rekabentuk. Pembangunan sistem berasaskan pengetahuan untuk komposit matriks seramik akan mempertingkatkan penggunaan bahan ini pada suhu yang tinggi.

Sistem yang dicadangkan akan membantu memilih bahan yang paling sesuai untuk komponen-komponen enjin kenderaan seperti omboh, rod penghubung dan gelang omboh. Bahan-bahan yang dipilih untuk kajian tersebut ialah komposit matriks seramik.

Untuk memilih bahan-bahan sebagai komponen-komponen enjin, beberapa spesifikasi telah dijadikan sebagai syarat penghad. Bahan-bahan yang memenuhi syarat-syarat tersebut akan dipilih sebagai bahan yang sesuai. Keputusan daripada pertimbangan syarat-syarat tersebut akan digunakan untuk memilih bahan. Untuk julat penghad yang berlainan, bahan yang akan dipilih akan berubah.

Nilai penghad dipilih daripada spesifikasi rekabentuk produk. Spesifikasi rekabentuk produk dipilih daripada rekabentuk terdahulu dan pengiraan dibuat berdasarkan tatacara yang telah dipilih. Kedudukan senarai bahan-bahan yang telah dipilih akan disusun berdasarkan sifat-sifatnya dan akan disimpan. Bahan yang paling sesuai akan dilabelkan sebagai bahan terbaik dan bahan yang lain akan disenaraikan kedudukannya berdasarkan sifat-sifatnya.

ACKNOWLEDGEMENTS

First of all Thank God, for given me wisdom and strength to complete my research. I would like to acknowledge the complete support and advice given by Ir. Dr. Mohd Sapuan Salit, my thesis supervisor and Mr .Faizal Mustapha, Dr. Napsiah Ismail my co-supervisors for their supervision and encouragement.

I am also grateful to my brother M.M.E.Jacob for his support during my studies. I am also grateful to my friends who have given moral support to complete my work within the time frame.

Finally, yet importantly I am thankful to my parents for their support and encouragement during my studies.

I certify that an Examination Committee met on 26th June 2002 to conduct the final examination of M. Suresh Devanesan Jacob on his Master of Science thesis entitled "A Prototype Knowledge-Based System for Ceramic Matrix Composites Material Selection of Automotive Engine Components" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

YOUSIF A.KHALID, Ph.D.
Associate Professor
Department of Mechanical and Manufacturing Engineering
Universiti Putra Malaysia
(Chairman)

MOHD. SAPUAN SALIT, Ph.D., P. Eng.
Department of Mechanical and Manufacturing Engineering
Universiti Putra Malaysia
(Member)

NAPSIAH ISMAIL, Ph.D.
Department of Mechanical and Manufacturing Engineering
Universiti Putra Malaysia
(Member)

FAIZAL MUSTAPHA, M.Sc.
Department of Aerospace Engineering
Universiti Putra Malaysia
(Member)

SHAMSHER MOHAMAD RAMADILI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 26 JUL 2002

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master Science

AINI IDERIS, PhD
Professor/Dean,
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 SEP 2002

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(M.SURESH DEVANESAN JACOB)

Date: 19.07.2002

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

f_r	stress
a	length of the surface crack
B	connecting rod small end width
c	change in the gap
d	diameter of the piston
D	external diameter of closed ring
d	piston diameter
d_g	gudgeon pin diameter
E_n	elasticity value
F	total load on the piston
I_1 & I_2	inertia force due to piston and rings
K	constant
l	length of connecting rod
m	total pin bearing length
p	gas pressure
P	diametral load to close ring
p	max cylinder pressure
r	radius of the crank
R	weight of reciprocating parts
t_r	radial thickness of piston ring
w	axial thickness of piston ring

Y	dimensionless geometry factor
Z_{xx}	modulus of section
γ	specific weight
σ_f	over all applied stress
ω	angular velocity

CHAPTER 1

INTRODUCTION

1.1 Background

As it has been for a hundred years, the future car will be determined primarily by these things: customer requirement and the manufacturers capabilities. Due to the rapid change in the market demand and requirements, new methodologies and technologies come into play major roles in the automobile industry. Basic engine designs tend to live a long time, but that design is continuously being developed and refined to power new models and platforms.

According to the United States of America Emission Technology Reports, (Gordon, 1995) more than half of current engines have to be fundamentally redesigned for market demand. The researchers foresee the changes mainly in engine components. It is expected that there will be a significant increase in new engine design in near future. The introduction of new design should increase the efficiency of the engines compared with existing design. As far as the change of new designs is concerned, there are so many important factors like those of efficiency of the design; reliability of the design and application of the design should be considered. Therefore, for any product development in an industry, the following sequences of activities are considered as important as the new design. They are, making designs, selecting materials, introducing new design changes to suit the material properties and cost estimation.

In an automobile industry, the manufactures are striving to develop components, which are less costly and light in weight without compromising the desired mechanical properties like stiffness, strength and toughness. At the same time, efficiency of an engine is considered as another important factor for success in the market especially in South Asian countries where the availability of hydrocarbon fuels is limited and the demand is more.

In order to increase the efficiency of the engine, the combustion, which occurs in the combustion chamber, should be complete in such a way that all the charge supplied into the combustion chamber should be burnt completely. This concept can be achieved in an adiabatic engine. An adiabatic means there are no heat loss or heat gains in the system. In order to design an adiabatic engine, the engine and its components should be manufactured with materials, which can able to withstand the high temperatures developed inside the combustion chamber. For achieving this design, there are moves to replace metallic materials with advanced materials like ceramic matrix composite.

1.2 Scope of the Research

Material selection is usually carried out by design and material engineers. Many systems are available to help the designer to choose the required and suitable materials. At the basic level, a designer can select materials from material handbooks. However,

selecting suitable materials with respect to the mechanical properties by referring records or material hand books are time consuming and inefficient.

Therefore, industrialists implemented computer based system and material selection tools. Knowledge-based system is one of the procedures designed for material selection. Definitions about a knowledge-based system and its functions have been well defined by the work of Dym (1985). A number of systems have been developed to select material for a specific operation or a set of operations.

In the past, a knowledge based system for material selection to automotive components has been designed for polymeric based composites by Sapuan et.al, (1998) and Sapuan (1998). The research work implemented an expert system for selecting material from polymeric based composites for automotive pedal box system. Knowledge engineering environment (KEE) is selected as knowledge based system. Another knowledge based system for material selection for injection-molded resins based on pre-design application has been described by Nielsen et al. (1986). The research describes the selection of plastic resins for injection moldering applications. GERES, a rule based program serves as a consultant for selection procedure.

With same design techniques, a computer based intelligent system for automatic tool selection by using a knowledge-based system called Kappa-PC has been described by Edalew et. al. (2001). Tool material selection procedure has been carried out by using kappa-PC. Kappa-PC works based on object oriented programming. A number of researchers like Waterman et. al. (1992) who describes about the material property data

systems and use of an expert system in material selection procedure and Robinson et. al. (1993) have carried out research work for surface coating and material selection by using PRECEPT knowledge-based system like those described above.

Research work are carried out by Naslain (1999), Zhou et. al. (1999), and Deng et. al. (1999) about the development, processing and properties of ceramic matrix composites and its application.

None of the above researchers have concentrated on a knowledge-based system that enables designers to select the most suitable materials for engine components from the ceramic matrix composites. The aim of this research is to illustrate the development of prototype knowledge based system that is designed to select an optimum material for engine components that of piston, connecting material and piston ring from the ceramic matrix composites.

1.3 Aim and Objectives of the Research

The aim of this research project is to develop prototype knowledge based system for ceramic matrix composites material selection of automotive engine components. The materials are selected from ceramic matrix composites.

The objective of this research is.

- to study the mechanical properties of ceramic matrix composites
- to develop a prototype knowledge-based system for ceramic matrix composites of automotive engine components

1.4 Structure of the Thesis

The thesis started with the introduction and objectives of the research. In chapter 2, the literature review on ceramic matrix composites, automotive engine components and Kappa-PC have been conducted. The literature review starts with the classification of different types of ceramics and their properties. Further, it explains the development of ceramic matrix composites for ceramics and their reinforcement besides the types of processing techniques for CMCs and their reinforcement. The later part of chapter 2 describes the design requirements for an automotive engine components and review of object oriented programming and an expert system.

In chapter 3, the methodology of the research has been explained. It consists of over all system descriptions, and explains each components and their functioning. It also explains how the knowledge base is created for ceramic matrix composites and how the material selection is carried out with the help of rule-based reasoning.