UNIVERSITI PUTRA MALAYSIA

COMPARISON OF COST, SURFACE ROUGHNESS AND TIME USING STEREO LITOGRAPHY AND 3D PRINTER FOR THE DESIGN OF COMPOSITE PEDAL

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October 2003

Chairman : Associate Professor Ir. Mohd Sapuan Salit, Ph.D.

Faculty : Engineering

This research presents the process of designing a non metal pedal box system for Proton Wira car. Closed form or non-numerical data analysis of non metal pedal box system is initially carried out. Calculations of bending stiffness and torsion strength to decide on the best pedal lever cross section were carried out. Similarly yield stress calculation for pedal lever was performed. Comparison between non metal pedal box system and steel pedal box system was carried out. This research also includes the measuring process with a coordinate measuring machine of the currently used steel pedal box system and followed by modelling the design in Unigraphics. The design of three pedals namely an accelerator pedal, a brake pedal and a clutch pedal as well as a mounting bracket was carried out. Rapid prototyping models using stereolithography (SLA 3500) by 3D System and 3D Printer Z402 by Z-corp were produced. Stereolithography and 3D printing were compared in terms of cost, speed of the process, user friendliness and model quality. The purpose of rapid prototyping models is to facilitate easy communication of product to the customers.

methods of rapid prototyping using various approaches and to decide on the best methods in term of quality, cost and speed of processing. Design communication using rapid prototyping is one of the important elements of concurrent engineering technique. The pedal box system was designed to meet the final objective of weight reduction produced using injection moulding process.

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

PERBANDINGAN KOS, KEKASARAN PERMUKAAN DAN MASA DENGAN MENGGUNAKAN STEREO LITOGRAPHY DAN PENCETAK 3D UNTUK REKABENTUK INJAK KOMPOSIT

Oleh

LEE HO BOON

Oktober 2003

Pengerusi : Profesor Madya Ir. Mohd Sapuan Salit, Ph.D.

Fakulti : Kejuruteraan

Penyelidikan ini mempersembahkan proses mereka bentuk sistem kotak injak bukan logam untuk kereta Proton Wira. Analisis data bukan berangka atau analisis bentuk tertutup bagi sistem kotak injak bukan logam telah dijalankan pada permulaan. Pengiraan-pengiraan kekukuhan lenturan dan kekuatan kehelan bagi menentukan keratan rentas injak yang terbaik telah dijalankan. Begitu juga pengiraan tegasan alah bagi injak telah dilaksanakan. Perbandingan antara sistem kotak injak bukan logam dan sistem kotak injak keluli telah dijalankan. Ia juga meliputi proses mengukur sistem injak keluli yang sedia ada dengan mesin pengukur kordinat dan diikuti dengan pemodelan reka bentuk dengan perisian Unigraphics. Reka bentuk bagi tiga injak iaitu injak pecut, injak brek dan injak cekam serta pendakap cagak telah dijalankan. Reka bentuk itu digunakan untuk membentuk model contoh sulung cepat dengan stereolitografi (SLA 3500) oleh 3D System dan 3D Printer Z402 oleh Z-corp. Kedua-dua cara ini dinilai dari segi kos, kecepatan proses, kemesraan kepada

ialah bagi memudahkan komunikasi produk dengan pelanggan-pelanggan. Kedua-dua kaedah telah digunakan bagi tujuan mempelajari pelbagai kaedah contoh sulung cepat menggunakan pelbagai pendekatan dan menentukan kaedah-kaedah terbaik dalam sebutan mutu, kos dan kecepatan pemprosesan. Komunikasi reka bentuk menggunakan contoh sulung cepat adalah salah satu unsur penting dalam kaedah kejuruteraan setemu. Sistem kotak injak ini direka bentuk dengan bertujuan memenuhi objektif akhir iaitu, pengurangan berat dengan menggunakan proses pengacuan suntikan.

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2D	-	Two-dimensional
3D	-	Three-dimensional
ABS	-	Acrylonitrile-butadiene-styrene
C	-	Section with C shape
CAD	-	Computer aided design
CAE	-	Computer aided engineering
CIM	-	Computer-integrated manufacture
CMM	-	Coordinate measuring machine
CNC	-	Computer numerical control
CO_2	-	Carbon dioxide
E	-	Elastic modulus
FEA	-	Finite element analysis
I	-	Second moment of area
I	-	Section with I shape
IPC	-	Intelligent process control
KBS	-	Knowledge based system
KEE	-	Knowledge Engineering Environment
LOM	-	Laminated object manufacturing
M	-	Section with M shape
M	-	Bending moment
NC	-	Numerical control
NVH	-	Noise, Vibration and Harshness
P	-	Load in Newton

PA	-	Polyamide
PBT	-	Polybutylene terephthalate
PC	-	Polycarbonate
PCB	-	Printed circuit board
PDS	-	Product design specifications
PEI	-	Polyetherimide
PP	-	Polypropylene
PPS	-	Polyphenylene sulfide
RP	-	Rapid prototyping
Rz	-	Mean roughness depth
SGC	-	Solid ground curing
SL/SLA	-	Stereolithography
SLS	-	Selective laser sintering
SOI	-	Standard Operator Interface
STL	-	Standard triangle language
U	-	Section with U shape
Z-corp	-	Z Corporation
θ_M	-	Torsion strength
σ	-	Yield stress
δ	-	Deflection
$\bar{y}$	–	Centre of geometry
Z	-	$\bar{y}/I$

CHAPTER 1

INTRODUCTION

1.1 Background

Business worlds nowadays often experience rapid change especially in the market place. Consumers were expecting more value added feature from the products they buy with the trend of cheaper prices. These have driven industrialists to search for more advanced methodologies and technologies to satisfy consumer demands. One of the potential areas is weight saving through the use of polymeric based composite to substitute metal component. By using composite as material the product can achieve lower weight. And this has been demonstrated for quite some time especially in automotive industries. The major weights saving examples so far are sheet body panel, body frames and even chassis. The advantages of polymeric-based composite are innumerable. It has high strength, high stiffness, and aesthetically pleasing, corrosion resistance and light weight due to low density. It also provided manufacturer flexibility in design. The manufacturing cost is also lower due to the ability of moulding several parts in one process thus shortens manufacturing lead-time and also reduces assembly time with part reduction. Injection moulding is a very good example. It is essential that more development and study on replacing more components in automobile to light weight composite to be carried out.

1.2 Statement of Problem

There are over 286 million cars in the world and about 10% is replaced or scraped every year. This means that 28.6 million vehicles need to be scraped each year. The components of the vehicle were usually recycled but not 100 percent of the vehicles can be recycled easily.

Vehicle needs fuel every time in operation. The limited petroleum reserves have urged manufacturer of vehicle to come up with more and more fuel-efficient vehicle. One of the tactics they currently interested in is to 'slim' down the vehicle or to reduce the weight of the vehicle. It is common sense that lighter weight vehicle always consume lesser fuel.

In order to have a lighter weight and easier recyclable vehicle, the manufacturer found their answer in composite material especially fibre reinforced polymeric composite material.

A lot of work has been carried out in the past on the application of polymeric composite material in automotive industries. Composite has been used for some components such as bumper, tailgate, and door panel, just to name a few. A number of applications of pedal box system using composite material were also found. But currently there is no example that deals with the design of the whole pedal box system. The manufacturer only design parts of the pedal box system and especially there is no work has been carried out on the development of composite brake pedal. In addition there is no work carried out on the use of rapid prototyping for composite pedal box system Therefore, there is a need to carry out design of the whole pedal box system from polymeric-based composite material and to develop rapid prototyping models using methods like SLA and 3D Printer.

1.3 Objectives of the Research

The main objectives of this research are:

i) to carry out a process of redesigning a pedal box system with a specific model of car. The vehicle selected is Proton Wira 1.5 litre manual transmission configuration. The pedal box must be able to be fitted in to a real vehicle. The performance is equal to its steel counterpart with the additional advantage of weight saving.

ii) to develop rapid prototyping models of the redesigned pedal system using stereolithography and 3D printing methods to facilitate design communication which is the essence of concurrent engineering.

iii) to compare both rapid prototyping methods in terms of cost, surface finishing and speed of the processes, in order to determine the optimum method of rapid prototyping process for a non metal automotive pedal box system.

1.4 Scope of the Research

The research focuses on the manufacturing process of the pedal box system. Previous work have already included the material selection using knowledge-based system (KBS) (1), concept design with product design specifications (PDS) (1), detail design process by 3D CAD (1) and finite element analysis (FEA) (1), and cost estimation using KBS (1).

By using the available data and information from previous work, this research work on the redesigning the models based on Proton Wira 1.5 model and on the development of the rapid prototyping models for pedal box system is presented. The redesigning process is carried out using conventional calculations such as torsion strength, bending stiffness and yield stress. It is to decide on the best cross section of pedal lever. Comparison between the design from non metal pedal box system and steel pedal box system is carried out. Basically, the size and location of both designs do not differ but the main difference is on some of the design features such as incorporation of ribbing, part integrations and others. Two different methods of rapid prototyping are used in this research and the models developed are compared. The criteria for comparison includes user friendliness, cost, time and other issues in both rapid prototyping methods. Two different rapid prototyping methods used were the Stereolithography and the 3D Printer. The former is a liquid based laser cure system and the latter is a powder-based system. Both of the systems are based on the Stereolithography (SLA) technique. This technique is always referred to as building a solid model by tracing a profile of a previously sliced digital model and stacking them layer by layer in their proper position to form the final solid model. The selection of the optimum method is essential to facilitate the design communication, which is the essence of concurrent engineering. It is shown in Figure 1.1.

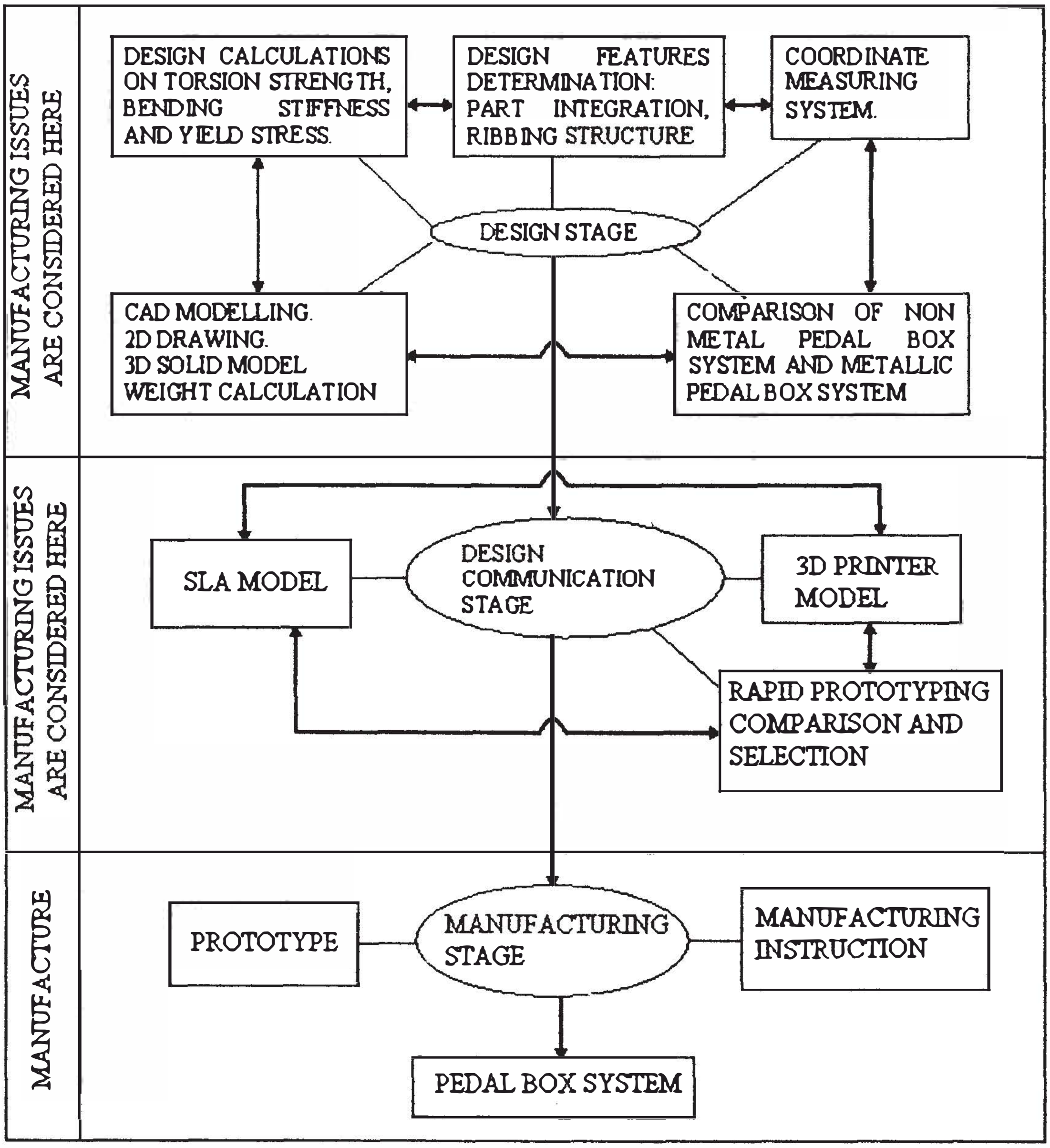

Figure 1.1: Concurrent engineering approach of pedal box design

1.5 Structure of the Thesis

The objectives and scope of the research are presented in chapter 1.A literature review is presented in Chapter 2. Literature review begins with some general background of polymeric-based composite and automotive pedal box system, and it is followed by the review of current development in the applications of polymeric-based composite in various parts of automobile especially the pedal box system.

It also includes some review on rapid prototyping and injection moulding technologies with particular emphasis on plastic injection moulding of thermoplastic materials.

In Chapter 3 the methodology a closed form non-numerical data analysis of the designed pedal box system is presented. Application and procedure to produce the rapid prototyping with the Stereolithography and 3D printer are explained in detail. This includes collecting the data and dimensions of the existing steel pedal system with the use of coordinate measuring machine and modelling the new design of the pedal box system by using Unigraphics package the results from the modelling were used to carry out the development of rapid prototyping models. Two different rapid prototyping methods were used namely the SLA 3500 by 3D System and the 3D Printer by Z-corp. The results, discussion and comparisons of both models are made in Chapter 4. Finally conclusions and recommendations are presented in Chapter 5.