TOPOLOGY OPTIMIZATION IN AUTOMOTIVE BUMPER BEAM DESIGN

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work and in opinion of me / we* this work was
adequate from the aspect scope and quality to the significance to awarded
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ABSTRAK

Sistem palang bamper automotif memainkan peranan penting bukan sahaja menyerap hentakan pelanggaran tetapi juga sebagai satu gaya reka bentuk. Banyak perhatian di dalam industri automotif telah difokuskan ke atas berat, keselamatan dan juga pengurangan penggunaan bahan sejak bertahun-tahun kebelakangan ini berdasarkan reka bentuk pengoptimuman. Teknik pengoptimuman topologi digunakan dalam mengoptimumkan rekabentuk palang bamper. Untuk projek ini, palang bamper Perodua Myvi telah dipilih sebagai kes kajian. Gambaran keseluruhan prosedur pengoptimuman topologi dan sesetengah perkara berkaitan dalam industri automotif berkaitan reka bentuk palang bamper dijelaskan dengan teliti dalam laporan ini. Reka bentuk palang bumper telah dioptimumkan berdasarkan teknik pengoptimuman topologi dan hasilnya empat rekabentuk konsep telah dibangunkan menggunakan perisian SolidWorks. Kemudian rekabentuk yang telah dioptimumkan dianalisis berdasarkan prestasi impak palang bamper menggunakan perisian analisis COSMOSWORKS Designer. Setelah dianalisis, keputusan analisis bagi setiap reka bentuk konsep tersebut dibandingkan untuk memilih reka bentuk optimum yang terbaik berdasarkan kajian optimum yang mangandungi fungsi objektif, perubahan reka bentuk dan kekangan. Daripada kajian ini didapati reka bentuk konsep 2 adalah reka bentuk optimum yang terbaik kerana ia memenuhi kriteria-kriteria kajian optimum tersebut. Akhir skali, penggunaan pengoptimuman topologi sepanjang proses pembangunan palang bamper automotif dibincangkan, termasuk mengenalpasti kebaikannya.

ABSTRACT

Automotive bumper beam system plays a very important role not only absorbing impact energy but also in a styling stand point. A great deal of attention within the automotive industry has been focused upon light weight, sufficient safety and also less material used in recent years based on optimization design. Topology optimization technique was used to optimize bumper beam design. For this project Perodua Myvi bumper beam was selected as the case study. An overview of topology optimization procedure and some closely related subjects in automobile industry focused on bumper beam design explained in details in this report. The bumper beam design was optimized base on topology optimization technique and the outcome is four concept design were developed using SolidWorks software. The optimized design then analyze regarding the impact performance using COSMOSWORKS Designer analysis software. From the analysis results then the four design concept have been compared to select the best optimized design base on the optimization study which defined by objective function, design variable and constraints. It was found that design concept 2 is the best optimized design because it fulfills the optimized study criteria. Finally, the application of topology optimization during the development process of an automotive bumper beam is discussed, including identification of its major benefits.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

SYMBOL	DEFINITION
PSM	Projek Sarjana Muda
UTeM	Universiti Teknkal Malaysia Melaka
FKM	Fakulti Kejuruteraan Mekanikal
CAD	Computer Aided Design
CAE	Computer Aided Engineering
RP	Rapid Prototyping
FEA	Finite Element Analysis
FEM	Finite Element Method
CFD	Computational Fluid Dynamics
MES	Mechanical Event Simulation
SLA	Stereolithography Apparatus
3DP	Three-Dimensional Printing
FDM	Fused Deposition Modeling

CHAPTER 1

INTRODUCTION

1.1 Project Background

This project will focus on how to produce innovative design of automotive bumper beam using topology optimization procedure. The project will start from studying the topology optimization in detail that will be applied in designing automotive bumper beam. Then generate conceptual design using Computer Aided Design (CAD) software and develop the concept in 2D topology optimization procedure and lastly, investigate and analyze the impact performance of bumper beam using COSMOSWORKS Designer software.

Since the topology optimization procedure in especially in automotive development industry is still new in UTeM, the project was chosen to expose the application of this process to all students in UTeM especially the mechanical engineering student. This project also describes the advantages and disadvantages using this procedure.

1.2 Problem Statement

Fuel price increase situation currently increasingly onerous vehicle consumer. Various state-of-the-art technologies to the car were created in order to reduce fuel consumption without effect the performance of the car itself. One of the aspects is reducing the weight of the car because the more weight of the car the more fuel per kilometer is used. Thus, in this case study I will focus on designing lighter car bumper beam using topology optimization procedure. The optimized bumper beam design that will improved fuel economy and performance of a car.

Topology optimization procedure in automotive industry is still new in UTeM and students here are not familiar with this process. Students also did not know the capability of this kind of method in producing the most optimize design in the beginning of product design development process with shorter lead time by using the applicable CAE software. Furthermore, the using of the Computer Aided Engineering (CAE) optimization software among UTeM's students is quite rare.

1.3 Objectives of Project

The objectives of the project are:

a) To produce innovative design of automotive bumper beam using topology optimization method focused on Perodua Myvi bumper beam.
b) Design lighter bumper beam that will improved fuel economy and performance of a car.

1.4 Scopes of Project

The scopes of the project are:

a) To study the topology optimization.
b) To generate conceptual design using CAD software.
c) To develop concept in 2D topology optimization procedure.

d) To refine 2D concept into 3D modeling using solid modeling software.

e) To investigate and analyze the impact performance of bumper beam using COSMOSWORKS Designer software.

1.5 Project Flow Chart

Figure 1.1 shows the project flow chart for PSM 1 and PSM 2:

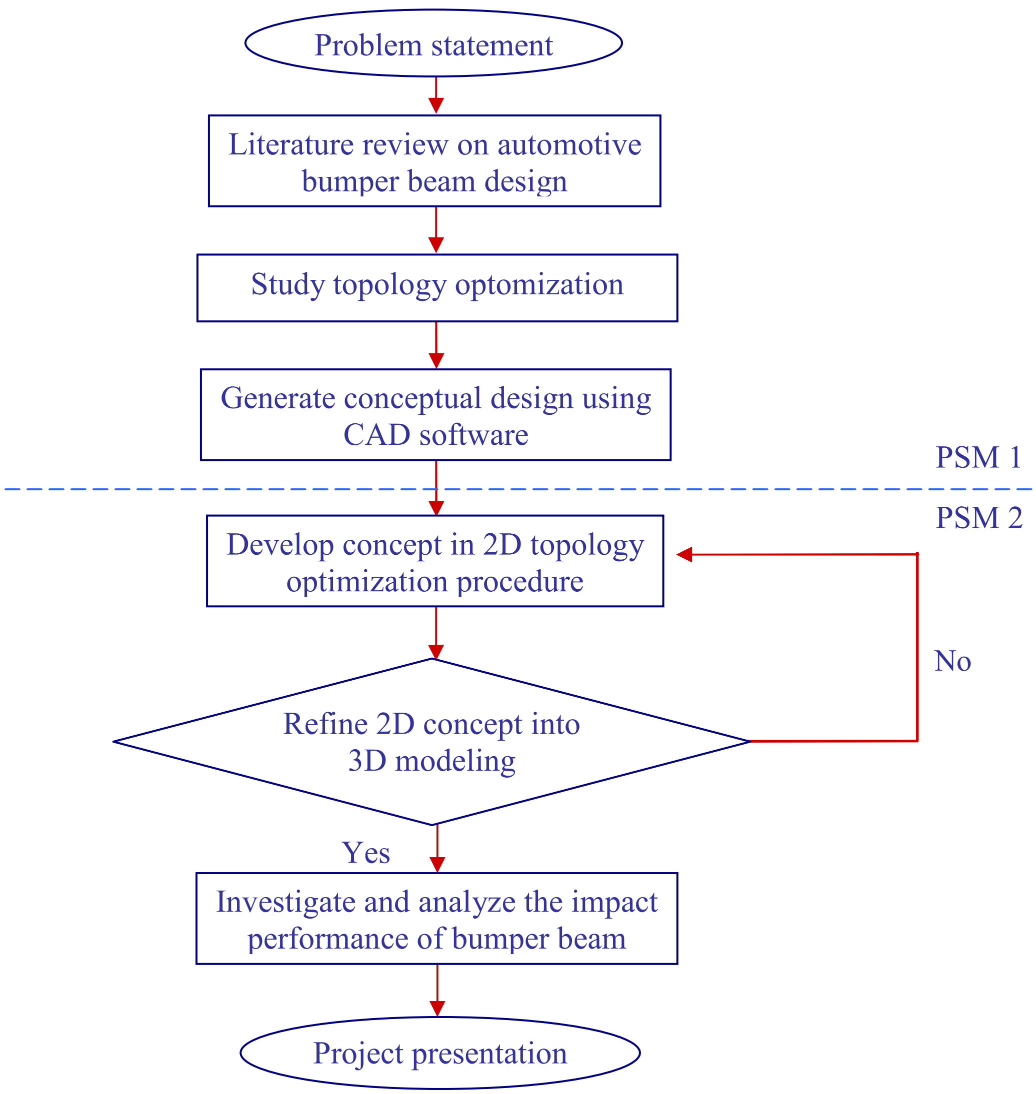

Figure 1.1 Project flow chart

1.6 Significant of Project

To see the potential of this topology optimization procedure, an automotive bumper beam was selected for this project. The development concept of the bumper beam will be done in 2D topology optimization procedure using CAD optimization software. Then, from the 3D modeling concept, investigate and analyze the impact performance of bumper beam using COSMOSWORKS Designer software.

1.7 Summary

Thus, hopefully this report will be reference to the UTeM's mechanical student about the important and capability of using this topology optimization method especially in automotive development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter explain in details about all topics that related in this project. The subject that will be covered are topology optimization, automotive bumper beam, computer aided design (CAD), computer aided engineering (CAE), rapid prototyping (RP) and automotive bumper beam.

2.2 Topology Optimization

One of the important modifications that could greatly influence the overall automotive frame or structure performance while reducing mass is optimization analyses. Successive optimization analyses would be performed to determine the optimal architecture, gauges, section sizes and shapes. Finite element-based structural analyses and optimization software tools would be used to design and optimize structures.

One type of the optimization analyses is topology optimization. Topology optimization generates an optimal material distribution for a set of loads and constraints within a given design space. The design space can be defined using shell elements, solid elements, or both. In the classical topology optimization setup, global loads and boundary conditions are applied to acquire the load paths (i.e., optimal design structure) by solving the minimum compliance problem. Manufacturing constraints can also be imposed using minimum member size and draw direction constraints [3]. **Figure 2.1** shows the basic process of topology optimization.

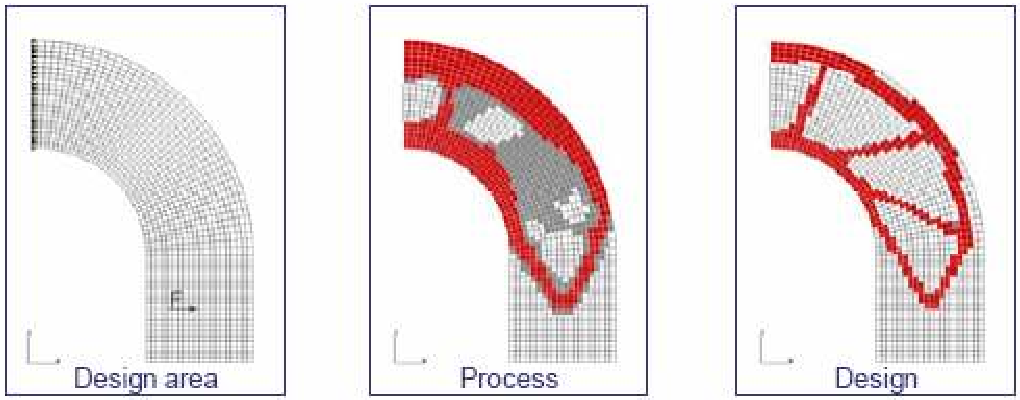

Figure 2.1 Topology optimization

Topology optimization is the latest type of optimization for the area of mechanically loaded components. With topology optimization structural parts are identified which do not contribute to the components behavior. In other words, in given design space material is distributed in such a away that under certain constrains specific objectives are met. **Figure 2.2** illustrates on the design configuration of topology optimization.

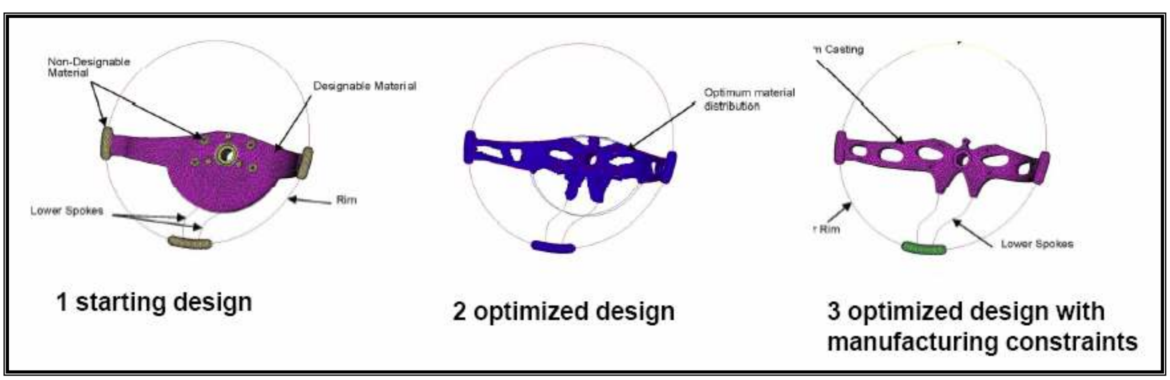

Figure 2.2 Design configuration of topology optimization

2.2.1 Topology Optimization Applications

Currently, there are three main fields where topology optimization is applied:

a) The very early design phase, where the design can easily be changed. Here the topology optimization starts from a rough design proposal.

b) When potential for reducing the components stresses and weight needs to be identified. Here the topology optimization starts from an already existing design model.

c) When parts of an already existing structure are completely redesign.

2.3 Computer Aided Engineering (CAE)

Computer-aided engineering (often referred to as CAE) is any use of computer software to solve engineering problems. In addition, CAE is the application of computer software in engineering to analyze the robustness and performance of components and assemblies. It encompasses simulation, validation and optimization of products and manufacturing tools. With the improvement of graphics displays, engineering workstations, and graphics standards, CAE has come to mean the computer solution of engineering problems with the assistance of interactive computer graphics.

CAE software is used on various types of computers, such as mainframes and superminis, engineering workstations, and even personal computers. The choice of a computer system is frequently dictated by the computing power required for the CAE application or the level (and speed) of graphics interaction desired. The trend is toward more use of engineering workstations, especially a new type known as supergraphics workstations [13].

2.3.1 CAE Tools

Considering information technology that provides tools and techniques to help in design and manufacturing support, the tools used are considered CAE tools. Design engineers use a variety of CAE tools, including large, general-purpose commercial programs and many specialized programs written in-house or elsewhere in the industry. Solution of a single engineering problem frequently requires the application of several CAE tools. Communication of data between these software tools presents a challenge for most applications. Data are usually passed through proprietary neutral file formats, data interchange standards, or a system database.

A typical CAE program is made up of a number of mathematical models encoded by algorithms written in a programming language. The natural phenomena being analyzed are represented by an engineering model. The physical configuration is described by a geometric model. The results, together with the geometry, are made visible via a user interface on the display device and a rendering model (graphics image).

In the future CAE systems will be major providers of information to help support design teams in decision making. In regards to information networks, CAE systems are individually considered a single node on a total information network and each node may interact with other nodes on the network [13].

2.3.2 CAE Applications

CAE areas covered include:

a) Stress analysis on components and assemblies using FEA (Finite Element Analysis).
b) Thermal and fluid flow analysis Computational fluid dynamics (CFD).
c) Kinematics.
d) Mechanical event simulation (MES).
e) Behavioral Modeling (BMX).
f) Analysis tools for process simulation for operations such as casting, molding, and die press forming.
g) Optimization of the product or process.

In general, there are three phases in any computer-aided engineering task:

a) Pre-processing – defining the model and environmental factors to be applied to it. (typically a finite element model, but facet, voxel and thin sheet methods are also used).