DESIGN ANALYSIS AND MODIFICATION OF FIRE FIGHTING MACHINE

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This report is submitted as partial requirement for the completion of the Bachelor of Mechanical Engineering (Design & Innovation) Degree Programme

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"I hereby, declare this thesis is result of my own research except as cited in the references"

Signature	: ……
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To

My Beloved Family

Soo Har

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ABSTRAK

Dalam projek ini, analisis dan optimasi reka bentuk mesin pemadam api dijalankan dengan menggunakan perisian *Computer-Aided Engineering* (CAE). Tujuan utama optimasi ini adalah untuk mengurangkan berat mesin tersebut serta meningkatkan mutu operasi. Pengurangan jumlah berat mesin akan mengurangkan pengunaan tenaga serta memanjangkan tempoh operasi mesin. Projek ini menglibatkan empat unsur dalam analisi dan modifikasi reka bentuk bermula dengan formulasi masalah kepada analisis kestabilan, analisis struktur dan optimasian. Dalam formulasi, semua maklumat berkenaan mesin yang dalam kategori yang sama dikumpul. Selain itu, kajian terhadap faktor keselamatan dilakukan. Dalam analisis kestabilan, pengurangan berat maksima dikenal pasti. Pengiraan dijalankan untuk mengenal pasti *moment of force* pada nozzle. Tekanan maksima 12 bars digunakan sebagai tekanan aliran melalui nozzle. Hukum *Bernoulli's* telah digunakan untuk pengiraan daya dari 12 bars aliran. Pengurangan berat maksima yang dibenarkan akan dikira secara langsung daripada perbezaan antara jumlah moment kepada minimum moment dalam mengekalkan kestabilan mesin. Komponen yang mengalami berat lebihan dikenalpasti dan dianlisis menggunakan perisian SolidWorks Simulation 2009. *Factor of Safety* (FOS) untuk struktur mesin didapati melalui analisis struktur. Nilai FOS ini dijadikan rujukan dalam proses optimasi. Selain itu, daripada stress plot untuk hasil analisis, relatif stress tinggi dikenal pasti. Optimasi dijalankan pada mesin struktur dengan rujukan kepada hasil analisis struktur. Optimasi ini tamat pada ulangan ketiga untuk struktur nozzle dan keempat untuk struktur badan, dimana minimum nilai FOS untuk kedua-dua struktur tersebut hampir kepada nilai FOS yang ditetapkan. Kesimpulan terhadap keputusan analisis dan optimasi dihasilkan. Cadangan telah dibentang untuk kajian masa hadapan.

ABSTRACT

In this project, analysis and optimization of the current design of fire fighting machine is make using Computer-Aided Engineering (CAE) software. The main focus of the optimization is to reduce the weight of the fire fighting machine to increase its efficiency. The reduction of the total weight of the machine will lower the power consumption and expand the time of operation. In this project, use four important elements in design analysis and modification process begin with problem formulation to stability analysis, structural analysis and optimization. In formulation, all information about the similar machines is gathered. Besides, related study such as factor of safety is performed. In stability analysis, allowable reduction in mass is determined. Manual calculation is made in determining the moment of force at nozzle. The pressure of maximum 12 bars was use as water flow through the nozzle. Bernoulli's equation is used to determine the force at nozzle due to 12 bar water flow. The moment of force is determined from the force calculated. The allowable mass reduction is determined directly from the different between total moments of force to the minimum moment to maintain the machine stability. The possible overweight component is detected and analyzed using SolidWorks Simulation 2009. The current fire fighting machine's structure factor of safety (FOS) is obtained through the structural analysis. This FOS value will be the reference in optimization process. Besides, from the stress plot of the analysis result, relatively high stress area is determined. Optimization is performed on the machine's structure by reference to the result from the structural analysis. The optimization stops at third iteration for nozzle structure and fourth iteration of body structure, where the minimum factor of safety of the both structure close to the target FOS value. Conclusion base on the analysis and optimization result was done. Besides, some recommendations were proposed for future work.

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LIST OF SYMBOLS

ρ	=	Fluid density, kg/m ^{3}
h_f	=	Friction losses
P	=	Pressure, N/m ^{2}
V	=	Velocity, m/s
Q	=	Volume flow rate, m ^{3}/s
D	=	Diameter, m
A	=	Area, m ^{2}
F	=	Force, N
M	=	Moment of force, Nm
θ	=	Angle, ^{o}
d	=	Displacement, m

LIST OF ABBREVIATIONS

CAD	=	Computer-Aided Design
CAE	=	Computer-Aided Engineering
CAM	=	Computer-Aided Manufacturing
CFD	=	Computational Fluid Dynamics
FEA	=	Finite Element Analysis
MES	=	Mechanical Event Simulation

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CHAPTER 1

INTRODUCTION

1.1 Background

Fire fighting is the act of extinguishing destructive fires. A firefighter fights these fires to prevent destruction of life, property and the environment. Fire fighting is a highly technical profession which requires years of training and education in order to become proficient. A fire can be extinguished or put out by taking away any of the four components of the "Fire Tetrahedron" which are reducing agent (fuel), heat, self-sustained chemical reaction and oxidizing agent (oxygen). In usual case firefighter perform high pressure water jet to extinguish a fire.

One of the advance technologies in fire fighting field is fire fighting machine. Fire fighting machine can be defined as an apparatus that help or replace firefighter in performing water jet fire extinguishing. The machine can be control either wired control or remote control from a designed distance. The main purpose of the machine is to reduce the rate of direct contact between fire fighting and high temperature. The machine allows the activities of fire extinguishing at narrow scene. Besides, it enhanced the efficiency of fire fighting.

Fire fighting machine's design has to be optimized to increase its working efficiency. Computer-Aided Engineering (CAE) is the most suitable technology to perform optimization. CAE is the use of information technology to support engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis, and repair. Software tools that have been developed to support these activities are

considered CAE tools. CAE tools are being used to analyze the robustness and performance of components and assemblies. The term encompasses simulation, validation, and optimization of products and manufacturing tools. CAE areas covered include, stress analysis using Finite Element Analysis (FEA), thermal and fluid flow analysis Computational Fluid Dynamics (CFD), kinematics, Mechanical Event Simulation (MES), analysis tools for process simulation and optimization of the product or process.

To perform optimization on the fire fighting machine, FEA approach is required. FEA is a numerical technique to solve engineering analysis problems for structural and field applications. The FEA represent a complicated structure into smaller elements and each element is based on the physical law using numerical computing techniques and all elements are assembled into a big matrix of algebraic equations. This matrix is solved by computer. Finally, the solution is obtained according to the engineer's requirements. Furthermore, modifying an existing product’s or structure’s design is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA will help determine the design modifications to meet the new condition.

1.2 Problem Statement

The problems of the fire fighting machine are power consumption, speed and acceleration. These problems are partly due to overweight of the machine's design. The period of operation of machine will be longer if the weight is reduced to minimum. Besides, the speed of the machine will increase with lower machine weight.

In the same time, the weight of the machine has to be balanced with the others possible external force on the machine to maintain stability during steady state and operation. The nozzle of the machine will release the maximum pressure of 12 bar water. Hence, force from the nozzle is the most significant force that needed to be taken into consideration. The current design of the fire fighting machine is not optimized. It efficiency is not in the maximum rate.

The overweight problem can be overcome by optimizing the design of the fire fighting machine using CAE software. By using CAE software, the current design can be analyzed and the minimum weight of the machine can be determined. In the optimization, factors such as strength of the nozzle elevation structure, chassis and chassis cover have to be taken in consideration. Analysis of strength of the nozzle elevation structure will be done using FEA software. The result of analysis will be the reference in optimization.