TOPOLOGY OPTIMISATION OF 5000 LB OVER-CENTER BUCKLE

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Degree of Master of Engineering

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A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Manufacturing Systems Engineering

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the Master thesis under my supervision. I also acknowledge the contributions made by Lecturer KH Janaka Mangala for the completion of the work.

Name of the supervisor: Senior Lecturer. R. K. P. S. Ranaweera

Signature of the supervisor: Date:

Abstract

Topology optimisation has for a considerable time been applied successfully in the automotive industry, but still has not commonly become a mainstream technology in the aerospace industry. The aircraft manufactures have already been achieving benefits with optimisation for some areas where as the bottom layer suppliers in the aerospace industry are still following conventional design techniques. Most of metal fittings which are widely used in the aerospace industry with safety nets and straps are identified as bulky and heavy as they are based on conventional designing techniques. 5000 lb over-center buckle (OCB) is one of the most frequently used tightening devices having the aforementioned characteristics.

The purpose of this study is to formulate a mechanism for a strength-based weight reduction on standard 5000 lb OCB which is used in the aerospace industry and consequently, to propose a light-weight design. First objective was to identify the relevant design considerations of existing 5000 lb OCB. Design specifications and standards related to 5000 lb OCB and 5000 lb safety strap were collected and reviewed for collecting necessary strength, functionality and other requirements of 5000 lb OCB. Second objective was to develop a finite element methodology for static structural analysis of 5000 lb OCB. 5000 lb OCB samples were carefully examined to identify the functionality and other necessary requirements of the OCB. OCBs were then subjected to a detail measurement check and the dimensions were used to build a computer aided design (CAD) model for the study. Engineering drawings were also created from the model for future reference. Then OCB samples with polyester webbing parts were subjected to various kind of strength tests using tensile testing machine. Purposes of these tests were to identify the failure loads and failure modes of the OCB itself and the OCB with safety strap in the operational conditions. These experimental results showed that the 5000 lb OCB used in the aerospace industry is an over-design. Last objective was to optimise the 5000 lb OCB using an effective optimisation scheme. Having reviewed on optimisation procedures and current trends in the aerospace industry, Altair HyperMesh software was selected as the numerical simulation tool to setup the finite element model and 'Topology Optimisation' was selected as optimisation method for the study. The finite element model was validated using simulation results and experimental results and the validated methodology was used to setup optimisation problem with aim of reducing weight. In formulating the topology optimisation problem, the minimum averaged compliance of the buckle was taken as the objective, and element density was used as the design variable.

Topology optimisation results were analysed and the elements in the critical regions were derived as geometries to compare those with original OCB model. Considering other functionality requirements with the topology optimisation results, a light-weight design was proposed with step-by-step modifications. Subsequently, FE simulations were repeated for the proposed light-weight design. Comparing the results of the light-weight design with the original model results, the proposed light-weight design can be noted as a better alternative. Nearly 7% (41g) weight reduction could be achieved for 5000 lb OCB using the proposed optimisation procedure.

Keywords:

Finite Element Analysis, Topology optimisation, 5000 lb over-center buckle, Weight reduction

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List of Abbreviations

Abbreviation	Description
OCB	Over-center Buckle
CAD	Computer Aided Design
CAE	Computer Aided Engineering
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Model
RL	Rated Load
SWL	Safe Working Load
IB	Inner Body
OB	Outer Body
SAE	Society of Automotive Engineers