OPTIMIZATION OF LIGHTWEIGHT FRONT LOWER CONTROL ARM USING ALUMINIUM CAST FOR C-SEGMENT PASSENGER VEHICLE

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MASTER OF SCIENCE IN MANUFACTURING ENGINEERING

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Manufacturing Engineering

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2021

DECLARATION

I declare that this Choose an item.entitled “Optimization Of Lightweight Front Lower Control Arm Using Aluminium Cast For C-Segment Passenger Vehicle” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : _____

Name : Mohd Hafizi Bin Abdul Rahman

Date : 23 September 2021

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Manufacturing Engineering.

Signature : 

Supervisor Name : Associate Professor Ir. Ts. Dr. Mohd Shukor Bin Salleh

Date : 27 September 2021

DEDICATION

Alhamdulillah, Praise to Allah

I dedicate this report to only

my beloved father, Haji Abdul Rahman Bin Haji Abdul Razak

my beloved mother, Hajjah Noor Aian Binti haji Nasiruddin

my beloved wife, Farahusna Binti Mohamed Yusop

my kind supervisor, Associate Professor Ir. Ts. Dr. Mohd Shukor bin Salleh

for giving me moral support, cooperation, encouragement and also understandings

Thank You So Much

ABSTRACT

In recent years, automakers are concerned with the amount of carbon dioxide released by the vehicle. To overcome this, some components of the vehicle can be reduced in terms of their weight which will result in less production of carbon dioxide. This research is requested by Proton as one of the vehicle weight reduction project. With such aim, this study was conducted to reduce the weight of front lower control arm (FLCA) for C-segment passenger car by cutting down about 20% percent of their weight using the method of optimization process and by using lightweight material as target set by Proton. The concept design of FLCA underwent the optimization process using topology optimization process to eliminate the excessive weight of the part. Then, the optimized design of FLCA was tested for structural strength and fatigue analysis to evaluate the performance of the part. The optimized design results achieved 39% of weight reduction compared to conventional design. It is fulfilling all the structural strength and fatigue analysis performance criteria. The performance for both criteria is on par with the current conventional FLCA. The sand casting process with secondary heat treatment, T6 process was used to fabricate the final design of the FLCA. The final product of aluminium cast FLCA achieved weight 3.20 kg which about 22.14% weight reduction compared conventional FLCA weight 4.11 kg. The fabricated product was tested for fatigue test using the Proton standard, PES-7029 and also mechanical testing to evaluate the structural and microstructural performance of aluminium cast FLCA. From the analysis of hardness, scanning electron microscope, and tensile test, it was shown that aluminium LM 25 has increased the hardness after the T6 heat treatment. Tensile test also showed an increase in ultimate tensile strength and elongation to fracture of heat-treated aluminium LM 25. From the research outcome, the new optimize design of aluminium cast FLCA fulfils all the criteria which are lightweight, very good strength as well as durability performance.

PENGOPTIMUMAN LENGAN KAWALAN BAWAH HADAPAN YANG RINGAN MENGGUNAKAN ALUMINIUM TUANGAN BAGI KENDERAAN PENUMPANG SEGMEN-C

ABSTRAK

Ketika ini, pengeluar kenderaan amat menitik beratkan berkenaan jumlah karbon dioksida yang dikeluarkan oleh kenderaan tersebut. Untuk mengatasinya, beberapa komponen kenderaan dapat dikurangkan berat yang akan menghasilkan pengeluaran karbon dioksida yang lebih sedikit. Pihak Proton telah meminta untuk membuat penyelidikan berkenaan pengurangan berat kenderaan. Dengan tujuan tersebut, kajian ini dilakukan untuk mengurangkan berat lengan kawalan bawah hadapan untuk kenderaan penumpang segmen-C dengan pengurangan sekitar 20 peratus menggunakan kaedah proses pengoptimuman dan juga dengan menggunakan bahan yang ringan yang telah ditetapkan oleh Proton. Reka bentuk konsep lengan kawalan bawah hadapan (FLCA) menjalani proses pengoptimuman topologi untuk mengurangkan berat bahagian yang berlebihan. Kemudian, reka bentuk FLCA yang dioptimumkan diuji untuk analisis kekuatan struktur dan kelesuan untuk menilai prestasi bahagian tersebut. Hasil reka bentuk yang dioptimumkan mencapai 39% penurunan berat bahan berbanding reka bentuk semasa. Ia memenuhi semua kriteria prestasi analisis struktur dan juga kelesuan struktur. Prestasi untuk kedua-dua kriteria ini setanding dengan FLCA semasa. Proses penuangan pasir dengan perlakuran panas sekunder, T6 digunakan untuk membuat reka bentuk akhir FLCA. Produk akhir FLCA aluminium tuangan mencapai berat 3.20 kg yang mana pengurangan berat sekitar 22.14% berbanding berat FLCA semasa iaitu 4.11 kg. Produk ini diuji untuk ujian kelesuan menggunakan ujian dari Proton, PES-7029 dan juga ujian mekanikal untuk menilai prestasi struktur dan mikrostruktur aluminium kor FLCA. Dari analisis kekerasan, dan ujian tegangan, menunjukkan bahawa aluminium jenis LM 25 telah meningkat tahap kekerasan setelah dilakukan perlakuran panas, T6. Ujian tegangan juga menunjukkan peningkatan kekuatan tegangan dan pemanjangan sehingga. Dari hasil penyelidikan, pengoptimuman baru aluminium tuangan FLCA memenuhi semua kriteria iaitu ringan, kekuatan yang sangat baik serta ketahanan prestasi.

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LIST OF SYMBOLS AND ABBREVIATIONS

BIW	-	Body in White
FLCA	-	Front Lower Control Arm
ABS	-	Anti-lock Braking System
EBD	-	Electronic Brake Distribution
CO_2	-	Carbon Dioxide
AM	-	Addative Manufacturing
SiC	-	Silicon Carbide
OEM	-	Original Equipment Manufacturer
$CuAl_2$	-	Copper Aluminide
LCAr	-	Lower control arm rear
LCAf	-	Lower control arm front
Mg	-	Magnesium
Cu	-	Copper
Si	-	Silicon
Mn	-	Mangan
Cr	-	Chromium
Ni	-	Nickle
LM 25	-	Corrosion resistant aluminium casting alloy
ICE	-	Internal combustion engine
HV	-	Hardness vicker

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LIST OF PUBLICATIONS

Indexed Journal

M.H.A. Rahman, M.S. Salleh, A. Abdullah, S.H. Yahaya, M.S.A. Razak, M.R.M. Kamal, Z. Marjom, L. Anuar and N.A.M. Saad., 2018. A New Design Optimization of Light Weight Front Lower Control Arm. In *Journal of Advance Manufacturing Technology* (Vol. 785, pp. 532-537). Universiti Teknikal Malaysia Melaka.

Mohd Hafizi Abdul Rahman, Mohd Shukor Salleh, Mohd Suffian Ab. Razak, Mohamad Ridzuan Mohamad Kamal, Zolkarnain Marjom, Liza Anuar and Nur Adzly Mohamad Saad., 2018. Design and Optimization of Front Lower Control Arm (FLCA) for C-Segment Passenger Car. In *International Journal of Engineering and Technology* (Vol. 7, pp. 71-75).

Conference Proceedings

M.H.A. Rahman, M.S. Salleh, A. Abdullah, S.H. Yahaya, M.S.A. Razak, M.R.M. Kamal, Z. Marjom, L. Anuar and N.A.M. Saad., 2018. Development of Light Weight Front Lower Control Arm for C-Segment Passenger Car. In *4th Internation Conference on Recent Advances in Automotive Engineering & Mobility Reserach (ReCAR 2017).*

Awards

1. “A New Lightweight Lower Control Arm for C-Segment Passenger Car”, GOLD Medal in ITEX, Kuala Lumpur (2018) .
2. “Processing & Developing of Lightweight Part for EEV Vehicle”, GOLD Medal in PECIPTA (2019) .

3. “A New Lightweight Front Lower Control Arm”, BRONZE in SIIF, Seoul South Korea (2019) .
4. “A New Method Development of Lightweight Automotive Components”, GOLD in Melaka International Expo (2019).

Intellectual Property

1. “A Method of Designing Vehicle Lower Control Arm”, Pattern Filing (2018)

CHAPTER 1

INTRODUCTION

1.1 Background

There are several factors such as global warming, increased energy price, emission and many more factors that influence automotive manufacturers to design lightweight vehicle (Ijagbemi et al., 2016). It is a challenge for automotive manufacturers to produce lightweight components while maintaining the performance of components at the same time. To produce lightweight components, the main criteria to look for are the advanced material and manufacturing technology. If all the components in a vehicle can contribute to about 10% to 20% of weight reduction, it is estimated that 20% of vehicle weight reduction could result in 8–10% of fuel economy improvement. There are several ways to ensure a successful production of lightweight components in vehicle. Changing to a new lightweight material such as composites and aluminium alloy can result in fair amount of weight reduction to the vehicle and improve the fuel economy (Asnafi et al., 2000). Nowadays, several automotive manufacturers have shifted from using steel alloy and cast-iron in vehicle production to alternative lightweight materials such as composite and aluminium alloy. In fact, the market trend for material shows that steel and cast iron usage has gradually decreased in automotive industries.

Nowadays, aluminium alloy is widely used in automotive sector to produce lightweight vehicle and improve fuel efficiency (Chen et al., 2017). Ford as one of the automotive manufacturers has widely used aluminium alloy in the body in white (BIW)

structure and closure such as the outer door panel, roof, outer hood panel, trunk lid, tailgate, etc. For example, Ford F150 model 2015 mostly uses Aluminium alloy for its body in white structure and also for closure panels. Meanwhile, Cadillac ATS and CT6 mix the materials such as aluminium casting, high strength steels and sheet metals on their BIW and closure panels (Joost & Krajewski, 2016).

There are two types of aluminium alloy that are widely used in automotive industries. The first type is non-heat treatable and the second type is work-hardening aluminium alloy. One example of non-heat-treatable aluminium alloy is AlMg (Mn) alloys (5000 series alloys), shows a good combination of strength and formability. While for work-hardening aluminium alloy type, AlMgSi alloys (6000 & 7000 series alloys) obtains the required strength through a heat treatment cycle (Mitra et al., 2016).

Most of the chassis components in vehicle that use aluminium alloy commonly use that non heat-treatable type for series 5000 because its showed good formability and weldability. However aluminium alloys that exposed to the heat treatment process can resist from the corrosion to occurred (Ju¨rgen Hirsch, 2011). Moreover, cast aluminium alloys (i.e A319, ADC 12 and A356) is used widely to fabricate engine components such as flywheel, cap camshaft and engine mounting.

There are several parts involved in suspension assembly such as the lower control, spring, damper, knuckle, and tie rod. In this study, the component that was focused for weight reduction was the front lower control (FLCA). The FLCA is a part connected between subframe and knuckle (Schiehlen & Iroz, 2015). The function of FLCA is to control the alignment of wheel to control the lateral and longitudinal loading transmitted from wheel to suspension subframe. Therefore, the FLCA needs a robust design to sustain a higher loading