DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL

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A report submitted
in partial fulfillment of the requirements for the degree of
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Faculty of Mechanical Engineering

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DECLARATION

I declare that this thesis entitled "DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have checked this report entitled “DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechanical Engineering with Honours

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

ABSTRACT

Elastomer is a natural or synthetic polymer having elastic properties and the main components for the fuel delivery system. It can undergo degradation of their physical properties when directly contact with biodiesel. The specimen of elastomer need to be prepare first before proceed with the experiment. However, the tensile test specimen cutting equipment in the market are expensive, heavy and consume more time for shipment. Thus, to overcome this problem, the tensile test specimen cutting equipment has been invented. This machine are mini in size, portable, durable and consume reasonable costs. The purpose of this study is to develop conceptual and detail design of tensile test specimen cutting equipment and to fabricate the prototype of tensile test specimen cutting equipment. Literature review must be done to make sure the specimen need to cut according to ASTM D412-06 standard to ensure the test is valid. The design process planning are needed to identify, search and assemble all the information related in product design specification. From the morphological chart, few conceptual designs were made and evaluated using Pugh concept selection method to obtain the final design. The final design is then modeled by using Solidworks. The functionality of the 3D model was analysed using finite element analysis. The purpose of this analysis was to determine the product's strength and define the critical stress area so that design improvements can be made to achieve a safety factor of more than one for the entire model. Then further process of fabrication was executed.

ABSTRAK

Elastomer adalah polimer semula jadi atau sintetik yang mempunyai sifat elastik dan komponen utama untuk sistem penghantaran bahan bakar. Ia boleh mengalami penurunan sifat fizikal mereka ketika bersentuhan langsung dengan biodiesel. Spesimen elastomer perlu disediakan terlebih dahulu sebelum meneruskan eksperimen. Walau bagaimanapun, alat pemotong spesimen ujian tegangan di pasaran mahal, berat dan memakan lebih banyak masa untuk penghantaran. Oleh itu, untuk mengatasi masalah ini, alat pemotong spesimen ujian tegangan telah dicipta. Mesin ini bersaiz mini, mudah alih, tahan lama dan memakan kos yang berpatutan. Tujuan kajian ini adalah untuk mengembangkan reka bentuk konseptual dan terperinci alat pemotong spesimen ujian tegangan dan membuat prototaip alat pemotong spesimen ujian tegangan. Kajian literatur mesti dilakukan untuk memastikan spesimen perlu dipotong mengikut piawaian ASTM D412-06 untuk memastikan ujian itu sah. Perancangan proses reka bentuk diperlukan untuk mengenal pasti, mencari dan mengumpulkan semua maklumat yang berkaitan dengan spesifikasi reka bentuk produk. Dari carta morfologi, beberapa reka bentuk konseptual dihasilkan dan dinilai menggunakan kaedah pemilihan konsep Pugh untuk mendapatkan reka bentuk akhir. Reka bentuk terakhir kemudian dimodelkan dengan menggunakan Solidworks. Fungsi model 3D dianalisis menggunakan analisis unsur terhingga. Tujuan analisis ini adalah untuk menentukan kekuatan produk dan menentukan kawasan tekanan kritikal sehingga penambahbaikan reka bentuk dapat dilakukan untuk mencapai faktor keselamatan lebih dari satu untuk keseluruhan model. Kemudian proses fabrikasi selanjutnya dilakukan.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
NBR	-	Nitrile Rubber
FAME	-	Fatty acid methyl ester
CAD	-	Computer Aided Design
UTM	-	Universal Testing Machine
IIR	-	Isobutylene-Isoprene Rubber
EPDM	-	Ethylene propylene diene monomer rubber
NR	-	Natural rubber
CR	-	Chloroprene Rubber
NBR	-	Nitrile butadiene rubber
Si	-	Silicone
MCO	-	Movement Control Order
Covid-19	-	Coronavirus disease 2019
FAEE	-	Fatty acid ethyl ester
HNBR	-	Hydrogenated nitrile butadiene rubber
FKM	-	Fluoroelastomer
PVC	-	Polyvinyl Chloride
FEA	-	Finite Element Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Biodiesel which is most often used as a blend with petroleum diesel fuel, can be used in many diesel vehicles without any engine modification because biodiesel shares same properties with diesel fuel. In addition, biodiesel also is renewable energy that will reduce the emission air pollution.

Elastomer is a natural or synthetic polymer having elastic properties for example, rubber. Elastomers as one of the most important groups of materials, used in fuel systems are of particular concern (Thomas, Fuller, Terauchi, & C, 2013). This is because the elastomers are vulnerable attack by various chemicals and can undergo degradation of their physical properties band stability (Mitra et al., 2006). The major concern for the biodiesel is that it may affect the elastomer which is the main components for the fuel delivery system. The fuel delivery system in a diesel engine is as shown in Figure 1.1.

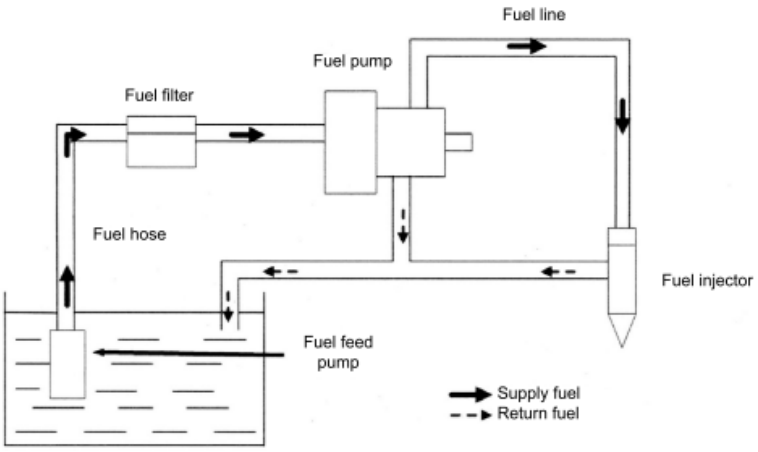

Figure 1.1: Fuel delivery system in a typical diesel engine (Chandran et al., 2016)

The fuel is stored in the fuel tank and the fuel pump draws fuel from the tank. It then travels through the fuel lines in order to support the combustion in the engine. This fuel lines are usually made of a few types of materials which are mainly from elastomer. The most common elastomer to be used in the engine is fluoropolymer elastomer (Chandran et al., 2018). The degradation will happen on the elastomer due to the chemical properties of biodiesel. This will cause the elastomer to be further degraded as the usage time increases. The elastomer hose in fuel line is considered as the specimen to be tested.

However, before the specimen need to be test, specimen need to be cut with specific size and cutting equipment. It is because the facilities do not have convenient cutting equipment for exact size of specimen. Thus, the cutting work done by previous researcher will use drawing of size specimen on a piece of paper and scissor to cut the specimen. As a result, there will be irregular shape and incorrect size of specimen are produced. Hence, design and fabrication of tensile test specimen cutting equipment for elastomer compatibility study subjected to palm-oil based biodiesel.

1.2 Problem statement

The dumbbell sample cutter for tensile test can be bought on the internet. It cannot be denied the dumbbell sample cutter for tensile test that bought on the internet is effective and give an accurate size with minimal error on the specimen. However, it is quite expensive and heavy. As a result of expensive price, previous researcher decided to cut it with scissor. It is also taken time to ship out the machine to the customer due to the machine was manufactured in another country. Figure 1.2 shows the dumbbell sample cutter for tensile test on the Alibaba.com website with price RM3467.20 - RM4334.00.

Figure 1.2: The dumbbell sample cutter for tensile test on the Alibaba.com website

Therefore, in this study will be done in order to design and fabricate cutting equipment for tensile test that can cutting the elastomer into desired size of specimen with minimal cost. This is important to produce first prototype so it can be improved in near the future.

1.3 Objectives of study

From the following problem stated in Section 1.2, this study is done in order to determine the solution of the problem. The objective of this study are as follows:

i. To develop conceptual and detail design of tensile test specimen cutting equipment.
ii. To fabricate the prototype of tensile test specimen cutting equipment.

1.4 Scopes of study

The outlined scope of this study are:-

i. To conduct literature review on existing dumbbell shape sample cutter in the market.
ii. To develop product design specifications for the dumbbell shape sample cutter machine.
iii. To develop new conceptual designs and select best conceptual design of the dumbbell shape sample cutter machine.
iv. To develop detail design of the dumbbell shape cutter machine including 3D CAD model, 2D detail drawings and Bill of Materials (BOM).
v. To perform structural analysis on selected critical components of the dumbbell shape cutter machine using FEA software.
vi. To purchase raw materials and components.
vii. To fabricate customized part and assemble the new dumbbell shape cutter machine prototype.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Nowadays, the quantity of fossil fuel, petroleum and coal are going decreasing and it is very important to make sure that the source of natural resources can be preserved. Coal and petroleum are called non-renewable resources because they cannot be formed quickly. They take a lot of time to form. They take even millions and billions of years to be formed. So, coal cannot be replenished within a given time. Resource of economic value that cannot be readily replaced by natural means at a quick enough pace to keep up with consumption. Therefore, it is considered to be non-renewable resources.

The diesel is one of the largest contributors to environmental pollution problems worldwide, and will remain so, with large increases expected in vehicle population causing ever-increasing global emissions. Diesel emissions contribute to the development of cancer, cardiovascular and respiratory health effects, pollution of air, water, and reductions in visibility.

The tension triangle provides more clarity on the tensions and relationships between fossil fuel derived equation use, climate change mitigation and well-being attainment and illustrating how fossil fuel derived energy use, well-being attainment, and climate change mitigation sit in tension to one another. The form of a triangle is

shown in Figure 2.1. At each point on the triangle sits a process; fossil fuel derived equation use, well-being attainment or climate change mitigation, with each process sitting in relation to the adjacent processes. The negative relationship between fossil fuel derived equation use and well-being is climate change. It is well proven that the combustion fossil fuels and the greenhouse gas emissions, are the largest contributor to continuing climate change. Climate change continues to have well-being impacts throughout the globe including an increased frequency of severe weather events, disrupted weather cycles, and irreversible damage to provisioning ecosystems (Wood & Roelich, 2019).

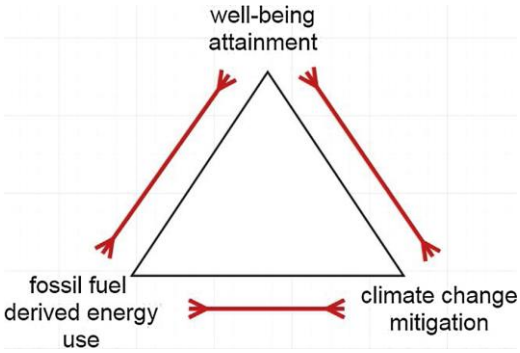

Figure 2.1: ‘The Tension Triangle’ (Wood & Roelich, 2019)

The focus of this study is to conduct experiment of elastomer tests soaked in B10 and B30 biodiesel to check the elastomer's mechanical-physical properties. The measurements were soaking test, mass test, hardness test and tensile test. This chapter discusses about the introduction, explanation of the equipment, testing method and materials used from other journal that is related to this study.

2.2 Biodiesel

Heavy vehicles such as lorry, busses, and trailer trucks typically use diesel as the power source to move the vehicles. Pure diesel has a lot of dangerous effects that can harm the environment. Moreover, diesel emissions contain numerous other compounds that are present in diesel emissions in smaller quantities, but still may be posing health threat to humans. The alternative fuels have been introduced to reduce the pollution. Some well-known alternative fuels include biodiesel, bio-alcohol (methanol, ethanol, butane), refuse-derived fuel, chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, propane and other biomass sources. The spotlight for this project is on biodiesel. Biodiesels are obtained from renewable resources and are biodegradable. Biodiesels also generate cleaner engine emissions, and offer superior lubrication (Boz et al., 2017)

Biodiesel is used as a fuel for hybrid electric vehicle. Therefore, two advantages could be obtained which are reducing the exhaust emission using the cottonseed oil as an alternative biodiesel fuel and improving the fuel economy (Mourad et al., 2014). Biodiesel usage has an effect that leads to a good potential and environmentally friendly solution to reduce the overreliance on the energy import. Biodiesel known as an alternative to diesel fuel produced by transesterification of vegetable oils or animal fats (Haseeb et al., 2010; Mourad et al., 2014). Biodiesel blend can be used in the diesel engine directly when mixed with diesel because it has the same physical properties of diesel fuel (Kumar et al., 2018).

The studies of many researchers on the study of vegetable oils on their properties and their impact on engine performance and exhaust emissions were well

recorded. The particulate emissions were consistently reduced with increasing quantity of oxygen added, particulate emission reduction was not linear with oxygen content and additional oxygen resulted in diminished particulate matter emissions reduction (Guan et al., 2017). According to Lapuerta et al., (2008), biodiesel oxygen content could not lead to an increase in NOx formation as the combustion flow occurs in the oxygen-fuel region around the stoichiometric region, which is normally around 3.58 for standard diesel fuel and 2.81 for typical biodiesel fuels. The use of biodiesel results in lower particulate emissions, unburned hydrocarbons and carbon monoxide than diesel (Lapuerta et al., 2008; Silva et al., 2017).

2.2.1 Production of biodiesel

Biodiesel is produced by four basic methods that include blending with diesel, micro-emulsion, thermal cracking, and transesterification. It is an esterification reaction between an alcohol and the fatty acids abundant in the lipid feedstock. If methanol is used the product is FAME (fatty acid methyl esters) (Metawea et al., 2018). Biodiesel is intended to be used as a replacement for petroleum diesel fuel or can be blended with petroleum diesel fuel in any proportion. There is some requirement in order to be called biodiesel and receive certain tax credits specifically intended for biodiesel which are biodiesel must be produced from naturally occurring fats and oils using transesterification. Second, biodiesel must be composed of fatty acid methyl esters. Third, biodiesel must be refined to remove all trace impurities. Lastly, biodiesel must meet the ASTM standard D6751-07B “Specification for Biodiesel (B100)” (Pacific Biodiesel, 2013).

The purpose of transesterification process is to decrease the viscosity of the vegetable oil from $40mm^2s^{-1}$ into lower viscosity approximately about $5mm^2s^{-1}$ which is said to be suitable for use in diesel engine because biodiesel is becoming an important alternative fuel in the global fuel market due to factors such as declining air quality (Chandran et al., 2016).

2.2.2 Transesterification process

The most common process used in biodiesel production is transesterification, where the triglycerides in the oil react with alcohol to form mono-alkyl ester (biodiesel), with glycerol as the by-product (Chyuan & Silitonga, 2019). To be specific, triglycerides react with alcohols mainly methanol or ethanol and add catalyst to generate biodiesel and glycerol by-product in a transesterification reaction is shown in Figure 2.2.

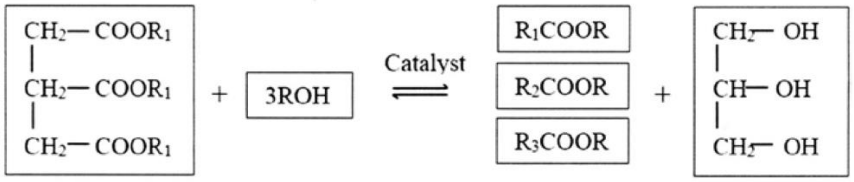

Figure 2.2: Transesterification process for biodiesel production from vegetable oil (Chandran et al., 2016).

When methanol (CH_3OH) is used, the biodiesel product will be fatty acid methyl ester (FAME). On the other hand, fatty acid ethyl ester (FAEE) is obtained when ethanol (C_2H_5OH) is used. Generally, methanol was used as a reagent for biodiesel production through transesterification reaction due to its suitable physicochemical properties, mild reaction conditions and easy phase separation.