UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF ULTIMATE SHIELD FOR FIRE FIGHTING PURPOSE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Bachelor's Degree of Mechanical Engineering Technology (Maintenance Technology)) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of (Bachelor‘s Degree of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Dengan cara semula jadi, perisai digunakan sebagai perlindungan bagi orang-orang untuk melindungi mereka daripada bahaya. Dalam projek ini, perisai ini digunakan sebagai perlindungan dari api dan haba. Perisai ini dijangka digunakan oleh anggota bomba dalam operasi mereka untuk menyelamatkan dan tujuan memadam kebakaran. Projek ini adalah terdiri daripada mereka bentuk dan membangun berdasarkan reka bentuk perisai Unit Simpanan Persekutuan (FRU) dan inovasi dilakukan dengan menambah aplikasi untuk melawan api. Penggunaan menentang kebakaran yang diketengahkan terdiri daripada pemilihan bahan, ergonomik / faktor manusia dan reka bentuk. Ini kerana perisai FRU mempunyai masalah dengan berat dan ia kurang fleksibel untuk ergonomik rakyat Malaysia dan kerana masalah itu, prestasi dan keselamatan unit penguatkuasaan undang-undang yang terlibat juga terdedah. Tujuan projek ini adalah untuk mereka bentuk dan reka perisai dengan kebakaran bukti dan bahan ringan. Dalam usaha untuk memastikan objektif tercapai, perisai akan direka dan dibuat simulasi ergonomic dengan menggunakan perisian CATIA V5 untuk melakukan Analisis RULA. Kemudian, karbon fiber telah dipilih sebagai bahan untuk menjadi badan perisai. Satu kajian telah dilakukan kepada anggota Jabatan Bomba untuk memastikan untuk mencari ciri-ciri terbaik dan fungsi untuk dimasukkan ke dalam perisai untuk memastikan mereka boleh menggunakan perisai dalam keadaan yang terbaik untuk melindungi mereka dan boleh meningkatkan prestasi mereka

ABSTRACT

In natural way, shield is being used as protection for people to protect them from danger. In this project, this type of shield is being used as protection from the fire and heat. This kind of shield is projected to be used by firemen in their operation to rescue and firefighting purpose. The project is consist of designing and developing based on the design of Federal Reserve Unit (FRU) shield and innovated by adding the application of resisting fire. The application of resisting fire that is considered of is the selection of material, ergonomics/human factors and the design. This is because the current FRU shield has issue for its weight and it also does not flexible for Malaysian people ergonomics and due to that problem, the performance and safety of the law enforcement unit is affected. The purpose of this project is to design and fabricate the shield with fire proof and lightweight material. In order to ensure the objective is reached, the shield was designed and undergoes ergonomics simulation by using CATIA V5 software for the RULA Anlaysis. Then, carbon fiber was selected as the body of the shield. A survey was done to the member of the Fire Department to ensure to find the best characteristics and function to be included into the shield to ensure they can use the shield in its best conditions to protect them and can boost their performance.

DEDICATION

To my beloved family,
My supervisor,
And to all my friends,
Thanks for all support and ideas.

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ASSALAMUALAIKUM Wrt. Wbt. and wish the best for the viewers of my thesis or this report. First of all, I am grateful to Allah S.W.T for giving this opportunity for me to complete this Final Year Project Report. I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. A special gratitude to my final year project supervisor, Mr Mohamed Saiful Firdaus Bin Hussin, whose contribution in stimulating suggestions and encouragement, helped me to coordinate my project especially in writing this report. All the guide, teaching, passion by the supervisor to me will be remembered for me to carry on to pursue a better knowledge. Best regards to my entire family member that continuously support me and helping until this research and my studies to be completed. Their support and prayers are helping me a lot to finish studies at UTeM. Special thanks go to my entire classmate 4BETM, that always provide assistance in any circumstances for me and all the students who participate in Final Year Project. With all their effort and guide, this report can able to finished within the time given. Last but not least, I am also grateful to all the lecturers, and any helpers which continuously guide me until this research to be completed.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

°C	-	Temperature
°F	-	Temperature
µg	-	Mass
2D	-	Two Dimension
3D	-	Three Dimension
BC	-	Before Century
BPA	-	Bisphenol A
C_2H_4	-	Ethylene
CAD	-	Computer-Aid Design
CAE	-	Computer-Aid Engineering
Cr^{2+}	-	Divalent Chromium
$Cr_2O_7^{2-}$	-	Dichromate
Cr^{3+}	-	Trivalent Chromium
Cr^{6+}	-	Hexavalent Chromium
CrO_4^{2-}	-	Chromate
G/cm3	-	Density
ILO	-	International Labor Organization
Kg/m3	-	Density
Mg	-	Mass
MPa	-	Tensile Strength
N/mm^2	-	Newton per Millimetre Squared
Si_3Ni_4	-	Silicon Nitride
WC	-	Tungsten Carbide
Wt%	-	Mass Fraction

CHAPTER 1

INTRODUCTION

1.0 Background

Throughout the years individuals have constantly attempted to protect themselves from their enemies, whether it was in the times of the stone age man, the Roman warriors or in our general public today, the need to protect oneself is there, and it won't leave after some time (Stanley, 2004). Shield is one of the type of body armour. A study by Richard (2008) stated that body armour is normally worn for delayed timeframes and over long separations amid military, police, law requirement, and security exercises. The historical backdrop of the body shield does a reversal to Stone Age which is a thousands of years ago. Stanley (2004) state that, the initially written history, body defensive layer was the Stone Age man's dress produced using thick animals' skin as covers up for protection. Later on shields made of wood or metal were utilized to protect one's body.

Chronologically, the main iconographical source representing without doubt Roman troopers with Italic oblong shields are reliefs from the Emilius Paulus landmark, dating to the mid-second century BC (Juliusz, 2012). The shield and body armour is also being used by the Greeks. A study by Hans (1994) state that, significantly more than the noise and the dust storms raised by men and stallions, the blazing of bronze covering and weapons is normal for Homeric fight scenes. At the point when the Greeks outfitted themselves with caps, shields, corselets and lances, the splendor lit up the sky, and all around the earth channelled in the sparkle of bronze. It blinded eyes, the glare of bronze from sparkling shining helmets, polished corselets and bright shields, as they progressed in their masses. After that, the use of body shield does goes back to 1931. The initially recorded utilization of body protective layer for cops was exhibited in 1931, however it didn't turn out to be effective at that time (Stanley, 2004). He also states that, between 1971 and 1976 the National Institute of Justice put more than 3 million dollars into the development of body armour.

1.1 Problem Statement

The main problem that occur in this project is there is no such design that act as shield for those fire fighter during the firefighting. As we know, across the globe, this type of shield is yet to be designed and made. So, as the solution to this problem, the design will be made to build this kind of shield that can be used by the firemen.

The other problems that must be faced is that the existing shield of Federal Reserve Unit (FRU) that being used by the law enforcement unit is not flexible in the ergonomics concept and does not compatible for firefighting purpose. According to Jose. J. Canas, et al. (2012), ergonomists are in a perpetual quest for thorough methodologies in which physical, intellectual, social and ecological parts of human exercises can be considered. When this issues are occurring, it will empower them to work legitimately because of its configuration and weight. As the solution, the suitable lightweight material will be outlined this shield and the best plan to make sure the criteria will meet.

The problem that must be faced during this research is the law enforcement unit always carrying extra weight that can affect their performance and safety. Based on the study from William J. Lewinski, et al. (2015), military research has exhibited that conveying overabundance weight over augmented timeframes, primarily as body armour and gear, diminishes performance and results in more prominent physiological requests. As the arrangement, the design of the shield will be picked wisely as indicated by the appropriateness of the weight with regards to the user, which is the law enforcement unit member.

Hence, this study will focus on the selection of lightweight and fire-proof material that will be used to design the shield to ensure the shield is more compatible and to ensure the fire fighters‘ safety.

1.3 Objective

Based on the problem statement are discussed above, the objectives of this study are listed below:

- To conduct a survey on ergonomics factor in designing fire-fighting shield.
- To analyze the suitability and comfort between manikin and shield using RULA Analysis.
- To design and fabricate the shield with the lightweight and fire-proof material.

1.4 Scope of the Project

In order to achieve the objectives, the scopes are prepared as shown below:

- The survey was done by interviewing at least five Fire Department officers.
- The data was analyzed by using RULA Analysis based on the suitability and comfort between manikin and shield.
- The designation of the shield was done by using Catia V5 software and the fabrication of the shield was done by using water jet cutting machine.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification of Material

2.1.1 Metal

According to the study from Kenneth (2010) stated that in chemistry, a metal can be characterized as a component with a valence of 1, 2, or 3. Be that as it may, a metal can best be characterized by the way of the bonds between the particles that make up the metal crystals. The metal can likewise be characterized as solids made out of molecules held together by a matrix of electrons. The most widely recognized metal that being known is aluminium. A study by Kenneth (2013) shows that the synthesis and characterization of an extensive variety of aluminium based composites has kept on creating a considerable measure of interest judging from the expansive volume of distributions in the area of materials science and building as far back as thirty years. This is because of the versatile applications from aluminium based composites have been effectively used in and the enormous prospects it has for such a large number of other new applications.

2.1.2 Polymer

From a prior study by Kenneth (2010), polymers is the engineering materials that known as plastics. This term originate from Greek words poly, which signifies "many" and meros, which signifies "part". According to Kenneth (2010), polymers are substances made out of long-chain repeating atoms and in most case, the component carbon frames the backbone of the chain. The regular polymer polyethylene is made out of rehashing ethylene atom (C_2H_4). Mikal (1999) states that, synthesis of ethylene and affectability are upgraded during certain phases of plant development and also by various biotic and abiotic stresses. It implies that ethylene is a naturally produced, simple two carbon gaseous plant development controller that affect the development, development and storage life of numerous natural products, vegetables and decorative.

2.1.3 Composite

A study by Kenneth (2010) shows that the mix of two or more materials that has properties that the compound materials do not have by themselves is called composite. Nature made the first composites in living things and wood is a composite of cellulose fibers that held together with paste or matrix of delicate lignin. He additionally expresses that clad metal is a critical metal composite. A study by Zita and Ahmed (2010) clearly shows metal matrix composites are developed by blowing metal powder at the same time with hard powder, generally carbides, into a melt pool that the laser beam generates. The point is to keep the carbides in place with negligible disintegration and just liquefy the matrix material. Due to the low heat contribution of laser cladding it can as a rule be accomplished, giving that the distinction of melting temperatures of matrix and the carbides is sufficiently high. In any case, similar abrasion data is frequently missing for various preparing parameters of laser.

2.1.4 Ceramics

A research by Kenneth (2010) states that the ceramics production is the components with a valence of 4 which is metalloids and they carry on as a metal, once in a while as a non-metal. A ceramic can be characterized as a mix, or compound, of one, or more metals with a non-metallic component. The basic properties for earthenware production are high hardness, chemical latency, and electrical insulation. Fibers and different materials are utilized to fortify ceramics. For instance, silicon carbide fibers are added to silicon nitride to enhance its qualities for metal cutting apparatuses.

Munro (1993) states that, silicon carbide and silicon nitride are the essential possibility for the materials to be utilized as a part of the improvement of heat exchangers for the Department of Energy's Combustion 2000 system. This is on account of the qualities, for example, high mmaximum use temperature, quality maintenance at high temperature, and chemical stability have held forward enticing conceivable outcomes for more productive motors, heat exchangers and recuperators and for more sturdy electronic bundling and chemical processing components.

2.2 Material Selection

2.2.1 Aluminium

From a study of C.Cevik (2012), in daily life or industry, aluminium are always been used in in many fields. Aluminium is always been used as it has low density, easy to mold, have high electrical and heat conductivity. However, the applications for engineering sector for aluminium and alloys are limited as it has poor surface properties, and low abrasion resistance. According to the study of Peter (2001), aluminium is a strongly electro-negative metal and possesses a strong affinity for oxygen; this is apparent from the high heat of formation of its oxide. For this reason, although it is among the six most widely distributed metals on the surface of the earth, it was not isolated until well into the nineteenth century. C. Grard (1920) states that aluminium is prepared by the electrolysis of alumina dissolved in fused cryolite and the electric energy is derived from waterpower.

According to the research from Peter, (2001), there are three main properties for the application of aluminium is based on which are the high corrosion resistance, high mechanical strength and low density. Other than that, aluminium also has high electrical and heat conductance, its reflectivity, its high ductility and resultant low. Furthermore, they also has magnetic neutrality, cheaper compare to other metal, and colourless nature of its corrosion products which facilitates its use in the chemical and food-processing industries. Peter (2001) also states, in its pure state, aluminium is a relatively soft metal with a yield strength of only 34.5 N/mm^2, tensile strength of 90 MPa and melting point of 659°C and its density is $2700kg/m^3$ ($2.7g/cm^3$).

2.2.2 Cast Iron

Based on the research from Kenawy, et al. (2001), cast iron is containing mainly a total of up to 10% carbon, silicon, manganese, sulpher and phosphorous as well as varying amount of nickel, chromium, molybdenum, vanadium and copper. From a prior study of E. Fras (2012), he states that cast iron discovered in 1920and it is widely used around the world. Elements such as Barium, Calcium and Strontium, which are usually introduced to a bath in ferrosilicon, are the most important inoculants of cast iron. According to Daru (2005), in 502 B.C, China has started to develop iron casting while in Europe, the iron casting does not happen until 1200-1450 AD. To this day, 70% of the global casting industries are using cast iron. One of the reasons that cast iron longevity is due to its affordable price.

Based on the research of Kenneth (2010), the tensile strength of cast iron is 223 MPa and the yield strength is 585 Mpa. Furthermore, the density of cast iron is $6800kg/m^3$ ($6.8g/cm^3$). From the study of J. Jezierski and D.

Bartocha (2007), the melting point of cast iron was nearly from 1325 to 1380 degrees Celsius.

2.2.3 Silicon Nitride

Based on the study of B.S. Bal and M.N. Rahaman (2012), silicon nitride (Si_3Ni_4) is a non-oxide ceramic that is one of the rare material as it has been found in particles of meteorite. In the 1950's, the material has increased in commercial due to various refractory applications. However, it was not until the 1980s that its potential as a structural ceramics was clearly recognized. During that time, people from around the world tried to develop this material for gas turbines and combustions engines.

Significant improvements were made in its synthesis, processing and properties. As a result, it is now one of the most extensively studied ceramics in history, its material properties are well understood, and its commercial use has expanded. However, there is a major problems regarding silicon nitride. According to the study of H.T. Lin and M.K. Ferber (2002), silicon nitride are not easily reproduced in the laboratory. Although it is possible to conduct mechanical tests under conditions of high-pressure and high-temperature water vapour, representative gas turbine velocities were very difficult to obtain. Burner rigs are capable of generating both high-pressure and high-velocities, but they generally do not have provisions for applying controlled mechanical stresses that components would be subjected to during engine operation.

According to Sheldon (1999), the microstructure of the silicon nitride is very different from that of sintered silicon carbide. Each grain of silicon nitride is surrounded by a silicate phase that results from a reaction between the sintering aid and residual silica on the surface of the silicon nitride powder. The grains of silicon nitride are separated by a 0.5nm to 1nm layer of amorphous silicate. For the strength of silicon nitride, the high toughness is achieved by debonding along the silicon nitride grains during fracture, thus promoting bridging across the propagating crack. The density of silicon nitride is nearly 3.19 g/cm^3 and its commercial grades have critical stress intensity factors as high as 8MPa.m$^{1/2}$ and bending strengths as high as 1000MPa (Sheldon, 1999). Sheldon (1999) also states that, most commercial grades of silicon nitride are made with sintering aids that promote liquid-phase sintering at temperatures of 1825-2080°C.

2.2.4 Silicon Carbide

According to Houyem and Emna (2011), Silicon carbide is an important non-oxide ceramic which has diverse industrial applications. In fact, it has exclusive properties such as high hardness and strength, chemical and thermal stability, high melting point, oxidation resistance and high erosion resistance. All of these qualities make Silicon Carbide a perfect candidate for high power, high temperature electronic devices as well as abrasion and cutting applications. However, Kun and Hui-Ji (2011) states that there is a great challenge with ion implantation because it inevitably produces defects and lattice disorder, which not only deteriorate the transport properties of electrons and holes, but also inhibit electrical activation of the implanted dopants. Meanwhile the swelling and mechanical properties of Silicon carbide subjected to desplacive neutron irradiation are of importance in nuclear applications. In such irradiations the most dramatic material and microstructural changes occur during irradiation at low temperatures.

Based on the research from Sheldon (1999), the microstructure of sintered silicon carbide depends on the method of manufacture. This is because silicon carbide is a covalent material, bulk diffusion through the grains is too slow to achieve full density without the use of sintering aids. According to A.H. Rashed (2002), silicon carbide does not melt under ambient pressure, rather, it dissociates when heated above 2700°C. Silicon carbide also has the density of 3100kg/m^3 (3.1g/cm^3) , tensile strength with an average of 129 MPa (19 ksi) and a standard deviation of 9.1 MPa (1.3 ksi). Furthermore, a Weibull modulus of 15.8 was obtained, indicating a good uniformity in the tensile strength values.