



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF ULTIMATE SHIELD FOR IMPACT RESISTANT PURPOSE

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

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DECLARATION

I hereby, declared this report entitled “Design of Ultimate Shield for Impact Resistant Purpose” is the results of my own research except as cited in references.

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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 Degree of Engineering Technology Bachelor of Mechanical Engineering Technology (Maintenance Technology) With Honours. The member of the supervisory is as follow:

.....

(Project Supervisor)

ABSTRAK

Perisai digunakan untuk melindungi badan dari bahaya dan kini digunakan oleh Penguatkuasa Undang-undang. Perisai haruslah mempunyai rintangan hentaman yang tinggi untuk menyerap daya yang dikenakan. Projek ini adalah untuk membina dan meningkatkan kebolehan perisai yang digunakan oleh Penguatkuasa Undang-undang melalui faktor ergonomik, pemilihan bahan dan reka bentuk. Ini adalah disebabkan oleh perisai semasa tidak mempunyai masalah dengan faktor-faktor ergonomik dan berat badan. Masalah ini boleh mengurangkan prestasi Penguatkuasaan Undang-undang dalam menjalankan tugas. Oleh itu, tujuan kajian ini adalah untuk mereka bentuk perisai untuk tahan impak. Untuk mencapai objektif ini, reka bentuk perisai dilukis melalui perisian Catia V5. Dalam projek ini, reka bentuk yang terbaik telah dipilih ialah untuk mewujudkan Slide In Shield. Perisai ini juga menganalisis kesesuaian dan keselesaan antara manikin dan perisai dengan menggunakan Analisis Rula. Dengan mempertimbangkan untuk menjadi bahan utama untuk perisai, kaji selidik itu telah dianalisis melalui soal selidik dan temubual. Hasil kajian menunjukkan bahawa lembaran polikarbonat sesuai untuk membina perisai kerana sifat dan keupayaan untuk menahan daya.

ABSTRACT

Shield is used for protecting body from danger and currently used by Law Enforcement. The shield should have high impact resistance to absorb the force applied. This project is to the developing and improvement a shield that currently used by Law Enforcement by considered of ergonomic factors, materials selection and it design. This is due to the current shield has an issue to the ergonomic factors and weight. Those problems can decrease the performance of the Law Enforcement. Thus, the purpose of this study is to design an ultimate shield for impact resistant. To achieve this objective, the design of shield is collaborated with Catia V5 software. In this project, the best design had been chosen is to create a Slide-In Shield. This shield also analyzed the suitability and comfort between manikin and shield by using RULA Analysis. By considering to the main material for the shield, the survey had been analysis through questionnaire and interview. The result shows that Polycarbonate sheet is suitable for build a shield due to its properties and ability to hold the impact.

DEDICATION

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

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

BVID	-	Barely Visible Impact Damage
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
C_nH_{2n}	-	Alkene
CVID	-	Clear Visible Impact Damage
F	-	Fahrenheit
GPa	-	Giga Pascal
HOQ	-	House of Quality
M-Chart	-	Morphology Chart
mm	-	Milimeter
MPa	-	Mega Pascal
ms-1	-	Meter per second
°C	-	Degree Celcius
PC	-	Polycarbonate
PE	-	Polyethylene
QFD	-	Quality Function Deployment
UHMWPE	-	Ultra High Molecular Weight Polyethylene

CHAPTER 1

INTRODUCTION

1.1 Background

Shield actually had been built in a long time ago. According to Stanley (2004), the shield was created by cavemen by using thick animal skin as their clothing. Then, the wood or metal had been applied to make a shield to protect human body from harm. During the middle ages, the shield was built by assembling it from metal strap. This shield used by Roman soldiers that wore a system of segments and called it as “Lorica” that stand for armor (Stanley, 2004). Shields were often the trusted defense of infantrymen and knights alike throughout history and this certainly did not change during the Middle Ages. The strong shields were used to block both attacks and projectiles from harm to the soldier. After that the plate armor became a commonplace form of protection. It was basically layered with the paste and tanned to make it tougher (Adam et.al, 2013).

Moreover, the other equipment that compile with the shield were short throwing spear, an open-face helmet, and a sword (Kagan and Gregory, 2009). According to Sharon Dettmer (2006), the soldiers used the shield was to protect their life during war and believed that it can protect them from harmful. Nowadays, demonstrations, civil unrest, public disorder, and riots were always happen in daily life for a number of reasons. This happens because of the economic hardships, social injustices, ethnic differences (leading to oppression), objections to world organizations or certain governments, political grievances, and terrorist acts (Dennis J, 2005).

In last few decades, the shield are been made from the material that have monolithic, usually of high hardness steel. Then in certain year, the lightweight shield

had been demand in the industry to lead for the personal protection. The materials that had been conducted such as non-metallic materials, such as ceramics and composites, have been increasingly incorporated into more efficient lightweight armors (Fawaz et.al, 2004). There are many different types of shields. There are also many factors that contribute to the quality of the shield which include size, thickness, and material. The size varies greatly because some are intended to protect the whole body, and others are meant to be easily moved to cover specific parts at any given moment. Like other forms of body armor, shields became less common and less effective after the invention of the gun. However, some civilizations still used them for identification (Deidre and Emma, 2003).

Lightweight armor design and analysis has been approached from all three analysis angles, namely: empirically, analytically, and numerically. Numerical models, based on solving all the governing equations over a spatial grid at successive time increments, have proven to be valuable design tools since they can help achieve a comprehensive understanding of the ballistic impact process (Fawaz et.al, 2004).

1.2 Problem Statement

The problem that faced in this project is the shield that used by the law enforcement is heavy to carry. When this issue happens, the law enforcement can't work properly because of the problem. According to military research, it has demonstrated that carrying excess weight over extended periods of time, primarily in the form of body armor and equipment, decreases performance and results in greater physiological demands (Cheuvront et.al, 2008). Based on research by Alcaraz et.al (2008), the study of athletes being tested by wearing resistant belts or vests, often weighing less than the average officer's protection and equipment, it shows that the movement of athletes are decreasing in stride length, flight time, speed, and acceleration. The time taken in ground contact and forward trunk lean also increases and become longer than before. The solution of this problem is to choose the proper materials that have lightweight properties and improved the shield to be more compatible and lightweight.

The other problem of this project is the shields that exist are non bullet proof. The shield made by polycarbonate can't hold much impact from the bullet. According to the study by Qasim H. Shah (2009), the polycarbonate plate are being investigate to test the impact limit that the polycarbonate plate can hold. In the experiment, the impact limit that can apply for the plate must be in the range 125–130 ms⁻¹. While the velocity applied by rifle bullets has a range 900ms⁻¹. The pertinent properties determine the response to rapid deformation and fracturing due to the high speed of bullets (A. Finney et al, 2013). Then the conditional incapacitation probabilities for 9mm NATO bullets have a velocity about 347.472 ms⁻¹ (Bruchey and Sturdivan, 1968). So, it can be proved that the polycarbonate plate can hold the impact range by bullet of pistol and rifle. The solution of this problem is the shield has to be improved with new material or adding other material to make the shield can hold the impact from the huge impact of bullet.

Then, the other problem faced in this study is the ergonomics concept not fully applied to the Malaysian Law Enforcement. The shield that had been used by our law enforcement does not suitable for the Malaysian size. So, this study will focus on the selective material and design of the shield to make the shield more compatible and achieve it to be a lightweight shield. According to Fabrice Czarneck (2003), the large of police department experienced failure of its ammunition, handguns, ballistic vests and automated external defibrillators. Once equipment is selected and issued, it has to be evaluated constantly for its efficacy, reliability, risks for acute or chronic injuries, and associated risk for litigation. So it can be concluded, if the shield is unsuitable for the used it can be risks to their body. This study will focus on the correct selective materials and design of the shield to make the shield more compatible and achieved the ergonomics concept.

1.3 Objective of Research

Based on the problem statement discussed above, the objective of this project are listed below:

1. To conduct a survey on the ergonomics factors in designing shield for impact resistance.
2. To analyze the suitability and comfort between manikin and shield using CAE.
3. To design and fabricate a lightweight shield with high impact resistance.

1.4 Scope of Research

To achieve the objectives above, the scopes of the project are prepared as shown below:

Developing an ultimate shield for impact resistance purpose;

1. The survey are done by conducting a survey by using questionnaire for Law Enforcement stated in Malaysia.
2. The data are analyzed by using CAE based on the suitability and comfort between manikin and shield.
3. The designing of the shield are done by using Catia V5 Software.
4. The fabrications of the shield are done by selecting different type of materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification Of Materials

2.1.1 Nature Of Metals

Nature of metals can be defined as a bond between the atoms that build up as the metal crystals. Metal crystals are depending on the properties of individual crystal also known as grains. Then, metals also are built up as a solid atom that combines with a matrix of electron together. Actually, metals are divided in much type of metallic properties such as luster, opacity, malleability, ductility and electrical conductivity. In this metallic material also have various of metal like examples are iron, aluminum, copper, zinc, etc. and their alloys. This metals have two conditions, they are can be found in bulk or powder form. As we known, metal have a good conductors of electricity and heat but they are not transparent to visible light, a polished metal surface has a lustrous appearance. Therefore, metal also are strong in physically, deformable which depending to the extensive use in structural applications. From this appearance and properties, metal are always in crystalline in nature. According of scientists, they had been developed non-crystalline or called alloys that can be very rapid cooling of melt or very high-energy mechanical milling (Kenneth et.al, 2010).

After that, reaction rates of metals increase highly when there are any increments in temperature, and at very high temperatures most reactions are

completed within a few minutes. Therefore, from this equilibrium state, oxygen and metal reaction are commonly happen and oxidation problems are mostly reduced to determining the reaction rate (Ivan, 2000). Furthermore, there are critical contamination problems and chemical reactivity of liquid metals at high temperatures because of a lack of the viscosity properties and measured of viscosity are vary widely. (Fathi Aqra et.al, 2012).

2.1.2 Nature Of Ceramics

Ceramics are the combination between metallic and non-metallic elements. They are most frequently oxides, nitrides and carbides (Kenneth et.al, 2010). According to Narasimha, in 2012 ceramics known as nonmetallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi-metallic elements. Ceramic have many type such as sodium, potassium, calcium, magnesium, aluminum, silicon, phosphorus, zirconium & titanium (Narasimha, 2012). Then, ceramics is come from decomposition of clay minerals, cement and glass. According to (Kenneth et.al, 2010) the glass has a similar properties but it are amorphous although in same grouped.

The properties of ceramic are high hardness, abrasion resistance, brittleness and chemical inertness (Kenneth et.al, 2010). The measurements of fracture strength of ceramics are significantly smaller than theoretical predictions. Fracture strength of ceramic may be greatly enhanced by creating compressive stresses at surface. Meanwhile, the compressive of strength in ceramics are ten times the tensile strength. It shown that ceramics has a very good structural material under compression (Jean.P et.al, 2004). After that, for the ceramics information of metal fatigue, there have a increment of uses of high strength and brittle materials such as ceramics, intermetallics and their respective composites, for structural applications where cyclic loading is critical (Harrison et.al). Moreover, the ceramics are insulation of electricity and heat while its has a

high temperature and harsh environments than metals and polymers. Although ceramic are hard but they are very brittle than the metal (Kenneth et.al, 2010).

2.1.3 Nature Of Polymers

Natures of polymers are combination of carbon and hydrogen and also called as organic substances. The part of polymer is plastic and rubber material. Polymers have divides by 3 type like thermoplastic polymers, thermosetting polymers and elastomers or better called as rubbers (Kenneth et.al, 2010). Firstly is thermoplastic, it can be form in solid or melts appearances. Thermoplastic have a choice to be material form and physical state because it more than a matter of convenience. Thermoplastic performance is depending on to the solid samples properties but it can be related to the process ability with the melts properties (Cox W.P et.al, 1958). Secondly, Thermosetting are network-forming polymers. The appearance like epoxy, phenolic, unsaturated polyester, polyurethane, dicyanate, bismaleimide, acrylate and many others. The thermosetting is different with thermoplastic because on the chemical reaction in their uses. Thermosetting polymers have a high viscosity, and eventually cross-link .meanwhile some of thermosetting product have a dual core mechanism to the heat or light activation (R.Bruce, 1997). Then lastly, elastomer is called as a rubber or elastic polymer. It was a versatile material that has many uses in industrial such as car tyres, running shoes, pencil rubber. Elastomer are very different and remarkable compare to another solid. Their type does not expand when react with heat although it as rubber. Rubbers are form from the vulcanising latex and a natural extract from the rubber tree (S.A.Atarah ,2008).

In additionally, the properties of polymers are high in molecular structures and have a very light in weight compare to metal (Kenneth et.al, 2010). Polymers also high resistance to thermal degradation and also to attack of inorganic and organic substances (Maria Curie, 2015). Meanwhile, according to

Kenneth et.al (2010), this polymer material is have low density, flexible and highly uses as thermal or electrical insulator. Polymers have a change of properties in tensile strength, colour, shape based on the under of one or more environmental factors such as heat, light or chemicals (Rafi et.al, 2012). There are example of polymers like polyesters, phenolics and polyethylene (Kenneth et.al, 2010).

2.1.4 Nature Of Composites

Nature of composite is a combination of two or more materials of metals, ceramics and polymers. Composite is widely used in engineered and industrial (Kenneth et.al, 2010). Then, composite are metallic alloys and it's retain with separate chemical, physical, and mechanical properties. The composite is dividing by two types which are reinforcement and a matrix. The advantage of composite material are its have high in high strength and stiffness while its combined with low density compared to with bulk materials. The reinforcing phase was provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate (F.C. Campbell, 2010). Then, a matrix is a supporter for the fibers to bond together in composite materials. Its can transfer any load to the fibers and keep it in right position while conducting with the environment and determine with the maximum service temperature (Ashby and Jones, 1980). After that, the ceramic matrix has a high temperature include silicon carbide, carbon, alumina, silica, zirconia and other elements (V.S. Aigbodion et.al, 2012).

This composite have a several examples which are wood, clad metals, fiber glass, reinforced plastics, cemented carbides, etc (Kenneth et.al, 2010). According to A Dorigato and A Pegoretti (2010), carbon fiber is a type of composite. Carbon fiber composite is useful in build of aerospace, automobile, sporting goods and other application that have high in strength, high modulus,

good fatigue resistance, low density and elevated chemical stability. Then, fiber glass also the common composite material that are embedded within a polymeric material. Its requires strength from the glass and flexibility from polymer (Kenneth et.al, 2010). In fact, in hybrid composites two or more types of fibers are simultaneously used as reinforcement (A Dorigato,2013). These materials as a class of engineering material provide almost an unlimited potential for higher strength, stiffness, and corrosion resistance over the 'pure' material systems of metals, ceramics and polymers polymer (Kenneth et.al, 2010).

2.2 Material Selection For Impact Resistance Shield

2.2.1 Polycarbonate

Polycarbonate (PC) is a material that has high ductility and low density that are widely used in industrial. Then, polycarbonate are being choose for some specialized application because of it properties that make it more light and have a very god impact resistance. It can be used to protect against the harmful and treat (Ajmer et.al 2012). According to Qasim H. Shah (2008), polycarbonate is have a highly ductile material at room temperature and huge plastic deformation occur when the high load was applied statically or dynamically. Polycarbonate is under polymers that are made by a long chain of molecules that are from carbon to carbon bond (Prashant, 2006). While according to Dong Wook (2016), it state that polycarbonate are blended with poly(methyl methacrylate-co-phenyl methacrylate) copolymer. So that, it make the polycarbonate been miscible at all of the compositions. According to the Qasim H. Shah (2008), he prove that polycarbonate is extremely used in building of bullet proof vest or Kevlar and armored vehicle because of it ability that highly ductile, transparent nature, and comparatively light weight. As it proven, there have a practice by using this material in plate and tested by pointing the impact to specific location for being study of its properties.