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MASTER OF ENGINEERING (MECHANICAL)

UPNM 2018

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Thesis submitted to the Centre for Graduate Studies, Universiti Pertahanan Nasional Malaysia, in fulfilment of the requirements for the Degree of Master of Engineering (Mechanical)

May 2018

ABSTRACT

Nowadays, armored personal carrier (APC) is largely used because of the revolution of war doctrine to carry the fighting element by vehicle, which means less infantry troops movement on foot. Malaysian Arm Forces has bought AV8 Gempita from Turkey and currently been deployed to carry out missions in our country. The APC will be faced lot of extreme conditions during war such as undulating terrain, landmine blast and armament fire. However, there are few studies done to assess AV8 Gempita performance when subjected to underbelly blast loading.

The main objective of research is to simulate the AV8 Gempita hull deformation and acceleration when subjected to underbelly blast loading by using Finite Element Analysis. The simulation result has been used to determined AV8 Gempita capability to sustain blast loading STANAG 4569 level III as per claimed by manufacturer. The thesis then investigated the effects of changing different parameters, such as stand off distance, panel thickness, amount of explosive charge, and gap distance. Manual measurement on the hull body was conducted to obtain the measurement of hull AV8. The data is needed to make CAD modeling using Solidwork version 2016. The finite element simulation model was be analyzed using LS-DYNA 2013. Based on analysis, maximum deformation of AV8 hull is 88.6 mm when subjected to 10 kg of TNT that cause 59.6g to the occupants of vehicle. The hull body is proved can sustain that blast but it lose mobility and the occupants experienced severe injuries. The result from this research can be used to evaluate the capabilities of AV8 frame based on simulation and as initial reference for next research using experimental approach.

ABSTRAK

Pada masa kini, pengangkut peribadi berperisai (APC) dominan digunakan kerana revolusi doktrin perang untuk membawa unsur mobiliti dan penghantaran udara dalam taktik pertempuran yang mengurangkan secara drastik pergerakan infantri secara berjalan kaki. Angkatan Tentera Malaysia membeli AV Gempita 8X8 dari Turki dan telah digunakan untuk menjalankan misi di negara kita. APC akan menghadapi banyak situasi ekstrem semasa perang seperti kawasan beralun dan berpaya, letupan periuk api dan ancaman misil anti-kereta kebal. Walau bagaimanapun, data prestasi AV Gempita berdepan letupan periuk api pada bawah perut badan kenderaan perisai sulit dan kurang kajian ilmiah.

Objektif utama kajian adalah mensimulasikan perubahan bentuk dan pecutan badan AV8 Gempita apabila tertumpu kepada impak letupan pada bawah perut tubuh kenderaan dengan menggunakan Analisa Unsur Terhingga. Hasil simulasi telah digunakan untuk menentukan keupayaan AV8 Gempita untuk mengekalkan pemuatan letupan STANAG 4569 tahap III. Kajian ini meneliti kesan perubahan ke atas parameter yang berbeza, seperti jarak, ketebalan panel dan jumlah cas letupan. Berdasarkan analisa, perubahan bentuk maksimum AV8 badan kapal adalah 88.6 mm apabila tertakluk kepada 10 kg TNT yang akan menyebabkan 59.6 g kepada penghuni kenderaan. Badan lambung terbukti dapat menampung letupan itu tetapi ia akan kehilangan mobiliti dan penghuni akan mengalami kecederaan teruk. Hasil daripada kajian ini boleh digunakan untuk menilai keupayaan rangka AV8 berdasarkan simulasi dan sebagai rujukan awal untuk penyelidikan seterusnya menggunakan pendekatan percubaan.

ACKNOWLEDGEMENT

Praise to Allah S.W.T for giving me the strength, patience and motivation to complete this research work.

First and foremost, I would like to give my sincere recognition to Dr. Risby bin Mohd Sohaimi for his advices and constructive criticism throughout the completion of this thesis. He has been supervised me with generosity and I am deeply impressed by his ability in responding to many kinds of things either related or not with the research.

I wish to acknowledge the exceptional contribution of the Universiti Pertahanan Nasional Malaysia (UPNM), 31 Workshop Armor Regiment and 74 Divisional Workshop members for their insights into the research methodology and findings. Nevertheless, the financial loan support from Malaysian Armes Forces is gratefully acknowledged.

Furthermore, my special gratitude goes to my colleagues in UPNM thermodynamic laboratory; Fahmi Isa, Mohd Noor Hafizi, Wan Hanif, Khalis and Azhar for their relentless guidance in problem solving during the simulation process. Yet, I am indebted to Col Ir Haji Mohd Hazani, Maj Hakimi Makhtar, Maj Yushaile and Maj Mohiddeen for their permission and supports throughout my post-graduate part time studies.

Lastly, I would like to convey my appreciation to my father, Kamarudin bin Deraman, my mother, Rashidah binti Abd Rahman, my fiancée and my siblings for their endless support throughout the completion of my studies.

APPROVAL

I certify that an Examination Committee has met on **11th May 2018** to conduct the final examination of **AHMAD RAJI BIN KAMARUDIN** on his degree thesis entitled '**FINITE ELEMENT ANALYSIS OF GEMPITA 8X8 UNDERBELLY DEFORMATION SUBJECTED TO BLAST LOADING**'. The committee recommends that the student be awarded the degree of Master of Engineering (Mechanical).

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APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirement for the degree of Master (Mechanical Engineering). The members of the Supervisory Committee were as follows.

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LIST OF ABBREVIATIONS

°C	Celsius
°F	Fahrenheit
AEP	Allied Engineering Publication
APC	Armoured Personal Carrier
CAD	Computer Aided Design
CFD	Computational Fluid Dynamic
EFP	Explosive Formed Projectiles
EOS	Equation of State
FE	Finite Element
FMJ	Full Metal Jacket
IED	Improvised Explosive Device
KE	Kinetic Energy
kg	Kilogram
kN	Kilo Newton
kW	Kilo Watt
mm	Millimetre
MPa	Mega Pascal
NATO	North Atlantic Treaty Organization
NDT	Non-Destructive Test
PE	Plastic Explosive
s	Second
STANAG	Standardization Agreement
OEM	Original Equipment Manufacturer

CHAPTER 1

INTRODUCTION

1.1 Research Background

The armoured vehicles have been a crucial key factor weapon in the ground battlefield due to its excellent operational mobility, tactical offensive and defensive capabilities. Armoured personal carrier has gone through lots of improvement in aspects of hull protection and vehicle maneuverer capabilities. The ground and human threats challenge the sustainability of the vehicle to maintain its serviceability and reliability for completing Armed Forces missions and tasks.

In battlefield, infantry battalion will be supported by armoured vehicle and air support. Deployment of armoured vehicle will carry troopers safely to the main battle area. The deployment of peacekeeping forces in conflict areas has shown that some armour systems are not sufficient to meet the latest threats. The discovery of more efficient weapons, such as the kinetic energy (KE) projectiles, shape charges and explosive formed projectiles (EFP) able to penetrate up to almost 1m of rolled armour steel meant that tanks produced during the 1960s and 1970s were vulnerable to personnel carried missiles nowadays (Sánchez Gálvez & Sánchez Paradela, 2009).

The Mine Ban Treaty signed in Ottawa on September 1997 has not put a stop, in any way, to the global landmine crisis, as an estimated 100 million mines lay strewn in around 60 countries all over the world. Figure 1.1 shows the sequences of AT mine blast during Chechnyan insurgence operation against Russian Armed Forces. The increasing use of Improvised Explosive Devices (IED) against military vehicles in war zones has become a severe threat to military personnel. Fighting infantry vehicle, armoured personnel carriers and mine clearing vehicles are example of vehicle deployed in such missions for post-war country. These vehicles are often deployed under military operations, patrol missions, convoys, mine-clearing, transport missions and medical evacuation task.

This study was aimed to simulate the blast response on the vehicle structure using numerical method to find the effect of hull structure when occurrence of land mines attack. From the simulation result, it will analyse impact, wave blast and stability of the vehicle armor hull. This study will be focus on AV 8x8 GEMPITA from *Angkatan Tentera Malaysia (ATM)* because there is lack of reported study conducted in term of blast protection and sustainability of the hull. Most of data are kept by the OEM but not available for the user. Figure 1.2 shown the picture of AV 8x8 after undergo inspections and final vehicle test before delivering to operational unit especially armor specialized and mechanize regiments.

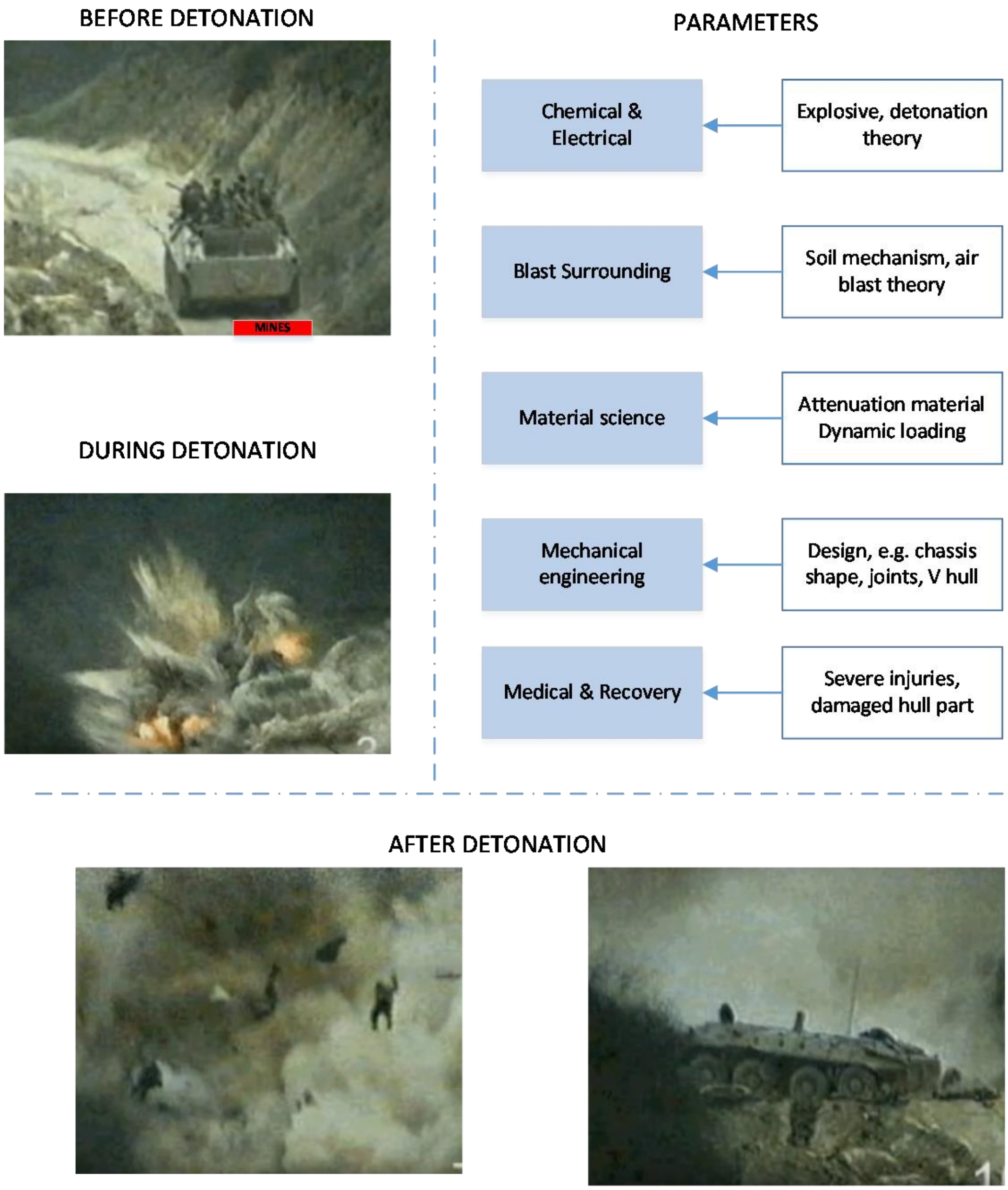

Figure 1.1 Parameters involved to enhancement of landmine protection (Trajkovski, Kunc, Perenda, & Prebil, 2014)

Figure 1.2 *Gempita AV 8x8* at *DEFTECH*, Pekan.

AV8 Gempita which is a FNSS Defence System product from Ankara, Turkey has undergo few of enhancement program conducted by DRB-Hicom Defence Technologies (DEFTECH) Sdn Bhd, a Malaysian Company producing and supplying combat vehicle and equipment to Malaysian Arm Forces. Known as PARS in Turkey or AV8 Gempita in Malaysia has 12 variants which are having their own special capability to accomplish multiple types of tasks and missions. Each variant carries different weapon caliber, special tools for recovery and medical purpose and internal compartment spaces.

Latest STANAG 4569 AEP 55 (Showichen, 2008) by NATO sets the level of protection for armoured vehicles. There are 4 levels of the protection is categorized based on the mine explosive weight in which Level II, III and IV corresponds to 6 kg, 8 kg and 10 kg of mass respectively. Whereas for level I protection only correspond to hand grenades, unexploded artillery fragmenting sub-munitions and small anti- personnel devices. Level II, III, and IV are then divided in two categories as shown in Table 1.1.

Table 1.1 Protection levels for occupants of armoured vehicles for grenade and blast mine threats (STANAG 4569).

<table>
<tr><th colspan="2">Level</th><th colspan="2">Grenade and Blast Mine threat</th></tr>
<tr><td rowspan="2">IV</td><td>4b</td><td>Mine Explosion under belly</td><td rowspan="2">10 kg (explosive mass) Blast AT Mine</td></tr>
<tr><td>4a</td><td>Mine Explosion pressure activated under any wheel or track location</td></tr>
<tr><td rowspan="2">III</td><td>3b</td><td>Mine Explosion under belly</td><td rowspan="2">8 kg (explosive mass) Blast AT Mine</td></tr>
<tr><td>3a</td><td>Mine Explosion pressure activated under any wheel or track location</td></tr>
<tr><td rowspan="2">II</td><td>2b</td><td>Mine Explosion under belly</td><td rowspan="2">6 kg (explosive mass) Blast AT Mine</td></tr>
<tr><td>2a</td><td>Mine Explosion pressure activated under any wheel or track location</td></tr>
<tr><td>I</td><td colspan="3">Hand grenades, unexploded artillery fragmenting sub-munitions, and other small anti-personnel explosive devices detonated anywhere under the vehicle</td></tr>
</table>

After equipping another layer of composite aluminum and steel armor at front and both side of AV8 Gempita, DEFTECH declare AV8 Gempita now already capable to sustain up to STANAG level IV which is one level higher than older model from FNSS. Some studies have been done in order to increase the combat capabilities and sustainability of this eight-wheeled armoured vehicle during war and insurgency. The analysis of AV8 Gempita hull is determined in this study to validate the AV8 sustainability when subjected blast loads at its underbelly.

1.2 Problem Statement

Armoured vehicles are typically been developed through an iterative process of destructive field testing in order to determine the level of blast protection for that particular armoured vehicle. A structural analysis of the hull is required in order to justify the explosive blast limit and the field of shock impact sustainability. Recent advances in computational power and high-fidelity multi-physics computational tools now offer the alternative of performing Simulation-Based Design (SBD), similar to what is currently done for crash protection. Finite Element Analysis (FEA) is a simulation tool can analyse the physical respond of prescribed condition before prototyping. The advantages of FEA is that it does not require physical testing of candidate armoured plate materials of the vehicle, which makes it a highly cost effective alternative to traditional way of physical blast testing. Besides that, there are disadvantage from FEA results that are less accurate than the actual models used to describe for example the explosives and materials that are modelled. Generally, such models are heavily dependent on material parameter input, which has to be found through material testing.

Indeed, for the early stages before doing actual blast test, it is necessary to assess the structural response of the AV8 hull using simulation method. Boundary conditions of AV8 Gempita hull material need to be determined and data used in the simulation work. Based from the author's knowledge, there is no reported study to assess the AV 8x8 blast response done by the manufacturer or from other researchers.

1.3 Objective

Pursuant from the problems above, this project aims completing following objectives:

a) To develop CAD model of AV8 Gempita from manual and photography geometry-based measurement data.
b) To determine the mechanical properties of the AV8 Gempita structure using non-destructive test (NDT) method.
c) To analyze the AV8 Gempita hull responses when subjected to underbelly blast loading by using Finite Element Analysis.

1.4 Scope of Work and Limitations

In order to make sure that the project will be completed within its objective, work scope is important so that it will guide the project specification. These are the scopes of this project:

a) Review recent research about armoured vehicle subjected AT threats
b) Determine the density of the AV8 Gempita hull material.
c) Analyse the mechanical properties of AV8 Gempita hull material by using non-destructive test (NDT).
d) Build up AV8 Gempita hull computer-aided design (CAD) model.
e) Analyse the blast test using TNT 6kg, 8kg, 10kg from AT and IED simulated situation.
f) Compare the effect of hull response due to 3 location of underbelly blast.

Since there are widespread of possible influential factors that would be in existence in various condition of parameter to be considered, this study will be only limited to this condition:

a) Soil and air density are been neglected.

b) Underbelly hull will be simplified which analyse will be carry out only on main hull body. Axel, exhaust pipe, suspension crossmember and tires will be neglected.

c) There is no such angle of attack fragment impact. The blast load is simulated within ground clearance.

d) Simulation blast is limited to static vehicle condition only. Moving vehicle need various parameter to be considered.

e) Test scenarios cover only high-explosive events and do not represent petrochemical explosions or any chemical substances caused burning effects.

1.5 Thesis Outline

This study contains five chapters consists of introduction (Chapter 1), literature review (Chapter 2), research methodology (Chapter 3), results and discussion (Chapter 4) and conclusion and recommendation (Chapter 5). The following paragraphs elaborate each of chapter in a more detail. The overall work flow for this thesis is as per shown in Figure 1.3.

Chapter one introduce the basic information of the study such as research background, problem statements, objectives, scope of work and limitations and project outline. Introduction shows the overview of the project, followed by the problem statements that state the problem occurred which lead the project to accomplish.

Chapter two is the literature review which is the most critical part of the study. This chapter contains the summary of the information needed from previous researches while completing the project. Chapter Two provides a comprehensive review on the armour hull especially the strucutre, fundamental understanding of armour application and some reviews of composite material, which are reported by other researchers. For simulating part, a general overview will be given about the blast and the primary parameters that describe a characteristic blast wave will be presented using computational method. The information is attained from several sources such as related books, master thesis, academic paper, journal and others.

Chapter three focus on research methodology. It illustrates the steps taken to complete the study. In order to fulfil the objective of the study and overcome the problems stated, several steps must be carried or passed. The methods should follow engineering specifications, concept generation and selection, engineering design parameters, final validation plan, project plan, and a description of simulation analysis to achieve the research objectives and some of the methods are based on the other researcher works.