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Aluminum Material as a Solution to Create Strong and Lightweight Combat Vehicles with Increased Efficiency from Fuel Savings

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Abstract

In the current era, combat vehicles are required for strong defense, extensive expedition, agile or nimble and lethal, with greater ability to conduct special operations. One of the problems in combat vehicles is their weight which makes a significant factor in their ability to achieve endurance with agility and speed. Some research shows that aluminum material is the solution to overcome the weight and durability of combat vehicles. Research shows how the determination of aluminum material in general can greatly save fuel when the mass is reduced from 0-15%. From this research, we hope to open people's minds, that the importance of specifying the material used for military vehicles by improving vehicle functions in terms of speed, strength, and fuel efficiency.

Keywords: *Aluminum; Combat Vehicle; Efficiency; Fuel; Mass Reduction*

Introduction

A strong defense along with a wide and fast expedition to conduct special operations is currently very important for the Army. Despite the advantages of lightweight vehicles, the challenge is the weight of the vehicle. The lighter weight of the vehicle will usually decrease its power performance. Lightweight vehicles deserve a lot of attention as significant energy savings are necessary for the economic sustainability of a country today and in the future. The Army's ground vehicles are getting heavier as threat mitigation technologies are introduced, so changing the mass of the vehicle is important to get the best performance. New techniques are needed for more accurate vehicle energy that aims to reduce energy consumption/reach that aims to reduce rider anxiety when long range is required [1].

A 10-15% diminish in vehicle weight can lead to a 6%–8% enhancement in fuel proficiency. The body weight of a vehicle can be decreased by up to 50% by supplanting conventional press and steel components with lightweight ones like high-strength steel, magnesium (Mg), aluminum (Al), carbon fiber, and polymer composites [2]. This diminishes the sum of gasoline that a vehicle employment [3]. In this research calculation, the Maung 4×4 Tactical Vehicle will be used as the basis for calculations that will be used to illustrate how well the Vehicle performs when its mass is lowered and it uses less gasoline.

The Maung tactical vehicle from PT Pindad has a vehicle mass of 2160 kg, which is mostly made of steel [4]. Aluminum makes the vehicle lighter, resulting in less fuel consumption. Aluminum's properties that are taken into account are that it does not rust easily. Aluminum has a light mass and good durability. This property can make the car accelerate faster. The large load of military vehicles due to carrying equipment and troops makes the car heavy, but if using aluminum it becomes less heavy. A 15% reduction in mass with aluminum from 2160 kg to 1836 kg.

Materials and Methods

In this research, a simple method is used to perform calculations, namely simple calculations using Matlab software. The first step we take is to determine the problem to be discussed, as for the problem is the large number of large losses when using heavy materials in transportation. The second step is to check theoretically, in this case by deriving a simple equation from physics, namely Newton's Second Law, the theoretical value will be obtained in the study and the equation will be entered into the calculation software. The third step is that we look for data, as for the data we use comes from many references and can be seen in Table 1 above, namely the Parameter Table. The fourth step discusses the results of the input data.

Results and Discussion

To find out the power requirements in driving a vehicle, we must consider all aspects of the force involved in the vehicle. Reviewing the aspects of the force applied will get a scalar value of the force so that we can get the total load power needed to drive a car [5-8].

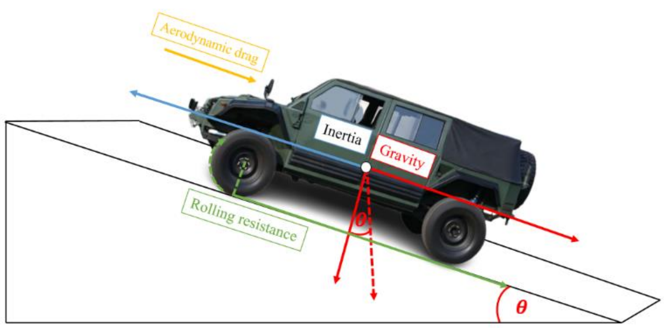


Figure.1 The forces involved in the movement of the Tactical Maung 4x4

$$P_{load} = \left(\sum F_{drivig} \right) . v_{vehicle\ speed} \quad (1)$$

$$P_{load} = P_{Rolling} + P_{Drag} + P_{inertial} + P_{climb} \quad (2)$$

From the above formula, we can prove that mass is very valuable from the power load required on the vehicle, so if we reduce the mass on the vehicle it will reduce the value of the power load resulting in reduced fuel requirements.

a. Rolling Resistance

As we know that a car or vehicle moves with the rotational force of the wheels. Rotation, namely on vehicle tires that run directly with uneven road layers will result in a drag force that accelerates rotation.

$$F_{Rolling\ Resistance} = C_R M_t g \quad (3)$$

$$P_{Rolling} = C_R M_t g v_s \quad (4)$$

C_R is the coefficient of rotational drag, M_t is the vehicle's overall mass, g is the value of the gravitational acceleration, v_s is the vehicle speed. From the above formula, it can be seen that the mass constant of the vehicle greatly affects the value of the power load on the vehicle. So if we regulate or manage the mass by reducing it, it will result in a decrease in the required power load which results in reduced fuel requirements.

b. Air Resistance

In the movement of vehicles, it is undeniable that air resistance will hinder the movement of the vehicle. Therefore, it takes the best design for the vehicle from the front to the rear so that it is an aerodynamic shape. For the movement of the vehicle to be good, the vehicle area is made to a minimum or made aerodynamic.

$$F_{Drag\ Force} = \frac{1}{2}\frac{\rho_{air} C_D A v_s^2}{1000} \quad (5)$$

$$P_{Drag} = \frac{\frac{1}{2}\rho_{air} C_D A v_s^3}{1000} \quad (6)$$

ρ_{air} is the air's density, C_D is the air resistance coefficient's value, and A's value represents the vehicle's front surface area.

c. Inertia

As is known, all objects have the property to maintain their position, so that if we have the position or position of the vehicle moving with a certain acceleration, we will get the value of the object's work. We can say that this power is the effort to run the vehicle.

$$F = M_t \frac{dv}{dt} \quad (7)$$

$$P = \frac{1}{2} M_t (a.v_s) \quad (8)$$

W is the effort of the vehicle to move. From the above formula, it is clear that the mass constant of the vehicle is seen to greatly affect the value of the power load on the vehicle. So if we regulate or manage the mass by being reduced or reduced it will result in the required Power Load will decrease which results in reduced fuel requirements.

d. Gravity

We cannot deny that the strength of the gravitational field or the acceleration of gravity will affect every object or object. Likewise with this vehicle, when an object is uphill on a high road, a force is needed to shift the position of the object or object. If we see an object moving up then the acceleration of gravity will hinder the movement of the vehicle with mass as the main factor.

$$F_{climb} = M_t g \sin\theta \quad (9)$$

$$P_{climb} = M_t g \sin\theta \ v_S \quad (10)$$

θ shows the slope of the incline traversed by the vehicle from the above formula, it can be seen that the mass constant of the vehicle greatly affects the value of the power load on the vehicle. So if we adjust or adjust the mass by reducing or reducing it will result in the required Power Load will be reduced.

From all the equations of force or load power, namely the equation above, then we input it into equation (1), then we will get the total load needed.

$$P_{load} = C_R M_t g v + \frac{\frac{1}{2}\rho C_D A v^3}{1000} + \frac{1}{2} M_t [a. v_s] + M_t g v \sin\theta \quad (11)$$

$$P_{load} = \frac{\frac{1}{2}\rho C_D A v^3}{1000} + M_t \left(C_R g v + \frac{1}{2}[a. v_s] + g v \sin\theta \right) \quad (12)$$

a is the acceleration value of the vehicle. The formula for the value of the fuel needed uses the equation below.

$$Q = \frac{P_{load}}{H\,.\,\eta} \quad (13)$$

Q is the value of liters of fuel per unit hour, H is the value of the form of calorific value, and η is the efficiency of the combustion engine.

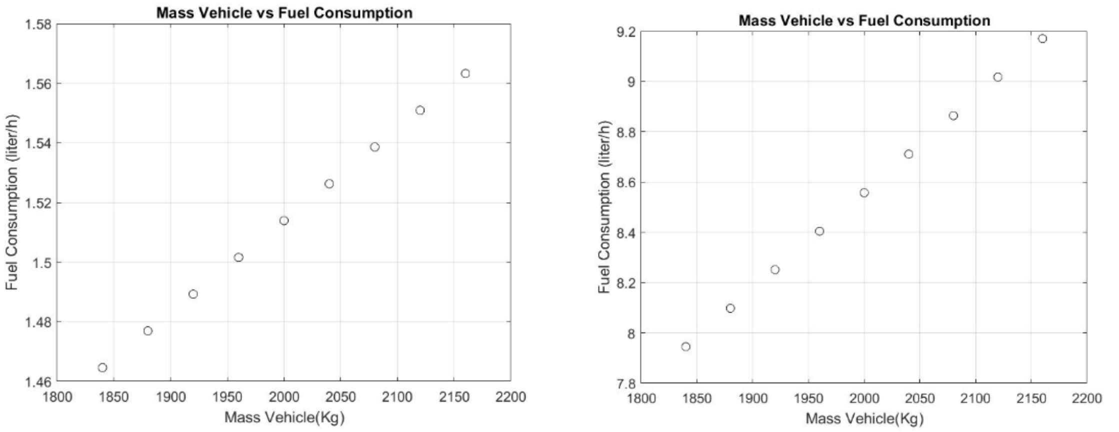
In this calculation, we assume that the PT. Pindad tactical combat vehicle is traveling at an initial speed of 70 km/h with a track distance of 95 km accompanied by an incline angle of 0 and 10 degrees. Data regarding constant values for force resultant calculations we seek from several sources. The following table contains the parameter values used for calculations.

In the experiment to calculate the relationship between mass reduction and fuel, we use the Matlab application. The results of this calculation we get values that show the effectiveness of the aluminum material for reducing the mass of 324 kg. The figure below shows that the more the mass reduction, the greater the reduction in fuel consumption Calculations are carried out in simple computations on combat vehicles from PT. PINDAD, namely Maung 4x4 Tactical vehicles [4], where the fuel reduction is quite large when the mass is reduced from 0-15%, while the mass of the vehicle is close to 2160 kg, when we reduce the mass, namely with Aluminum, it will get a mass reduction of 15% which is 324 kg.

Table 1. Parameter values used in calculations

NO	Symbol	Value	Source
1	C_R	0.015	http://what-when-how.com/
2	M_t	2160 kg	https://pindad.com/maung
3	v_s	70 km/h	assumption
4	C_D	0.64	sau1601 automotive aerodynamics
5	θ	0° & 10°	assumption
6	H	9.9 kWh/l	blog.52north.org
7	η	95 %	assumption
8	a	50 km/h^2	assumption
9	ρ_{air}	1.2 kg/m^3	theory
10	g	9.81 m/s^2	theory
11	A	2.99 m^2	sau1601 automotive aerodynamics

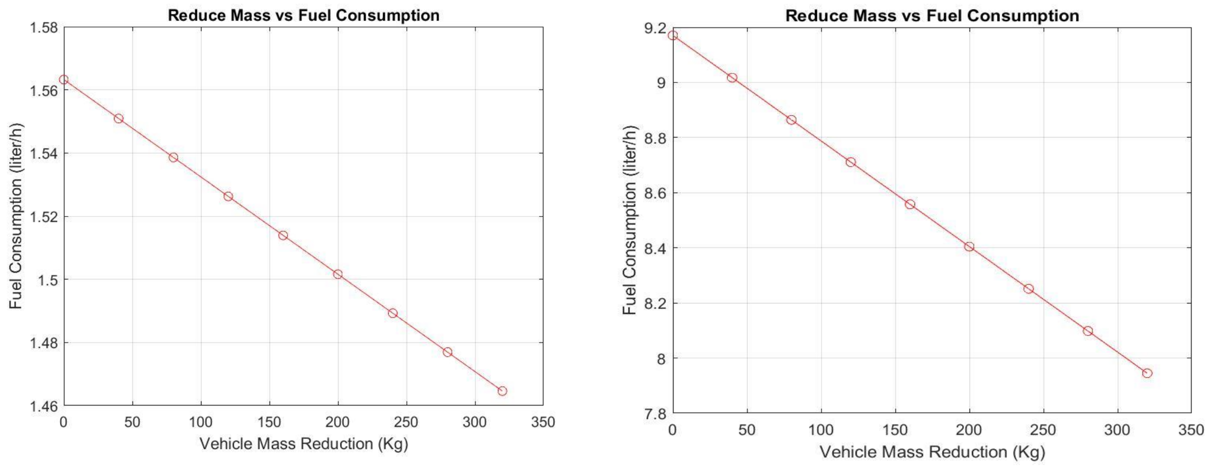
From Figures 2-4, it can be seen that the greater the mass value of the vehicle, the more load power is needed, on the contrary, the greater the mass value of the vehicle, the less load power is needed. Table 1, which is the data sought from many sources, these values are sufficient to be calculated simply to show the greatness of mass reduction.



(a) 0° (b) 10°

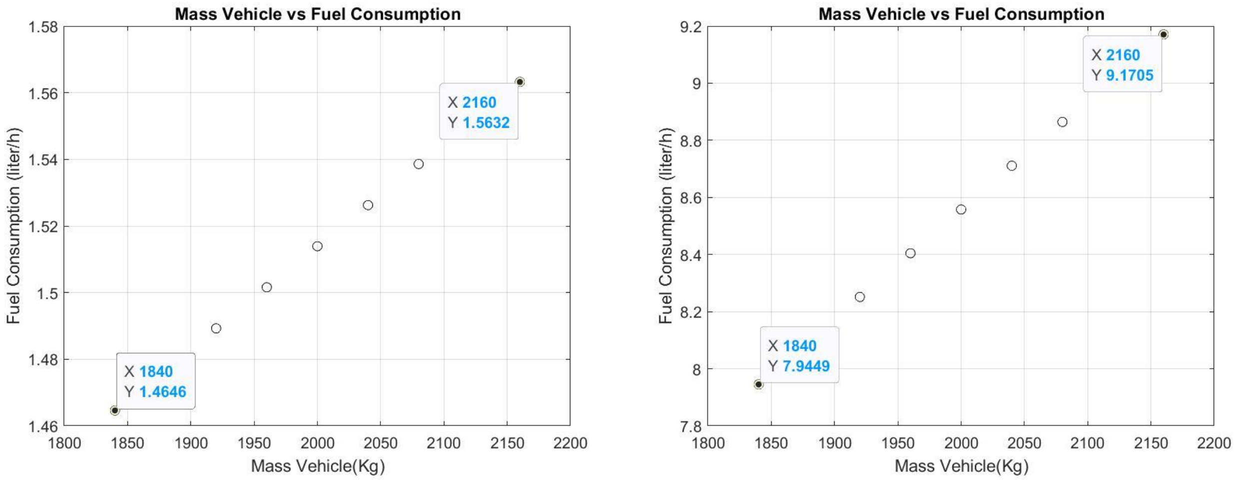
Figure 2. The appearance of the value of the increase in fuel demand when the mass is increased. images that are (a) for values of 0 degrees or no incline angle and images that are (b) for 10 degrees on incline.

Despite not moving, the engine still uses fuel, therefore material use is still reasonable. All tested technologies used the same methodology. In fact, a moving vehicle will definitely go through inclines and descents, so that the calculation of specific fuel additions will be very difficult. In this calculation we do it in general, namely by taking a view when the car passes an incline angle of 0 degrees or on a straight road and an incline angle of 10 degrees or uphill on a plateau.



(a) 0° (b) 10°

Figure 3. The appearance of reduced mass results in reduced fuel consumption. images that are (a) for values of 0 degrees or no incline angle and images that are (b) for 10 degrees on incline.



(a) 0° (b) 10°

Figure 4. Relationship of mass reduction in Maung 4x4 Tactical vehicles. Mass Reduction Comparison 0% to 15%. (a) for values of 0 degrees or no incline angle and images that are (b) for 10 degrees on incline.

According to Figure 2 for part (b) that is 0 degrees, a mass reduction of 0% on the Tactical Maung 4x4 with a mass of 2160 kg will result in a fuel requirement of 1.5632 liters, and a mass reduction of 15% on the vehicle will result in a fuel requirement of 1.4646 liters. The achievement attained 0.0986 L or saves 0.1 liter of gasoline for a 1-hour travel in a diesel vehicle or a 1-hour drive over a 95 km distance with the recording of fuel to lower the mass of 324 kg with aluminum. With a 15% reduction, this calculation shows that the fuel economy is 6.3%, which is a significant decrease in fuel consumption.

According to Figure 2 for part (a) that is 10 degrees, a mass reduction of 0% on the Tactical Maung 4x4 with a mass of 2160 kg will result in a fuel requirement of

9.1705 liters, and a mass reduction of 15% on the vehicle will result in a fuel requirement of 7.9449 liters. The achievement attained 1.2256 L or saves 1.2 liter of gasoline for a 1-hour travel in a diesel vehicle or a 1-hour drive over a 95 km distance with the recording of fuel to lower the mass of 324 kg with aluminum. With a 15% reduction, this calculation shows that the fuel economy is 13.36%, which is a significant decrease in fuel consumption.

In this research there are still many shortcomings that must be resolved. First, in this research we only use data that we seek from several sources without conducting experiments directly. Second, we do not weigh in terms of drag on the components attached to the vehicle and other forces when the car is stopped. Third, this research does not consider the electric power used in vehicles such as lights, connected electronic devices, air conditioners, and others. But in this calculation we get a value that shows the influence of mass which greatly affects fuel requirements. Basically, when this combat car is in driving or operational condition, it will pass through bad or uneven terrain, can go up 30 degrees or even 45 degrees. So that a suitable mass reduction is needed to operate properly without reducing the vehicle's function.

Conclusion

Enhancements to land vehicles have been sought for as a way to support air transport capabilities for quick deployment, improve fuel efficiency, more readily cross open water obstacles, and boost battlefield mobility and speed. Many vehicles needs, like as speed, mobility, and survival against various threats, have been successfully met by tactical vehicles using aluminum and other materials as the primary hull material for protection.

By recording the fuel savings of 324 kg mass reduction with Aluminum and in calculations with a 95 km track with a slope value of 0 degrees on an incline, savings of 0.0986 L are obtained or close to 0.1 liter fuel savings for 1 hour trip on a diesel vehicle or 1 hour trip on a 95 km track distance. From these calculations, it was found that there was a fuel saving of 6.3% when there was a reduction of 15%, this figure indicates a significant reduction in fuel. By recording the fuel savings of 324 kg mass reduction with Aluminum and in calculations with a 95 km track with a slope value of 10 degrees on an incline, savings of 1.2256 L are obtained or close to 1.3 liter fuel savings for 1 hour trip on a diesel vehicle or 1 hour trip on a 95 km track distance. From these calculations, it was found that there was a fuel saving of 13.36% when there was a reduction of 15%, this figure indicates a significant reduction in fuel. Basically, when this combat car is in driving or operational condition, it will pass through bad or uneven terrain, can go up 30 degrees or even 45 degrees. So that a suitable mass reduction is needed to operate properly without reducing the vehicle's function.

Mass reduction is very good for all military vehicles because this mass reduction will result in enormous fuel savings and is economical for the state budget. By replacing this vehicle material with a lightweight and strong material such as aluminum, a large fuel advantage is obtained along with an increase in vehicle speed and agility.

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