DESIGN AND ANALYSIS OF PLUG-IN HYBRID MOTORCYCLE CHASSIS

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Abstract - *Plug-in hybrid electric motorcycle (PHEM) is an alternative to promote sustainability lower emissions. However, the PHEM overall system packaging is affected by restricted area in an exceedingly motorcycle chassis. In this paper, a chassis applying the concept of a half-duplex cradle (double cradle) is analysed to apply in PHEM. The chassis 3dimensional (3D) modelling is built with CAD software. The PHEM power-train components and drive-train mechanisms are replaced with the same size and material blocks into the 3D modelling to ensure the chassis provides enough space. Besides that, a human dummy model is built into the 3D modelling to ensure the rider's posture and comfort. The chassis 3D model then undergo to the analysis in ansys. The analysis predicts the stress distribution, displacement and strain. The data are used to identify the critical point, thus suggesting the chassis design is applicable or need to redesign/ modify to meet the require strength. Critical points mean highest stress which might cause the chassis to fail. This point happens at the joints at triple tree and bracket rear absorbent for a motorcycle chassis. As a conclusion, this analysis predicts the stress distribution and guideline to develop a safe prototype chassis.*

Key Words: PHEM chassis, Half-Duplex cradle, computational analysis.

1. INTRODUCTION

A plug-in hybrid electric motorcycle (PHEM) is equips with two or more energy source, typically a gasoline internal combustion engine is coupled with an electric motor to propel the PHEM. The electric system in PHEM operates at high efficiency, allow diversification of energy resources, zero local emission and work silently [1,2]. However, PHEM require more components and complex drive-train mechanism as compare to conventional internal combustion engine motorcycle [3,4]. These cause the design of PHEM overall system packaging is challenging as constraint by limited space in a motorcycle chassis [5].

For instant, there are several motorcycle chassis design available with varies features and applications. These include Cruiser, Sport Bike, Touring, Standard, Dual-Sport, Scooters and Off- Road type [6]. The chassis is the central frame of the motorcycle which upholds the components and loads. These include the weight of each component and the forces manifest during acceleration, deceleration and cornering [7]. The chassis design must be able to withstand above loads besides consideration for the rider safety, fuel efficiency and aerodynamics [8-10].

Half-duplex cradle framed one is type of sport motorcycle, which originally meant for high speeds and deeper turns purpose. Its built from scratch to have compact appearance. The main features in present frame include widened frame, raked fork, Clubman handlebar and feet backward riding posture. Figure 1 illustrates the features in Half-duplex cradle type motorcycle.

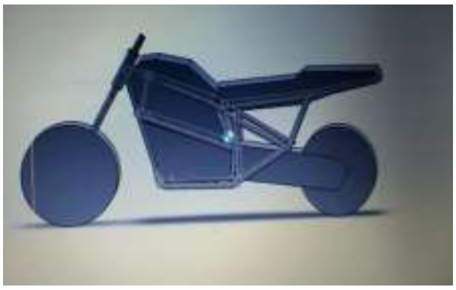

FIG-1: A Half duplex cradle chassis is modelled in solidworks.

2. LITERATURE SURVEY

A hybrid electric vehicle (HEV) consist of two or more power source namely, internal combustion engine and an electric motor to improve its fuel efficiency and the reduction of harmful emissions. A plug-in hybrid vehicle (PHEVs) is an HEV with the ability to recharge its energy storage system with the supply of electricity from the electric utility grid. The terminology between PHEV and HEV can be classified further into charge-sustaining mode, charge-deleting mode, all-electric range (AER), electrified Miles, PHEVxx, SOC, degree of hybridization and utility factor .

The hybrid electric motorcycle are introduced as motorcycles are the major mode of transportation especially in South Asia and Asia region. Motorcyles are favoured due to limited space, short daily trip distances, population density, easy operation and maintenance. The number of motorcycles has increased by 0.35 million per year for domestic sales and 1 million for export into South Asia market. The development of hybrid electric motorcycles are driven by the 'go green' technological push, economic sense as well as to reduce harmful exhaust emissions

In the design of plug-in hybrid electric motorcycle (PHEM), the chassis plays a significant role as it supports the powertrain components, drivetrain parts and rider. A chassis is essentially the skeleton of a motorcycle. It must be straight to provide a secure mounting for the steering apart from proper wheel alignment. The frame must be structurally sound to support the weight of the rider, the engine and the other components attached to it.

One of the chassis design types of the sport motorcycles is the Half-duplex cradle or feet backward type. This type of chassis is characterized by the footrests being backward from the seat, short forks. The handlebars may be lower as compared to the seat which is often positioned relatively high. The riding position is as such that the legs of the rider are folded backward.

3. PROBLEM STATEMENT

The arrangement of a plug-in hybrid electric motorcycle (PHEM) components in a constrained space of a motorcycle frame is becoming a challenging task. Therefore, the design of the chassis is important to ensure enough space is given to mount all the peripherals well.

The chassis design should also provide enough strength to support the powertrain components, rider and remaining forms of weight contributions. Plug-in hybrid electric motorcycle (PHEM) are heavy when compared to conventional motorcycles. Therefore, it is essential that the chassis could withstand the before mentioned contributing loads other than providing required support.

Hence, the combination of the above-discussed aspects as well as other factors such as aerodynamics, economics and comfort are commendable in the design of such chassis.

4. MOTORCYCLE CHASSIS DESIGN

In chassis design, the most important thing that must be constraint is about the reference geometry on that chassis. The importance of reference chassis geometry is to produce new chassis in fully characteristic in design such as aerodynamically stability, manoeuvrability and safety consideration. Figure 2 shows the main parameter of reference motorcycle chassis geometry.

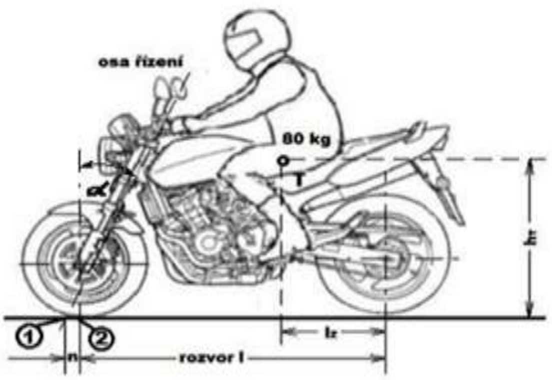

FIG-2: Main parameters of motorcycle chassis geometry

The rake angle of the front fork indicates the angle between the steering axis and the ground plane. A smaller rake angle of the front suspension rods results in a greater stabilizing effect on the front suspension system. The rake angle (angle of steering axis) exists within the limit 24□to 30□to the ground. Steering axis and ground interaction point is the point of contact with the ground is indicated as wheel axis contact perpendicular to the base of a stationary bike at a point of their contacting. Trail is the distance between the steering axis and ground contacting point and the point of wheel contact. The trail has a important effect on the stability and handling of a motorcycle. The wheelbase is the distance between the rotation axis of the wheels in a straight-line drive. Centre of gravity is determined by vertical and horizontal position.

The driving attributes can be mainly effected by modification of the basic parameters. Therefore, if to alter the driving stability of an already fabricated motorcycle, it must have the following parameters. Position can be adjusted the centre of gravity. This can be accomplished by altering of a riding positioning, which is, however, bounded by positioning of control and support components of the motorcycle. Still, these changes are not always easy to guide properly because it is impossible to encrypt all the variety of co-rider's weights. Further parameters of chassis are: wheel base, trail, rake or steering axis angle.

5. SPECIFICATIONS

Wheel base = 1350mm = 53.149 inches.

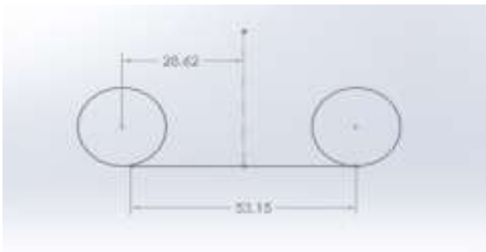

FIG-3: Wheelbase of the motorcycle

Total weight = 140 kgs =308.647 lbs.

Load on front wheel (LF)calculated from the CG value got from the solid works software.

Load on rear wheel (LR) calculated from the CG value got from the solid works software.

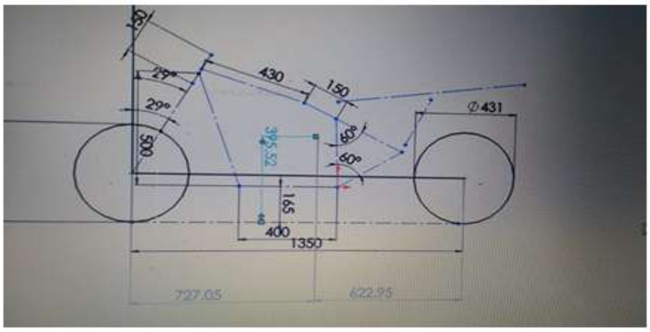

FIG-4: Centre of gravity(CG) point which was obtained from Solidworks.

Behind the front wheel = 727.05 mm = 28.624 inches.

Above the ground = 395.52mm = 15.571 inches.

6. THORETICALLY CALCULATED VALUES FOR CG

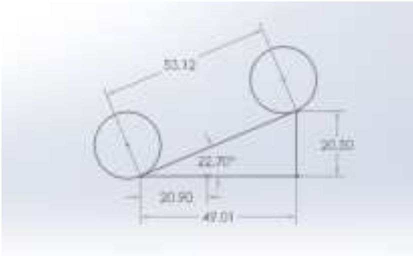

FIG-5: wheel base shown from above the ground with an angle.

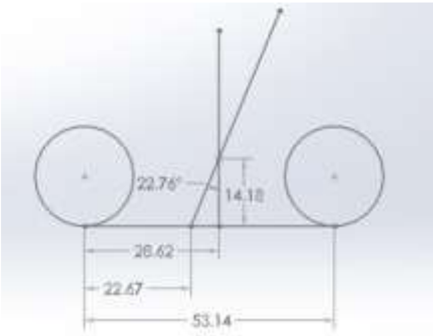

FIG-6: The CG point distance shown from the ground

Behind the front wheel = 726.948 mm = 28.62 inches.

Above the ground = 360.17 mm = 14.18 inches.

From solving the above-mentioned figure 5 sequentially we can get the final theoretical CG value from the figure 6.

7. RESULTS

7.1 Static structural analysis

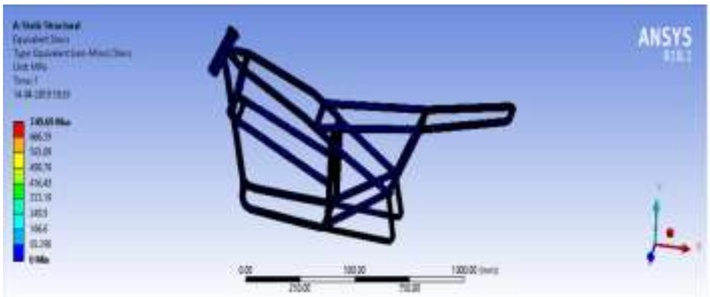

FIG-7: shows the result for von Mises Stress of maximum of 749.69 Mpa.

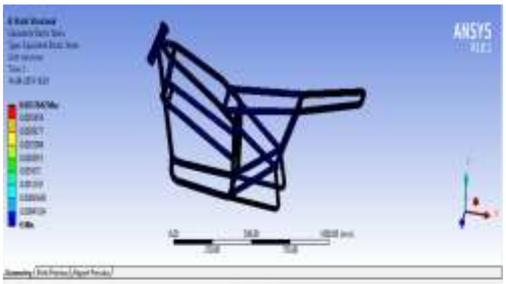

FIG-8: shows the result for strain maximum value of 0.0037642 mm/mm.

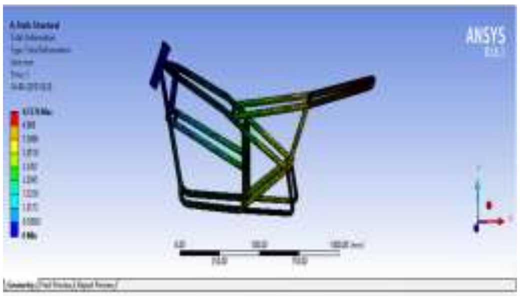

FIG-9: shows the result for displacement

The analysis result for displacement (figure-9) show highest displacement is at the frame where the rider sits and the frame supporting the weight of engine, electric motor, controller, batteries and drive-train mechanism. The maximum displacement is 4.57mm, thus providing insignificant undesirable effect on neither chassis nor rider.

7.2 Vibrational Analysis

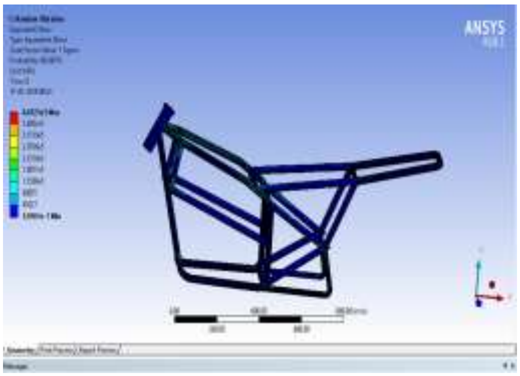

FIG-10: shows the result for equivalent stress of maximum 4.0525e5 Mpa.

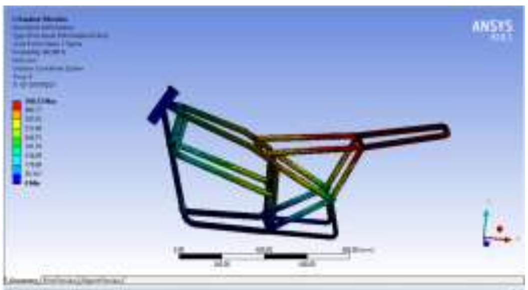

FIG-11: shows the result for deformation.

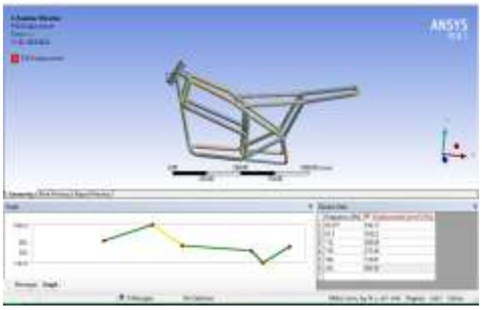

FIG-12: shows the result for vibrational displacement.

7.3 Impact Analysis

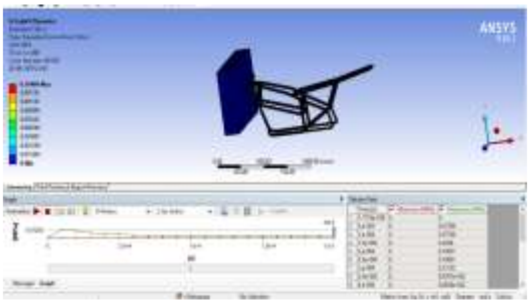

FIG-13: shows the result for equivalent stress of maximum 0.10484 Mpa.

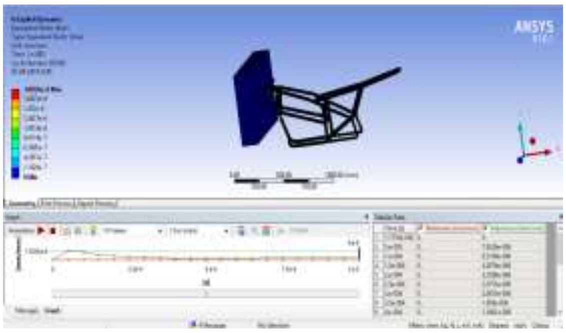

FIG-14: shows the result for equivalent elastic strain.

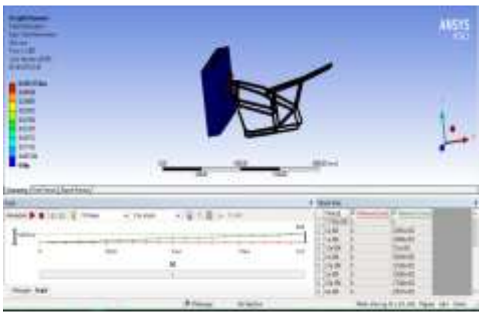

FIG-15: shows the result for total deformation.

REFERENCES:

[1] Chau K T and Wong Y S 2002 Overview of power management in hybrid electric vehicles Energy Conversion and Management 43 1953–68

[2] Amjab S, Neelakrishnan S and Rudramoorthy R 2010 Review of design considerations and technological challenges for booming development and preparation of plug-in hybrid electric vehicles Renewable and Sustainable Energy Reviews 14 1104-10

[3] Sheu K B and Hsu T H 2006. Design and implementation of a novel hybrid-electric-motorcycle transmission Applied Energy 83 959-74

[4] Wu X, Cao B, Li X, Xu J and Ren X 2011 Component sizing optimization of plug-in hybrid electric vehicles Applied Energy 88 799-04

[5] Bayindir K C, Gozukucuk M A and Teke A 2011 A comprehensive overview of hybrid electric vehicle: Powertrain configuration, powertrain control techniques and electronic control units Energy Conversion and Management 52 1305-13

[6] Teoh E R and Campbell M 2010 Role of motorcycle type in fatal motorcycle crashed Journal of Safety Research 41 507-12

[7] Mat M H and Ghani A R 2012 Design and analysis of„ Eco‟ car chassis Procedia Engineering 41 1756-60

[8] Kamal M, Rahman M M and Rahman A G A 2012 J Mech Eng Sci 3 291

[9] Robertson S A and Minter A 1996 A study of some anthropometric characteristics of motorcycle riders Applied Ergonomics 27 223-29

[10] Kamal M, Rahman M M and Rahman A G A 2013 Inter J Automot Mech Eng 7: 912