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COMPUTATIONAL ANALYSIS ON PLUG-IN HYBRID ELECTRIC MOTORCYCLE CHASSIS

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ABSTRACT

Plug-in hybrid electric motorcycle (PHEM) is an alternative to promote sustainability of energy and lesser emission. However, the PHEM overall system packaging is constraint by limited space in a motorcycle chassis. In this paper, a chassis applying the concept of a Chopper is analysed to apply in PHEM. The chassis 3dimensional (3D) modeling is built with CAD software. The PHEM power-train components and drive-train mechanisms are intergraded into the 3D modeling to ensure the chassis provides sufficient space. Besides that, a human dummy model is built into the 3D modeling to ensure the rider's ergonomics and comfort. The chassis 3D model is then undergoing stress-strain simulation. The simulation predicts the stress distribution, displacement and factor of safety (FOS). 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 occurs at the joints at triple tree and bracket rear absorber for a motorcycle chassis. As a conclusion, computational analysis predicts the stress distribution and guideline to develop a safe prototype chassis.

***Keywords*:** Hybrid Motorcycle; Chassis Chopper; 3Dimensional model; Critical point.

INTRODUCTION

The electric system in plug-in hybrid electric motorcycle (PHEM) operates at high efficiency, allow diversification of energy resources, zero local emission and work silently (Chau and Wong, 2002; Shaik et al., 2010). A 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. PHEM require more components and complex drive-train mechanism as compare to conventional internal combustion engine motorcycle (Kuen and Tsung, 2006). These cause the design of PHEM overall system packaging is challenging as constraint by limited space in a motorcycle chassis (Kamil et al., 2011)

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 (Teoh and Campbell, 2010.) 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 (Mat and Ghani, 2012). The chassis design must be able to withstand above loads besides consideration for the rider safety, fuel efficiency and ergonomics (Robertson and Minter, 1996)

Chopper is type of cruising motorcycle, which originally means custom made motorcycle (“chopped”) or built from scratch to have unique hand-crafted appearance. The main features include extended frame, raked fork, hardtail-style, chrome finishes, ape hanger handlebars and feet forward riding posture. Figure 1 illustrates the features in Chopper type motorcycle.

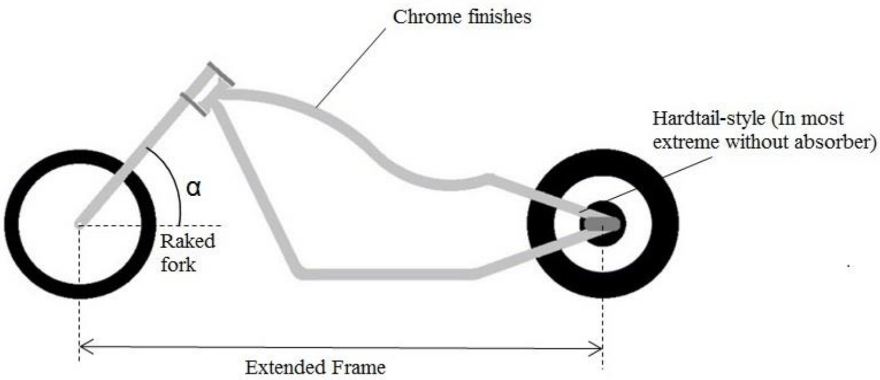


Figure 1. Features in Chopper type motorcycle.

CHASSIS DESIGN

A Chopper type motorcycle chassis is chosen due to increasing demand (Micro, 2009) but market is lack of hybrid electric Chopper type motorcycle besides providing sufficient space for the PHEM components and drive-train mechanism. Material selected for the 3D modeling is round tube hollow stainless steel 304 diameter 1.5 inches thickness 1.2mm and diameter 1.0 inch thickness 1.0mm. Material stainless steel 304 is chosen due to its manufacturability, strength and reflective appearance which suit to build a Chopper type chassis. Figure 2 shows the chassis 3D modelling with CAD software SolidWorks 2012.

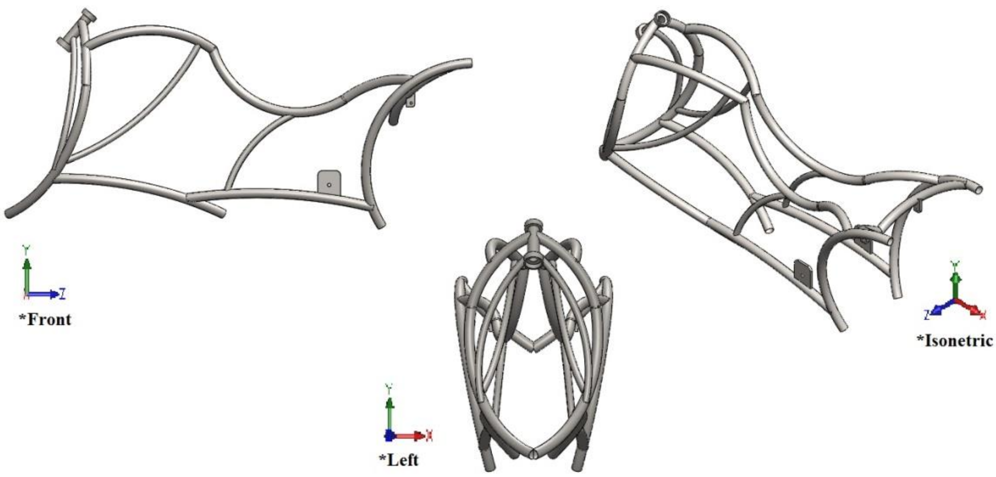


Figure 2. Chassis 3D modelling with CAD software SolidWorks 2012.

The PHEM components and drive-train mechanisms are intergraded into the 3D model to ensure the chassis provides adequate space. Figure 3 shows chassis 3D modeling intergraded with PHEM components and drive-train mechanism.

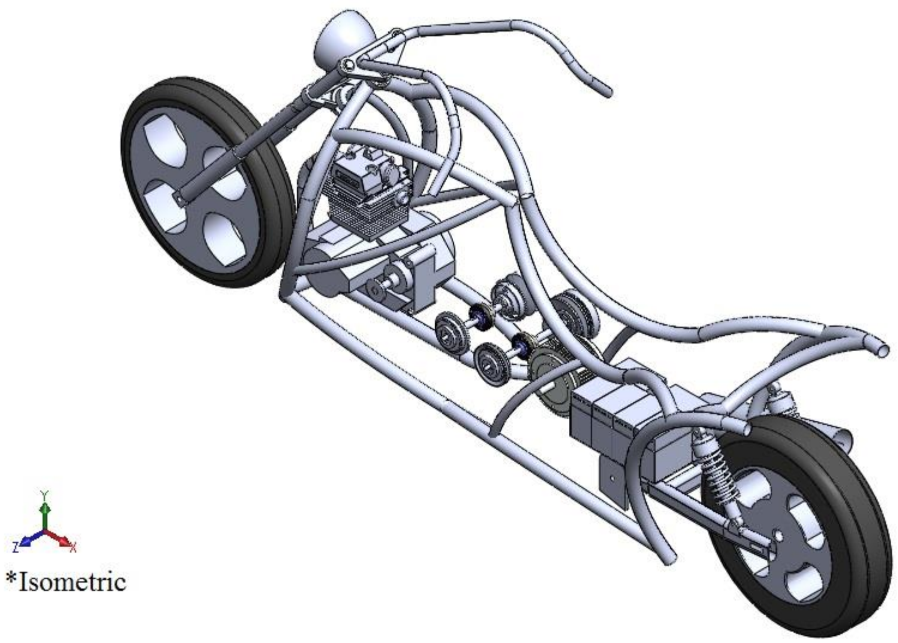


Figure 3. Chassis 3D modeling intergraded with PHEM components and drive-train mechanism.

Then, an adult human dummy model is built into the 3D modeling to verify the rider's ergonomics and comfort. Figure 4 shows the 3D modeling with an adult human dummy.

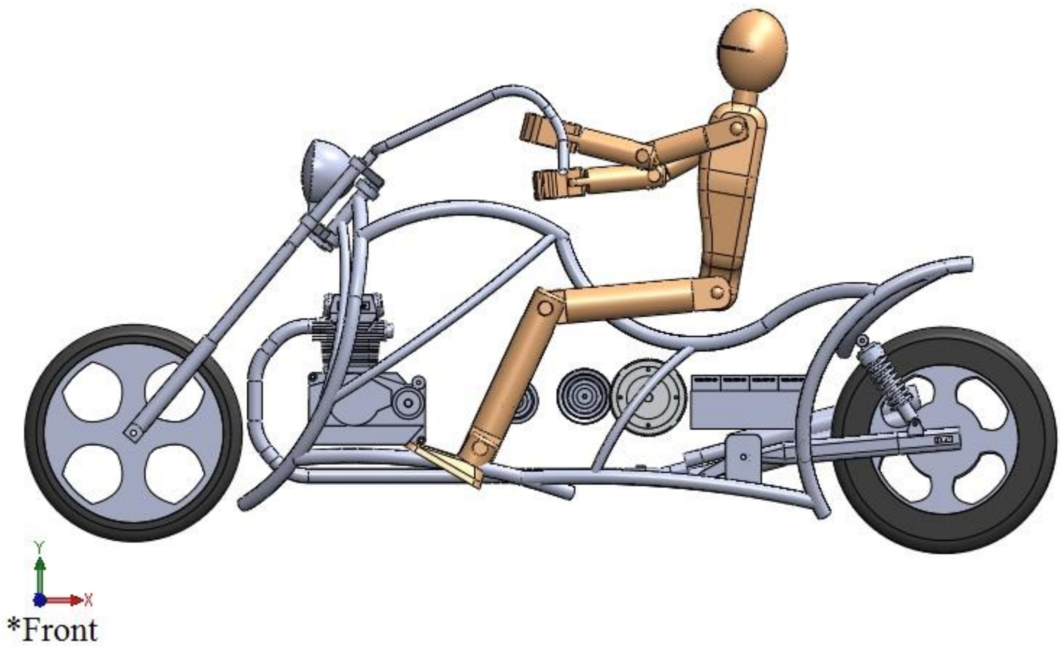


Figure 4. 3D modeling with an adult human dummy.

FINITE ELEMENT ANALYSIS

Stress-strain simulation feature is available in SolidWorks 2012. In static load, triple tree and bracket absorber rear are set as fixed geometry, forces are applied on the chassis as the load from the components and the weight of the rider. Force F_1 is the weight from the petrol tank, force F_2 force is the weight of the rider. F_3 includes the weight from engine, control box and drive-train mechanism, force F_4 include weight from drive-train mechanism, batteries and electric motor. Finite Element Analysis (FEA) provides reliable numerical technique for analysing chassis design. The FEA software mesh the model with a number of small pieces of standard shape or element, connected at common points or nodes. Figure 5 illustrates chassis 3D model with fixtures, loads and meshing.

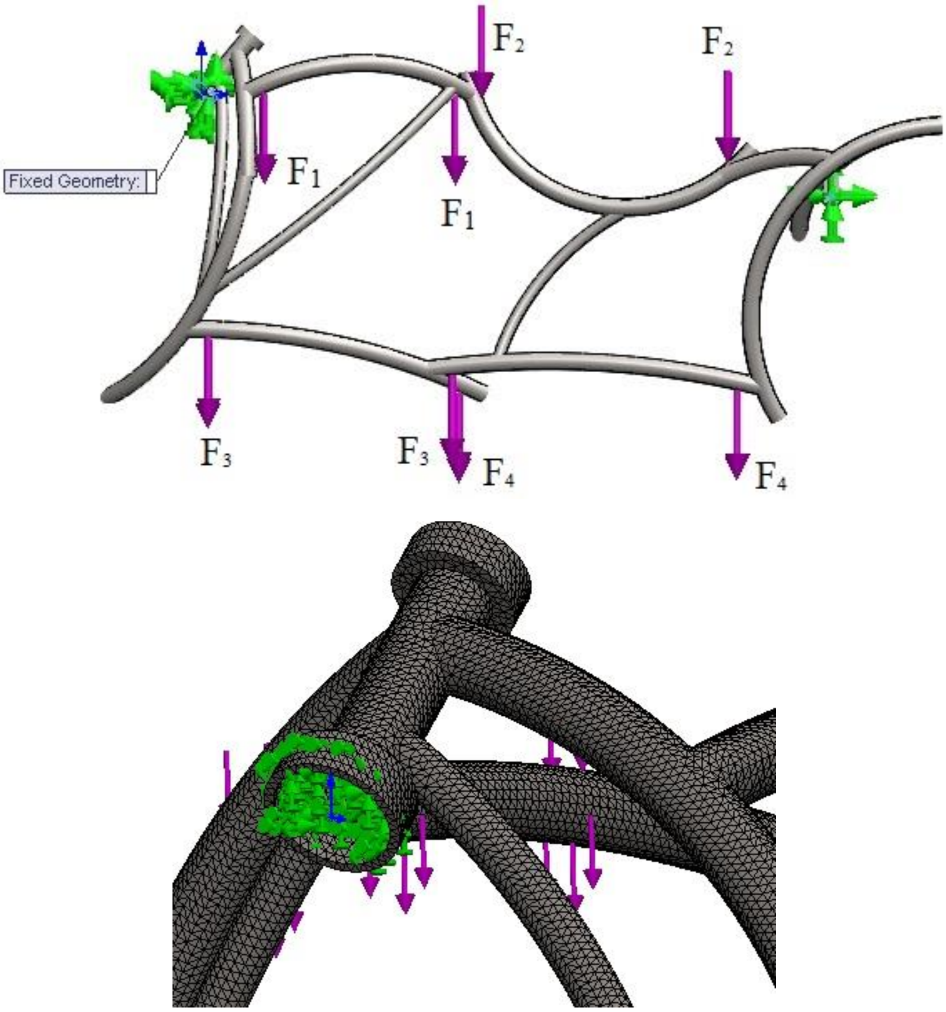


Figure 5. Chassis 3D model with fixtures, loads and meshing.

Static load stress-strain analysis parameters:
Standard mesh, mesh size (mm) = 5; 0.25
Force, F_1 (weight from the petrol tank) = 150N
Force, F_2 (weight of the rider) = 800N
Force, F_3 (weight from engine, control box and drive-train mechanism) = 800N
Force, F_4 (weight from drive-train mechanism, batteries and electric motor) = 300N

GOVERNING EQUATION

The study of mechanics of materials is to analyse and design of load-structures. Both the analysis and design of a given structure involve the determination of stresses and deformations. When loads are applied to the chassis while being held fix, the chassis deforms both locally and throughout the body. These induce internal forces as well as reaction forces to render the body in state of equilibrium (Beer et al., 2009).

In general, the stress analysis software package offers four failure criteria to access the safety of design and list in Table 1.

Table 1. Summary of failure criteria

Criterion	Material Type
Maximum von Mises stress	Ductile
Maximum shear stress	Ductile
Mohr-Coulomb stress	Brittle material with different tensile and compressive strengths
Maximum normal stress	Brittle

The maximum von Mises stress criterion is based on the von Mises-Hencky theory, also known as Shear-energy theory or the maximum distortion energy theory. In terms of principal stresses σ_1, σ_2 and σ_3, the von Mises stress is expressed as:

$$\sigma_{von\ Mises} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}} \tag{1}$$

The theory states that a ductile material starts to yield or at a location when the von Mises stress becomes equal to the stress limit:

$$\sigma_{von\ Mises} > \sigma_{limit} \tag{2}$$

In most cases, the yield strength is to be used as the stress limit. The factor of safety (FOS) at a location is calculated with below equation. The chassis is safe when the FOS value is more than 1.

$$FOS = \frac{\sigma_{limit}}{\sigma_{von\ Mises}} \tag{3}$$

In this case, the highest stress occurs at the joint at triple tree housing and bracket rear absorber. The loads, F_1, F_2, F_3 and F_4 are transfer to triple tree housing and bracket rear absorber by means of forces and moments, thus calculating the stress, displacement, factor of safety and strain. Figure 6 illustrates loads transfer to triple tree housing and bracket absorber rear.

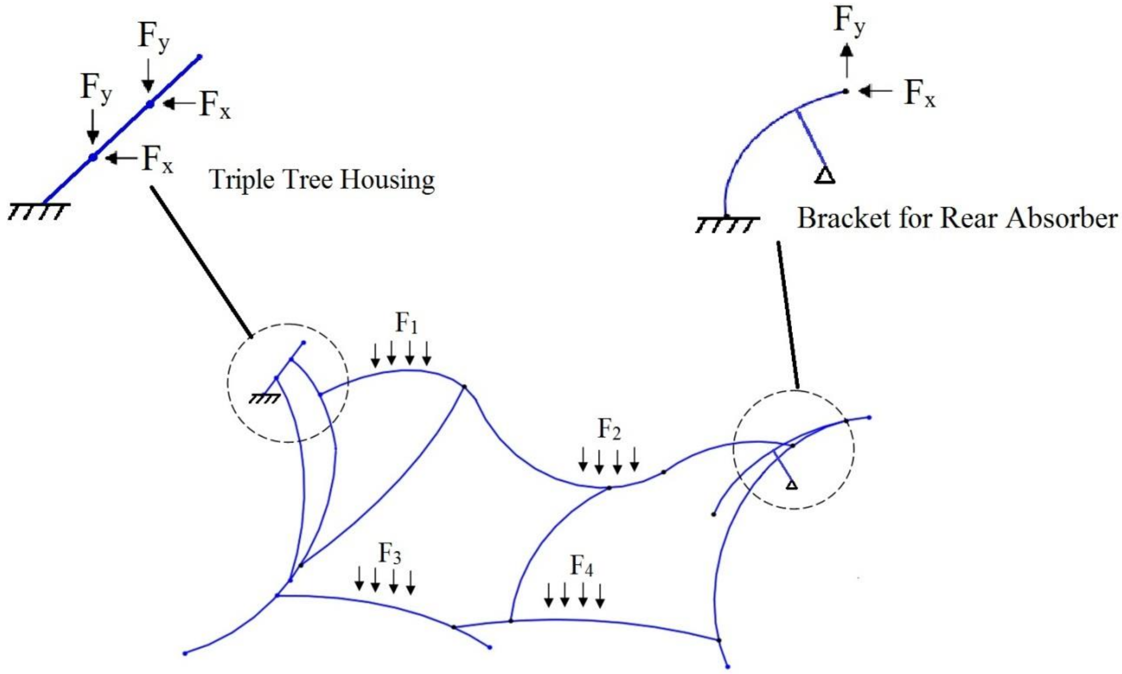
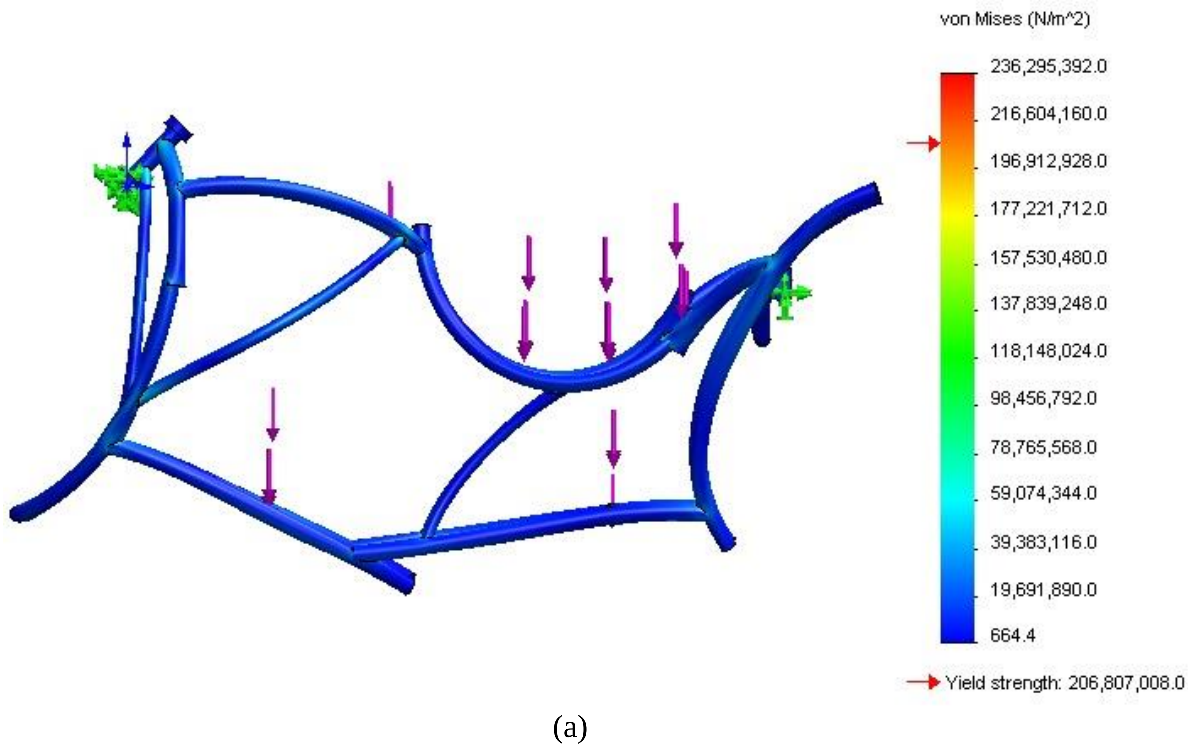


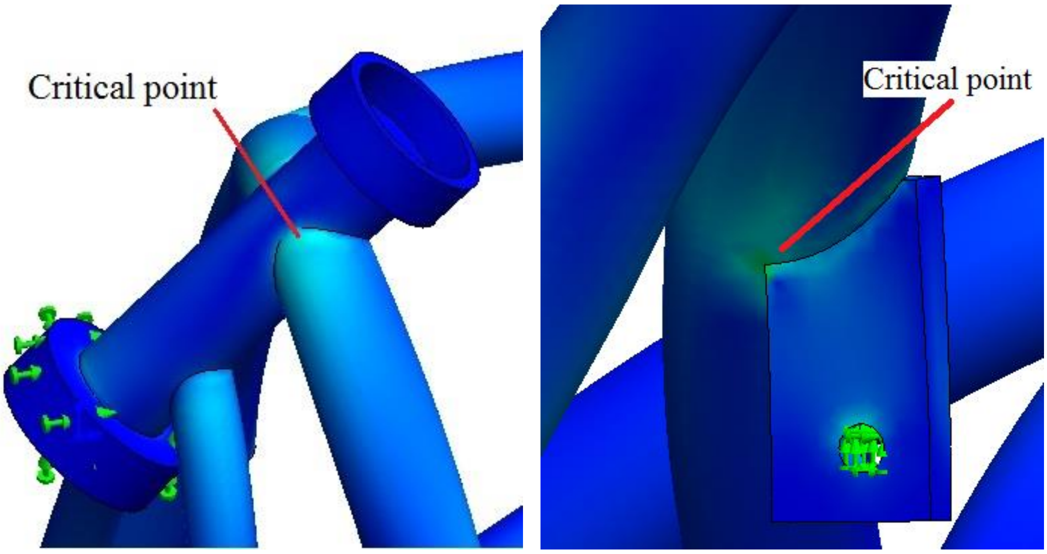
Figure 6. Loads transfer to triple tree housing and bracket absorber rear.

RESULTS AND DISCUSSION

Figure 7 shows the simulation result for von Mises Stress.



(a)

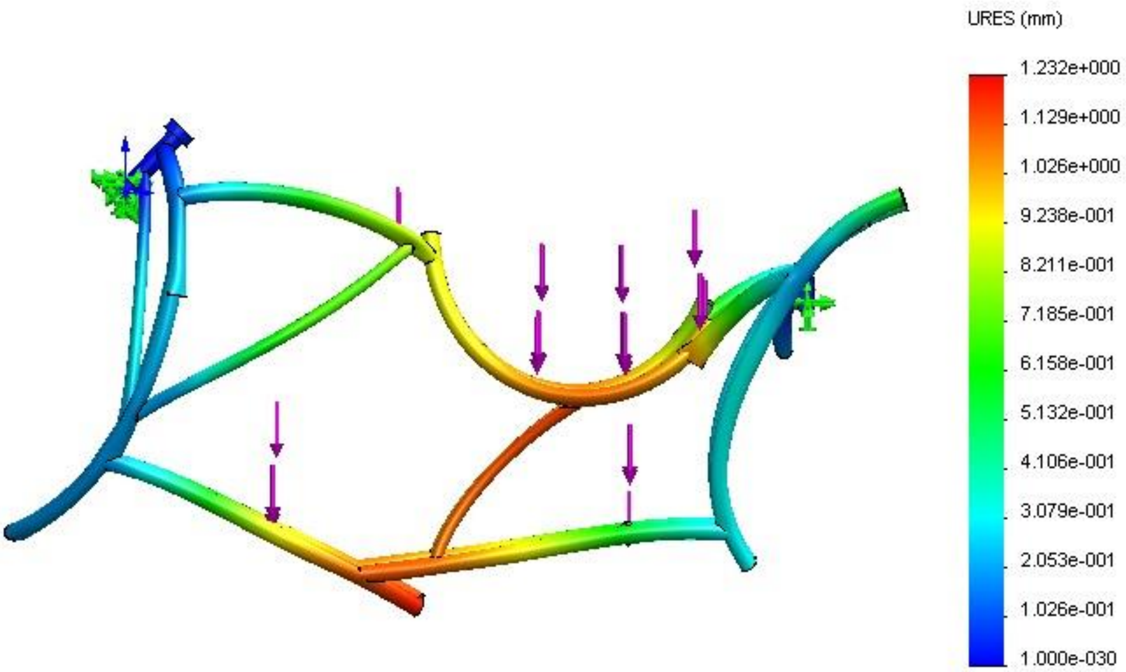


(b) (c)

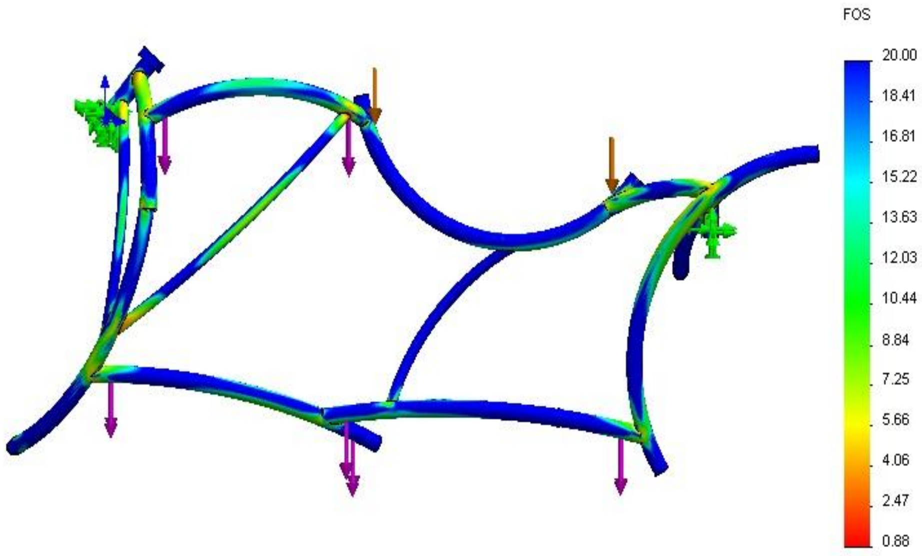
Figure 7. Simulation result (von Mises Stress).

The simulation predicted the stress distribution. The area with greenish colour shown in Figure 7(b) and 7(c) suggested the highest stress occurs at the triple tree joint and bracket for rear absorber. In other word, the critical point where the chassis will likely to fail at excessive load.

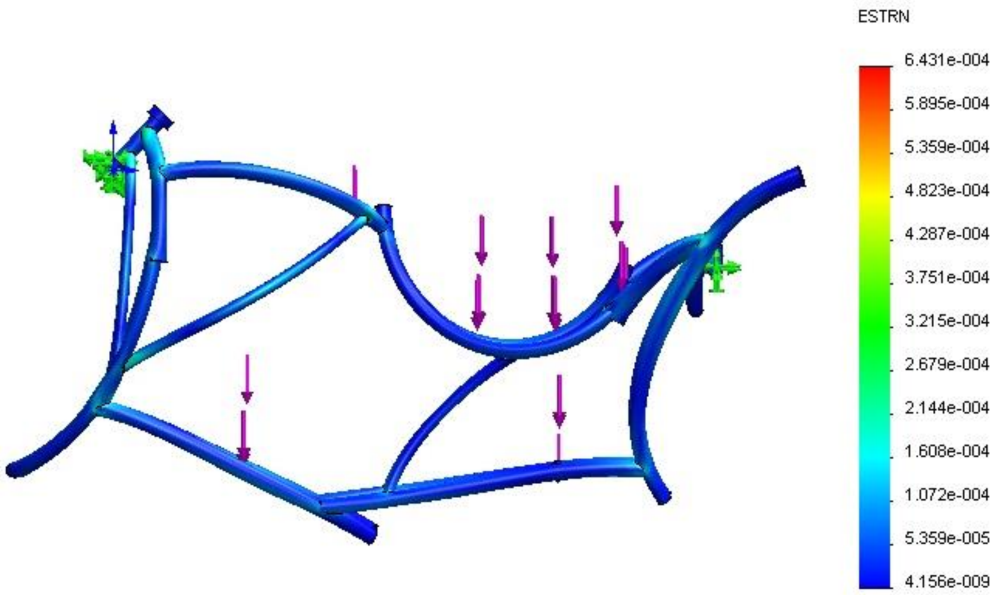
Apart from predicting stress distribution, the FEA software also calculates for displacements, FOS and strain. Figures below show the simulation results.



(a)



(b)



(c)

Figure 8. Simulation Results (a) Displacement, (b) FOS and (c) Strain.

The simulation result for displacement 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 1.232mm, thus providing insignificant undesirable effect neither chassis nor rider. The simulation result for FOS shows foremost of the chassis is having FOS value > 20 and part of the chassis FOS value range 5 – 20. There is little area showing FOS value < 1 suggesting strengthening is require.

Upon achieving required FOS, the PHEM chassis will be undergoing construction stage. Computational analysis predicted the stress distribution, displacements, factor of safety (FOS) and strain for the PHEM chassis.

CONCLUSION

Computational analysis is widely used in engineering design especially in chassis or framework design. This is because data from computational analysis is able to provide guideline to develop a safe structure in shorter time. In this study, the computational analysis predicted the stress distribution, displacements, factor of safety (FOS) and strain for the PHEM chassis, the data are analysed and used to strengthen the critical area, as a result, a safe PHEM chassis design is developed. Figure 9 shows the chassis fabrication in progress.

Figure 9 Chassis fabrication in progress.

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