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FINITE ELEMENT ANALYSIS OF MODIFIED IN-WHEEL ELECTRIC MOTOR FOR HYBRID ELECTRIC MOTORCYCLE

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Abstract

Motorcycles are agile transportation widely found in major cities like Jakarta. Hybrid propulsion system in vehicle are proven to increase fuel efficiency and reduced pollution. Major mmotorcycles can be modified by attaching an in-wheel electric motor to achieved a hybrid system. A modified in-wheel electric motor with 565 Watt of Power are redesigned and implement to the motorcycle, the design also analysted using FEA method discussed in this paper. The result from simulation shown the maximum stress at 2,058 Mpa with the maximum displacement 2.532e-4 mm occur in the bearing housing.

Keywords: two-wheeled hybrid vehicles, electric motors, in-wheel electric motor

INTRODUCTION

Personal transportation system which dominates the big cities such as Jakarta is a motorcycle, most people choose it because it is cheap, agile and fuel efficient. Jakarta has at least more than 16 million population of motorcycle. Even though the good fuel efficient of internal combustion motorcycle is good with large number of motorcycle population will increase the pollution index [1]. Electric bicycle are the zero emission vehicle which can overcome the pollution problems but has many drawbacks such as vehicle speed are low with a 45km/h are the maximum speed achieved, short mileage because of limited battery capacity, lack of availability of charging station also as a consideration, long charging time at least 5 hrs. to fully charged the battery. Hybrid electric system is the system which combines an Internal Combustion Engine found in motorcycle and an Electric Motor attach in the electric bicycle, this combination gives a more fuel efficient and less pollution in motor cycle and can overcome drawbacks found in the electric bicycle. The 5,65 kW of Internal Combustion Engine with the fully automatic Continuous Variable Transmission system build in engine system is used and the power are transfer using a sprocket system to rear wheel. The rear wheel itself are replaced with the *in-wheel* electric motor with 0,5 kW of power. These in-wheel electric motor have to be modified in order to fit in the rear wheel and fully compatible with the original sprocket system as well as the braking system of the motorcycle.

An aluminum wheel hub adaptor is designed to connect the power from internal combustion system through sprocket to rear wheel, also a *in wheel* electric motor with *a traction wheel cover* need to be redesigned in order to fit to this wheel hub. Both of these components are the major parts to be design and modified based from the original, so design has to be checked using an FEA analysis, to analyzed the stress of those components, displacement behavior subject to the load, as well as the stress location in the particular component.

METHODOLOGY

FEA is a numerical procedure which provides estimated solutions to general field problems by discretizing the continuum into a finite number of small elements. The main

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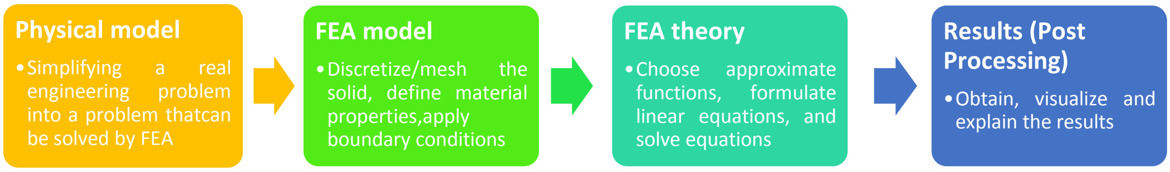
goal of FEA strength and deformation analyses is to evaluate the mechanical properties of a component or assembly when it is subjected to real or assumed loads and/or pressures. This is done at an intermediate stage of the design process, before expensive and time-consuming test rig experiments are initiated. FEA has many advantages in order to optimized the design, with nowadays FEA software embedded in the CAD the designer can investigated their design like [2].



DESIGN OF WHEEL HUB AND TRACTION WHEEL COVER

The rear wheel component are modeled in 3D CAD model which represents the actual shape and component of the system, the 17 inch of the original motorcycle rear wheel is replaced with the 14 inch *in-wheel* 0,5kW electric motor. This electric motor use 48Volt DC Brushless type with the static rotation speed up to 527 revolution per minute. Altough the motor used is from the electric scooter but original design of the electric motor doesn’t fit to assembled in the motorcycle, therefore few modification needed to overcome the problem. 3D model from motorcycle component was generated based on the actual rear wheel motorcycle construction and based from the 3D CAD model the wheel hub and Traction Wheel Cover is designed, both of the design configuration are shown in the Figure1.

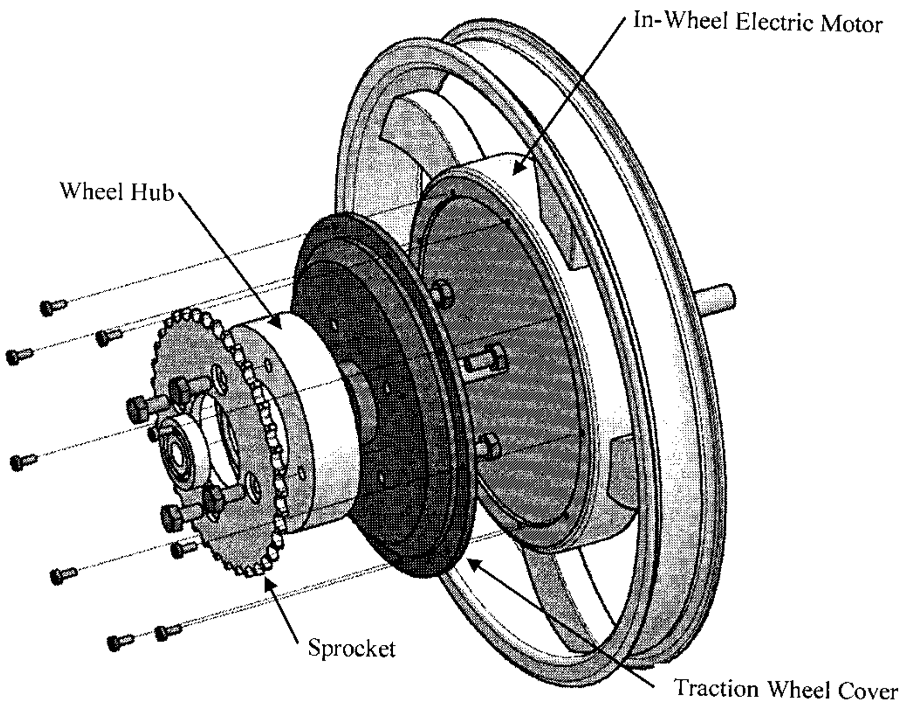


Figure 1. Design of Modified *In-wheel* Electric System

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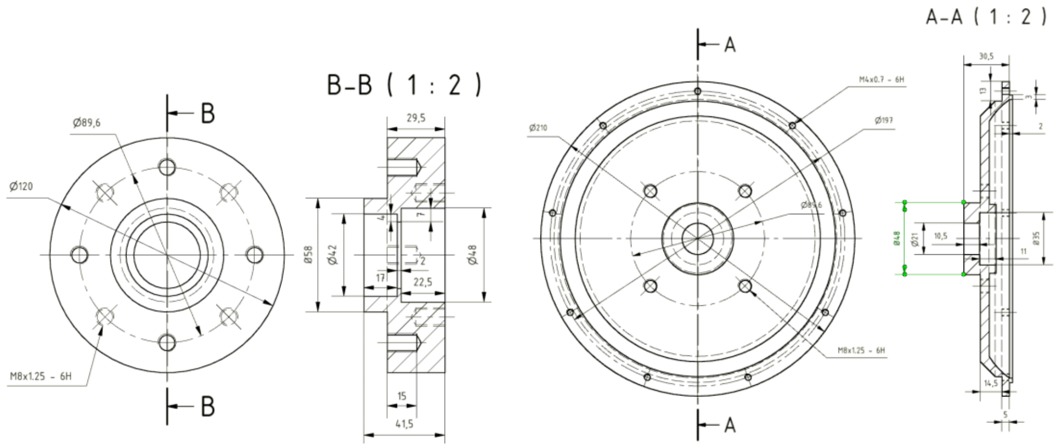

Figure 2. Wheel Hub Design (left) Traction Wheel Cover Design (right)

From the above figure it is clearly seen the construction of the modified in wheel system, the purpose of wheel hub was to connect and transfer torque from the transmission system of the motorcycle trough sprocket from the factory designed component, and the traction wheel cover is redesign from the factory designed cover of electric motor. The purpose from factory designed cover is just to protect the electric motor from water splash, dust, dirt, etc. so it designed as thin as purposed. The new redesign called traction wheel cover is designed with additional purpose which is withstand to torque from the hub and the sprocket. Both of the components are need to be analyzed to ensure enough strength to withstand load both from the sprocket and electric motor. The material of Traction wheel cover use ASTM A36 and for the Wheel hub use Aluminum 6061, the material spesifications are shown at the table below:

Table 1. Material Properties

Name	Steel ASTM A36		Name	Aluminum 6061	
General	Mass Density	7,84905 g/cm^3	General	Mass Density	2,71 g/cm^3
	Yield Strength	248,225 MPa		Yield Strength	275 MPa
	Ultimate Tensile Strength	399,9 MPa		Ultimate Tensile Strength	310 MPa
Stress	Young's Modulus	199,959 GPa	Stress	Young's Modulus	68,9 GPa
	Poisson's Ratio	0,3 ul		Poisson's Ratio	0,33 ul
	Shear Modulus	76,9073 GPa		Shear Modulus	25,9023 GPa
Part Name(s)	Hub.ipt		Part Name(s)	Tempat Sproket.ipt	

SIMULATION

The simulation tool used in this research is the embedded in the CAD software, Autodesk Inventor 2016 is used. The simulation study used static linear type of simulation, because the load assumed are static and the material used are linear type material, according to the stress strain diagram of the material. Both of the component are assembled using standard bolted connection, both connection uses 8 pieces of M8 bolt with the arrangement 4 pieces on the hub with the sprocket, and another 4 pieces connected between hub and the traction wheel cover. All of the bolted connections are verified using standard bolted connection calculator on the software.

Boundary condition to perform the FEA analysis is done in the assembly environment fix constraint applied in the surface area of traction wheel cover which attached at the motor housing trough bolted connection. Inside traction wheel cover there is a bearing seating which defined as pin constraint, represent in yellow color in the figure 3.

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Contacts between these two components are defined as a bounded connection, since these assumed as both plate bounded with bolted connection. At the wheel hub side, a pin constraint applied at the bearing housing which represent in red color.

Loads are the important factor in performing simulation, the static loads are applied in the wheel component. Passangers load and motorcycle load with a 1,5 magnitude is considered as a bending load with a total bending load 3300N at the rear wheel. In addition to load, torque load also occur which are generated from the motorcycle internal combustion engine as 8,1 Nm and Brushless DC electric motor as 3,42 Nm.

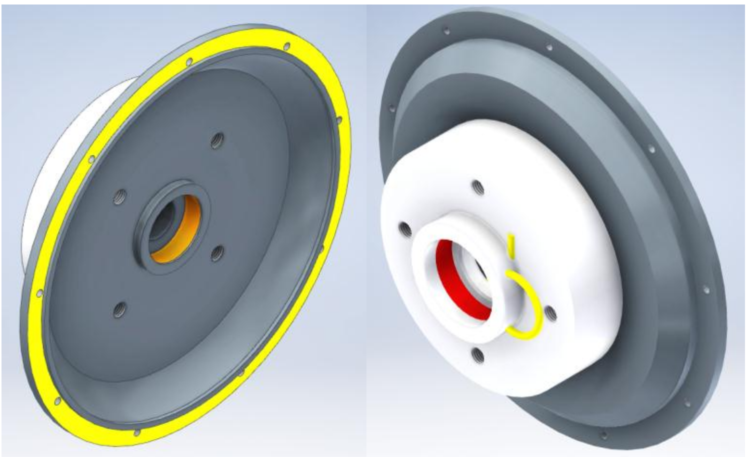

Figure 3. Boundary conditions

RESULT AND DISSCUSIONS

After conducting simulation with the mesh setting is set to adaptive mesh control and with the maximum number of refinement 5 then the result of meshing and Von Mises stress shown in figure 4. The number of nodes are 64867 nodes and the number of elements are 40682 elements then the result the convergence rate is 3,345%, at the maximum Von Mises stress is 2,058 MPa. The result of displacement also shown in figure 5, with the maximum displacement value is 2,532e-4mm, location of the maximum displacement can be examine in the figure.

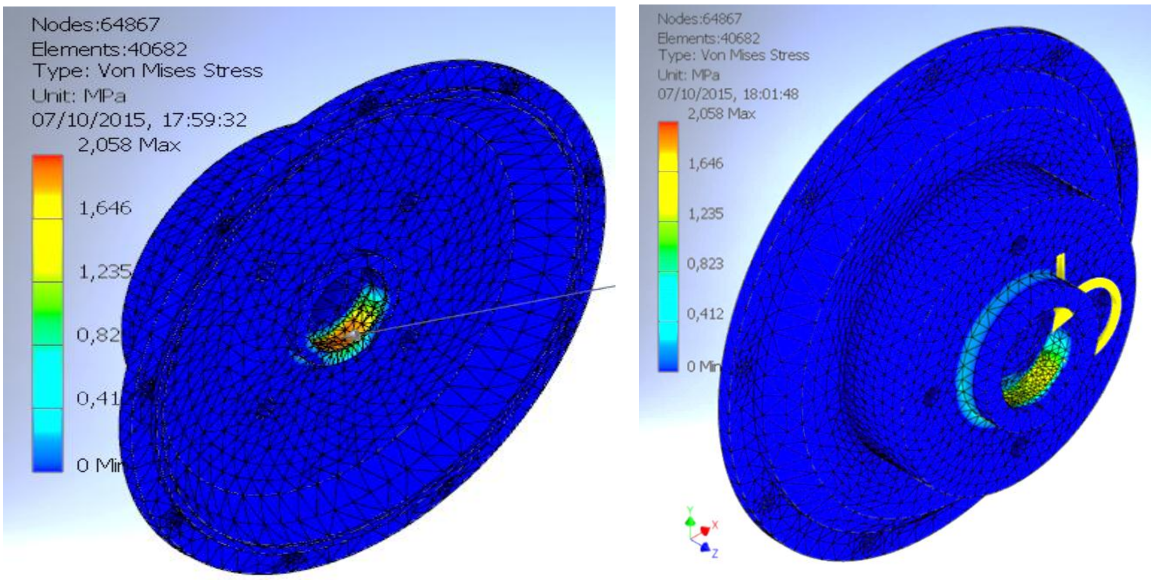

Figure 4. Von Mises stress inside view(Left) and outside view (Right)

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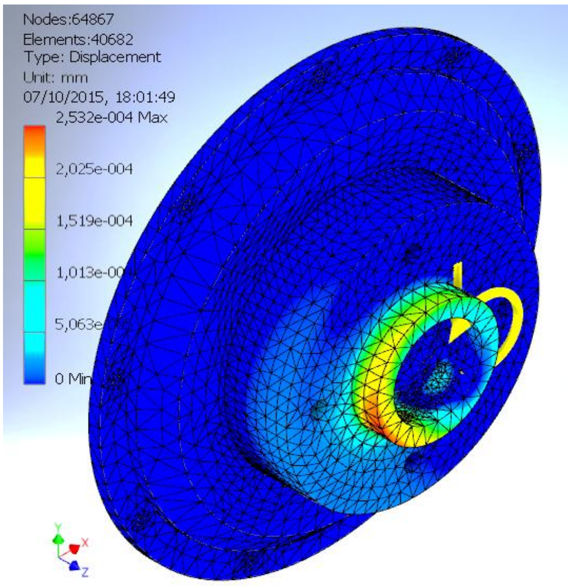

Figure 5. Displacement result (outside view)

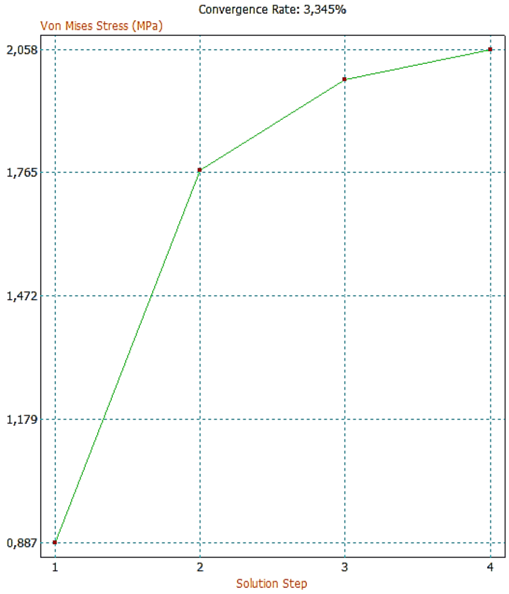

Figure 6. Convergence Plot

As the simulation result indicates the design are safe, but tends to be over design because of the gap value of the occurring stress value from the simulation result and allowable stress from the material properties are large, and also shown from the displacement value of the simulation result is very low. The effect of the load on the simulation result seem that bending load is more dominating than the torque load, it can be seen from Figure 4 that the load on the pin constraint tends to be greater at the bottom, and the effect from the torque also seen at the surrounding area of the wheel hub as indicate from figure 4 (right).

PROTOTYPING

After performing design and simulation which are the usually known as digital prototyping, this research also continues to the physical prototypes. The wheel hub and the traction wheel cover comes to the manufacturing, the common conventional manufacturing processes is used to manufacture these components. Because of the diameter of the traction wheel cover is large, so the material is choose from block instead cylinder. From the figure 7 the both components are shown.

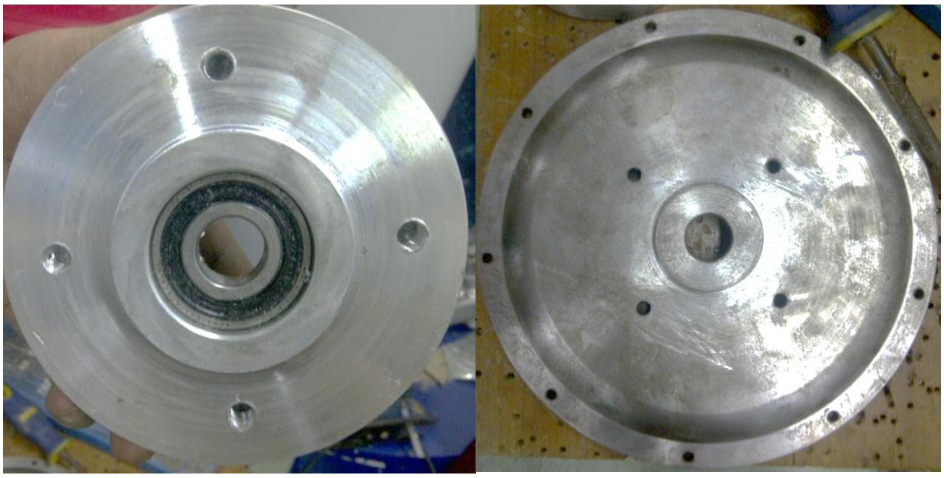

Figure 7. Wheel hub (left) and Traction Wheel Cover (right)

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The final assembly also perform to demonstrate the design is fits and fully functional in the motorcycle and as well as electric motor as a system. So the figure 8 is shown the final result of the Hybrid Electric Motorcycle.

Figure 8. Final Assembly of Hybrid Electric Motorcycle

CONCLUSION

Based on the simulation result indicates the design was safe, the dominant stress is come from the bending load from the passengers, even tough the simulation is analyzed in static mode but since the safety factor is high, then it is confidence to test the component in real driving condition. Drawback from the design is the heavy weight as much as 2,5Kg of the total weight is added to the motorcycle, but for further research is needed to optimize the design to produce the less weight with good in strength as well. The dynamic loading condition is also to be considered since the real driving condition of a motorcycle is dynamic, hope with the future research the optimization can be maximum.

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