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# Structural Design and Analysis of The Mount and The Shaft for ICE Motorcycle Conversion to Electric

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**Abstract**: This study aims to develop mountings and shafts for two-wheeled motorcycles with a 110cc as a supporting component in scope of electric conversion vehicles. This study provides added value related on supporting components as the initial conversion stage from conventional two-wheeled vehicles to electric ones. The research is limited to 110cc two-wheel motorcycle in Indonesia. This research provides benefits to accelerate transitioning from internal combustion engine vehicles to electric vehicles in Indonesia. Prototyping method that used starts from the design stage, followed by static and temperature tests to assess the durability and feasibility of the mounting and the shaft. The results show that the mounting design can withstand a load of 10kg and heat up to 100ºC without any deformation. Meanwhile, the results of the shaft design show that the shaft will remain safe at a load of 1500 N and the keyway test shows that the shaft can return to its original shape. In addition, the safety factor of the shaft is typically high but is expected to drop if dynamic loads are considered. It is recommended to conduct further studies involving dynamic load to evaluate the designs more comprehensively.

Keywords: BLDC motor; electric motorcycle conversion; engine mounting; static simulation

## 1. Introduction

The contribution of the transportation sector almost reaches 30% of the total CO2 emissions in Indonesia[1]. The total emission generated is around 88% from land transportation. This is because there are still many conventional vehicles in Indonesia and the number is increasing by an average of 5% per year[2,3]. To reduce the impact of CO2 emissions in Indonesia, a change in land transportation is needed[4,5]. These changes can be made by transitioning from conventional vehicles or internal combustion engine (ICE) vehicles to electric vehicles.

The transition to electric vehicles is supported by government policies in accelerating the battery electric vehicle program for road transportation[6–8]. The Indonesian government has two electric vehicles programs, the first one coming from manufacturers and the other one is the conversion of the ICE vehicle. Related to the conversion of the ICE vehicle to electric vehicles, there are several components that are allowed to be converted based on the Minister of Transportation Regulation Number 65 of 2020[9]. Components that can be converted are batteries, battery management system (BMS), DC to DC converter, electric brushless direct control motor (BLDC) motor[10], controller/inverter, battery charging inlet, and other supporting equipment. In terms of readiness, other supporting tools play a critical role in supporting the success of conversion[11].

Based on previous research, there are several different studies that have focused on the exploration of electric vehicle (EV) topology, emission reduction[12], efficiency maximization strategy[13,14], cost minimization and power conversion technology[15] integrated into the electric power grid. The three interrelated main branches of EV technology have greatly attracted academics and industrial R&D researchers[16], namely: (i) advanced electric drive system (EDS)[3,17–21]; (ii) Power generation and energy storage system (ESS)[22–30]; and (iii) electric vehicle construction[31–34]. In addition, research topics related to conversion components are of concern[35,36]. The idea of converting ICE motorcycles to electric motorcycles is to keep the budget of conversion as low as possible. Instead of buying a new electric motorcycle, converting ICE to electric by keeping the ICE components as much as possible would be the main idea of this work. Therefore, the main components such as battery, BMS, DC to DC converter, electric BLDC motor, and inverter will be the only parts that will be used to do conversion. Engine and gasoline tank are the main ICE motorcycle components that will be removed, and electric BLDC motor and battery will replace their position. In this paper, the ICE motorcycle type that is used is 110 cc automatic motorcycle which using continuously variable transmission (CVT) as the transmission system. The reason for choosing that type of motorcycle is based on market demands and spread in which this type is largely used in public. Other existing ICE parts such as CVT will be kept for reducing the budget of conversion.

Since the electric BLDC motor takes the place of the ICE engine, it should have a steady and rigid position. The dimensions of the existing ICE engine are not the same as those of the electric BLDC motor. Thus, some modification of electric motor mounting should be done. Also, the electric motor should connect to CVT to drive the motorcycles' rear wheels. To connect the electric BLDC motor to CVT, a shaft to conjugate the electric motor rod to CVT should be designed. The main work of the paper is to design and manufacture proper mounting and shaft for electric BLDC motors in the scope of electric conversion vehicles.

## 2. Research Method

The method used in this study is an experimental method with rapid prototyping. As an initial stage, a literature review of electric vehicles, mechanical design, assembly, and conversion technology are carried out. Calculations are carried out to obtain the optimal size, so that performance and compatibility with efficient vehicles are achieved[37)]. An experimental method is used in which two-wheeled conventional motorcycles is modified or converted into two-wheeled electric motorcycles. This research focuses on designing and manufacturing the mounting and shaft for the conversion of two-wheeled conventional motorcycles with 110cc automatic type.

### 2.1. Modelling

After conducting literature review regarding mounting and shaft design for electric motor, only a few studies have the same concern, but most of them worked for automobiles[38–40)]. Therefore, the mounting and shaft model is developed through observation of the crankshaft and the shaft, which connects the ICE engine to the CVT. The mounting dimension is acquired by measuring the electric BLDC motor dimension using a vernier caliper to achieve its expanse. Then, the mount is designed to be connected to the motorcycle chassis with bolted connections, as depicted in Fig. 1. The right side of the mount connects to the BLDC motor, while its left side goes to the motorcycle chassis. The shaft design also experiences the same treatment where initial design is conducted by measuring the gap between the existing shaft in electric BLDC motor and the transmission system. Also, the diameter of the existing BLDC motor shaft is bigger than the ICE engine, and it is not long enough to reach the CVT. Therefore, an additional shaft is constructed to conjugate the motor and the CVT. The paint points when designing the additional shaft are the differences in diameter between the two ends and the appropriate length. In this study, a simulation will be carried out to evaluate the performance of the mount and the shaft under static test.

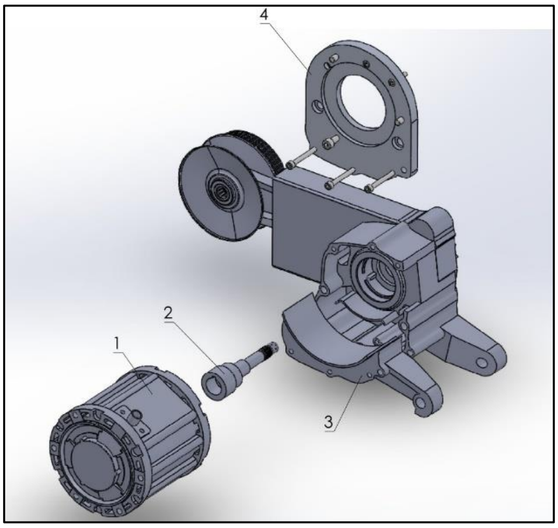


**Fig. 1:** Assembly of mountings and shafts into a convertible two-wheeled motorcycle (1) electric motor, (2) shaft, (3) crankcase, and (4) mounting.

### 2.2. Material Selection

Design testing is based on a simulation using the SolidWorks application. Materials used in vehicle chassis are usually DP 600, BSK 46, AISI 4130, and HSLA[39)]. Based on it, AISI 4130 and HSLA are used for electric car mounting[38)]. In this study, the mounting material should possess characteristics of corrosion resistance, thermal and energy conductivity, lightweight, non-magnetic, softness and cold working facilities, and good formability and fusibility. Therefore, aluminum is selected as the mounting material. For the shaft, the material should have good machinability, high strength, and impact properties, and machining operation is possible to be carried out. Hence, the selected material is S45C Carbon steel or AISI 1045. The properties of selected materials can be seen in Table 1.

### 2.3 Meshing

The mesh used in the design is curvature-based mesh to cover the geometry complexity of the mount and the shaft. The mesh quality is selected as fine for both the mount and the shaft, with the maximum element size and minimum size of the shaft being 1.97 mm and 0.65 mm, respectively. The maximum element size of the mount is 13.32 mm, and the minimum element size is 2.66 mm.

Figure 2 shows the detailed mesh of the mount and the shaft.

Table 1. Material properties of AISI 1045 and Aluminum 5052.

| Material | AISI 1045 | Aluminum 5052 |
|---|---|---|
| Density (kg/m$^3$) | 7850 | 2680 |
| Yield Strength (MPa) | 530 | 195 |
| Tensile Strength (MPa) | 625 | 230 |
| Elastic Modulus (GPa) | 205 | 70 |
| Poisson's Ratio | 0.29 | 0.33 |

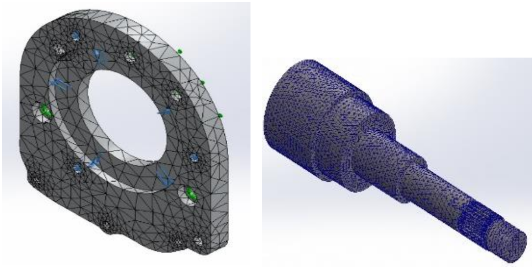

**Fig. 2:** Mesh model of (a) the mount, and (b) the shaft.

### 2.4 Boundary and operating condition

Static tests against the mount and the shaft were carried out to determine their strength in holding a BLDC motor weight. It is estimated that the electric motor weighs about 5-7 Kg. During vehicle operation, there will be a substantial load from both the driver and the passenger, assuming two individuals on the motorcycle weighing approximately 60-150 Kg. However, this load will not significantly impact the mount or the shaft as the shock absorber will absorb it. Since we provide a rigid structure at the bottom of the BLDC motor by using the existing crankcase, the load of the mount comes only from the BLDC motor.

The shaft, on the other hand, should be able to receive all the power from the BLDC rod and transfer it to the CVT system. The shaft should be able to grip the BLDC rod firmly and should not slip or break. Therefore, we designed a keyway at the end of the shaft, which connects to the BLDC motor. In order to have proper simulation, the loading condition needs to be defined. The force around the keyway is formulated as follows.

$$F = T/r \qquad (1)$$

In Eq.1, F is the force in N, T is motor torque in Nm, and r is the keyway radius in m. As per datasheet of the BLDC motor, its torque is 30 Nm and the designed shaft has a radius of about 20 mm. The force is 1500 N then will be computed for static tests. Material selection for this shaft should be carefully matched. Otherwise, the shaft could slip or break during high revolutions per minute (RPM) The AISI 1045 is well-known for use in any mechanical parts, especially shafts.

## 3. Result and Discussion

The results of the static load test of the mounting in this study are adjusted to the weight of the electric BLDC motor, which is about 5-7 kg. The area to be tested for static loads is in direct contact with the electric BLDC motor and the bolt holes. Figure 3 shows 10 kg static load test on the mounting. The mounting expands to the outside due to excessive load on the central hole depicted in green marks. The bolt holes also experience a slight expansion due to the load, but the impact is still acceptable on the mounting. This result is statistically sound since the load is less than 10 kg. Therefore, the impact of expansion on the mounting will be minimal. This result is also supported by the mounting displacement data, where the observed displacement is insignificant, about 27.37 μm, as it only shifted on a micrometer scale. Therefore, the deformation of the object under a 10 kg stress test has no noticeable effect. The detailed displacement distribution is shown in Fig. 4.

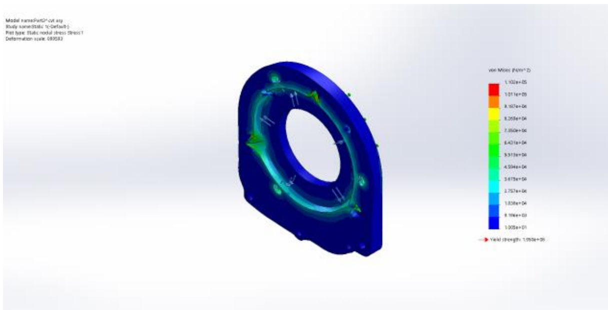

**Fig. 3:** Maximum static load test on mounting.

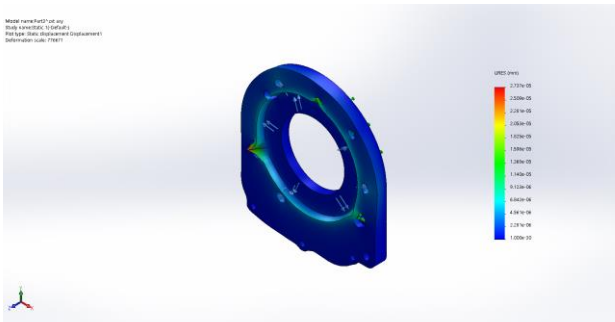

**Fig. 4:** Maximum displacement distribution on the mount.

The results of the temperature test on the mounting design were carried out at temperatures of 40-65°C and 65-100°C. Figure 5 shows the results of heat dispersion at a temperature test of 40-65°C. The direction of the arrow is the heat source coming from the electric BLDC motor. The blue color indicates mounting does not impact heat increase, while the red color means heat rises because of electric BLDC motor activity. Based on Fig. 5, there is no deformation sign of the mounting design at this temperature.

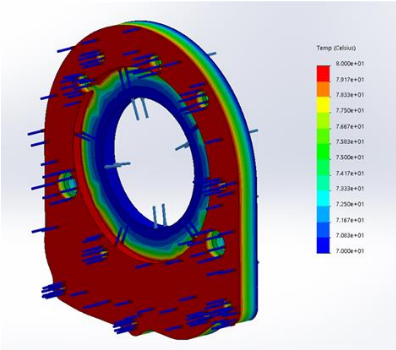

**Fig. 5:** Static test temperature resistance 40-65°C on mounting.

The results of the mounting test at a temperature of 65-100°C showed that the heat is increased. However, there is no change in shape or any deformation, as depicted in Fig. 6. The direction of the arrow turning orange means that the heat is increased, but the mounting does not show any shape change. The simulation results also show that only. The hot area is slightly widened, and the heat can be delivered to the back area of the mounting, which is indicated by the presence of a blue area on the mounting. Based on the results of the static and temperature tests carried out on the mounting design, it can be concluded that the mounting design meets the required parameters. The mounting design can withstand 10 kg of pressure and has a resistance of up to 100°C.

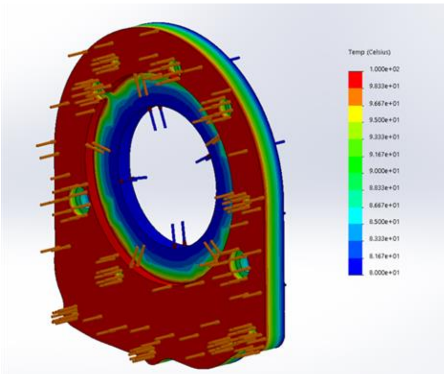

**Fig. 6:** Static test temperature resistance 65-100°C on mounting.

The shaft design used in this study uses AISI 1045 because it has high strength and impact characteristics both under normal conditions and when exposed to hot temperatures. Simulations applied to the shaft design are static tests on stress, strain, a factor of safety, and displacement with loads of 1500 N. Figure 7-9 show the results of the static test simulations on the shaft. The maximum stress that occurs is 58.74 MPa, with the maximum stress point located inside the keyway (Fig. 7). The yield strength of the material used to design the shaft is 530 MPa. Comparing the stress on the shaft to the material's strength, the shaft structure is rigid, as the generated stress is approximately one-tenth of the yield strength. The strain test resulted in a maximum equivalent strain $2x10^{-4}$ and minimum equivalent strain $2x10^{-14}$ (Fig. 8). These results are not significant in causing deformation to the shaft structure. In terms of displacement, there is no displacement occurs on the shaft as shown in Fig. 9. In general, the selection of AISI 1045 is suitable for the shaft as the results of the stress, strain, and displacement tests show a tendency to withstand the real forces.

The other test in static test involving safety factor measurement. The higher safety factor does indicate that the design is statically safe. However, having safety factor value in the hundreds is not reasonable as well. Research conducted in[38] discusses the structural design for electric car engine mount. Simulation results showed that maximum safety factor is nearly 20 and could potentially dropped if dynamic loads were used. Similar work provided in[40] shows dynamic tests for engine mount bracket. The safety factor under dynamic loading

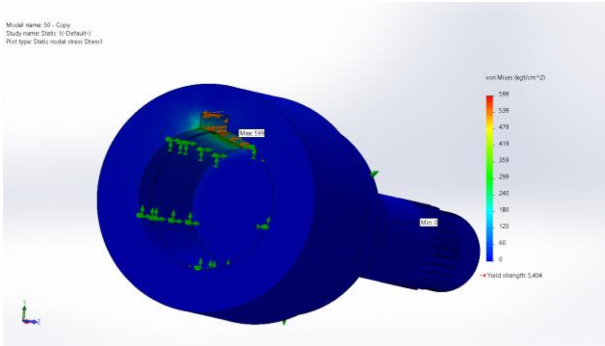

**Fig. 7:** Maximum static stress distribution on shaft.

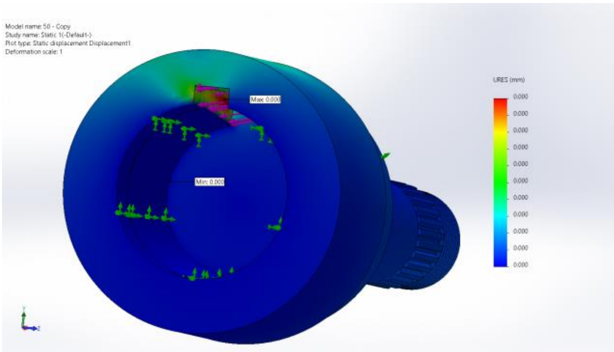

**Fig. 8:** Maximum static strain distribution on shaft.

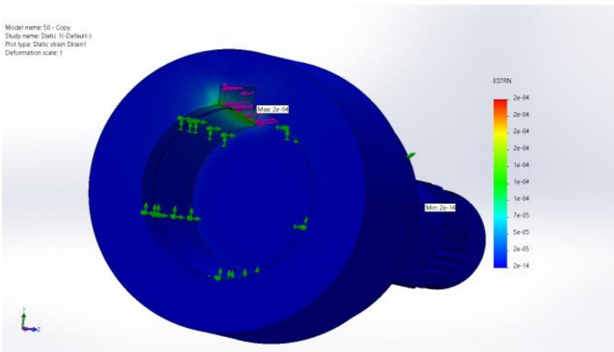

**Fig. 9:** Maximum displacement distribution.

condition was 1.34. Simulation in Fig. 10 shows that our safety factor value is 9. Based on previous works mentioned earlier, the acquired safety factor is safe since conducting dynamic load tests will eventually decrease the safety factor. It is important to consider the selection of the materials used to cut down costs and increase production efficiency.

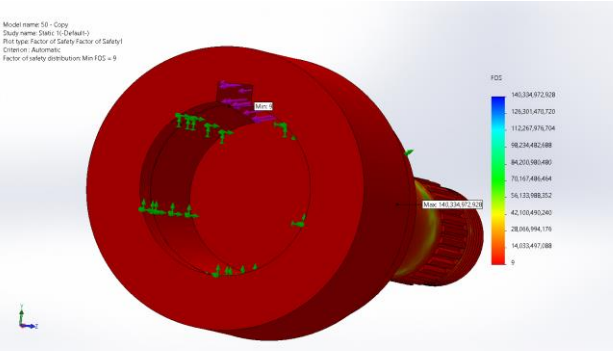


**Fig. 10:** The factor of safety of the shaft.

## 4. Conclusion

A structural design was conducted to evaluate the current design of the mount and the shaft under static loads. The simulation results indicate that under the design's maximum load, the factor of safety is still considered high. For the shaft, its factor of safety for is 9. Therefore, materials with lower physical properties are suitable to be used to achieve cost reduction as well as production efficiency.

The simulation conducted in the paper only considers static loading. It is important to include dynamic loading simulations to achieve optimization. The contribution of this research is the development of supporting component designs for the conversion of conventional two-wheeled motorcycles to electric ones. The simulation results can serve as a reference for electric vehicle conversion workshop in determining the most suitable materials for their standards.

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