Implementation Carbon Fiber TC35-12K/Epoxy at Frame Y125Z using FEA

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Abstract. The motorcycle frame is made to support loads such as the engine, rider, and other supporting devices. The motorcycle frame must have strength, rigidity, and light weight and is expected to withstand certain conditions. The frame of a motorcycle functions as a support for the weight of the vehicle, rider, engines, and other loads. In motor racing, a good rigidity frame is needed because it is constantly subjected to compressive and twisting forces when maneuvering. Generally, the frame is made of steel to support the engine and rider. In this study, carbon fiber will be applied to the critical zones of the vehicle so that the frame remains rigid or rigid when driving. Research is done with the processing system to find the best configuration to be applied. The author modeled the motorcycle frame and applied TC35-12K-Epoxy Carbon Fiber to the Y125Z Motorcycle Frame using the FEA (Finite Element Analysis) Method. The Y125Z motorcycle was used as the object of research with a 124.3 cc cubication specification, a two-stroke engine with air conditioning and combined with 6 manual transmissions. Power reaches 17.2 HP at 8,000 rpm, and a torque of 16.2 Nm at 7,500 rpm.

Keywords: Motosport, Carbon fiber, epoxy, stiffness, Strength, FEA.

1 Introduction

One of the important elements in the series of making a motorbike is the motorbike frame itself. The motorcycle frame is made to support loads such as the engine, rider, and other supporting devices[3]. Motor frames that are made in the factory certainly have certain procedures and conditions that exist, after conducting research and analysis by the motorcycle company so that the motorbike can survive in certain conditions[1]. The frame of a motorcycle functions as a support for the weight of the vehicle, passenger engines, and other loads [7]. Usually, the frame is made of steel framework that supports the body and engine of a vehicle. During the manufacturing process, the vehicle body is formed according to the frame structure. In principle, the frame that is designed is expected to keep the vehicle rigid or stiff and not experience turns while driving.

Many attempts were made to minimize the weakness of steel by changing to aluminum material, but aluminum is not able to accommodate shock loads that are too large. Some researchers such as Rastogi [4] found a solution, namely a hybrid alloy by combining carbon fiber, glass fiber,

ABEC 2023, September 21, Bengkalis, Indonesia

DOI 10.4108/eai.21-9-2023.2342923

and aluminum as the outer layer. The results of the torsion test from the combination of the three elements produce better strength. Knowing the benefits of composites, automotive companies also apply them to reduce vehicle weight and reduce the use of metal materials. If each part uses composite materials, the overall weight of the vehicle will be lighter and this method is effective for optimizing fuel economy[2].

Fig. 1. Conventional Y125Z Frame.

With this computational system in place, the authors modeled the motorcycle frame and applied TC35-12K-Epoxy Carbon Fiber to the Y125Z Motorcycle Frame using the FEA Method [3]. The target application is in a critical zone where twists often occur when used in motor racing events. Y125Z motorbike with 124.3 cc specifications, 2 strokes with wind cooler, and combined with 6 manual transmissions. Standard power reaches 17.2 HP at 8,000 rpm, and a torque of 16.2 Nm at 7,500 rpm. The analysis was carried out using a computational system with the FEA (Finite Element Analysis) method. This method can solve complex structural problems in solid body mechanics to produce solutions in the form of stresses, strains, deflections to fatigue life.

2 Research Methods

2.1 Research Object

Figure 1 shows the shape of the conventional Y125Z chassis in use today. The specifications of the motorbikes that will be used as research objects are in Table 3.1:

Table 1. Research object specification.

Motorbike specification	
Engine type	2 stroke
Cylinder volume (cc)	124,3 cc
Maks Power (HP/rpm)	17.2 HP/8000 rpm
Maks Torque (Nm/rpm)	16,2 Nm/7500 rpm

2.2 Material Research

The composite material used is TC35-12K woven carbon fiber and epoxy resin as the matrix. The following is in Table 2 and Table 3 the mechanical properties of each parent material that will be combined in one laminate as follows:

Table 2. High strength carbon fiber.

Mechanical properties	Value	Units
Modulus young (E_f)	123,420	GPa
Bulk modulus	121	GPa
Shear modulus (G_f)	46,397	GPa
Poisson ratio (v_f)	0,33	-
Tensile yield Strength	1723,7	MPa
Tensile Ultimate yield Strength	3447,4	MPa
Compressive yield Strength	1275,5	MPa
Compressive Ultimate yield Strength	2413,2	MPa
Density (ρ)	1,58	g/cm^3

Sources: Imumbhon Johnson, et al (2021).

Table 3. Epoxy resin properties.

Mechanical properties	Value	Units
Modulus young matric epoxy (E_m)	3,78	GPa
Shear modulus (G_m)	1,4	GPa
Poisson ratio (v_m)	0,35	-
Density (ρ)	1,16	g/cm^3

Sources: Technical Fabrics Handbook, 2010

Carbon fiber has good strength if the fiber direction is the same as the direction of loading [16]. In the simulation, it is stated that the composite is an orthophic or anisotropic material, namely the strength of the composite is strongly influenced by fiber orientation and volume fraction. When the fiber orientation is changed from the direction of the load, the strength of the composite decreases. The basis for determining the best fiber orientation that affects the strength of the composite (σ_c) is as follows:

$$\sigma_c = \acute{\eta} \,.\, \sigma_f \,.\, V_f + \sigma_m \,.\, V_m \tag{1}$$

Determine the directional Young's modulus x (E_x):

$$E_x = E_f \,.\, V_f + E_m \,.\, V_m \tag{2}$$

The type of fiber used is woven, so the strength in the x and y directions is considered:

$$E_x = E_y$$
$$E_y = E_f \,.\, V_f + E_m \,.\, V_m \tag{3}$$

Determine Young's modulus is z (E_z):

$$E_z = \frac{E_f . E_m}{V_f . E_m + V_m . E_f} \quad (4)$$

Determining the shear modulus (G_{xy}) of carbon fiber TC35-12K epoxy resin:

$$G_{12} = \frac{G_f . G_m}{V_f . G_m + V_m . G_f} \quad (5)$$

Poison ratio (v_{12}) is the elasticity constant that each material has or the ratio between transverse strain and longitudinal strain when subjected to tensile or compressive forces, it will change shape.

$$v_{12} = V_f . v_f + V_m . v_m \quad (6)$$

Density or density (ρ) is a quantity of the mass density of an object expressed in the weight of the object per unit volume[5]. Density can help explain why objects of the same size have different weights. The higher the density of an object, the greater the mass of each volume.

$$\rho_c = \rho_f . v_f + \rho_m . v_m \quad (7)$$

2.3 Research Procedure

Modeling is the process of forming objects using a computational system so that the results of the model (part) look real according to the original object[10]. The overall modeling process includes the formation of parts, the assembly process (assembly parts), and a two-dimensional projection model (2D engineering drawing). The output of modeling is in the form of volume, mass, and so on[11]. In the simulation stage, the surface is needed as an initial reference (core) from adding the number of carbon fiber/epoxy layers on the drive shaft. The file extension for creating a surface is “STEP”.

Fig 2. Y125Z frame model and geometry.

Meshing is the process of dividing objects into smaller parts[13]. The smaller the meshing size used, the more accurate the calculation results will be, but it requires high computational specifications. In this study, the solid mesh type was applied with 177.201 elements and 320.940 nodes, and the size of each element was 8.7 mm.

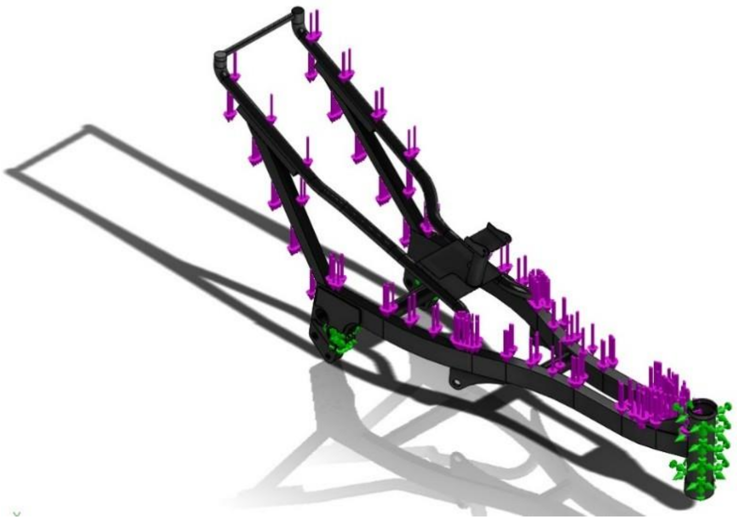

Fig 3. implementation of load at the frame.

Figure 3 shows the force points which are divided into concentrated and evenly distributed forces. To get the best results in the use of carbon materials, the thickness of the carbon fiber and the stiffness properties are factors that affect the ability of composite materials. The material used in this study was carbon fiber/epoxy woven wet TC-35 12K.

3 Result and Discussion

From the results of calculations using equations 1 to 7 and supported by several references, the property values of TC35-12K epoxy reinforcing carbon fiber are obtained as shown in Table 4:

Table 4. Carbon Fiber TC35-12K reinforced epoxy properties.

Yield strength	1275,5	MPa
Tensile strength	1723,7	MPa
Compressive strength	2413,4	MPa
Elastic modulus	123,42	GPa
Poisson's ratio	0.33	-
Mass density	1,85	Kg/m^3
Shear modulus	46,397	GPa

3.1 Von Mises Stress

The Von Mises stress results use color contours to provide information on the maximum and minimum stresses that occur. The TC35-12K/epoxy carbon fiber material on the Y125Z motorcycle frame is said to begin to yield when the von Mises stress reaches the yield strength value[9]. The von Mises stress is used to assist in predicting the failure zone and the yield rate of the material due to overall loading.

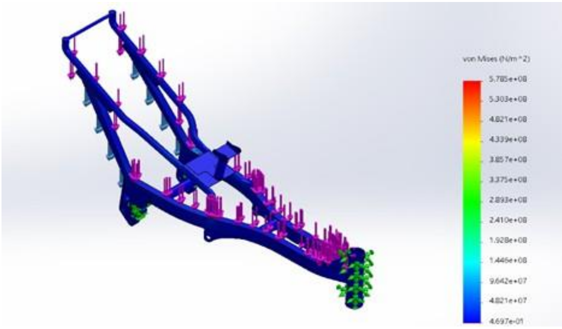

Fig 4. Zone of maximum von Mises stress.

It is observed from Figure 4 that overall the construction with TC35-12K/epoxy material can support the load very well although there are several points that have a fairly high stress level of 578,5 MPa. But still below the yield value.

3.2 Displacement

Displacement provides information on the deformation that occurs in the motorcycle frame with TC35-12K/epoxy material when the maximum load is applied [8]. The results of the computations carried out found that the critical parts of the Y125Z frame were deformed. However, the maximum deformation that occurs at the critical point is only 0,46 mm. This shows that the TC35-12K carbon fiber material with epoxy reinforcement has excellent strength and rigidity.

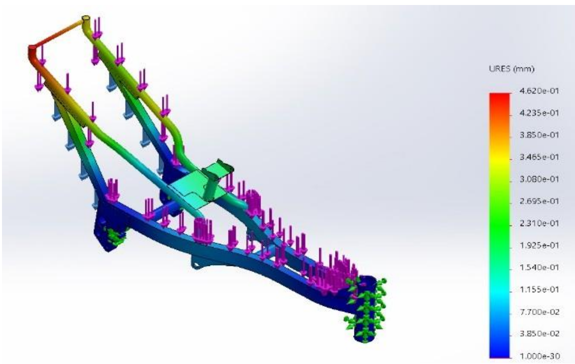

Fig 5. Displacement mapping of the frame.

3.3 Factor of Safety (FOS)

The safety factor of frame construction with TC35-12K material with epoxy reinforcement can be measured, calculated, and predicted. if the safety factor equation is the ratio of yield strength to maximum stress (actual stress), then its value must be greater than 1,0 to avoid failure [10].

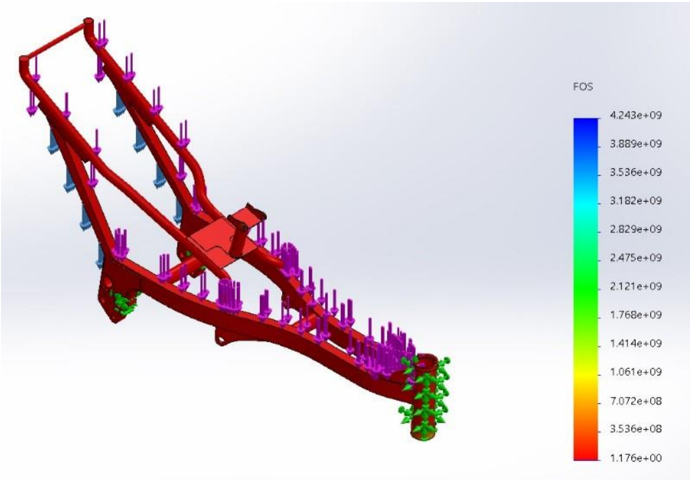

Fig 6. Factor of safety material carbon fiber TC35 at frame Y125Z.

Figure 6 explains that from the 4 main points of applied load, the simulation results show that several zones tend to experience low FOS levels. In the critical zone, the lowest factor of safety value was found to be 1.2 but still above the established FOS standard (> 1). Overall the Y125Z frame with TC35-12K/epoxy carbon fiber material has entered the "Safe" category.

4 Conclusion

Based on the FEA analysis that has been carried out and the observation of the point distribution of the load applied to the Y125Z frame with epoxy reinforced TC35-12K carbon fiber material, it can be concluded that:

1. Using TC35-12K/epoxy material with a density of 1.85 kg/m3, the weight of the motorcycle frame can be determined as ±2.78 kg. Able to reduce weight up to about 82% of the previous material (SM45=16 kg).
2. The 2 mm thickness TC35-12K/epoxy material works very well on the Y125Z frame. The maximum von Mises stress occurs at one point of 578,5 MPa but overall it is still below the yield strength value of 1275,5 MPa.
3. Deflection only occurs 0.46 mm from its original shape, so it can be concluded that the stiffness and strength of the TC35-12K/epoxy material is very good.
4. Further development requires a combination of several types of materials so that the ability of the frame matches the applied load so that it is more economical in the manufacturing process.

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