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Frame e-Bike Optimization Capacity 48V

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Abstract

This study aims to find out the old frame data with a new frame so that the data obtained from these two frames can be used as a comparison of the results of the data in both frames and to obtain data optimization by choosing a lighter frame. With a lightweight frame can save electricity on the battery because of the use of electric power that is not as big as a heavier frame. The author tries to find alternative models of lightweight frames and saves energy on electric motorbikes with calculations such as simulation analysis, calculation of frame volume, calculation of gravity, calculation of centre of gravity, calculation of stability, calculation of strength and analysis of calculation of energy consumption horizontal and uphill paths. HK-40 material has proven to be better, the difference in both materials when the road is horizontal distance of 300 m, there is a power difference of 0,14 W and when the road climbs 60 m distance, a power difference of 0,07 W. occurs in HK - 40 material can save power of 0,14 W on the horizontal road and 0,07 W on the uphill road. Then the difference in power produced will be even greater. So that there is a considerable power efficiency if used in a considerable distance.

Key-word: - Material, Structural, Energy Efficency.

1.0 PRELIMINARY

Electric two-wheelers have become a significant mode of transportation in the past decade. Though marketed and publicized by some as zero-emission vehicles, little pastresearch has been done to quantify the environmental impacts of electric two-wheelers. This quantifies some of the environmental impacts of the production pro-cesses and use phase of electric two-wheelers and compares them to the environmental impacts of competing modes, including bicycles, buses, motorcycles and cars. The results show that elec-tric two-wheelers emit several times lower pollution per kilometer than motorcycles andcars, have comparable emission rates to buses and higher emission rates than bicycles [1]. Due to increasing oil price and global warming, theelectrical traction of transportation means represents aconvenient solution in terms of cost and environmental cleanness. Therefore, the use of electric power is particularly compliant with urban mobility, since the distances covered by vehicles are relatively short insidecities. Among urban electric vehicles, bicycles are certainly the least noisy and polluting ones. Moreover, electric bikes are cheaper than the other electric vehicles. In the electric bicycle, so-called “E-bike”, a part of the classical energy source, that is muscle power, is replaced by electricity, providing the possibility of an electric assisted pedal [2]. An e-bike frame includes a top tube, a downtube and a seat tube. Further, a bottom bracket is arranged in a housing which may be a bottom bracket receptacle element. An electric motor is also provided in the housing. A battery is connected with the downtube. A channel element is arranged laterally beside the battery. The same serves to receive wires, shift cables, brake cables and / or hydraulic lines [3]. The modified HK 40 heat resistant steel with higher chromium and silicon content has improved resistance to carburization and metal dusting [4]. To compare material prices can be selected based on the list of the lowest quality prices, for AISI 1040 for US $ 700/Ton, while HK-40 for US $ 610/Ton.

That the material to be optimized, the HK-40 has a cheap price so that for the parameters related to price, this material is cheaper than the old material. With the existence of cheap and light prices, it can make scientists and researchers interested in being able to implement this research [5]. Formulation of the problem includes:

1. How to design lightweight E-bike frames and save electricity consumption?
2. What are the technical parameters of calculating E-bike frames that have renewal?
3. What material is suitable for E-bike frames in terms of economical and energy-saving aspects?

This study has the objectives, namely:

1. To look for alternative model of frame that lightweight and save energy.
2. To find out the old frame data with a new frame so that the data obtained from these two frames can be used as a comparison of the results of the data in both frames.
3. To get data optimization by having a lighter frame, so that it can save electricity on the battery.

In conducting research on the E-bike frame, it is expected that it can produce something useful as follows:

1. Obtain data on old and new materials with analytical calculations.
2. To determine the operating load that is feasible to use in accordance with the material used / selected.
3. The results of this analysis are used as applications between existing materials and their lighting methods.

In conducting research must understand the physical properties of the material because of the physical nature of the material as a support for the research base. Specifications of the physical properties of the material can be seen in Table 1.

Table 1. Physical Properties of Materials [6].

Typical Chemical Composition (%)		
Material	HK-40	AISI 1040
Carbon	0,35 - 0,45	0,37 - 0,44
Manganese	1,5	0,6 - 0,9
Phosporus	0,04	0,04
Sulfur	0,04	0,05
Physical properties (kg/m³)		
Material	HK-40	AISI 1040
Density	7750	7850
Minimum Mechanical Properties		
Material	HK-40	AISI 1040
Hardness, Brinell	170	201
Tensile, Mpa	430	518,8
Yield, Mpa	240	353,4
Elongation (%)	10	25

2.0 RESEARCH METHODS

Research Materials

In this study, the materials used in the study were batteries and electric motors. Li-ion batteries have an unmatchable combination of high energy and power density, making it the technology of choice for portable electronics, power tools, and hybrid/full electric vehicles. If electric vehicles (EVs) replace the majority of gasoline powered transportation, Li-ion batteries will significantly reduce greenhouse gas emissions. The high energy efficiency of Li-ion batteries may also allow their use in various electric grid applications, thus contributing to their more wide spread use and building an energy-sustainable economy. Therefore Li-ion bat-terries are of intense interest from both industry and government funding agencies, and research in this field has a bounded in the recent years [7]. The battery used can be seen in Figure 1.

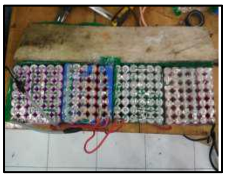

Figure 1. Battery

Brushless DC motor has gained popularity over a broad range of motion controller applications. The 3-phase permanent magnet BLDC motor inherently needs an electronic commutation circuit to drive it as it is not a self-commutating motor [8]. BLDC used can be seen in Figure 2.

Figure 2. BLDC motor

Research Tools or Instruments

The tool that supports this research is the controller, gas handle, MCB, and Power meter. The electric bike speed controller sends signals to the bike's motor hub in various voltages. These signals detect the direction of a rotor relative to the starter coil. The proper function of a speed control depends on the employment of various mechanisms. In a purpose-built electric bike, Hall effect sensors help detect the orientation of the rotor. If your speed controller does not include such sensors and the speed controller on an adaptive bike may not the electromotive force of the undriven coil is calculated to get the rotor orientation [9]. The controller used in the E-Bike used as this research can be seen in Figure 3.

Figure 3. Controller

An improved twist gas strip for the handlebar of a motorcycle or the like in which a bowden cable return roll housing has a continuous slit for suspending the bowden cable, which slit is closed above the return roll by a detachable lid [10]. The gas handle used can be seen in Figure 4.

Figure 4. Handle Gas

An operating mechanism of an electrical circuit breaker comprises a handle coupled to a transmission rod to form a toggle, a movable contact support device having a plate mounted with rotation on a pivot, and a mechanical link breakable by the action of a trip lever. The link is formed by a retaining catch of the trip lever cooperate ing with a latch pivotally mounted on a spindle of the plate. The rod is coupled directly to the latch, the as sembly constituting a gearing-down stage enabling the tripping force to be reduced. The MCB used can be seen in Figure 5 [11].

Figure 5. MCB

A bicycle power meter having components which replace the rear axle hub assembly of a conventional chain driven bicycle. Inner and outer hubs are coupled to the usual freewheel chain drive cluster and to the rear wheel, respectively. The hubs are interconnected by a plurality of torsion rods which transmit driving torque form the inner hub to the outer hub. The torsional deflection of the rods is evidenced by a change in the relative angular displacement between a pair of hub disks attached to the hubs, respectively. The rate of rotation of the outer hub disk reflects wheel speed. A sensor head converts the relative angular displacement between the disks, and the rate of rotation of the outer hub disk, into signals which are applied to a processing and display module that calculates and displays horsepower. The power meter used can be seen in Figure 6 [12].

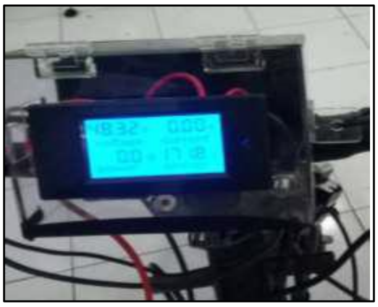

Figure 6. Power Meter

3.0 Data Collection and Collection Procedures

The first step is making technical drawings using the Pro-E application. Then the simulation analysis to determine the design voltage value that will be used to calculate the comparison parameter between the old frame value and the new frame. Analytical calculations both calculation of strength both sf, actual stress, aerodynamic force etc. Then it is processed to get the electrical power value of the specified frame type. The final step after calculating is making comparison tables and graphs where the new material must have better data as the advantages of this research can be made an optimization even though not all parameters can be optimized. The research flow chart will be explained in Figure 7.

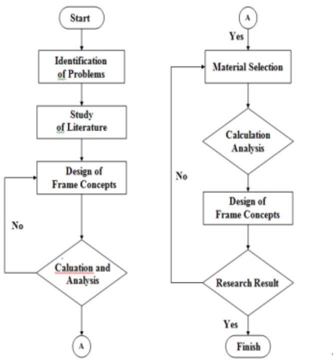

Figure 7. Research Flow Chart

4.0 RESULTS AND DISCUSSION

Temporary test results for calculating energy consumption when horizontal. The total power needed per unit of time for the total force acting on electric motorcycle riders.There are several styles that resist the motion of an electric motor so that the driver needs enough power so that the motorcycle can move forward. To make an optimization in reducing electricity consumption, reference data is needed which can be seen in Tables 2 and 3.

Table 2. Interim Test Results for Energy Consumption in AISI 1040 Material Horizontal Conditions

No	Parameter Perhitungan	Jarak 100 m	200 m	300 m
1	t (s)	19	28	38
2	v (m/s)	5,5	7,14	7,89
3	a (m/s^2)	0,29	0,255	0,21
4	F_{Ia} (N)	29,11	25,6	21,08
5	F_m (N)	24,62	24,62	24,62
6	F_{ad} (N)	0,513	0,86	1,06
7	F_t (N)	54,24	51,08	46,76
8	τ (Nm)	11,72	11,03	10,1
9	P_{total} (W)	298,32	364,71	368,94

When the uphill conditions are not much different from the calculation, the difference is that there is an uphill style and there is no rolling force. For testing uphill conditions are carried out at a distance of 20 m, 40 m and 60 m.

Table 3. Interim Test Results for Energy Consumption in AISI 1040 Uphill Conditions

No	Parameter Perhitungan	Jarak 20 m	40 m	60 m
1	t (s)	10	14	18
2	v (m/s)	5,5	7,14	7,89
3	a (m/s^2)	0,55	0,51	0,44
4	F_{Ia} (N)	55,19	51,18	44,15
5	F_m (N)	25,26	25,26	25,26
6	F_{ad} (N)	0,513	0,86	1,06
7	F_t (N)	81	77,3	70,47
8	τ (Nm)	17,5	16,7	15,22
9	P_{total} (W)	445,5	551,92	556

Simulation analysis was then carried out using the Pro-E application and carried out theoretical calculations on the frame design. Theoretical calculations on the frame include calculation of center of gravity, stability and strength in the frame. The design of the frame design can be seen in Figure 8.

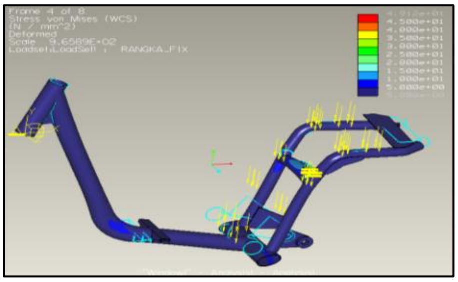

Figure 8. Simulation of Loading and Results of Von Mises Stress on Seat Rail

From the simulation results obtained the largest stress results seen in red which is equal to 49,12 N/mm² or equal to 49,12 x 10^6 N/m² and the lowest voltage result is equal to 0,87 N/mm^2 or equal to 8.7 x 10^5 N/m^2. Because the biggest stress that occurs in the frame is still below the yield stress on steel material AISI 1040 and HK-40 because both of these materials are classified as steel.

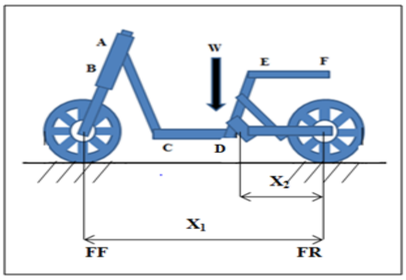

Figure 9. Body Frame of Electric Motorbike Weight Diagram [13]

Calculation of total frame length needs to be calculated for each part of the frame length, and data can be obtained that can be calculated as described in equation 1.

X_1= 1319,28 mm d_1 = 31,75 mm

X_2 = 528,92 mm d_2 = 27,75 mm

X_T = 728,92 mm

By getting the data above, the value of I can be determined.

$$l = X_1 + X_2 + X_T \quad (1)$$

The frame volume can be measured by equation 2 [14].

$$V_{frame} = ((\pi/4 \text{ x } d_1^2 \text{ x } 1) - (\pi/4 \text{ x } d_2^2 \text{ x } 1)) \quad (2)$$

To calculate the frame mass can be seen in the completion of equation 3. The mass of the frame type is obtained by the value 7750 kg / m3 [15].

ρ = 7750kg/m^3

V_{frame} = 5,605 x 10^{-4} m^3

$$m_{frame} = \rho \text{ x } V_{frame} \quad (3)$$

The driver's mass is based on the assumption of the mass of a motorcycle driver in general, which is 80 kg. Calculation of total mass and gravity can be seen in the explanation of equation 4 and equation 5 [16].

m_p = 80 kg

m_{motor} = 8 kg

m_b = 8 kg

$$m_{tota} = m_p + m_{frame} + m_{motor} + m_b \quad (4)$$

$$W = m_{total} \text{ x } g \quad (5)$$

In calculating the center of gravity the body weight diagram is needed, the following will be explained the body weight diagram in Figure 10.

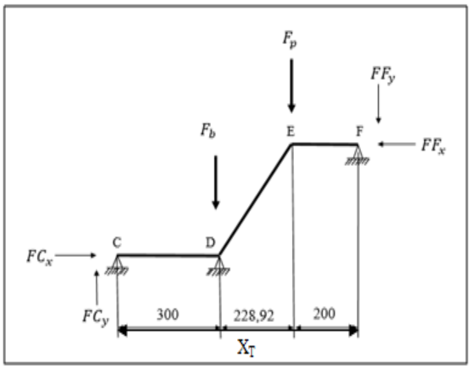

Figure10. Body Weight Diagram on the frame (frame) [17]

This emphasis will be calculated to get the value of the front frame style and style on the rear frame. Values are calculated in equations 6 and 7 [18].

$F_p = m_p$ x g (6)

CD = 0,3 m

$F_b = m_b$ x g (7)

CE = 0,529 m

X_T = 728,92 mm

In calculating stability, it takes a mass of battery (mb) and mass of the driver (mp), for stability in both materials is not different because it does not relate the mass value of the material. The value of good stability is zero, because in the neutral position and in the calculation of stability the material mass is not affected. Explanation of stability calculations can be seen in equations 8, 9 and 10 [19].

$$(F_b).(CD) + (F_p).(CE) - (F_x).(X_T) = 0 \quad (8)$$

$$(F_p).(FE) + (F_b).(FD) - (F_{cx}).(X_T) = 0 \quad (9)$$

Equilibrium Framework:

$$(F_x + F_{cx}) - (F_p + F_b) \quad (10)$$

Calculation of surface area and stress that occur is used to determine the surface area of a tubular frame such as a pipe. For the calculation of surface area can use equation 11 [20].

$$A_k = ((\pi.\ d_1.\ l) - (\pi\ .\ d_2.\ l)) \quad (11)$$

The value of the stress that occurs can be calculated by knowing the value of surface area and gravity, W = F. Equation 12 is needed to calculate the stress value that occurs [21].

$$\sigma_{actual} = \frac{F}{A_k} \quad (12)$$

The value of security factors can be searched using equation 13 . The tensile strength of HK-40 is 348 MPa [22]. And the design voltage value is 49.12 N/mm^2 based on frame simulation analysis using the Pro-E application [23].

$$Sf = \frac{\sigma y}{\sigma D} \quad (13)$$

The sf value is still relatively safe because it is greater than 1 and smaller than 9.

5.0 Energy Consumption Calculation Analysis

The equation calculating the acceleration value can be calculated using the calculation of acceleration calculated based on the value of the speed that has been tested, time and distance traveled. v_1 and t1 values are always zero because of the stationary conditions. v_2 and t_2 values can be seen in Tables 4 and 5.

On electric motorbikes with distance, travel time, and speed of equation 14 [24].

$$a = \frac{v2 - v1}{t2 - t1} \quad (14)$$

The acceleration force on an electric motorbike is calculated from the sum of the total electric motorbike (including the driver's mass) then multiplied by the acceleration (a). The acceleration force on an electric motorbike can be calculated by referring to equation 15 [25].

$$F_{Ia} = m. a \quad (15)$$

The rolling force produced by motor-electric bikes has a friction coefficient of 0.025 times the total period of electric motorbikes. Then multiplied by the gravitational acceleration of the earth 9.8 m / s2. The calculation of rolling forces at close and long distances is the same. The rolling force on an electric motorcycle can be calculated by referring to equation 16 [26].

$$F_m = \mu_m .m. g \quad (16)$$

Uphill force (Fm) on an electric motorbike has a total mass, then multiplied by the earth's gravitational speed 9.8 (m/s^2) and a slope angle of 13 °. The uphill force on an electric motorcycle can be calculated by referring to the friction coefficient of 0.025. And the uphill force must be greater than the rolling force on the horizontal path. For uphill forces can be seen in equation 17 [27].

$$F_m = \mu_m .m. g. \cos\theta \quad (17)$$

The calculation of aerodynamic forces on an uphill road with a horizontal path is no different for the calculation formula, the most important factor that distinguishes the value of aerodynamic force is speed. Calculation of aerodynamic forces can be seen in equation 18 [28].

$$F_{ad} = ½. \rho.A. C_d. v^2 \quad (18)$$

Calculations for the total force that occurs require acceleration force parameters, uphill forces and aerodynamic forces. The total force equation that occurs can be seen in equation 19.

$$F_t = (F_{la} + F_m + F_{ad}) \quad (19)$$

In calculating the torque required l (the circumference of the circle) by knowing the wheel diameter of 17 inches or 0.432 m, means that the radius is 0.216 m. In calculating torque you can use equation 20 [29].

$$\tau = F_t \text{ x } r \quad (20)$$

After the total force value and speed are obtained. Only then can the value of mechanical power be sought. Mechanical power calculations can use equation 21 [30].

$$P_{total} = F_t \text{ x } v \quad (21)$$

6.0 Results of Material Calculation for HK-40

The value of power when climbing is greater than when horizontal, although the AISI 1040 material with HK-40 has a slight difference, but in terms of energy consumption, the HK-40 material is superior. In a flat and uphill condition, the HK-40 material is more efficient in energy and energy. So that when used long distances, the difference in power consumption will be very different. The description of the calculation of the horizontal condition of the HK-40 material will be explained in Table 4.

Table 4. Results of Calculations in Material HK-40 horizontal conditions

No	Parameter Calculation	Space 100 m	200 m	300 m
1	t (s)	19	28	38
2	v (m/s)	5,5	7,14	7,89
3	a (m/s^2)	0,29	0,255	0,21
4	F_{Ia} (N)	29,09	25,59	21,07
5	F_m (N)	24,61	24,61	24,61
6	F_{ad} (N)	0,513	0,86	1,06
7	F_t (N)	54,21	51,06	46,74
8	τ (Nm)	11,71	11,029	10,09
9	P_{total} (W)	298,15	364,57	368,78

And at uphill distances, the difference that occurs will be even greater if the incline is quite far. Explanation of the calculation of HK-40 material will be explained in Table 5.

Table 5. Results of Calculation on Material HK-40 uphill conditions

No	Parameter Calculation	Space 20 m	40 m	60 m
1	t (s)	10	14	18
2	v (m/s)	5,5	7,14	7,89
3	a (m/s^2)	0,55	0,51	0,44
4	F_{Ia} (N)	55,19	51,17	44,15
5	F_m (N)	23,97	23,97	23,97
6	F_{ad} (N)	0,513	0,86	1,06
6	F_{ad} (N)	0,513	0,86	1,06
7	F_t (N)	79,67	76	69,18
8	τ (Nm)	17,49	16,69	15,22
9	P_{total} (W)	438,19	542,64	545,83

In the horizontal path and uphill road, between medium and long distances it has a slight difference in the speed value. So the power differences that occur are also getting thinner. To be more clear the comparison of mechanical power to speed will be explained in Figure 11.

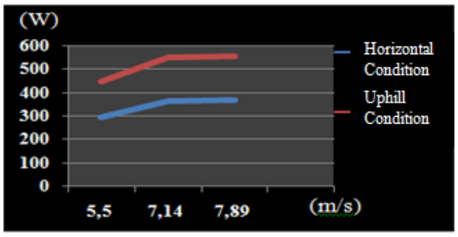

Figure 11. Comparison of Mechanical Power to Speed

When climbing, the ratio of mechanical power to speed does not change. The higher the speed, the greater the power consumed, the speed at which uphill is affected also by distance as well as on the horizontal road. When the speed of 5.5 m / s with a power of 298.15 W to a speed of 7.14 m / s with a power of 364.57 W, there is a drastic change in power due to the difference in speed which is slightly far away causing a large difference in power, namely 66.42 W. at medium speed with a power of 364.57 W towards high speed with a power of 368.78 W there is a change that is not too large, only has a power difference of 4.21 W. In conditions of rising power gap is greater than the horizontal condition because when you climb it requires more electrical power than when flat. The difference in power at low speed towards medium speed is 106.4 W, while the difference in power at medium speed to high speed is 4.1 W.

7.0 CONCLUSION

The design of a good electric motorcycle frame must pay attention to the physical and chemical composition in it and most importantly have a density that is lighter than the frame material of an electric motorcycle in general. Because the AISI 1040 material has a density value of 7850 kg / m3 while the density of the material used in this study is HK-40 has a value of 7750 kg / m3. In the 60 m distance, when the conditions climbed, the HK-40 material consumed 545.83 W of power, whereas in the AISI 1040 material it consumed 556 W. So in this study it could be called material optimization because the new material is more efficient electrical power. For AISI 1040 for US $ 700 / Ton, HK-40 costs US $ 610 / Ton. That the material to be optimized, the HK-40 has a cheap price so that for the parameters related to price, this material is cheaper than the old material.

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