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Power Capacity and Speed Analysis for Elevator Motors at Madani Hospital Pekanbaru

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***Abstract*—A Elevator is essential for quick vertical transportation in high-rise buildings. Three-phase induction motors are commonly employed as drivers, providing torque to propel the elevator. Passenger weight influences the motor's power and torque. To investigate this, data on passenger count and lift motors at Madani Hospital were collected through observation. Subsequently, measurements and calculations were conducted to determine the torque, power, and speed of the elevator motor. Results reveal that as the number of passengers increases, the motor's power and torque rise when the elevator ascends. The mechanical torque required to move between floors remains consistent when the floor distance is the same. Notably, the addition of passengers does not impact the speed of the elevator motor, as it maintains a constant motion.**

Keywords—Elevator Motor, Passenger Load, Power, Torque, Speed

I. INTRODUCTION

Advances in technological development at this time are able to be a solution to the problem of land which is decreasing day by day. One way is by constructing high-rise buildings to minimize land use in the city. Furthermore, to make it easier for people to move from one floor to another in a building, an effective and efficient means of vertical transportation is needed, one of which is the elevator [1]. The hospital is a health service institution that is visited by many people. Madani Hospital is a multi-stored building with 3 floors that uses an elevator as an effective and efficient vertical transportation [2]. The elevator can operate vertically up and down using an electric motor as the driving source. Torque is the output of a three-phase induction motor which has the function of driving the elevator. People or goods that are moved through the elevator have different loads or masses. Where the load on the lift increases, the torque and power will also increase [3].

Based on this, this research was conducted to determine the suitability between the power capacity of the motor in the elevator and the load received by the elevator and to calculate the speed of the motor as the driving force of the elevator by varying the load on the elevator passengers.

A. Elevator

Elevator or elevator is a vertical transportation tool that has a function to connect between floors in multi-storey buildings as a substitute for stairs. The working principle of the elevator depends on the use of pulleys and electrical energy as a source of power to move passengers from one floor to another [4]. Some of the elevator components are as follows; machine room, gliding room (hoistway), cage lift (car), ground space (pit).

B. Induction motor

An induction motor is an electric motor (AC) where the rotation of the rotor does not match the rotation of the stator field. An induction motor operates on the basis of electromagnetic induction from the stator coil to the rotor coil. If the stator coil of a 3-phase induction motor is connected to a 3-phase voltage source, the stator will produce a three-phase current, this current will then produce a magnetic field that rotates at synchronous speed. The lines of induced flux force from the stator coil will cut the rotor coil causing an emf or induced voltage. Since the rotor coil is a closed circuit, current will flow in the rotor coil. The current-carrying rotor coil is in the line of flux force originating from the stator coil [5]. The change in speed of a three-phase motor that uses the induction principle is affected by the number of poles on the stator and the frequency of the voltage source used. The synchronous speed of the motor refers to the speed of the rotating magnetic field. At a fixed power source and frequency, the synchronous speed of each motor is also fixed [6].

C. Power

The principle of power in mechanics is the basis for calculating power in dynamic electricity. In mechanics, power is defined as the speed of doing work. Whereas in dynamic electricity, electric power is defined as the amount of electrical energy used every second [7].

$$P = \frac{W}{t} \quad (1)$$

Information: P = Power (Watts), W = Electrical Energy (Joule), t = Time (seconds)

D. Induction motor torque

The moment of force or torque is a force magnitude acting on an object causing the object to rotate. The ability of a motor to rotate the load is also determined by the torque [8]. The general torque formula for an induction motor can be formulated as follows:

$$T = \frac{P}{\omega_r} \quad (2)$$

Information: T = Motor torque (Nm), ω_r= Rotor Angular Speed (rad/s)

E. Energy

Energy is the ability to do work. According to the law of the conservation of energy, energy cannot be created or destroyed but can be changed from one form to another. One form of motion energy is mechanical energy. Mechanical energy is the energy possessed by a moving object. Mechanical energy is divided into potential energy and kinetic energy [9]. Potential energy is the energy possessed by an object because of its position relative to a reference point. An object that is lifted to a certain height, then the object will have potential energy [10].

F. Induction motor control system

Control (drive control) is a system that regulates electric power so as to produce movement according to a pre-planned pattern such as acceleration, full speed or contact speed, deceleration and stopping [11].

II. Methodology

A. Electrical mechanical structure in passenger elevator

The electrical mechanical structure of the passenger elevator has several parts such as operating controls and controls for the drive motors which are used to make the elevator cage move up and down.

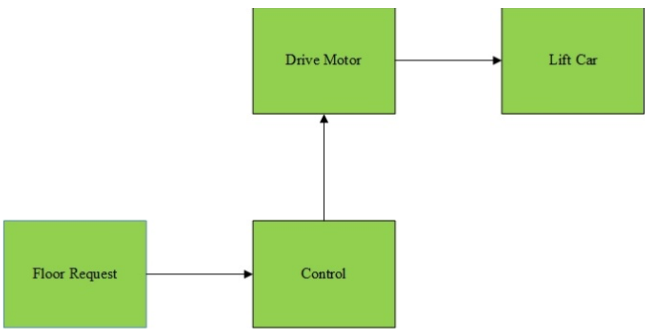

Fig. 1. Elevator Working Block

B. Determining Mechanical Factors Affecting Motor Load

In practice, usually to determine the weight of an empty cart can be determined by the result of subtracting the height of the cage multiplied by the maximum capacity of the lift [12].

$$\text{Empty car weight}(Q_{k)} = (2.38 - 1.7) \times 1350$$
$$\text{Empty car weight}(Q_{k)} = 918 \text{ kg}$$

To determine the balanced weight can be formulated with the following equation:

$$Q_{cw} = Q_k + (OB \times Q_p)$$
$$Q_{cw} = 912 + (0.425 \times 1350)$$
$$Q_{cw} = 1{,}485.75 \text{ kg}$$

The height of the building is directly related to the distance traveled in the elevator because the elevator serves passenger requests to move from one floor to another. The height of the building also affects the load moving in the elevator because the load moving at a certain height has potential energy in it.

C. Determine the Elevator Driving Motor

In an elevator driving motor there is power and torque in mechanics as well as power and torque in electricity. To determine the mechanical torque of the motor in this study, first determine the amount of load that will be carried by the elevator. In an elevator the load to be carried by the motor is in the form of the weight of the cage and the counterweight.

Cage potential energy:

$$E_p = m_{total} \cdot g \cdot h$$
$$E_p = 2262 \cdot 9.8 \cdot 21 = 465{,}519.6 \text{ J}$$

The potential energy of the balanced weights

$$E_p = m_c \cdot g \cdot h$$
$$E_p = 1486 \times 9.8 \times 21 = 305{,}818.8 \text{ J}$$

Because the object is at rest and only the motor is moving, the kinetic energy of the elevator is zero. So that the effort needed by the motor to move the elevator upwards is equal to the value of the potential energy generated.

$$\text{Motorcycle business} = 465{,}519.6 - 305{,}818.8$$
$$= 159{,}700.8 \text{ J}$$

$$P = \frac{W}{t}$$

$$P = \frac{159.700{,}8}{21} = 7{,}604.8\, Watt = 10.2\, hp$$

To calculate the mechanical torque produced by the load, you can use the equation:

$$T = \frac{P}{\omega_r}$$

$$T = \frac{7604.8}{7.222}$$

$$T = 1.503\text{Nm}$$

To determine the electrical power in this study is done by means of measurement. The thing to do is to measure the voltage and current on the motor panel so that the calculation of the output power of the motor in the elevator is obtained. To determine the speed of the elevator motor in this study, first determine the type of drive on the elevator. Because the type of motor used in the lift is gearless traction where the pulley is located on the motor directly through steel rope friction. In this study to determine the speed of the motor can be done by measuring directly on the lift motor. To determine the type of motor needed to operate the lift in transporting loads, the mechanical and electrical torque values of the motor are first sought so that it can be determined that the motor used is in accordance with the load being carried by the lift.

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D. System Analysis Method

- Determining the effect of building height on lift mechanical torque
- Determining the effect of mechanical torque on motor power capacity
- Determining the effect of changes in load on motor speed
- Determining the effect of changes in load on motor power

III. Result And Discussion

In this chapter, we discuss the calculation of power capacity, motor torque, and motor speed for the elevators in Madani Regional Hospital Pekanbaru.

A. Electric Mechanical Structure of the Passenger elevator at Madani Hospital

It can be explained that the elevator mechanism works at Madani Hospital where when a passenger presses the button on the elevator door, the controls in the control room will order the door to open. Then when a passenger enters the elevator cage and selects the desired floor by pressing the button on the right side of the elevator, the elevator control will order to close the elevator door. When the command for the intended floor is read by the control, the control will act as a mechanism to move the motor so that the elevator cage can move up or down to the desired floor. General Data of Passenger Elevators at Madani Hospital

TABLE I. Elevator Specifications Data at Madani Hospital

Parameter	Information
brand	Sigma
Elevator Type	Passenger Elevator
Number of floors served	3 Floor
Nominal Speed	60 meters/minute
Control Type	AC VVVF
Travel	21m
Maximum Passenger Mass	1,350 kg (18 people)
Train Weight	912 kg

B. Calculation Results of Elevator Motor Torque

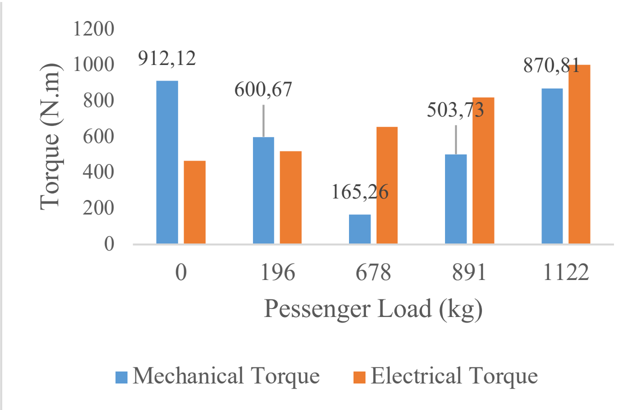

Fig. 2. Mechanical Torque and Electrical Torque When Elevator Rises

Based on Figure 3, it can be explained that with different passenger loads, different mechanical torque and electrical torque values are produced when the elevator moves up. When the elevator moves upward, it requires an electric torque value that is greater than the mechanical torque at each increase in the weight of the elevator passengers because when the elevator rises with a greater passenger load, the motor requires greater power. The more the elevator passenger load increases, the motor power (torque) to transport the cages up to the top will also be greater.

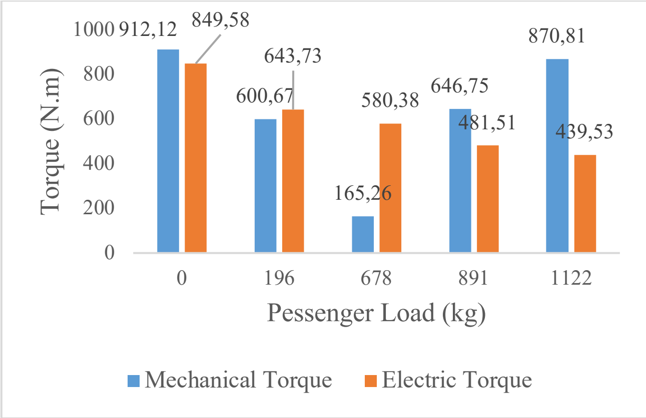

Fig. 3. Torque calculation when Elevator Drops

From Figure 4, it can be interpreted that when the elevator moves down, it produces mechanical torque and electrical torque on different motors as well. From the diagram above, it can be interpreted that when the elevator moves down, the passenger load increases, the motor will produce a small electric torque. This is because the motor moves according to the load carried by the elevator.

C. Analysis of the Effect of Building Height on Mechanical Torque

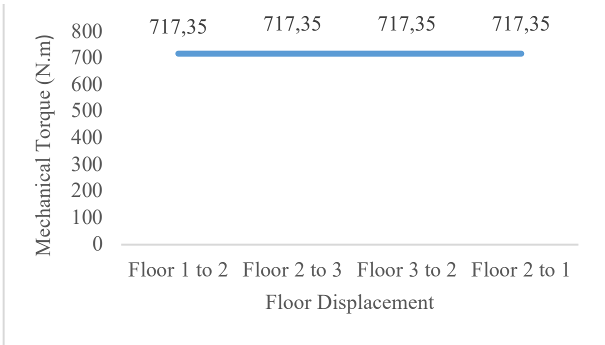

Fig. 4. The Effect of Building Height on Mechanical Torque

Based on Figure 5, it can be explained that with the same passenger load of 1122 kg there is no effect of the mechanical torque of the motor needed to move between floors in the elevator at Madani Hospital if the distance between the elevator floors is the same. Based on the graph in Figure 6 above, it can be explained that when the elevator moves up, the increase in the load on the elevator passengers causes the power needed by the motor to drive the elevator to be large and the torque generated will also be large. While the mechanical torque produces a different value when the passenger load increases, this is because the mechanical torque produced by the motor is affected by the weight of the balanced weight.

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D. Analysis of the Effect of Lift Mechanical Torque on Motor Power Capacity

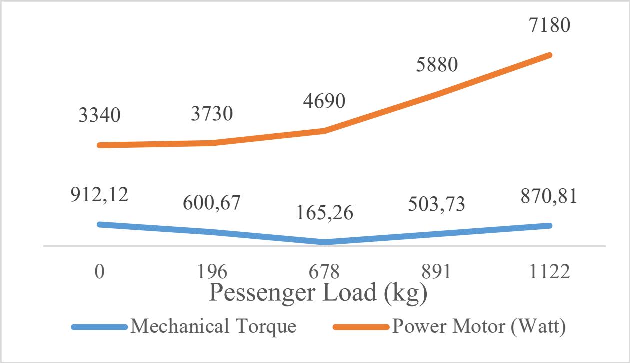

Fig. 5. Mechanical Torque and Motor Power when the Elevator Rises

E. Analysis of the Effect of the Number of Passengers on the Motor Speed in the Elevator

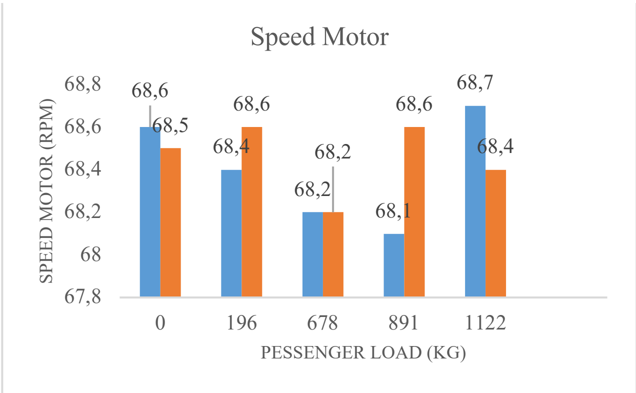

Fig. 6. The Effect of Passenger Load on Motor Speed

Based on the diagram in Figure 7, it can be interpreted that the average motor speed generated for each passenger load by moving the elevator from the 1st to the 3rd floor is in the speed value range of 68 Rpm. The resulting motor speed is constant in the value range of 68 Rpm due to the control of the motor. This proves that as the number of elevator passengers increases, the resulting motor speed remains constant. Based on the above diagram, it can be inferred that when the elevator is ascending with a transition from floor 1 to 3, as the passenger load increases, the motor power will also increase. On the other hand, when the elevator is descending and the passenger load increases, the motor power decreases. Based on the available data, it can be explained that there is an influence of passenger weight on the elevator motor power. As the elevator load increases, the required power and torque of the motor will also increase when the elevator moves upwards, and vice versa when the elevator moves downwards. However, the influence of changes in passenger weight on the motor speed is relatively constant due to the control system in the elevator motor.

F. Analysis of the Effect of Number of Passengers on Motor Power in the Elevator

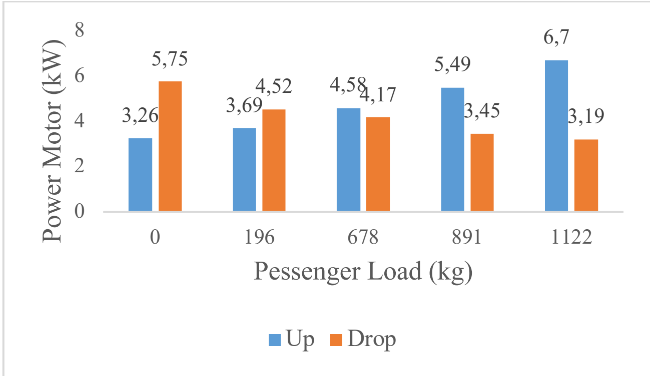

Fig. 7. Diagram of Influence of Passenger Load with Motor Power

IV. Conclusion

When the elevator moves up, the additional load of the elevator passengers will result in an increase in motor torque. On the other hand, when the elevator moves down, the additional load on the elevator passengers will result in a decrease in motor torque. When the elevator moves up and down, the magnitude of the motor mechanical torque required to move between floors is the same, if the distance between the floors is the same. The mechanical torque of the motor is directly proportional to the power requirement of the lift motor. However, in this study the mechanical torque of the motor is affected by the weight balance. When the elevator moves up and down, the additional passenger load does not affect the rotational speed of the elevator motor. When the elevator goes up, the change in passenger load is directly proportional to the increase in the lift motor power. Conversely, when the elevator goes down, the change in passenger load is inversely proportional to the power required by the elevator motor.

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