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Innovation in Designing a 500 kg Capacity Passenger Elevator in a Multi-Storey Building: A Study at Suzuya

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Abstract

This study aims to analyze and design the working system of a passenger elevator, including the working mechanism of the elevator, the design of the lifting system, the calculation of cage capacity, the design of power and the selection of the main drive motor, the calculation of the main components, the design of the transmission, the calculation of maintenance costs, the selection of component materials, and the creation of technical drawings. The design results show that the specifications of the drive motor used have a power of 6.28 Hp with a rotation of 800 rpm, a lifting speed of 15 m/min, and a lifting capacity of 500 kg. The shaft components are designed using S45C carbon steel, with details of Shaft I with a diameter of 24 mm, Shaft II with a diameter of 41 mm, and Shaft III with a diameter of 41 mm. The gears consist of Gear I with a pitch circle diameter of 42 mm, a circle diameter of 37 mm, a head circle diameter of 46 mm, a width of 16 mm, and 21 teeth; Gear II with a pitch circle diameter of 210 mm, a circle diameter of 205 mm, a head circle diameter of 214 mm, a width of 16 mm, and 105 teeth; Gear III with a pitch circle diameter of 68 mm, a circle diameter of 63 mm, a head circle diameter of 108 mm, a width of 16 mm, and 34 teeth; and Gear IV with a pitch circle diameter of 270 mm, a circle diameter of 265.5 mm, a head circle diameter of 270 mm, a width of 16 mm, and 21 teeth. The drum used has a diameter of 253 mm, a weight of 100 kg, a length of 1073.79 mm, and a thickness of 16 mm.

Kata kunci: Teknologi digital, lembaga keuangan, hukum, fintech, regulasi

Abstrak

Penelitian ini bertujuan untuk menganalisis dan merancang sistem kerja lift penumpang, termasuk mekanisme kerja lift, desain sistem pengangkat, perhitungan kapasitas kabin, desain tenaga dan pemilihan motor penggerak utama, perhitungan komponen utama, desain transmisi, perhitungan biaya pemeliharaan, pemilihan bahan komponen, dan pembuatan gambar teknis. Hasil desain menunjukkan bahwa spesifikasi motor penggerak yang digunakan memiliki daya 6,28 Hp dengan putaran 800 rpm, kecepatan pengangkatan 15 m/menit, dan kapasitas pengangkatan 500 kg. Komponen poros dirancang menggunakan baja karbon S45C, dengan rincian Poros I berdiameter 24 mm, Poros II berdiameter 41 mm, dan Poros III berdiameter 41 mm. Gigi terdiri dari Gigi I dengan diameter lingkaran pitch 42 mm, diameter lingkaran 37 mm, diameter lingkaran kepala 46 mm, lebar 16 mm, dan 21 gigi; Gigi II dengan diameter lingkaran pitch 210 mm, diameter lingkaran 205 mm, diameter lingkaran kepala 214 mm, lebar 16 mm, dan 105 gigi; Gigi III dengan diameter lingkaran pitch 68 mm, diameter lingkaran 63 mm, diameter lingkaran kepala 108 mm, lebar 16 mm, dan 34 gigi; dan Gigi IV dengan diameter lingkaran pitch 270 mm, diameter lingkaran 265,5 mm, diameter lingkaran kepala 270 mm, lebar 16 mm, dan 21 gigi. Drum yang digunakan memiliki diameter 253 mm, berat 100 kg, panjang 1073,79 mm, dan ketebalan 16 mm.

1. INTRODUCTION

Along with the development of science and technology, humans continuously develop equipment that can simplify and lighten human work to complete a job. An effective and efficient material transfer or transportation system is needed to support progress in the industrial sector and the construction of high-rise buildings (offices, hotels, shopping centers, etc.). This is because the population continues to increase while the available land is increasingly limited, especially in urban areas so that high-rise buildings are becoming increasingly tall, so by building high-rise buildings can be a solution in overcoming the problem of population density, especially in urban areas because the population will always continue to increase, so in every high-rise building a machine or tool is needed as a lifting machine to support activities in high-rise buildings and is also called vertical transfer transportation. One of the most important lifting systems in the industrial sector and the construction of high-rise buildings, and supporting facilities for high-rise buildings is an elevator.

This equipment is used to make it more efficient in terms of time, distance, and energy for humans to get to the next floor they want in a high-rise building. The existence of this elevator is also a partial replacement for the function of stairs and reaches each subsequent floor in a multi-storey building, thus the existence of the elevator is not set aside, because it can make the energy and time of the elevator user more efficient. But the elevator system and all the progress and reliability do not necessarily experience gradual development, since its existence was first built. In accordance with the planning of this Final Assignment, namely the lifting aircraft, the author only conducted a review of one lifting device, namely the Elevator Planning in the Yanglim Plaza multi-storey building. Yamglim Plaza is a mall or shopping center in the city of Medan, the Yamglim Plaza building was founded in 2004. The Yanglim Plaza building is located on Jl. Emas, Sei Rengas II, Medan Area district, Medan City, North Sumatra. Where in the building an elevator is needed that functions as a substitute for stairs to make it easier for visitors to reach each floor. This aims to make the time, distance and energy of Yanglim Plaza visitors more efficient.

1.1 Formulation of the problem

The problem formulation in elevator design is as follows:

1. How does an elevator work?
2. How is the lifting system designed?
3. How to calculate cage capacity?
4. How to design the power and main drive motor for the elevator?

5. How are the main components of the elevator calculated?
6. How is the elevator transmission designed?
7. How are elevator maintenance costs calculated?
8. How to select component materials?
9. Engineering drawings.

1.2 Scope of problem

Due to the breadth of the issues involved in this planning, it is necessary to limit the issues to be studied to prevent the discussion from becoming too broad. The limitations in this planning focus on the appropriate transfer of materials, namely:

1. Calculation of components.
2. Transmission system.
3. Selection of drive motor.
4. Planning drawings and also height lift and passenger capacity.
5. The elevator control system will not discussed in depth.

1.4 Objectives

The purpose of writing assignments is this end:

1. For the Author

   This plan aims to fulfill the requirements to complete the Bachelor's Degree Program (S1) at the Faculty of Mechanical Engineering, Darma Agung University, Medan. This plan is also expected to provide an overview and comparison of various calculation analyses that must be carried out in obtaining efficient, effective and safe elevator machine performance, in this case the elevator used is in accordance with the theories contained in the literature and compared with the work process in the field or actual conditions.

2. For Campus/Academic

   This planning also aims to improve students' ability to apply the knowledge gained during lectures and train students to use existing literature/reference books as well as to increase their knowledge in disciplines related to transfer machines, both in academic environments and in the world of work, of course.

3. For society and industry/ company

   In order to increase public insight into how elevators work, the parts of elevators, the elevator work process and for companies, especially in the mall or shopping center sector, to make it easier for visitors to reach the desired floor.

1.5 Benefits of the Final Project

The benefits of this design are:

1. For writers

   To increase the author's insight into designing elevators and as evidence for the author's final assignment.

2. Campus

   Adding insight for juniors if they want to take the same design title as a reference in the future.

3. For the community

   This planning is useful for designing an elevator unit / to help lighten, simplify the time, distance traveled and human energy in reaching a place in a multi-storey building with a capacity of 500 kg in Suzuya with a working system of lifting /

moving people from one floor to another floor with a certain capacity in a high-rise building, by paying attention to safety and comfort factors for its users.

2. LITERATURE REVIEW

2.1 General Understanding of Elevator Machines

An elevator is a material handling machine used to move heavy loads from one location to another over short distances, such as in offices, shopping centers, factories, and construction sites. A material handling machine only moves a certain amount of load over a certain distance, moving the material vertically, horizontally, or a combination of both. This differs from other means of transportation that move loads (usually goods or people) over long distances.

There is also something called a lifting machine, a lifting machine is a tool for moving materials from one place to another, usually used in departments, factories, construction sites, storage areas, unloading and so on. The moving process here also includes the process of loading and unloading or installation. The transfer of the load is carried out by using a force greater than the load to be moved.

This machine can only lift a certain amount of load and within a certain lifting distance. The types of loads lifted vary both in shape and weight and volume ratio for the purposes of loading and unloading operations, some types of lifting machines are equipped with load lifting machines that can be operated using auxiliary machines or by human power (manual).

2.2 Types of Elevator Machines

2.2.1 Cage Elevator

A cage elevator is a machine or lifting tool specifically designed to lift or move goods or people from one floor to another in a cage that moves on fixed guide rails with a vertical movement mechanism.

Figure 2.2.1. Passenger Cage Elevator

2.2.2 Stacker/Stocker Elevator

The stacker can be operated manually or with a self-propelled design. This lifting mechanism, a cantilever platform cover wheel running along a vertical guideway, consists of several machine components such as a drum, a worm gear drive, a double shoe brake with electromagnetic control, and an electric motor with a starter.

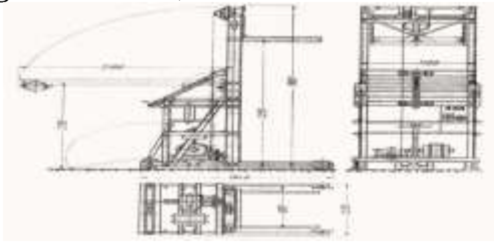

Figure 2 .2.2 Stacker Elevator

2.2.3 Vertical bucket elevator

Mechanism lifter This consists of from motor electric, pulley lifter, steel rope and vertical bucket.

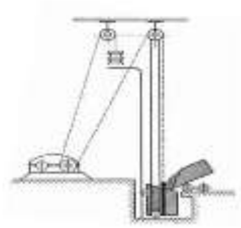

Figure 2.2.3. Vertical bucket elevator

2.3 How a Lift Works

Elevators operate thanks to a digitally programmed control panel. Information from the user's buttons is then transmitted to the control panel. After being processed in this panel, the program is relayed via wires connected to the elevator's engine, allowing it to operate according to the user's instructions.

The purpose of this instruction is for the user to instruct the elevator to operate (vertically or upward) by pressing the buttons provided on each floor wall. Once the user enters the elevator room and is heading to the desired floor, they must press the button corresponding to the floor they wish to go to.

2.4 Main Parts of a Lift/Elevator

2.4.1 Cage

The lift in the elevator functions as a place or container for passengers. Cages/carriages for goods or passengers, the cage must be sturdy and strong but light

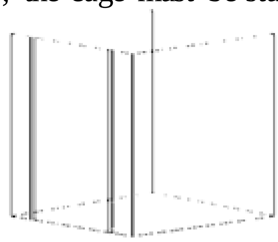

Figure 2. 4.1 Elevator cage

2.5 Guiding Tools

The guiding device, the cage moves in the aisle on a fixed guide rail and the two vehicles at the top and bottom are provided with two guides that fit the guide rail.

2.6 Elevator Corridor

The elevator aisle is the room where the cage is located. Apart from the cage, in the aisle there are also guide rails, counterweights, recovery wheels, ropes and tying machines.

2.7 Elevator Counterweight

Elevator counterweight to eliminate the load on the lifting machine, the weight of the cage is balanced by a weighing scale which is connected by a rope to the cage with the drum of the lifting machine, the counterweight is made of cast material, gray cast iron, the weight of the pendulum is equal to half the maximum load weight. So the machine only lifts half and maximum weight allowed.

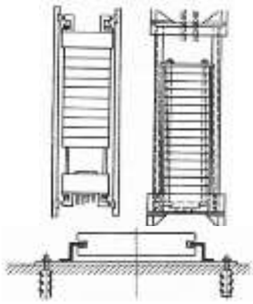

Figure 2. 7 Cage Elevator Counterweights

2.8 Motor

The motor on the lift or elevator functions as the main driver in moving the elevator to raise or lower the elevator.

Figure 2.8 Elevator Motor

2.9 Steel bar plate

The function of the steel plate in this elevator is as the main material in making the elevator cage walls.

Figure 2.9 Steel Plate

2.10 Axis

The function of the shaft in this elevator design is to transmit rotation from the electric motor to the pulley.

Figure 2.1 0 Elevator Shaft

2.11 Pulley

The function of the pulley is to act as a successor to the spindle produced by the motor to rotate the steel rope to raise or lower the elevator.

Figure 2. 11 Pully

2.12 steel rope

The function of the steel rope in this design is as a fastener for the elevator and functions as a puller.

Figure 2.12 Steel Elevator Rope

2.13 Electrical cable/panel

The function of the panel in this design is as the main component in regulating the movement of the lift and as an electrical regulator in the lift.

Figure 2.13 Elevator Panel

2.14 Air conditioning

The function of the AC in this design is as a room cooler or more commonly called a sangkat because if it is not used, the air in the elevator will feel hot.

Figure 2.14 AC Lift

2.15 Light

The function of the lights in this design is as the main lighting for the lift or elevator.

Figure 2.15 Elevator Lights

2.16 Hanging equipment

The hanging equipment for cages and counterweights uses parallel spun wire ropes to make the use of smaller diameter ropes more effective. The counterweight cages are hung with two, four or six ropes.

2.17 All elevators

It must be equipped with a special safety device, namely a device that can stop the cage automatically.

2.18 Control Panel

Control panel, to regulate the operation of the lift while the lift is working so that the lift can be controlled and stop at the desired location.

3. IMPLEMENTATION METHOD

3.1 Count Elevator Power

a . Counting Elevator Capacity

For look for Power or capacity lift on the elevator so can searching for with :

Power = amount passengers x average weight of passengers

Then will obtained capacity or Power lifter

b. Count motor power driving force in the elevator

For determine driving motor power on mechanism lifter This can determined with formula as following :

$$\mathbf{N} = \frac{Q \cdot v}{75 \cdot \eta} \ldots\ldots\ldots\ldots$$

Where :

N = power (Hp)

Q = load (kg)

η = coefficient mechanism

V = speed lift (m/ sec)

3.2 Count Main Components

Component main in planning This is wheel tooth straight .

1. Round on each wheel tooth

   On wheel 1st gear , rotation wheel gear 1 (n_1) = motor rotation

2. Calculation tension flexible

   Calculation tension bending that occurs can counted with formula :

$$\sigma_{bi} = \frac{F_n}{b_1 m_1 \, Y \, f_v} \ldots\ldots$$

Where :

σ_{bi}= bending stress (kg/mm ^{2})

F_n = force tangential

b_i = width side wheel tooth one

m_2 = module

Y = shape factor tooth

f_v = dynamic factor

3. Determining the axle size

   a. The moment of planning

$$\mathbf{T_1 = 9.74 \cdot 10^5 \cdot \frac{Pd}{n}}$$

   Where :

   Pd = design power (kW)

   n = shaft rotation (rpm)

   b. Allowable shear stress

   The allowable shear stress (σ_i) can be calculated using the formula:

$$\sigma_i = \frac{\sigma_i}{sf_1 sf_2}$$

   Where :

   σ_i= allowable shear stress (kg/mm ^{2})

   sf_1 = Safety Factor Spin Fatigue

   sf_2 = surface hardness

   c. Shaft diameter

$$Ds = \left[\frac{5,1}{\sigma_i}\ K_t C_b T\right]^{1/3}$$

Where :

σ_i = allowable shear stress (kg/mm ^{2})

K_t = correction factor

T_1 = design moment (kg/m)

Cb = bending load

3.3 Drive Motor Power

To determine the motor power in this lifting mechanism, it can be determined using the formula:

$$N = \frac{Q \cdot v}{75 \cdot \eta}$$

Where:

N = Power (Hp)

Q = Load (1863 kg)

Q = 1414 kg

= Mechanism coefficient (0.90)

v = Lifting speed (l5 m/min = 0.25 m/sec)

So :

$$N = \frac{1863 \ . \ 025}{75 \ . \ 0,9}$$

= 6.9 Hp

Meanwhile, in determining motor power (Nd) it can be determined using the formula: Nd = Fc . D

Where :

Fc = Correction factor (1,2)

D = Motor power (Hp)

So:

Nd = 1.2 . 6.9

= 8.28 Hp

4. RESULTS AND DISCUSSION

4.1 Static Moment

This drive motor needs to be checked for overload. To determine the static torque, use the formula:

$$M_{st} = 71.620 \ . \frac{N_{br}}{n_{br}}$$

Where :

M_{st} = Static resistance moment (kg.cm)

N = Motor power (8.28 Hp)

n = Rotation (800 rpm)

so:

$$M_{st} = 71{,}620 \frac{8{,}28}{800}$$

= 0.741 kg.cm

= 1 kg.cm

4.2 Dynamic Moment

To determine the dynamic moment of force (m_{dyn}) the formula can be used:

$M_{dyn} = \frac{\delta.GD^2.n}{375.ts} + \frac{0,975.G^1.v^2}{n.ts.\eta}$

Where:

η = Transmission coefficient
GD^2 = Motor rotor gyration moment
ts = Start time
G^1 = Load = 1414 kg
y^2 = Lifting speed (l5 m/min = 0.25 m/sec)

then:

$M_{dyn} = \frac{1,2 \,.\, 0,12 \,.\, 800}{375 \,.\, 2} + \frac{0,975 \,.\, 1414 \,.\, 0,25^2}{800 \,.\, 2 \,.\, 0,85} = 0.1536 + 0.00633$
= 0.21

4.3 Gear Planning

Rotation of each gear

a. In gear 1, gear rotation I (n_1) motor rotation (n, motor) = 800 rpm
b. Gear rotation 2 (n_2) = gear rotation 3 (n_3)
c. Then: $I_1 = \frac{n_1}{n_2}$ or $n_2 = \frac{800}{5} = 160$ rpm
d. Gear rotation 4 (n_4) = drum rotation (n drums)
e. Then: $I_2 \frac{n_3}{n_4}$ or $n_4 = \frac{160}{4} = 40$ rpm

To determine the difference in the number of each gear is the same as the rotation ratio, namely:

$I_1 = \frac{Z_2}{Z_1}$: $I = \frac{Z_4}{Z_3}$

If the number of gears 1 (z_1) is planned to be 21 teeth, then the number of teeth on gear 2 (z_2) is:

$I_1 = \frac{Z_2}{Z_1}$; $z_2 = 5.21 = 105$ teeth

If the number of teeth on gear 3 (z_3) is planned to be 34 teeth, then the number of teeth on gear 4 (z_4) is:

$I_2 = \frac{Z_3}{Z_4}$; $z_4 = I_2 \,.\, z_3 = 4 \,.\, 34 = 136$ teeth

4.4 Determining the Gear Axle

The number of gear shafts planned for this transmission system is 3 (three), namely:

a. Axle I, namely on gear I with drive motor
b. Axle II, namely on gear II, with gear IV
c. Shaft III, namely on gear IV with drum

The planned shaft is made of S 45 C. The tensile strength (σ_t) for S 45 C material is 58 kg/mm ^{2}

4.4.1 Determining the size of the shaft I

a. Design moment

The design moment (T_1) can be calculated based on the formula:

$T_1 = 9.74 \,.\, 10^5 . \frac{Pd}{n_1}$

Where :
Pd = Design power = 2.984 Kw
n_1 = Shaft rotation 1 (n_1 = 800 rpm)
then:

$$T_1 = 9.74 \cdot 10^5 \cdot \frac{2,984}{800}$$

= 3633.02 kg/m

b. Allowable shear stress

Allowable shear stress (σ_t) can be calculated using the formula:

$$\sigma_i = \frac{\sigma_t}{sf_1 sf_2}$$

Where:
σ_i = allowable shear stress (kg/mm ^{2})
σ_t = tensile stress of the shaft for material S 45 C = 58 kg/mm ^{2}
Sf_1 = rotational fatigue safety factor (6.0)
Sf_2 = surface hardness (1.3 – 3) taken as 2.5
So :

$$\sigma_i = \frac{58}{6,0 \cdot 2,5}$$

= 3.86 kg/mm ^{2}

c. Shaft diameter

$$ds = \left[\frac{5,1}{\sigma t} K_t C_b T_1\right]^{1/3}$$

Where :
σ_i = allowable shear stress (kg/mm ^{2})
K_t = correction factor taken as 2.0
T_1 = design moment (3633.02 kg/m)
C_b = bending load is taken as 2.0
So :

$$ds = \left[\frac{5,1}{3,86} 1,4 \cdot 2 \cdot 3663,02\right]^{1/3}$$

= 23.78 = 24 mm

4.4.2 Determining the size of shaft II

a. Design moment

Design moment (T_2) can be calculated based on the formula, namely:

$$T_2 = 9.74 \cdot 10^5 \cdot \frac{Pd}{n_2}$$

Where :
Pd = Design power = 2.984 Kw
n_1 = Shaft rotation 2 (n_1 = 160 rpm)
then:

$$T_1 = 9.74 \cdot 10^5 \cdot \frac{2,984}{160}$$

= 18165.1 kg/m

b. Allowable shear stress

Allowable shear stress (σ_i) can be calculated using the formula:

$$\sigma_i = \frac{\sigma_t}{sf_1 sf_2}$$

Where:
σ_i = allowable shear stress (kg/mm ^{2})

σ_t = tensile stress of the shaft for material S 45 C = 58 kg/mm ^{2}
Sf $_1$ = rotational fatigue safety factor (6.0)
Sf $_2$ = surface hardness (1.3 – 3) taken as 2.5
So :

$$\sigma_i = \frac{58}{6{,}0\ .\ 2{,}5}$$

= 3.86 kg/mm ^{2}

c. Shaft diameter

$$ds = \left[\frac{5{,}1}{\sigma t}\ K_t C_b T_2\right]^{1/3}$$

Where :
σ_i = allowable shear stress = 3.86 (kg/mm ^{2})
K $_t$ = correction factor taken as 2.0
T $_2$ = design moment (18165 kg/m)
C $_b$ = bending load is taken as 2.0
So :

$$ds = \left[\frac{5{,}1}{3{,}86}\ 1{,}4\ .\ 2\ .\ 18165{,}1\right]^{1/3}$$

= 40.486 = 41 mm

4.4.3 Determining the Size of Shaft III

a. Design moment

Design moment (T $_3$) can be calculated based on the formula, namely:

$$T_3 = 9.74\ .\ 10^5\ .\frac{Pd}{n_3}$$

Where :
Pd = Design power = 2.984 Kw
n $_3$ = Shaft rotation 1 (n $_3$ = 40 rpm)
then:

$$T_3 = 9.74\ .\ 10^5\ .\frac{2{,}984}{40}$$

= 72660.4 kg/m

b. Allowable shear stress

Allowable shear stress (σ_t) can be calculated using the formula:

$$\sigma_i = \frac{\sigma_t}{sf_1 sf_2}$$

Where:
σ_i = allowable shear stress (kg/mm ^{2})
σ_t = tensile stress of the shaft for material S 45 C = 58 kg/mm ^{2}
Sf $_1$ = rotational fatigue safety factor (6.0)
Sf $_2$ = surface hardness (1.3 – 3) taken as 2.5
So :

$$\sigma_i = \frac{58}{6{,}0\ .\ 2{,}5}$$

= 3.86 kg/mm ^{2}

c. Shaft diameter

$$ds = \left[\frac{5{,}1}{\sigma t}\ K_t C_b T_1\right]^{1/3}$$

Where :

σ_i = allowable shear stress (kg/mm ^{2})

K_t = correction factor taken as 2.0

T_1 = design moment (71660.4 kg/m)

C_b = bending load is taken as 2.0

So :

$$ds = \left[\frac{5{,}1}{3{,}86}\ 1{,}4\ .\ 2\ .\ 71660{,}4\right]^{1/3}$$

= 64.249 = 65 mm

5. CONCLUSION

CONCLUSION

In planning the gear transmission on this elevator, the parts planned are:

Suggestion

The design results, including construction data and working drawings, still require further review for confirmation. Broadly speaking, the maintenance planning and schedule consist of:

1. Creating a maintenance plan
2. Preparation of maintenance plans
3. Implementation of maintenance
4. Recording and reporting of maintenance results

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