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Automatic Opening and Closing of Institute Main Gate

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Abstract - *Automatic gate is an automated movable barrier installed in the entry of any infrastructure to restrict access. There are several automatic systems have been employed in various sectors like industries, apartments, colleges, hospitals, etc. This system is operated by different mechanisms such as sliding on screw, rack and pinion, piston operated and rotary operated. Various mechanisms are available in the market which is costly. The objective of this project is to study, analyze, design and develop more feasible mechanism that is simple to operate, cheap in price and easily available. Rack and pinion mechanism is best in overall comparison with other drives such as chain drive, belt drive etc. Frictional resistance is less and which is affect in overall reduction of power requirement and energy consumption. Mechanism is designed and finite element analysis is used to analyze stress, load and different parameters related to design. Therefore, the durability assessment results are significant to reduce the cost and improve the product reliability. By using finite element analysis, the stress distribution and the deformation of elements are been determined.*

Key Words*: *(Automatic gate system, rack and pinion mechanism, mechanical system, frictional resistance)

1. INTRODUCTION

Electro-mechanics focuses on the interaction of electrical and mechanical systems as a whole and how the two systems interact with each other. Electromechanical system is used in opening and closing of gate, door, windows etc. There are different types of mechanisms which are used in electromechanical system. Rack and pinion mechanism is most widely used such as to control or actuate motion of sliding gate. Frictional resistance is less and which is affect in overall reduction of power requirement and energy consumption. It is capable of withstanding huge loads with noiseless operation.

Nowadays, the automatic gate mechanisms have been improved and developed with various features. These features have increased the cost of production and installation cost. Many people especially with low income are not able to withstand this feature of gate mechanism. The gate mechanism needs a very skilled person to install the mechanism to the gate. Development of Electromechanical gate mechanism should help in minimize a cost of product and easy installation of mechanism.

Desai et al. [1] in their research paper "AUTOMATIC SLIDING GATE" used chain drive mechanism for the linear movement of gate. A. Daniyan et al. [2] in the research of "Design of a Material Handling Equipment" used belt drive for linear motion. Sohail Anjum et al. [3] in research of "Design of Non-Conventional Chain Drive Mechanism for a Mini-Robot" used chain mechanism for the operation.

2. EXPERIMENTAL SETUP

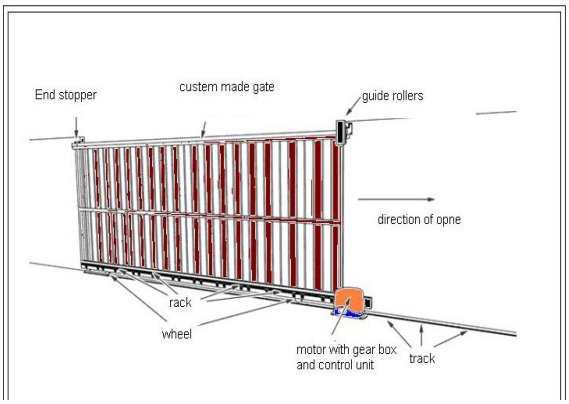

Fig.1, Experimental Setup Diagram

The project is mainly consists of following components. :-

1. Motor -

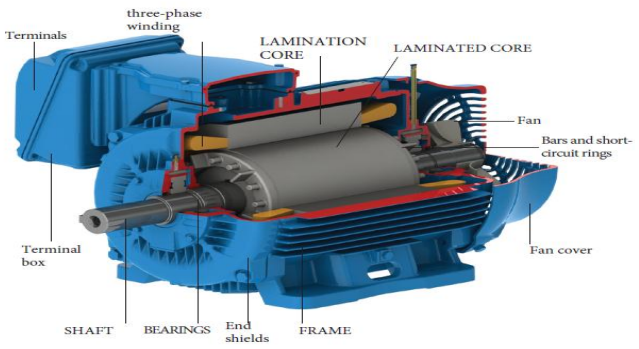

Fig.2, Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Ac motor is used in this system.
Specifications-

- Type- Flange Mounted Motor
- Pole- Four pole
- Speed- 1440 rpm
- Maximum Power- 1 hp

2. Rack and Pinion -

A rack and pinion is a type of linear actuator that comprises a circular gear (pinion) engaging a linear gear (rack), which operate to translate rotational motion into linear motion.
Specifications-

- Module- 2.5M

3. Gearbox –

Fig.3, Gearbox

Gearbox is a mechanical device used for torque increase/decrease via speed reduction/increase. It consists of two or more gears with one of the gears driven by the motor. The output speed of the gear box will be inversely proportional to gear ratio. Gear Boxes are typically preferred in constant speed application.

Specifications-

- Type- Impel Worm Gearbox
- Reduction Ratio- 10:1
- Output Speed- 144 rpm

3. EXPERIMENTAL WORKING

1. In this setup initially the motor which is vertical flanged mounted is running on alternating current.
2. The gear box is coupled with the motor in this the gearbox performs the function of speed reduction.
3. In this arrangement the gear ratio is 10:1, i.e. the speed of motor is reduced from 1500 to 150.
4. This reduction is necessary for obtaining the output at the motor end.
5. We have used a pair of rack and pinion. The output shaft the motor is coupled with the pinion.
6. The rack is attached to the gate at particular height at which mesh with the pinion.
7. The wheels of the gate roll over the rack rod which gives the horizontal movement of the gate.
8. Along with track rod guide rollers are also provided for proper motion.
9. By changing the flow of current we can change the direction of motion.
10. The motion can be controlled by a switch.

4. DESIGN

- **Calculation of Power Required-**

Force, $F = [\mu \times M \times g]$
F= [0.20×650×9.81]
F = 1275.3 N ----------(1)

Torque, $T = [F \times x]$
Where, x is distance between rack and pinion
So, x = Pd/2 = 0.029 m (Diameter of pinion = 58 mm)
T = [1275.3×0.029]
T = 36.9837 Nm ----------(2)

Velocity, V = Distance/time
Time, t = 15 sec
Distance = 6.5 m
V = 6.5/15 = 0.4333 m/s
Also, $V = [\pi \times Pd \times N/60]$
0.4333 = [(π×Pd×150)/60]
Pd = 55.173 mm
Therefore, Pd = 56 mm ----------(3)

Speed of revaluation, N = 150 rpm
Power required, P = [2×π×N ×T/60]
=[(2×π×150×36.9837)/60]
P = 580.9386 W ----------(4)

We know that, 1HP = 746 W
So, P = 580.9386/746
P = 0.7787 HP
So power of motor is to be taken as 1 HP

- **Design of Rack and Pinion-**

Table 1, Design Calculations

No.	Item	Symbol	Formula	Example	
				Spur Gear	Rack
1	Module	m		2.54	
2	Pressure Angle	α		20°	
3	Number of Teeth	z		23	—
4	Coefficient of Profile Shift	x		0.6	
5	Height of Pitch Line	H		—	30
6	Working Pressure Angle	α_w		20°	
7	Center Distance	a	$\frac{zm}{2} + H + xm$	60	
8	Pitch Diameter	Pd	zm	58	—
9	Base Diameter	d_b	$d\cos\alpha$	48	
10	Working Pitch Diameter	d_w	$\frac{d_b}{\cos\alpha_w}$	52	

- **STRESSES IN COMPONENTS**

1. Rack and Pinion

Transmitted tangential load (Ft) = $\frac{p}{v} = \frac{746}{0.433}$ = 1721.67 N

Elastic co-efficient (Z_E) = 21 mpa

Overload factor (K_O) = 1

Dynamic factor (K_U) = 1

size factor (K_S) = 1

Load distribution factor (K_H) = 1

Face width (b) = 24 mm.

Geometry factor for pitting resistance (Z_1) = 0.115

Pitch radius of pinion (r) = 29 mm

Contact Stress (σ) = $Z_E\sqrt{Ft.Ko.Ku.Ks.\frac{kh}{2.r.b.Z1}}$

= $21\sqrt{10.75}$

= 68.853 mpa

So, the stress in pinion is 68.853 mpa.

2. Gate Wheel

m = Mass of gate = 650 kg

g = Gravitational acceleration = 9.81N/m^2

d = Diameter of wheel = 45 mm

Weight of gate = m.g = 6376.5 N

In design of the wheel the failure will occur in shearing action

Shear stress = $\frac{\text{shearing force}}{\text{resisting area}}$

As there are four wheel the load is equivalently distributed to four wheel.

Therefore,

Total load (T) = 4.T_w

Where,

T_w = shear load on single wheel

$$T_W = \frac{6376.5}{4}$$

T_W = 1594.125 N

The Torque in wheel is given by,

T = T_w x a

Where, T_w = Tangential load

a = perpendicular distance

T = 1594 x 45/2 = 35865 N-mm

Bending stress in wheel is given by,

$\sigma_b = \frac{M}{Z}$

$= \frac{2t/n}{\frac{\pi}{32}.b1.(a1)2}$

Where, T = Torque

n = no. of rims

b_1 = Minor axis

a_1 = Major axis

$\sigma_b = \frac{2 \times 35865/1}{\frac{\pi}{32} \times 16 \times (32)2}$ .....(n = 1 as there is rim throughout)

= 44.617 mpa

Therefore, the stress in wheel is 44.617 mpa.

5. FINITE ELEMENT ANALYSIS

A numerical simulation was done with ANSYS software, which uses the finite element approach to simulate the physical model. The geometry of Rack and Pinion and Gate wheel is analyzed so as to get desired results.

- Finite element analysis of rack and pinion in terms of stress distribution and deformation.

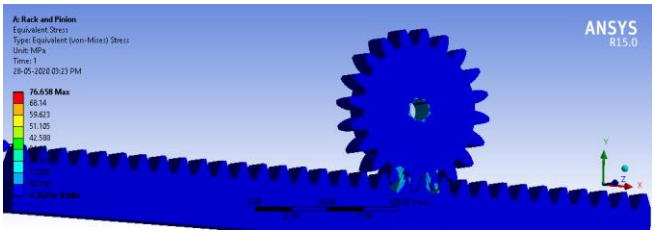

Fig.4, Equivalent (Von Mises) Stress in Rack and pinion

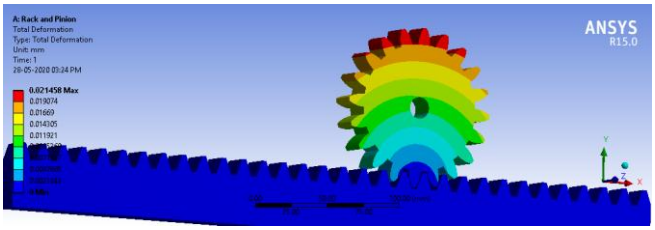

Fig.5, Total Deformation in Rack and pinion

The stimulation of rack and pinion by using Workbench 15.0 software stimulate the stress distribution and total deformation. 3D model of rack and pinion is generated using the design modeller with the same dimension of experimental setup. The stress distribution is observed and is between 1.35 x 10^{-8} to 76.658 MPa. The total deformation is observed and is between 0 to 0.021458 mm.

- Finite element analysis of Gate Wheel in terms of stress distribution and deformation.

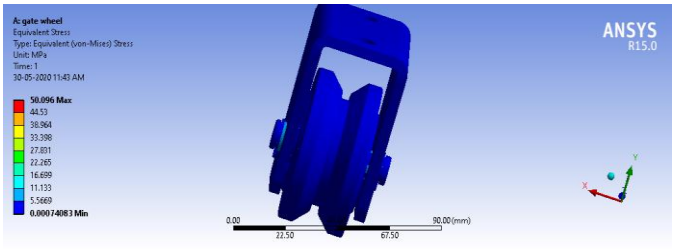

Fig.6, Equivalent Stress in Gate Wheel

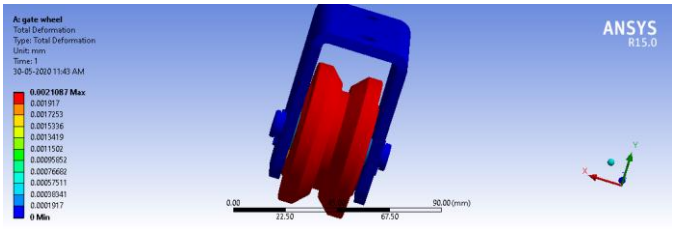

Fig.7, Total Deformation in Gate Wheel

The stimulation of wheel by using Workbench 15.0 software stimulate the stress distribution and total deformation. 3D model of wheel is generated using the design modeller with the same dimension of experimental setup. The stress distribution is observed and is between 7.4083 x 10^{-4} to 50.096 mpa. The total deformation is observed and is between 0 to 0.0021087 mm.

6. RESULTS

Time required for gate opening is 15 sec. as per calculation. By using this mechanism human effort is being reduced. This mechanism has less maintenance compared to other mechanisms. The cost of the setup is low compared to others. The equivalent stress acting on rack and pinion is between 68.853 mpa. The equivalent stress acting on Gate wheel is between 44.617 mpa. The gear box is combination of two stages with the two gear pairs of spur and bevel in which the stress concentration is within the limit and the factor of safety is greater than theoretical value so the design is safe.

As per the analysis done by using the finite element analysis in ANSYS software the stress distribution of the rack and pinion is been observed in fig. 4, The value of stress of rack and pinion is 1.35 x 10^{-8} to 76.658 mpa, as per the analytical calculation the value lies between this limits, so the design of rack and pinion is safe. In the analysis of wheel, the stress distribution of the wheel is been observed in fig. 6, the value of stress is 7.4083 x 10^{-4} to 50.096 mpa, as per the analytical calculation the value lies between this limits, so the design of wheel is safe.

7. CONCLUSION

This mechanism installed is cheap and more reliable compare to other mechanism. The time for gate opening of the system is 15 sec. which was in one direction. The design of the gear box for the motion used the two gear pair spur and bevel gears. The human fatigue is reduced by the system. the design of the system is very simple and the installation of the system can be done very easily.

The stress analysis of the rack and pinion which was done by using Finite Element Analysis in ANSYS software which stated the design is safe and analytical value of stress of rack and pinion is within limits that are obtain from the results in ANSYS software. Again for wheel the analytical value of stress is within the limits that are been obtained from the ANSYS software.

The energy required by the human to open the gate manually was more than the energy required to drive the motor i.e. the energy required for the operation is been reduced. The system is successfully installation with various

mechanical components which are working efficiently to perform the satisfactory functioning of gate. Finally, the operation on basis of mechanical component are performed efficiently.

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