

Design, Construction and Testing of a 3.04m/60 kg /50W, 24V D.C. Capacity Electrically Powered Sliding Residential Gate

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Abstract

The need for a non manual and affordable residential gate by both rich and middle-class populace has brought out the need for designing, constructing and testing for reliability a remote controlled residential sliding gate. The design principle entails effecting a sliding motion of the gate through a rack and pinion mechanism. A rack of the same length as the gate length was attached to the gate in mesh with a pinion powered by a D.C. 50W, 24V motor. Control sensors were connected for remote control operation and detection of the terminal points of gate movement. The gate is of length 3.04m by 1.4m covered with aluminium sheet of thickness 0.2mm. The gear pinion and gate track roller diameter were 61mm and 100mm. The weight of the gate was made variable by attachments of known weight falling within 40 Kg to 80 Kg. Support guide made of low carbon steel pipe of square section 50mm was used to hold the gate in an upright position. Four rollers made of medium carbon steel was welded to the gate to aid the movement of the gate on the rail track which comprised of two angle bars formed into T shape. Operational performance tests showed a maximum opening velocity of 0.21m/s to 0.15m/s corresponding to gate weights 40 to 80kg respectively. Rolling track friction also affects velocity of the gate. The lubricated track indicated higher velocity than the dry track.

Keywords

Sliding gate, aluminium sheet, remote control, rack, pinion, rail track.

1. Introduction

Power gates are the gates that are being controlled either by electrical or mechanical means with less human power applied (24 V hydraulic, 2014).

Powered gates are of different types i.e. sliding, swing, overhead, barrier, tiger teeth etc. Sliding gate- A sliding gate moves on wheels from left to right and right to left (Dictionaery.com, 2015), swing gate that can open to either sides or both through mechanical means or through operator i.e switch or remote (Automation, 2014), barrier gate- It is an automatic gate consisting of a breakaway gate arm, motor assembly and housing installed to block the road usually at toll gate or car park (Gate Operator, 2014), overhead gate- Overhead gate are gates used in underground parking garages where space is limited. Residential gate are gate that are used by people dwelling in a building, while industrial gates are gates used in the industries or organisations. The materials used in fabrication of gate vary depending on installation location and purpose for installation. The material varies from wooden, aluminium, net, steel etc. (24 V hydraulic, 2014).

The aim of this research work is to design, construct and test for reliable operation, a remote controlled sliding gate which is reliable and affordable to average people of the populace, by examine an existing powered gate, identify weaknesses in the design and work on possible improvement and fabricate a remote controlled sliding gate based on the acquired improvements.

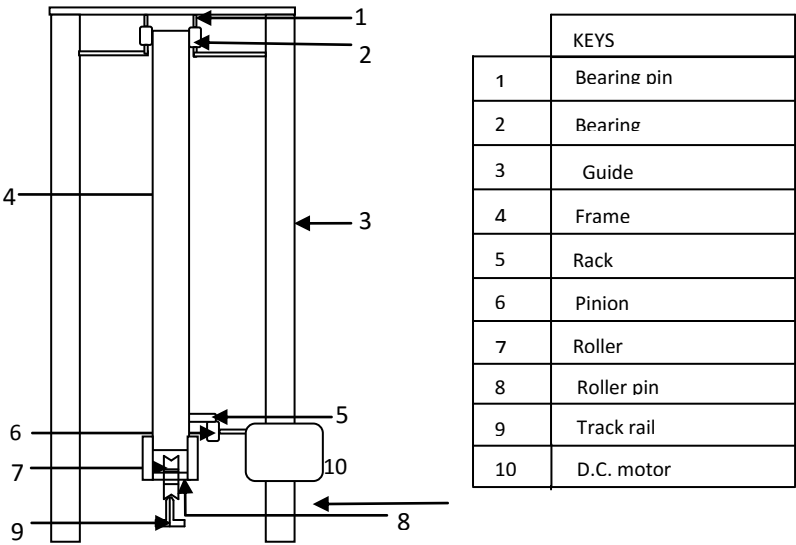


Figure 1 Sketch of the gate system

2. Design and Production Processes

2.1 Design

The gate-frame was analysed for stress acting on it (Figure 1). Selected components are shown in Figure 2.

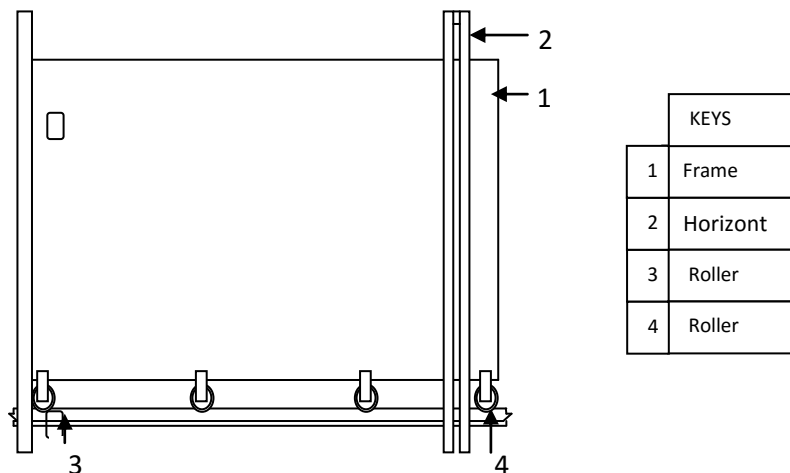


Figure 2 Sketch of front view of the gate

(a) Shaft diameter calculation

Shaft diameter is,

$$D = \sqrt[3]{\left(\frac{60}{N} (P)\right)} \quad (1)$$

(Pump and system, n.d.)

where P = Motor Power (Hp), N = Angular speed (rpm), Substituting N = 22 rpm and P = 0.033Hp in Equation (1). D = 8.6mm

(b) Gear evaluation

(i) Tangential loading

$$W_T = \frac{P}{V} C_S \quad (2)$$

(Khurmi and Gupta, 2013)

where P = power transmitted by the gear = 50W, D = pitch circle diameter = 0.051m

The pitch line velocity in m/s , $V = \frac{\pi DN}{60} = 0.059\text{m/s}$,

C_S = service factor = $\frac{1}{0.65} = 1.54$

Therefore; $W_T = \frac{50}{0.059} \times 1.54 = 1.3\text{kN}$

(ii) Dynamic loading of the gear W_D

For W_D = dynamic load on the tooth, the width of the gear,

$$b = \frac{W_T \cdot 6 \cdot h}{\sigma_w \cdot t^2} \quad (3)$$

(Khurmi and Gupta, 2013)

where W_T = tangential loading acting at the tooth = 1300N, Therefore, $b = 8\text{mm}$

Dynamic factor, $C = 566\text{N/mm}$, so that dynamic load on the tooth,

$$W_D = W_T + \frac{21V (b \cdot C + W_T)}{21V + \sqrt{b \cdot C + W_T}} \quad (4)$$

(Khurmi and Gupta, 2013)

Therefore $W_D = 939.5\text{N}$

(iii) Static tooth load (endurance strength of the tooth) W_S

$$W_S = \sigma_e \cdot b \cdot \pi \cdot m \cdot y \quad (5)$$

(Khurmi and Gupta R.S., 2013)

where flexural endurance limit of steel, $\sigma_e = 252\text{MPa}$; space width, $b = 8\text{mm}$, module, $m = 1.75$, and lewis form factor, $\sigma_e = 0.1225$, Computed, $W_S = 1357\text{N}$

For safety against tooth breakage, endurance strength, W_S , must be greater than dynamic tooth load, W_D and this is satisfied in this design. i.e. $W_S = 1357\text{N} \geq W_D = 939.5\text{N}$

For steady load as obtained in this research work, it is recommended that $W_s \geq 1.25W_D$. this minimum W_s is satisfied. This implies it satisfies the condition i.e since it not up to 1357N

(iv) Maximum load for wear W_w

Maximum load for wear is expressed as,

$$W_w = D_p b Q K \quad (6)$$

(Khurmi and Gupta R.S., 2013)

W_w = maximum load without wear, D_p = pitch circle diameter of the pinion = 51mm, b = face width of the pinion = 8mm, Q = ratio factor = 1, K = load-stress factor (N/mm^2) = $299.3 N/mm^2$, Therefore, $W_w = 122.114 kN$. It is recommended that maximum limiting wear load must be greater than the dynamic load i.e $W_w = 122.114 kN > W_D = 939.5 N$ and it is satisfied in this design.

2.2 Production Process

2.2.1 Gate Parts Production

(a) Pinion production

Pinion specification are m = module = 1.75, diametral pitch = 14.51, circular pitch = 5.5mm, Pitch circle diameter = 51mm, addendum = 1.75mm, Dedendum = 2.19, tooth thickness = 2.75mm, working dept = 3.5mm, minimum clearance = 0.44mm.

The pinion was made from medium carbon steel giving it required hardness and strength. The teeth were made out following the design specification stated above by generating cutter method using a milling machine with model T universal mill.

(b) Rack production

Rack specifications are addendum = 1.75mm, Dedendum = 2.19, tooth thickness = 2.75mm, working dept = 3.5mm. The rack was made from medium carbon steel giving it required hardness and strength to match the pinion. The teeth were cut out following the design specifications and model T universal milling machine was used through generating cutter method.

(c) Gate production:

The gate structural frame was made from a square pipe of 50 mm welded together to form a rectangular shape and the rectangular shape was sub-

divided into three sections by 50 mm square pipe to reinforce the centre of the frame. Aluminium sheet covering of 0.2 mm thickness was used. Four rollers of 100 mm diameter were welded at four equidistance location along the gate base. The material used was selected to give a fair weight and good strength.

(d) Support-guide production

The support guide was made from 50mm square pipe and welded to form a pair of rectangular shapes of 609.6 mm by 302.8mm. Four ball bearing rollers were welded to the top side and created a groove for the gate to slide through and hold it in upright position.

(e) Rollers production

The roller specifications are; roller diameter = 100 mm, groove diameter = 70 mm, thickness = 25 mm, the material used was medium carbon steel to obtain the required hardness needed and Lathe machine was used in grooving and tapping the roller into shape.

(f) Rail-track production

The rail-track was made from two angle edged bars of 50mm thickness and length of 3.04m. It was made from medium carbon steel. The two angle edged bars were welded together both at the top and bottom to give a rigid long single bar. The upper part was grinded to remove excess filler from the surface in order to give a smooth running track for the roller.



Figure 3 Gate pictorial view

2.2.2 Assembly of Parts

The self produced and purchased parts was coupled together following the design assembly drawing to produce the gate as intended. Figure 3 shows the front pictorial view of the gate produced to the design specification.

3. Tests result and discussion

3.1 Effect of Friction

The gate was powered from closing position to opening position and vice visa. The time taken to open and close was taken against the fixed displacement of the gate, which was used to calculate the velocity respectively.

Table 1 Rolling track friction effect on the gate velocity

Medium	Opening Velocity, m/s	Closing Velocity, m/s
Dry medium	0.20	0.21
Wet medium	0.21	0.21
Sand	0.20	0.21
Grease	0.21	0.22

Tables 1 shows the sliding gate velocities when the model gate of 40 kg was moved along the rail track with different contact surface mediums of dry, wet, sand and grease with the roller. In Table 1, the result shows that there was higher velocity in the closing than opening and this was generally observed in all surface conditions as shown in the Figure 4 which may be due to the fact that the motor was connected directly to the battery and the connection configuration of the motor windings. The lubricated track surface has the highest opening and closing velocities which was due to the lowest coefficient of friction attributable to the applied lubricant (Friction and coefficient, 2015), while in the wet medium, both opening and closing velocities were approximately the same but not as high as the lubricated medium. However, in the sand medium, there was distinct difference in the velocities which was also the same in the dry steel medium. It was noted from the graph that the lubricated track surface and the watered track surface had similar effect on velocity, while the sand and dry medium were almost the same thereby making it to fall between the known classes of coefficient of friction i.e. lubricated/greased medium and clean/dry medium (Friction and coefficient, 2015).

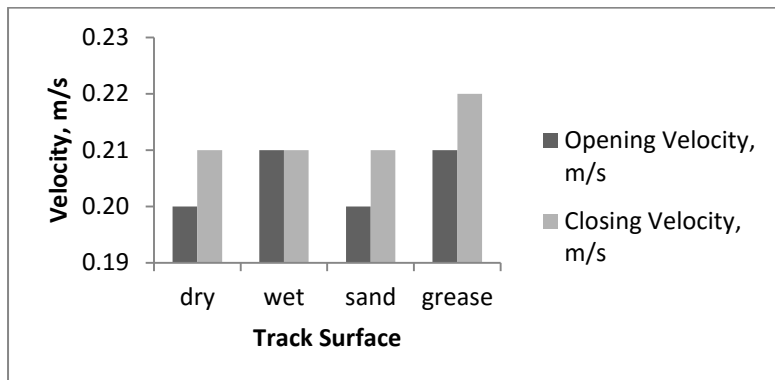


Figure 4 Friction medium against the opening and closing velocity

3.2. Effect of Gate Weight on Gate sliding Velocity

Table 2 shows the results of obtained velocities when the weights of 5, 10, 20, 30 and 40 kg were applied to the gate model of 40 Kg making the gate weight to increase to 45, 50, 60 70 and 80 kg respectively.

Table 2: Opening and closing velocity against gate weight.

Weight (kg)	Opening Velocity (m/s)	Closing Velocity, m/s
40.00	0.21	0.22
45.00	0.20	0.20
50.00	0.20	0.20
60.00	0.18	0.20
70.00	0.19	0.19
80.00	0.15	0.18

Table 2 shows the test result obtained when incremental weight of 5 kg was added to the initial weight of 40 kg. The average velocity of the four repeated test carried out on the 45 kg gate was 0.20 m/s and 0.20 m/s for both the opening velocity and closing velocity, respectively.

However, the opening and closing velocities of 50 kg gate was 0.20 m/s and 0.20 m/s. When 60 kg was tested, the average velocity of the four repeated test carried out was 0.18 m/s and 0.20 m/s for both the opening and closing velocities which is most fits with the maximum velocity stated by european union standard for gates and doors (Bircher, 2015).

Table 3 also shows the test results when 70 kg gate was moved, the average velocity of the four repeated tests was 0.19 m/s and 0.19 m/s for both the opening and closing velocities and with 80 kg gate, it was 0.15 m/s and 0.18 m/s for both the opening and closing velocities.

Figure 5 shows that both opening and closing velocities of 45 kg and 50 kg weight gate were approximately the same. It was noticed from Figure 3.2 that 60 and 70 Kg weight gates had the most suitable speed that is close to the maximum closing speed recommended by the EU legislation and requirement law (Hong kong Electrical and Mechanical Department, 2015).

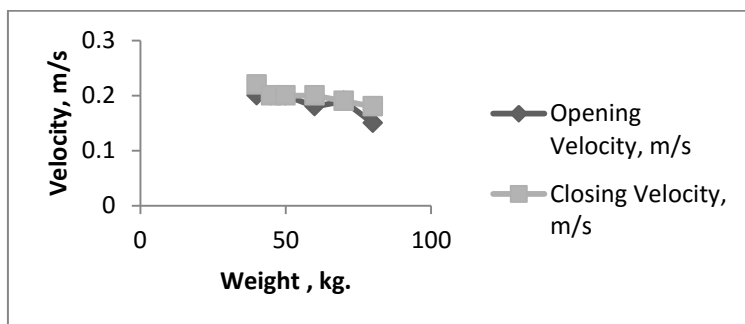


Figure 5 Opening and closing velocity against the gate weight

The more the load added, the lower the velocity until it reaches the point of stalling (Electrical4u, 2015) (Motor Challenge, 2015). The difference in the opening velocity and closing velocity of the model gate may be due to the fact that the motor was connected directly to the battery and the connection configuration of the motor windings.

4. Conclusion

The following conclusions were drawn:

- (i) A locally sourced 24 V, D.C. motor can effectively power a gate weight of 70 Kg.
- (ii) The locally produced gate is more effective when compare with similar imported versions.

- (iii) The produced gate performed to expectation in dry and lubricated track-roller medium which makes it a useable in all condition.

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