4-Section Compact Door

Description, composition, assembly recommendations

1. Introduction

4-Section Compact Door is intended for use in garages for entrance openings. This model is implemented in accordance with US patent 8907328 and is based on the key points of the claims. The design has four sections that fold like an accordion, which ensures a significant compact design. Additional benefits also include a low headroom, high speed opening - 5-8 seconds, no cables and torsion springs. All this significantly reduces the cost of service (low maintenance) and provides a longer operation life. The model is simple in design, therefore, reliable in operation and affordable in production.

The goal of this draft is to demonstrate how to build a commercial prototype, as well as describe the technical characteristics of the new design and to ensure technological and economic calculations for commercial product manufacturing.

2. Device composition

2.1 Panels

Sectional door is formed by panels 1, 2, 3, 4 that are hinged together, Fig.1, from top and bottom edge sides. The folded panels are shown in Fig. 2. The three sections 1, 2, 3 have a height of 500 mm, section 4 has a height of 560 mm since on roller mechanism 10 with the lower drive roller 20 is located on it, Fig. 5.

2.2 Roller mechanisms

On the edge sides of each section are arranged roller mechanisms.

On the top of panel 1, Fig. 1, is attached the roller mechanism 6, Fig. 6, consisting of a U-shaped plate 11 with fork hinge 13 fastened onto through the three racks 12. The U-shaped plate 11 has a side arm with an embedded axis 14, Fig. 9, which has a strict axial alignment with a virtual hinge 5, as if it was there. The mechanism by means of screws 15 is fixed to the top edge side of the panel 1. This mechanism is shifted to the left.

On the bottom of panel 1 is attached the roller mechanism 7, Fig. 1, consisting of a U-shaped plate 16 with clamped axis 17 on which is placed the pulley 18 and the inner track roller 19, Fig. 4. The mechanism by means of screws 15 is fastened to the bottom edge side of the panel 1. This mechanism is shifted to the right.

On the top of panel 2 is attached the roller mechanism 8, Fig. 1, consisting of a U-shaped plate 16 with clamped axis 17 on which is placed the pulley 18, Fig. 3. The mechanism by means of screws 15 is fastened to the top edge side of the panel 2. This mechanism is shifted to the right.

On the bottom of panel 2 is attached the roller mechanism 8, Fig. 1, consisting of a U-shaped plate 16 with clamped axis 17 on which is placed the pulley 18, Fig. 3. The mechanism by means of screws 15 is fastened to the bottom edge side of the panel 2. This mechanism is shifted to the left.

On the top of panel 3 is attached the roller mechanism 9, Fig. 1, consisting of a U-shaped plate 16, with clamped axis 17 on which is placed the pulley 18, the outer track roller 20, Fig. 7, Fig. 8 and the fork hinge 13 which has a strict axial alignment with the hinge's axis 5. The mechanism by means of screws 15 is fastened to the top edge side of the panel 3. This mechanism is shifted to the left.

On the bottom of panel 3 is attached the roller mechanism 7, Fig. 1, consisting of a U-shaped plate 16 with clamped axis 17 on which is placed a pulley 18 and the inner track roller 19, Fig. 4. The

mechanism by means of screws 15 is fastened to the bottom edge side of the panel 3. This mechanism is shifted to the right.

On the bottom of panel 4, is attached the roller mechanism 10, Fig. 1, consisting of a U-shaped plate 34 clamped with two axes, Fig. 5. On the top axis 17 is the pulley 18 on which the drive belt 21 completely encircles it and is rigidly fixed. On the lower axis 35 is located the outer track roller 20. This axis is made in a long version, since it must engage with spring return 30. This mechanism is shifted to the left.

2.3 Drive device

The drive device consists of the belt drive 21, the pulley 18, the winding drum 22 and the electric motor with worm gear (these elements are not shown), Fig. 1. The drive belt is a 12,5mm width flat belt made of polymer reinforced inside with hi-flexible steel cable. This design allows apply a 38mm diameter pulley using it in reverse movements. Belt drive has several advantages, among which there is a significant service life of 10 years or 3 million operations.

Winding drum 22 is placed on the horizontal part of the frame 23. Diameter of the winding drum is 122mm, the total length of the drive belt is about 6.5m. When the panels are folded the drum must take in 4.5m of the belt.

2.4 Frame

The frame consists of vertical part 24, horizontal part 23 and the two curved rails 26, 27, Fig. 10.

The vertical part of the frame 24 is divided into three sections. The first straight section has the shape of the profile shown in cross-section A-A, Fig. 10. The length of this portion is about three sections, after which the inner part of the rail extends from it and forms curved rails 26 and 27 the section C-C, Fig. 10. The rest continues to move upwards forming the outer rail, cross-section B-B, on which are located the rotation axis 28 and 29, Fig. 10.

The horizontal part of the frame 23 is a small segment equal to the section's height. On it is located the winding drum 22, swivel bar 25 and the pulley 18, Fig. 1.

Curved rails 26 and 27 have three segments. Segment *a-b*, Fig. 10, is called the door lock. It dropped straight down on length of 20-30 mm, where the inner track roller 19 holds the panel 1 from deflection inside. Farther goes the segment *b-c*, which is called the entry site because the fork hinge 13 is engaging here with the axes 28, 29. It should be noted that the right inner edge side of the fork hinge 13 is slightly longer and has inclination to the right from the vertical, Fig. 8. This is because it is necessary to ensure a smooth transition of the motion vector from movement up to the radial motion. The last segment is *c-d* having a strict form of radius R which is the distance between the fork hinge axes of panels 1, 3 and the rotation axes 28, 29 consequently. The curved rail is designed to prevent horizontal displacement of the panels to the right but the fork hinge, turning, holds the panels from falling down. So works this mechanism.

Spring return consists of springs 30, which are placed inside the straight part of the rail. The aim of this mechanism is creation of sufficient force for reliable lowering of the bottom panel. Because of its own weight is not enough, the spring creates a force in the 5-7kg. Initially, the spring is located in slightly stressed state to ensure a compact arrangement inside. The lower edge of the spring is fixed at the bottom and the upper edge has a gripping device 31, which with help of the stub and shaft 32 is fixed in the slot 33. Capturing of the spring occurs when the lower pair of panels starts the folding process. The spring provides a full force in 5-7 kg when the panels are completely folded.

3. Device operating principle

Initially, the panels are unfolded, that is, the opening is closed. In this position, the inner track roller 19 of the panel 3 rests against the inner side of the track 24 but track roller of panel 1 abuts the door lock segment of the curved rail 26. Accordingly, the outer track rollers 20 abut the outer side of the track 24.

The process of the door opening starts from turning on an electric motor which begins to rotate the winding drum 22, which in its turn via the pulley 18 on horizontal part 23 starts lifting up the whole door. Inner track roller 19 of panel 1 initially moves upward along the segment *a*-*b*, then goes off and starts moving along the section *b*-*c*. At this time, the fork hinge 13 of panel 1 rises and begins to engage with the axis 28. When the inner track roller 19 moves already along the segment *c*-*d*, fork hinge 13 is fully aligned with the axis 28, and further it just rotates counterclockwise. As shown, the curved rail 26 is cut off compared to 27. This is because the panel 1 is held by the swivel bar 25 from being horizontally displaced to right therefore further extension of this curved rail is not required. As the first couple of panels are folded, comes the turn the next. Farther, the process described for the first couple of panels repeats. The only difference is that the curve rail 27 is in full form, because in this case the fork hinge 13 must be fixed in relation to the axis 29.

4. Initial data and recommendations for assembly

6.1 The door consists of 4 panels each represents a sandwich panel of 50mm thick. The recommended width of the panels is 2.4m. Accept the height of panels 1, 2, 3 be 500mm, panel 4 - 560mm. From this the total surface of the door is about 5m2. The approximate weight of 1m2 of such sandwich panel is 10 kg hence the total mass of the door will be about 50 kg.

6.2 An important element of the all design is polymer belt FL8 of 12.5 mm width and 2 mm thickness produced by Gates Mectrol Ink., USA. Through the use of Hi-flex steel cord, the diameter of the pulley is equal to 38mm with a rim of 2 mm. Belt specification is given in the attached file «GatesMectrol_Belt_Pulley_Catalog» file, p. 45. It should be noted that the technical characteristics are shown for 25mm width.

6.3 U-shaped plate is made of galvanized steel with a thickness of 3mm. Hence, the thickness of each panel will increase on 6 mm totally giving 560mm. In order not to increase further the gap between the panels in their folded state, should pick up and mount the appropriate hinges. Thus, the four folded panels will be 218mm thickness.

6.4 Total length of the drive belt is approximately 6.5 m. In the folded state on the pulley left around 2m therefore 4.5m will be wound on the drum. Considering the initial winding drum diameter of 50mm and 2mm thickness of the belt, 4,5m will provide the 18 layers. Therefore, the drum must have an entire diameter of 122mm.

Thus, the total height of the folded sections plus the winding drum will be 340mm if the location of the drum is over the pulley 18, Fig. 2. This option can be optimized by moving the drum to the left and move it down then it is possible to achieve a height of 300mm. This is an important parameter, called the headroom.

6.5 In order to achieve a speed of opening in 5-8 seconds, it is necessary that during this time all 4.5 m of the belt be wounded on the drum. Assume the opening speed is 6 sec. During this time the drum should make 18 turns, or within 1 minute it will be 180 rpm. Thus, when using an electric motor with 3000 rpm, the reduction ratio of worm gear must be 1:17. It should be emphasized that it is better to choose electric motor with higher rpm, because the worm gear ratio depends on this parameter. And after on this parameter depends on capability the force from spring 30 to untwist the worm gear in the opposite direction when the sections are folded. In other words, the larger the worm gear ratio, the smaller this effect.

6.6 Swivel bar 25 must have a length about equal to the panel's height. This is due to the fact that its turn down occurs radially and the smaller the radius, the larger the deviation the upper edge of

panel 1 takes place when the door goes down. Next, turning it down leads to lowering the entire door, this should not be more than 50mm. This is the length of the inner track roller 19 movement between the point *a* and *c* on the curved rail 26, Fig. 10. That is, the inner track roller 19 must be moved linearly down from the point *c* to *a* no more than 50mm. This is due to the fact that in this case the curve rail 26 can be placed over a curved rail 27 in one plane and obstacles to inner track roller 19 of panel 3 will not be.

6.7 All pulleys and rollers can be made of plastic, because they are not subject to heavy loads. Their rotation on the axis occurs by means of rolling bearings. The axes are rigidly mounted on U-shaped plate. Axis length should not greatly protrude beyond the edge of the roller mechanism, in other words, the roller mechanism has to be made as compact as possible.

6.8 The rotation axis 28, 29, Fig. 7 are designed as sliding bearings.

6.9 The racks 12 on Fig. 6 are sufficiently long, so these can be reduced giving greater strength to this mechanism. However in this case the rotation axis 28 must be brought on the same distance. This can be achieved, if the surface of the frame, where the rotation axis are to press into a desired distance (see 6.10)

6.10 Also, in mass production, where it becomes possible to immediately press detail of the desired form, it is necessary to unite the disparate frame elements 23,24,26,27 into a single element. It will be technologically and economically profitably.

6.11 Experimental and empirically on the working prototype will be necessary to carry out the development of three additional devices:

- The first is a belt tension sensor, which has the task of monitoring the integrity of the drive belt. This is a safety element for stopping the electric motor in the event of broken belt.

- The second is a locking mechanism if the belt is broken. It is a safety requirement to stop the door in the event of broken belt.

- The third devices are end switches – the bottom switch gives a signal to stop the electric motor because the door closed and the top switch signals to stop an electric motor since the door is open.

5. Notes

Fig. 1-9 have scale 1:1, so that their dimensions are real. At the same time, they are recommended, since only on the working prototype the optimal sizes and shapes of the elements can be identified