Design and Development of Easy Access Crisper/Shelf in a Refrigerator

Addanki Sambasiva Rao, Vinayak H. Khatawate, and Sumit Mane

Abstract The category of premium refrigerators available in market is different from regular household refrigerators, with the former being bigger in size. In such refrigerators, the depth can go up to 70–80 cm, and the items placed at the back side or in corners are ergonomically less accessible. The taller items need to be placed at the back side of the refrigerator to easily access the short items. Also, due to the limitations of the support structure, the full extension of the crisper is not achievable. Currently, the crisper is pulled out only in a linear manner. Hence, it is advantageous to make the crisper rotate to make it accessible from more number of sides. In this paper, a mechanism to achieve the rotational motion of the crisper was developed. Finite element analysis (FEA) was carried out to check the permissible deflection of the crisper and is validated using experimentation.

Keywords Shelf · Crisper · Accessibility · Mechanism · Refrigerator · FEA

1 Introduction

Refrigerators are apparatuses configured to store food under low temperature conditions. Such a refrigerator includes a main body provided with a storage compartment, and a movable door connected to the main body to open and close the storage compartment. The storage compartment may be divided into a refrigerator compartment and a freezer compartment.

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1.1 Crisper

Crispers are nothing but sealed drawers that help to keep fruits and vegetables. Vegetables require higher humid conditions, while fruits require lower humid conditions, which is why many refrigerators have two separate (marked) drawers called crispers.

1.2 Shelf

Shelf is a horizontal plate attached to the inner side of the cabinet in order to facilitate the placing of items in the refrigerator compartment.

2 Literature Review

Hoshbin et al. designed a rotary type fruit and vegetable box for a refrigerator, wherein a box body is an object containing drawer formed by a quadrilateral bottom surface and four walls surrounding it [1]. Yuan Kaijun et al. designed a rotary shelf which swings together with a door of the refrigerator for being externally drawn out when the door is opened [2]. Lazy Susan, a fixed small rotary compartment, is already present in many refrigerators (Fig. 1). A 1954 refrigerator of certain brand consisted of two rotary shelves. It resulted in less storage area available on shelves (Fig. 2).

2.1 Outcome of Literature

After studying the above literature, the following points are extracted:

Fig. 1 Lazy Susan

Fig. 2 GE refrigerator

1. A quadrilateral box is designed with upward protruding cylindrical cavity for assembling the rotating shaft. This reduces useful volume of the crisper, and also, the crisper is rotated at its fixed axis [3].
2. In one model, there are four chambers in which refrigerator body is divided and an actuating unit in the power chamber has an upper and a lower transmission shafts extending out along the centre line of a circular chamber. This system is not reliable and too complex [4].
3. A 1948 general electric model was launched, but it came with semi-circular refrigerator cabinet, thus wasting too much volume of the refrigerator.

2.2 Problem Statement

In a refrigerator, it is generally less convenient to access the items placed at the back side of the shelf/crisper. The taller items need to be placed at the rear/back side of the shelf/crisper, otherwise they would obstruct while reaching to comparatively shorter products which are placed at the back. Finally, the full extension of the crisper is not achievable because of which there are some constraints while accessing the items at the back side.

3 Concept Formation

In order to facilitate the rotation of the crisper, a smooth curvature has to be provided at the outside of the crisper (Fig. 3).

In this case, the crisper is to be pulled out by 150 mm, i.e. half the length of the crisper, and then, it is turned out about the pivot point which is located at the centre of two crispers. The area lost in this case is 2.4% of the original available area which is acceptable. The above generated concept gives us the following benefits:

Fig. 3 Shape of crisper

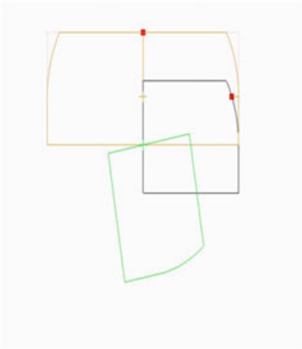
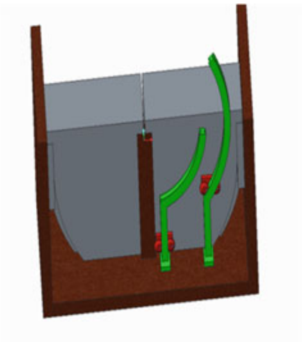


Fig. 4 Guideways with rollers



1. As the crisper is first pulled out and then rotated as its position is shown in green, the area at the backside bottom corner is easily accessible.
2. The rear side of the crisper becomes accessible, hence increasing the more number of accessible sides.
3. The full extension of the crisper is achievable, opposed to the current partial (85–90%) extension.

Two concepts are generated here for the achievement of the rotary and linear motion of the crisper. These concepts are presented below in brief and are compared to each other using Figs. 4 and 5 as reference, to see the relative merits and demerits (Table 1).

4 Concept Selection

For finalizing the concept, a tool called Pugh matrix [6] was used in which various considerations are given points and the best concept is identified (Table 2).

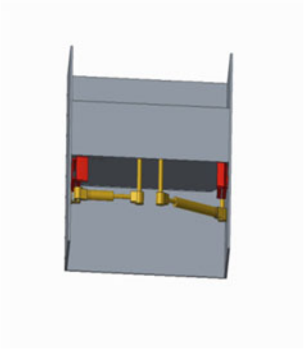


Fig. 5 Mechanism with extraction links

Table 1 Comparison of concepts

Guideways with rollers (Fig. 4)	Mechanism with extraction links (Fig. 5)
In this concept, the guideways are given the curvature in such a way that they give the desired motion sequence of the crisper	In this concept, the linear motion is provided with the help of guideways, and the precisely cut curved slots at the bottom of the crisper facilitate the rotation
There are two guideways for each crisper with each guideway provided with a set of two rollers which are connected to the crisper via a roller block	The endcaps on the glides will match the profile of that of the curved slots
When the crisper is pulled, the roller will roll along the surface of the track, and the crisper will come out and rotate	There is a provision of the extracting links at the either side of the bottom of the crisper, which supports the overhanging portion of the crisper when it is at fully extracted position
Due to the complete length of the tracks being the cantilever, the bending stress at the support will be excessive with large deflection at the end of the tracks which would result in failure of the system [5]	When the crisper is being closed, the links retract back, obtaining their initial position
A sharp change in the direction of the tracks from linear to curvature will be difficult to manage considering the required continuous and smooth motion of the rollers [5]	This mechanism gives the desired motion output in the most effective way

5 Concept Development

To develop the concept further, various components and ideas were generated. It includes the parts, joints, working/function of various parts as follows.

Table 2 Pugh matrix

S. No.	Key criteria	Importance	Guideways with rollers (Fig. 4)	Mechanism with extraction links (Fig. 5)
1	Design safety	5	4	4
2	User experience of crisper opening	5	2	4
3	User experience of crisper closing	5	2	4
4	Manufacturing/assembly complexity	4	−4	−3
5	Cost	3	−3	−3
Weighted sum of positives			40	60
Weighted sum of negatives			−25	−21
Total			15	39

5.1 Glides

The glides were of adjustable type, wherein the length of the glide extension can be controlled.

5.2 Endcaps

To maintain the constant contact of the glides with the crisper, endcaps were needed. To make sure that endcaps would always remain in contact with the crisper even in turning motion, they were given specific curved profile corresponding to the distance from the pivot point.

5.3 Crisper with Slots at Bottom

At the bottom of the crisper, curvilinear slots will be cut to accommodate to endcaps in them. The radius of the slots will be determined by the distance of the starting point of the slot from the pivot point of rotation.

5.4 Extending Links

5.4.1 Fixing Member

One end of the link will be a structural member which will be fixed to the support structure and will transmit all the loads and forces to it. This member will also have a provision for a rotary joint for the next part.

5.4.2 Turning Joint

This joint will connect the fixed member with the rotating link. This joint and the fixed member will have snap fit for the ease of the assembly and operation.

5.4.3 Cylinder (Outer Link)

It will be joined to the fixed member through rotary joint. It will act as the outer member for the sliding pair with next member.

5.4.4 Piston (Inner Link)

It will form a sliding pair with the cylinder. The rotation of the crisper will be facilitated by this joint, i.e. it will act as a telescopic link.

6 CAD Design

The final CAD design which is made from the idea is shown in Figs. 6 and 7. As could be seen in Fig. 6, curved wall for crisper is created at the rear-right side of the crisper. Figure 8 shows the front view of the crisper subsystem which clearly shows

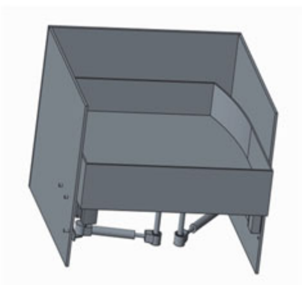


Fig. 6 Final CAD design

Fig. 7 3D crisper view

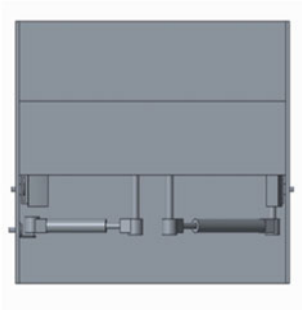


Fig. 8 Extended crisper view

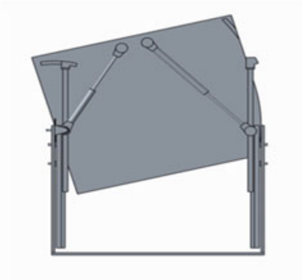


Fig. 9 Extended crisper bottom view

the position of the extending links just below the crisper bottom surface. Figure 8 shows the final extended position of the crisper, and Fig. 9 shows the same position from the bottom side. As could be seen from Figs. 8 and 9, the maximum extension of the crisper is possible due to the extension of the links as clearly seen in Fig. 9.

7 Finite Element Analysis

The material used for various components is as follows.

Support structure, screws, glides, bracket, cylinder, piston rod—Mild Steel (MS)

Crisper—Acrylic and endcaps, screw caps, connectors—ABS plastic

Thus, allowable working stress calculated for each material is as follows:

MS—Yield point stress/FOS = 200/3 = 66.6 MPa

Acrylic—Yield point stress/FOS = 70/3 = 23.3 MPa

ABS—Yield point stress/FOS = 40/3 = 13.3 MPa.

Figures 10 and 11 show the boundary conditions applied and deformation results, respectively.

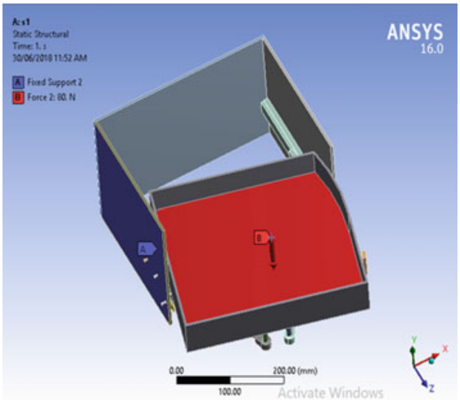


Fig. 10 Boundary conditions

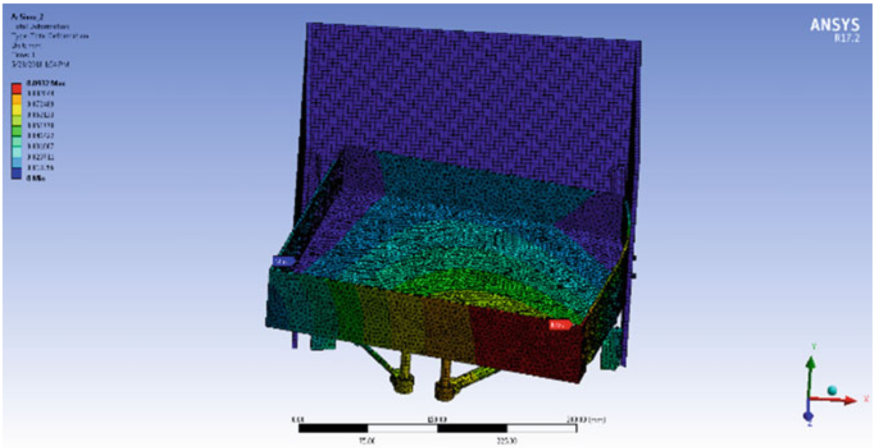


Fig. 11 Total deformation

Table 3 Comparison of results

	Simulation (mm)	Actual (mm)	Permissible (mm)
Position 1 (closed)	0.022	0.07	3
Position 2	0.093	0.21	3

7.1 Results and Conclusion of Simulation

(a) The maximum stress (von-Mises stress) induced at the position 2 is 31 MPa which is also induced at the right side screws, is almost half of the allowable limit for steel which s 66 MPa.
(b) Stresses induced in ABS and acrylic are up to 5 MPa which is also safe.
(c) The maximum total deformation in the position 2 is 0.09 mm which occurs due to overhanging which is safe considering allowable limit is 3 mm.

8 Testing and Validation

The prototype was built and then tested for the maximum deflection under specified lab conditions (Table 3).

9 Prototype Modification and Final Design

Instead of using the side by side structure glides, new configuration of the glides was used in which two members were assembled on top of each other with the bottom member fixed to the L-shaped bracket which was then screwed to the cabinet. The endcap was attached to the top moving member so that there is no friction and noise as in earlier case. For extending links, the brackets are to be directly fixed to he glides. Thus, it would result in the saving of the space as unnecessary space is avoided below the crisper, and hence, original system of pantry crisper can also be accommodated.

As in the initial design, the rotation of the crisper was restricted up to 25° due to length of the RH link, and it was decided to increase the extension of the link. As more than twice the extension was quite difficult to achieve, it was decided to increase the initial length of the link itself, for this purpose, the fixing point of the link to the glide was moved towards the back side of the glide so as to increase the length as shown. The small connector which was used at RH link was also eliminated and was replaced by the additional bracket. Modified design and prototype of crisper are shown in Figs. 12 and 13, respectively.

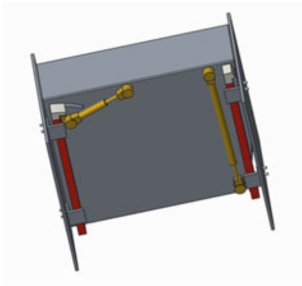


Fig. 12 Modified design

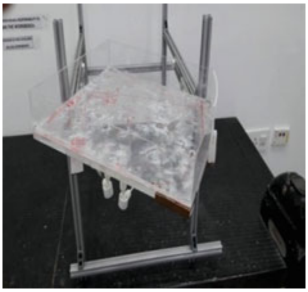


Fig. 13 Prototype

10 Conclusion

In this work, different concepts were conceived for the rotation of the crisper to increase the accessibility. For the selection, Pugh matrix was used in which different considerations were taken. After giving weightage to each criterion, the best concept was selected. The selected concept was then developed in detail, such as generating the mechanism, preparing the CAD model and performing FEA. FEA was run on the CAD design to determine its safety, and results were then validated with the actual test results. The final FEA tests were run on new design, and it passed the tests.

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