

# **Cost Reduction and Value Engineering of WHIRLPOOL Single Door Direct Cool Refrigerator**

*A Dissertation Submitted  
In partial fulfilment of the requirement  
for the Degree of*

Masters of Engineering  
In  
Production Engineering

**Submitted by  
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**Under Guidance of  
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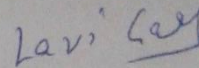
**MECHANICAL ENGINEERING DEPARTMENT  
THAPAR UNIVERSITY, PATIALA-147004**

**JULY, 2015**

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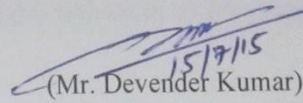
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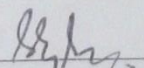
  
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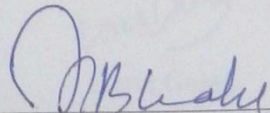
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**(Lavi Garg)**

**Reg. No. 801382016**

# Abstract

Emerging Indian market offers more challenges and opportunities to the Indian as well as multinational companies making products for Indian market. Sales data shows that single door direct cool refrigerators is still in large demand as compared to double door refrigerators. Utilizing more available space inside refrigerator with new innovative designs and materials at reasonable cost is the prime requirement of the industries. Present work deals with the cost reduction and design optimization of Whirlpool's single door direct cool refrigerator. Finding new alternate materials for cabin manufacturing, eliminating the less important features, improving the material strength with new techniques with less cost of manufacturing is the aim of present work. Present work is in collaboration with **Whirlpool of India Ltd.**, focusing on cost reduction, interior design for more appealing aesthetics and introducing unique features for more space utilization in existing dimensions of the cabin.

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# Chapter 1- Introduction

## **1.1 Introduction to Organisation [1]**

**Whirlpool**, in 1911 right from its beginning as the first trade manufacturer industry in the current market position of being world's number one manufacturer and vendor of home appliances, Milestones and benchmarks are always set the trade mark at the beginning. A product maker and salesperson of major household appliances, with yearly sales of near about \$18 billion, more than 72,500 workers, approximately 80 manufacturing and research study centres across the world.

Whirlpool initiated its transnational development in 1958 by incoming Brazil. This encouraging trend transported the company to India in the late 1980's. However, it emerged as strictly global forerunner in the 1980's.

Kelvinator India Limited is attained by whirlpool in 1995. The company's set is to stretch in the Indian subcontinent to microwave ovens, refrigerator, washing machines and air conditioners.

Today, Whirlpool is the most recognized trademark in household appliances in India and the market share of over 22% holds by whirlpool.

### **1.1.1 Whirlpool of India Ltd.**

Faridabad plant manufactures only direct cool (D.C.) products in the range of 165L, 170L, 175L, 180L, 195L, 215 L and 230L category. Whirlpool policies to start on products to dress the Indian customer in a number of earnings groups. Whirlpool portfolio will track its top-4 agenda:

- Refrigerators
- Microwaves
- Air conditioners
- Washing machines

Whirlpool guarantees consistency, promise and performance of its products. All Whirlpool products are assisted by suitable warranties and a wide association of service centres. Whirlpool tries to attain these goals.

In refrigerators, the industry growth has been less than 27%. The 195L occupy nearly 75% division of market. The main players in the market are LG, Godrej, Samsung, Toshiba, Whirlpool, Sansui, Haier, Hitachi, Electrolux, Panasonic, Bosch, IFB and Videocon. Whirlpool has a marketplace of about 30%.

## 1.2 Refrigerator Cabinet Description [2]

Parts in refrigerator

1. Compressor
2. Gas refrigerant R600A
3. Copper tubes
4. Freezer frame
5. Foamed cabinet
6. Outer metal sheet
7. Hinges (top and bottom)
8. Lock assembly
9. Chiller tray assembly
10. Glass shelves (2)
11. Door handle
12. Bottle racks



Figure 1.1: Refrigerator used for the study

## 1.3 Benchmarking <sup>[3, 4]</sup>

A team/group is conducted for benchmarking to find the similar products to our planned design to get ideas from all team members and to find the way to become better on-going technologies. There were lot of different moveable refrigerators out in the market place, individually using different power sources, different cycles, and cooling capacities with changing interior designs of the single door or double door refrigerator. A number of dissimilar products were related to their strengths and faults examined for better-quality on the existing refrigeration.

In the Benchmarking method, we compare one running business process and performance features with other same former business. Which we calculate some dimension values like cost, quality and time. Like comparing cost between two same product and quality difference between those product and how much time it utilise to make that product. In this process of benchmarking, controlling management make some groups by choose some special organisations that are related to their business processes or in the company where similar product are made or similar processes are done. In this means, they learn that how well the goals are achieve significantly, the profitable product of the company gives idea that why these business are going well.

### 1.3.1 Types of Benchmarking

Benchmarking can be internal or external, in the internal type we compare the process and performance of different firms with the organisation and in the external type we compare the routine of our industry with another industries.

There are some specific types of benchmarking:

- 1) Process benchmarking
- 2) Performance benchmarking
- 3) Financial benchmarking
- 4) Product benchmarking
- 5) Strategic benchmarking

**Process Benchmarking** – A process benchmarking application often gives information to an organisation to clearly understand and express its current process and providing the organisation a better hold of its beginning point as it considers possible change initiatives.

**Performance Benchmarking** – it allows to find the performance of the product or to find their position where they exist, they had compare the products with the main or prime moving firms.

**Financial Benchmarking** – Financial benchmarking is acting as a cost-effective analysis and where it compare the cost of the feature and processes and comparing the final solution to measure in general effectiveness and productivity.

**Product Benchmarking** – In this type of benchmarking, new product is designed or upgrade the presently using ones. In this process, reverse engineering takes place with the competitors to find out the strong point and weak points in their product.

**Strategic Benchmarking** – Strategic benchmarking involves that how other industries compete in the market.

### **1.3.2 Benchmarking Process**

**1. Identify Trouble Areas:** Benchmarking is to be useful for any work improvement or progress, a wide variety of investigation ways and means may be essential. Using some investigation methods that is concentration on groups or in amount marketing to do investigation, process plotting, economic percentage analysis, questionnaires or feedback form, analyses, re-engineering exploration, quality control modification information, or basically go over cycle time periods or former performance pointers. This gives relaxed discussions with trades, employees or workers. Before get on relationship with additional societies it is significant to identify the importance of the organisation and procedures base lining demonstration gives an opinion against which improvements effort can be dignified.

**2. Find former Industries that take part in Related or similar Processes:** If one and only were involved in improving habits of management, individual would categorize another areas that have similar experiments. This may be involved air traffic flow regulator, telephone substituting between strong hold connections, transfer of patients from surgical treatment to retrieval places.

**3. Identify Groups that are Front-runners in these regions:** find the most experience in the business in any state or in the country. Conversant with the clients, dealers, journals commercial predictors, and contract associations to decide that which one all companies are well-intentioned of study.

**4. Survey groups or companies for Measurement and Observation:** Companies main objective is the detailed business processes by means of faced surveys of actions and performs to categorize in the business process for another possibility. Analyses of customer views are normally secret to look afterward not to be disclosed the records by independent relations and consultants or professionals.

**5. Stopover the important companies to recognise the leading edge:** Main leading firms are normally agreed to make jointly adjustment over valuable data to all groups in the benchmarking and result is shared with each of the firm.

**6. Apply the new and better developed business processes:** Find out the most important authority practices and enlarge execution strategies that contain identification of thorough opportunities, finance the design plan and sale those designs to the association for the basis of gaining confirmed price from the development.

### **1.3.3 Benefits and use**

The analysis on benchmarking was modified by international Benchmarking organization, the proposal or ideas for benchmarking system is gives by 22 countries. At last the result is that Client Reviews and mission/vision statements are the mostly used by 77% of organizations, this gives the idea about the strengths, weaknesses, opportunities, and threats in their features and make to be aware of this SWOT analysis.

## **1.4 Cost Engineering** <sup>[6]</sup>

**Cost Engineering** is the engineering research devoted to the society of organisation for the project cost, relating such actions as cost and organize approximating values, which is cost regulator and cost predicting, judgement, and threat analysis. Cost Engineers budget, groundwork and display investment projects. They look for the best possible balance fixed between cost, quality and interval requirements.

A cost engineer is an engineer whose statement and knowledge are make use in the application of regular principles and methods to difficulty of approximation, cost control. The directive of 'cost engineering' can be measured to take a large range of cost-related features of engineering and plan managing, but in tough cost valuing, cost study/cost measurement, design-to-cost, plan analysis and risk valuation.

## **1.5 Value Engineering** [7, 8]

**Value Engineering (VE)** is efficient ways to become better the "value" of goods and chattels or products and services by using a scrutiny of function. Value is defined as the proportion of function to cost. Value can therefore be increasing by also refining the function or reduction of cost. It is a most important role of value engineering that basic functions be conserved.

Value engineering techniques is applied to any manufactured goods or service in any type of business or economic movement including construction, industry, governance, health care and in the service sector. If marketers supposed a manufactured goods to suit practically or stylistically outdated within a specific interval of time, they can plan it to only most recent for that exact lifetime. The products might be building with higher-grade working components, but with value-engineering they are not for instance, this would mete out an avoidable cost on the industrialist and to a limited range also an increased cost on the customer. Value engineering will shorten these costs. A manufacturer will typically use the slightest expensive components that satisfy the product's lifetime forecasts.

Value Engineering can make impressive savings, much better than what is likely possible through conventional cost reduction employment even when reduction of cost is the main objective of the task. Value Engineering is a powerful line of round for resolving problems or reducing overhead costs, whereas maintaining or improving performance and quality requirements.

### **Details for Poor Response for value engineering**

There are many reasons why superfluous cost or values creeps in design. Even though there is large number of reasons for poor values. Owners have an effect on value of a task because they establish a prime standard of the design and because they run to preserve the final services. Not only all these reasons are specific to the designer other depends on atmosphere of individual also. The succeeding reasons seems to be happen most often.

Table 1.1: Reasons for poor response

<ol style="list-style-type: none"><li>1. Temporary conditions that accidentally become permanent</li><li>2. Lack of plans and policies</li><li>3. Lack of thoughts</li><li>4. Absence of information</li><li>5. Misconception</li><li>6. Habits or behaviours</li><li>7. Lack of time</li><li>8. Attitudes</li><li>9. Politics</li><li>10. Others</li></ol>
---

### 1.5.1 Process for value engineering

Value engineering is normally done by through a successive multi-stage job plan. Others have mixed the job plan to accept their restrictions. Depending on the presentation, there may be four, five, six, or more stages. One existing type has the following eight phases:

1. Ground work (preparation)
2. Information (data)
3. Analysis (study)
4. Formation
5. Estimation
6. Development (growth)
7. Presentation
8. Follow-up

Four simple steps in the work plan are:

**Preparation and data collection-** This asks what are the necessities for the item. Function analysis, and important performance in value engineering, is normally prepared in this early stage. It tries to regulate what purposes or performance characteristics are important. It asks questions like; what is the objective to do? What necessity to do? What could it do? What should it do? What must it not do?

**Alternative Generation** - In this stage value engineers asks; what else will complete the desired function? What are the several alternate ways of meeting requirements?

**Evaluation** - In this stage all the substitutes are measure by evaluating how well they come across the necessary functions and how more the cost savings will be.

**Presentation** - In the last stage, the best exceptional method will be selected and presented to the user for final decision

## 1.6 Value Engineering and Cost reduction

Moving customer needs and harder competitions have made value engineering is important for manufactured product companies to preserve their leadership position. Infosys value engineering services support the clients to improve the manufactured products that maximize value, performance, consistency, quality and reliability, while reducing development and progress costs, and lead time to defeat challenges including:

- From top to bottom cost per function and feature
- Engineering process and tooling optimization
- Opponent product performance and features
- High stock chain costs

Table 1.2: Difference b/w value engineering and cost reduction

<b>Value Engineering</b>	<b>Cost Reduction</b>
<ul style="list-style-type: none"> <li>• It is functional oriented</li> </ul>	<ul style="list-style-type: none"> <li>• It is product or item oriented</li> </ul>
<ul style="list-style-type: none"> <li>• It applies advanced approach and thinking</li> </ul>	<ul style="list-style-type: none"> <li>• It follows previous practices</li> </ul>
<ul style="list-style-type: none"> <li>• It exercise maximum imagination</li> </ul>	<ul style="list-style-type: none"> <li>• It is critical in approach</li> </ul>
<ul style="list-style-type: none"> <li>• There could be divergent- convergent ideas</li> </ul>	<ul style="list-style-type: none"> <li>• There is only convergent ideas</li> </ul>
<ul style="list-style-type: none"> <li>• There is joint effort approach</li> </ul>	<ul style="list-style-type: none"> <li>• There is distinct approach</li> </ul>
<ul style="list-style-type: none"> <li>• There is multi-disciplinary attitude</li> </ul>	<ul style="list-style-type: none"> <li>• There is no multi-disciplinary attitude</li> </ul>
<ul style="list-style-type: none"> <li>• It is a systematic and progressive approach</li> </ul>	<ul style="list-style-type: none"> <li>• Its approach is arbitrary</li> </ul>

## 1.7 Rapid Prototyping <sup>[9]</sup>

Rapid prototyping is a technique used to manufacture a prototype of a physical models and assembly by making a STL file of computer aided designing software. The all three dimension

of the model are generally constructed by 3D printing or additive layer manufacturing. In rapid prototyping, firstly make the model in the CAD file and then constructed by the RP machine. This is main step to finalise the model or the design of the product. A prototype is tested firstly to start manufacturing of that design.

In RP process, the layers of the material are placed on one another according to the shape of the part that means it is the additive process. Material is not removed in this process like grinding, milling etc. in which design is formed by plastic deformation or material elimination. In all RP Processes, the material is added on the part by deposition of layers of the material by moving the arm in x-y direction horizontally and the z direction is work only when the one layer is completed and this z axis is moved only in upward direction to set the layer on top of earlier layer. This movement of z axis making layers is called stair-stepping effect. It is very accurate in x-y direction. If this layer thickness is less that gives very fine finish to the model.

Table 1.3: Rapid Prototyping Processes

PHASE	METHOD	PHASE VARIATION STYLE	LAYER CONSTRUCTION METHOD	INGREDIENTS
<b>Liquid</b>	Stereo-lithography	Photo polymerisation	Liquid layer curing	Photopolymers(acrylates, epoxies, filled resins)
	Fused deposition modelling	Solidification by cooling	Extrusion of melted plastic	Wax, Polymers
	Solid base curing	Photo polymerisation	Liquid layer curing and milling	Photopolymers
<b>Solid</b>	Laminated object manufacturing(LOM)	No phase change	Deposition of sheet material	Paper, Polymers
<b>Powder</b>	3D Printing	No phase change	Binder droplet deposition onto powder layer	Metal powder with binder

	Selective laser sintering	Laser driven sintering and melting	Layer of powder	Metals with binder, Sand with binder
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### 1.7.1 Fused deposition modeling (FDM)

In this process, a nozzle is moved in X-Y direction on to a platform. A molten polymeric is extruded on platform which are thin like threads. The temperature of the build material is slightly more than its melting temperature because it takes very short time to solidify. Several significant basic factors need to be measured which affects the model. These are steady nozzle or moving with slow speed, extruded material speed and material for overhanging features gives support structures and nozzle head speed, which varies the slice thickness. In new fused deposition modelling systems have two nozzles. One nozzle is used for part making and second nozzle is for giving support to that part for overhanging features. The material used for support is quite poor quality because it has no use after making the model that can be easily removed from substrate after making the model. Now in the recent technology, the support structure material used is water-soluble that is easily removed because support material has less density than the part material.

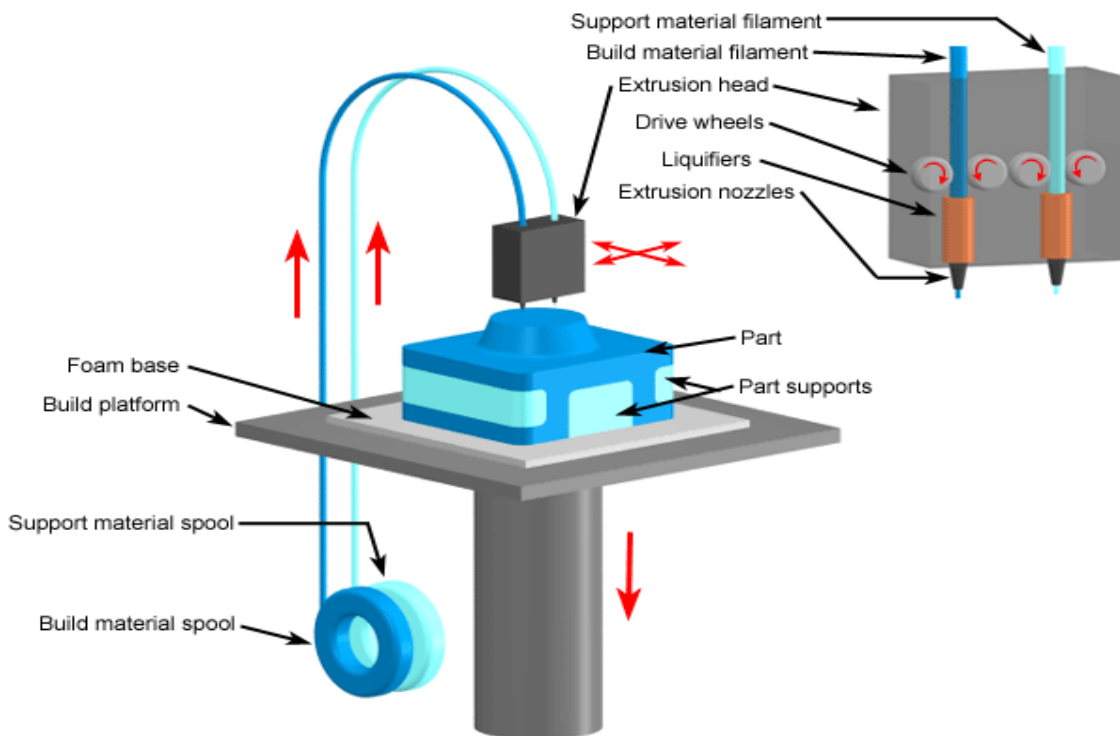


Figure 1.2: fused deposition modelling [10]

## Chapter 2- Literature Review

[11] Seong et al. 2015 based upon the design optimisation of refrigerator door hinges. The capacity of the refrigerator is 712 litre. Design optimisation method is using on the top hinge of the door. The strength of hinge material and cost of the door hinge are the main factors. The new design in this paper is to bear maximum load of the door. The design is the combination of slider crank and crank rocker mechanism. This design gives smooth opening and closing of the door.

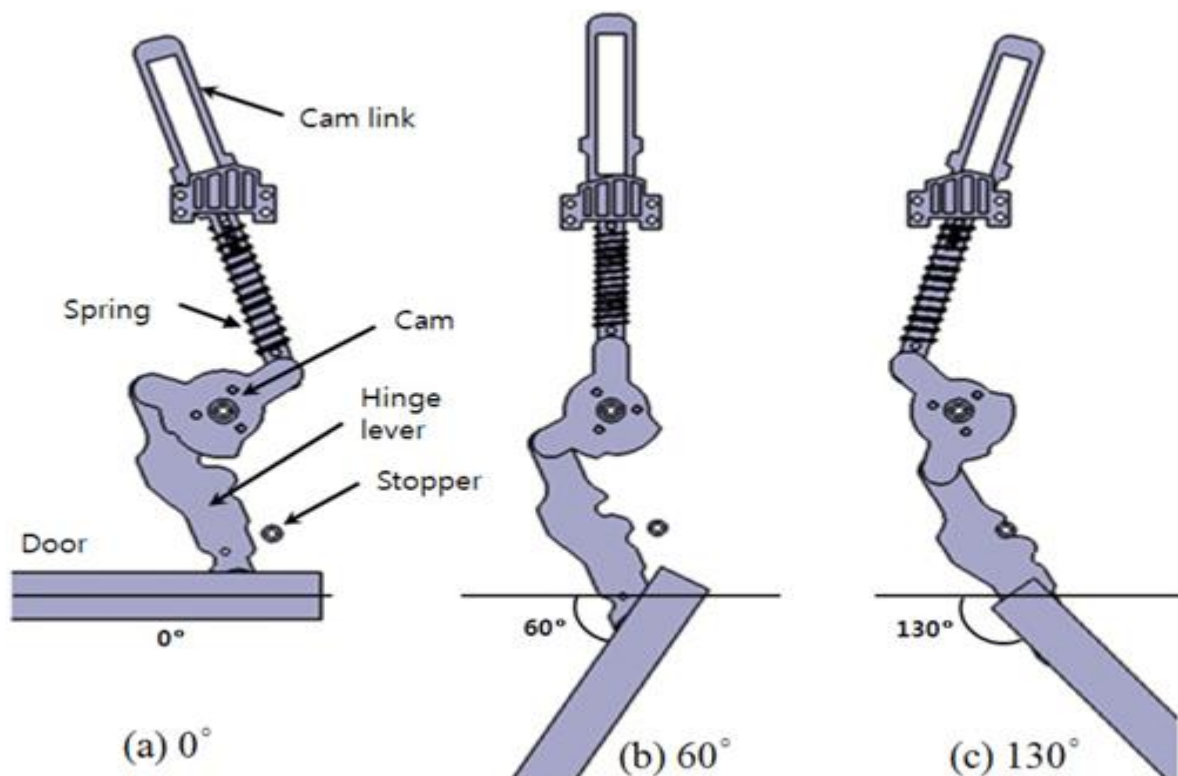


Figure 2.1: Top Hinge [11]

[12] Eres et al. 2014 describe the importance of design and the customer related factors, such as the customer satisfaction with the new optimised design. The requirement of the customer is to be fulfilled with the advanced design and cost is to be equal or less than the older one. The customer requirement are worked as key motivation in the business. The new design need to retain the customers in order to differentiate from internal and external competitors.

[13] Kumlutas et al. 2012 represent the design parameter values of single door refrigerator. The parameters like the height of evaporator, temperature of surface in refrigerator, temperature of glass shelves. To predict these parameters, the artificial neural network was used. These are to be measured for calculating the efficiency of the refrigerator.

[14] Khangura et al. 2012 determine the importance of various refrigerator parameter for user, design for lower cost alternative and high performance. First of all we have focus on customer requirement that what they require in their refrigerator for household purpose. Some benchmarks are required in this process. Its benchmarks are Godrej, Samsung and Videocon. This makes the house of quality and set the target values according to the priorities of the customer. By this analysis author conclude the most important parameter for improvement of the design.

[15] Lannsjö et al. 2012 presented the improvements in single door refrigerator through a project which was carried out in cooperation with Electrolux. Their aim was to develop a refrigerator concept that changes the user to adopt more sustainable behaviour. It tells about that how can we design the meaningful products with added values and make more utilisation of the product in an optimal way. This is primarily done by customer survey that what are the requirements of the customer or feedback by the users.

[16] Qingmin Yu 2012 main task is to control the cost of features of refrigerator in the design stage. The first key area is the price of raw material and labour wages. In the designing procedure, four steps are involved- Product planning stage, development stage, design stage and production stage. In these steps, the cost is controlled in product planning and designing stage. The function of research and development department is to focus on the features and ignore the cost of the product. In the planning process, meet the requirement of the market and customer and make the product by keeping in mind the cost of the competitive products and finally cost planning of refrigerator by determining the cost of various parts of the refrigerator.

[17] Prasad et al. 2011 concerned with the cost control and cost estimation. In the design phase of product, it is essential to produce the product with minimum cost and desired quality as requirement of customer. Optimisation of product design with respect to cost and design requirement. Value engineering is used to obtain the required function of user at lowest possible cost without reducing the necessary quality of performance. Cost management will not be successful with the help of value engineering. This gives the best way to perform. So this improves the product development, cost management, quality of product and customer satisfaction.

[18] Gholap et al. 2007 main aim of this study is to minimise the energy consumption and reduce the material cost. Representation in this work to optimise the geometry of the heat exchanger used in the refrigeration system. In the heat exchanger, it have many design variables

like as geometry of heat exchanger, surface finish, extra used material etc. These can be change according to necessity of refrigeration system and improve the efficiency and reduction in cost.

[19] Vincent et al. 2006 studied about the performance of refrigerator. The system performance is most affected by the compressor and cost is also mainly affected by the compressor. As the reduction of cost affected the efficiency. It says the fixed air velocities are send to the condenser and evaporator assuming the pressure drop and the power of fan is negligible.

[20] Elmuti et al. 1997 Benchmarking is the process of identifying the highest standard of products and processes. Benchmarking is the means of gathering data that how will companies perform against each other. It can used for services or manufacturing. It is the method of finding new ideas and ways to improve the process so as able to meet the customer requirement. It is also beneficial for increasing productivity, improving designs and growth potential of industry. By using benchmarking, the companies remain competitive in the market. It is the tool to involve everyone including management and workers.

[21] Johnson et al. 1994 Benchmarking and customer survey is the best method to improve the quality of product. It makes the house of quality, on which target values are defined and then select the benchmark for the same product and improve the quality according to customer feedback. Benchmarking involves making visit to the firms of the competitors and understand the processes in the line and think what else is possible. Smaller firms gain both process improvement and customer focus by using quality function deployment.

[22] Robert H. Sturges 1992 explain Value engineering as improving the product value by reduction of cost or by improving the features of the product. This is the necessary process for industries to grow with less input and gives more output. It is the process of improving the level of the existing product from low level to higher level. Innovation evidently occurs whether or not a designer is conscious of the process by which he explores new possibilities.

[23] [www.hettich.com](http://www.hettich.com) The Company have designed new door hinges. A controlled door opening is made that is highly practical and stop the door at different angles to prevent the colliding with adjacent furniture elements. Its maximum door opening angle is  $115^{\circ}$ . This can also be used for changing door mounting i.e. left opening to right or vice-versa. Cost of door hinge is INR 180 and refrigerator is to be closed by fully pushing at the end but there is some limitation that we cannot stop at intermediate and closing of door need continuous force till it crosses its intermediate hold point.



Figure 2.2: Top hinge [23]

[24] W.T.Singleton describes the ergonomics of human body when we remove the bottles from the rack of the refrigerator. We have always to be bend down to remove the bottle and same to put the bottle at that place. In summer, we have to remove the bottles many time and for old age user those have difficult to bend or some back problems become a serious problem. According to ergonomics this large time bending position is wrong for back problem so to remove this difficulty for the user, we have to move the bottle rack at the top most of the door and other products which are not used in daily routine that are placed in bottom.

[25] [www.geometricglobal.com](http://www.geometricglobal.com) Companies always try to reduce or optimise the cost of the product. For this purpose company to adopt several technique for optimisation and cost reduction. Cost optimisation helps to increase the profit. Under this program, companies has to be focus on functions like production, design of product, operational overhead costs. They have to make target value of cost reduction of a suitable function. This reduction of cost plays an important role in growth strategy for all industries.

[25] [www.geometricglobal.com](http://www.geometricglobal.com) **Case study 1-** optimising product design and cost to increase the product footprints. A leading manufacturer of specialised lighting equipment was looking for market expansion opportunities. The major sale of lightening product was from commercial market. Market research data showed that due to its high price point, it was not able to enter the domestic markets. Company wanted to redesign the product to make it relatively more affordable for domestic use.

The product was redesigned cost effectively. During product development, certain control features not required for domestic use were eliminated. The mechanical and electrical subsystems were redesigned using alternative materials and simplified by reducing components. The existing light source was replaced by LED's. Which significantly lowered the total power consumption. After redesign, the product cost was brought down significantly

from 400 USD to approx. 200 USD. The product is successfully sold in domestic markets at a lower price.

[26] Sharma et al. 2012 **Case study 2-** Part name- Flush Valve

Manufactured in Summid engg. Pvt. Ltd.

Steps used in the analysis

1. Detailed information about the part is collected.

- a. Material brass.
- b. Cost of scrap is INR 310 per kg.
- c. Parts produces 1000/month.
- d. Process used electric induction furnace.
- e. Present cost INR 55/piece.
- e. Temperature of furnace is approx. 1800<sup>0</sup>C.

Material cost	INR 45
Machining cost	INR 6
Plating cost	INR 4
Total	INR 55

2. Functional definition sheet is prepared.

- a. Provide – Cover and Support
- b. Prevent – Movement and Damage
- c. Improve – Appearance

3. Creative worksheet is developed.

- a. Change the material to plastic.
- b. Use stainless steel pipe.
- c. Use ZAMAK (Zinc + Aluminium)
- d. Change the design of part.
- e. Use rubber.

4. Evaluation is done through decision matrix.

- a. Implementation
- b. Maintenance
- c. Quality
- d. Safety

5. Finding and recommendation.

Table 2.1: Cost evaluation

Item	Material cost	Machining cost	Plating cost	Total cost
Brass sleeve	45	6	4	55
ZAMAK sleeve	25	0	4	29
Difference	20	6	0	16

## 6. Result

- a. Cost of part before value engineering - INR 55
- b. Cost of part after value engineering – INR 29
- c. Saving per part – INR 16
- d. Expected annual saving – INR 192,000

### **Other benefits-**

- a. Material saving
- b. Reduced labour cost
- c. Reduced machining time
- d. Reduction in production time
- e. Better quality
- f. Increased efficiency

### **[27] Customer Feedback of Whirlpool refrigerator on the internet**

<http://www.customerservicescoreboard.com/Whirlpool>

Zilak Khan 05/09/2014 6.49pm

Purchased the whirlpool refrigerator in 2013 and face some problems due to design. We have congested space to place the refrigerator. When we open the door about  $110^{\circ}$ , it will touch with nearby items and made scratches on door. This will have to be open to about  $100^{\circ}$  when we place the container in it and this will go automatically to its full rotational angle. This is the main problem in it. Whirlpool have to solve this for domestic purpose.

Ankur 31/05/2014 6.37am

Purchased the Whirlpool refrigerator in May 2014. He starting facing problems in refrigerator in Oct 2014. When he placed 2 bottles on bottle rack, the tray break in pieces and side locks are break for handling the rack.

Maria 28/05/2014 5.17pm

He have owned a whirlpool side by side refrigerator several year ago. As each year passes, the interior shelves and drawers are either broken or plastic holding insulation is chipped away.

Bobd16116 13/03/2014 10.00am

He purchased stove, microwave and clothes washer in March 2011. There are some problems regarding all of the product. In refrigerator, water leakage problem from the defrost system. The microwave door is falling apart in pieces.

Miki 22/01/2014 6.43pm

He have no complaint about the whirlpool refrigerator. But suggestion to whirlpool is that the space wastage is very high in their refrigerator. They need to improve their internal feature designs so that it has to be utilised more.

Anonymous 19/05/2013 1.22pm

His refrigerator still in warranty. The Glass top of the door is cracking. He is very disappointed with this. This changed my mind on purchasing the whirlpool product any more.

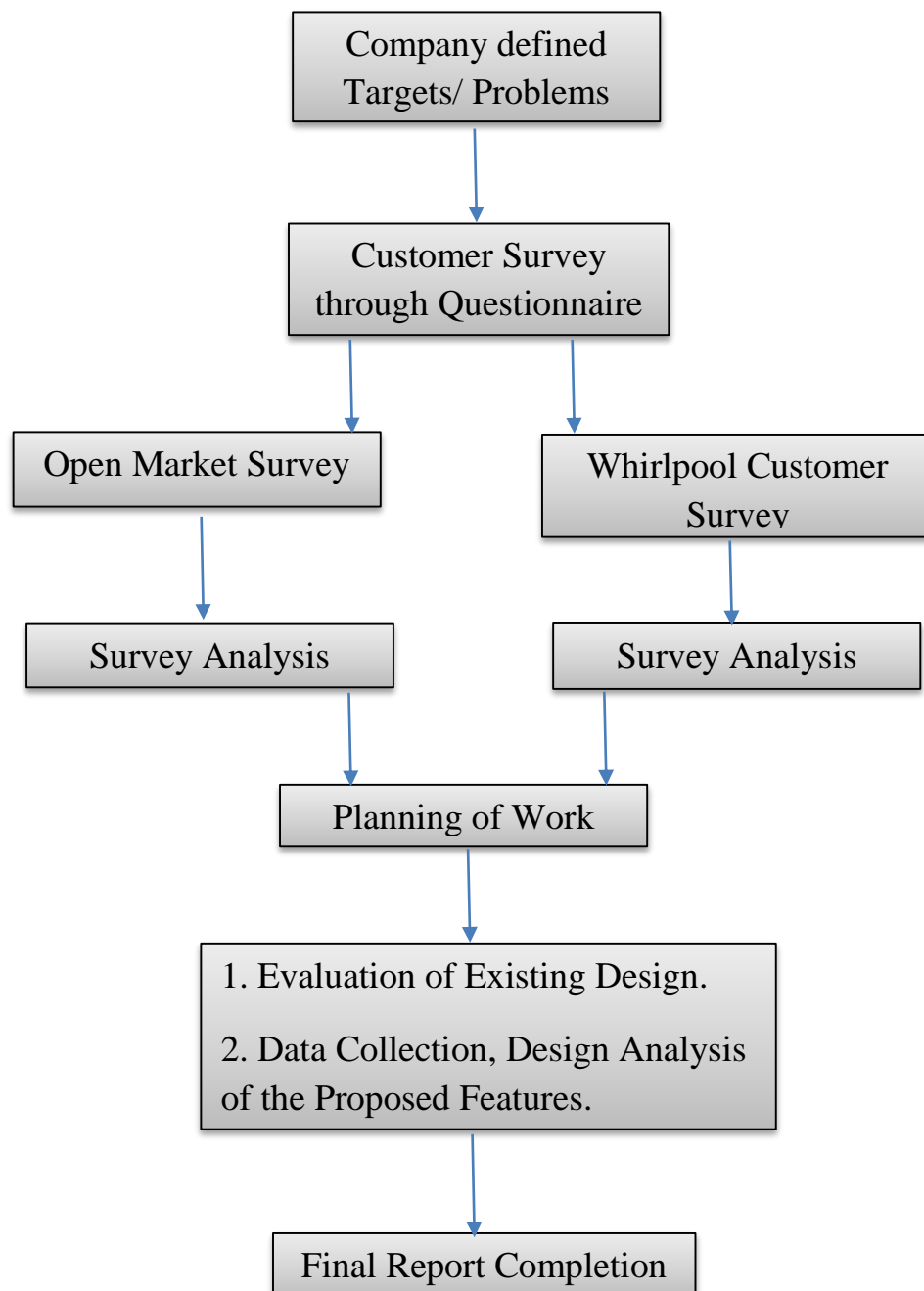
## **2.1 Literature summery and objective of present work**

Different researcher have studied the requirement of customer and they proposed different ways to improve the customer satisfaction by improving the product value, cost reduction and other engineering techniques. Data obtained from market survey was used by many researcher to improve the product.

Objective of present work is to reduce the cost of existing single door direct cool refrigerator through optimisation of some features. Work also involve the introduction of new cost effective feature through value engineering to enhance the customer satisfaction.

## Chapter 3- Methodology

Whirlpool of India Ltd. gives some targets to improve the design of their single door refrigerator. Their main objective is to fulfil the customer requirement by changing some designed features at less cost. Now our main task is to find out the requirement of customers. For this purpose, a customer survey is take place. Which divided it into two groups. One is the open market survey and second is only whirlpool refrigerator user survey. After the survey, the analysis phase is start, by which the requirement of customer is defined. Now by these defined targets, planning of work is start and design of new feature as per survey and at last these new designs are accepted by Whirlpool.



# Chapter 4- Project Execution

## 4.1 Target of the project

**a. Cost Reduction** - The main objective is to reduce the cost of the refrigerator by improving the design of some features which can be modified in another design that will do same work as earlier and reduction of cost is possible or the cost is to be reduced by eliminating the extra feature which are not in use.

**b. New design features addition** - Now a days, the customer required some extra feature which may be in the form of aesthetics or daily usage. The extra feature can be more costly but the value of the product is increased more than its added cost. We measure the space wastage in the exiting design of the refrigerator is high that can be reduced that is also a part of value engineering.

## 4.2 Customer survey

### 4.2.1 Questionnaire for survey

#### STUDY ABOUT CONSUMER SATISFACTION TOWARDS REFRIGERATOR

Name:-	Contact no.:-
Gender:- Male <input type="checkbox"/> Female <input type="checkbox"/>	Location:-
Occupation:- Govt. job <input type="checkbox"/> Private job <input type="checkbox"/> House wife <input type="checkbox"/> business <input type="checkbox"/> Student <input type="checkbox"/>	

#### Section – A

**Your general views about the refrigerator you are using at presently or you have used in past**

#### 1. Which brand you are currently using?

- |                                    |                                     |                                     |                                |
|------------------------------------|-------------------------------------|-------------------------------------|--------------------------------|
| Whirlpool <input type="checkbox"/> | Samsung <input type="checkbox"/>    | Toshiba <input type="checkbox"/>    | LG <input type="checkbox"/>    |
| Panasonic <input type="checkbox"/> | Videocon <input type="checkbox"/>   | Bosch <input type="checkbox"/>      | IFB <input type="checkbox"/>   |
| Sansui <input type="checkbox"/>    | Electrolux <input type="checkbox"/> | Kelvinator <input type="checkbox"/> | Haier <input type="checkbox"/> |
| Hitachi <input type="checkbox"/>   | Godrej <input type="checkbox"/>     |                                     |                                |

#### 2. How long did you own this Refrigerator?

- |   |   |                                      |
|---|---|--------------------------------------|
| a. Less than six month <input type="checkbox"/> | b. Six month <input type="checkbox"/>         | c. One year <input type="checkbox"/> |
| d. Two year <input type="checkbox"/>            | e. More than 2 years <input type="checkbox"/> |                                      |

#### 3. What is the capacity of your refrigerator?

- |                              |                              |                               |                              |
|------------------------------|------------------------------|-------------------------------|------------------------------|
| 185 <input type="checkbox"/> | 190 <input type="checkbox"/> | 215 <input type="checkbox"/>  | 235 <input type="checkbox"/> |
| 245 <input type="checkbox"/> | 253 <input type="checkbox"/> | 260 <input type="checkbox"/>  | 270 <input type="checkbox"/> |
| 275 <input type="checkbox"/> | 280 <input type="checkbox"/> | >280 <input type="checkbox"/> |                              |

**4. Which feature do you like the most about your refrigerator?**

(Tick which is applicable)

- Space  Freezer capacity  Bottle arrangement   
 Looks  Cooling efficiency  External temp. Controlling system   
 Tray arrangement  others

Others specify here -: \_\_\_\_\_

**5. Do you have any Dislike/problem with your refrigerator?** Yes  No

If Yes, what?

(Tick which is applicable)

- Less space  Noise  Electric shock   
 Shifting not easy  Vibration  Supporting leg not strong   
 Freezer capacity  Over Heating  Fit and finish   
 Less bottles space  Odour  Rusting   
 Power consuming  Easy Cleaning  Vegetable tray capacity   
 Low cooling  others

Others specify here -: \_\_\_\_\_

**6. Listed below are some product features rate them as:**

<b>Very Poor - 1</b>	<b>Poor - 2</b>	<b>Average - 3</b>	<b>Good - 4</b>	<b>Excellent - 5</b>
----------------------	-----------------	--------------------	-----------------	----------------------

- A. Shelves**
- Quality of Shelf material (wire/toughened glass)  1  2  3  4  5
- Numbers of shelves (2 / 3 / 4)  1  2  3  4  5
- Adjustment of shelves as per requirement  1  2  3  4  5
- Shelf space  1  2  3  4  5

**B. Chiller section capacity** More  Less  Sufficient

- Chiller door operations  1  2  3  4  5
- Frosting of chiller/freezer  1  2  3  4  5
- Vegetable tray capacity (more/less)  1  2  3  4  5

**C. Bottle racks**

- Space  1  2  3  4  5
- Utility  1  2  3  4  5
- Adjustment  1  2  3  4  5
- Utilization of available space  1  2  3  4  5

**D. Is there any problem regarding breakage supporting legs while sliding or shifting the refrigerator?**

- Yes  No

**E. Door finish and colour**

1. Would you like metal finish? Yes  No
2. Would you like without any flower print? Yes  No
3. Would you like flower print? Yes  No
4. Would you like mat finish paint? Yes  No

**F. Which color would you like to buy?**

- White  Pink  Red  Black   
 Dark gray  Silver gray  Light silver  Dark silver   
 Maroon  Golden  Cream

<b>Section – B</b>				
<b>Your views about new features, you want to have in your refrigerator</b>				

<b>Not required - 1</b>	<b>Less important - 2</b>	<b>Important - 3</b>	<b>Very important - 4</b>	<b>Recommend - 5</b>
-----------------------------	-------------------------------	----------------------	-------------------------------	--------------------------

7. Do you like adjustable bottle racks to adjust different size bottles when required?  
 1  2  3  4  5
8. Do you face problems of hitting the refrigerator door to the wall / nearby items while opening the door?  
 Yes  No
9. Do you like the door stopper mechanism to avoid full door opening instantly?  
 1  2  3  4  5
10. Do you want to have External storage space at bottom of refrigerator? Yes  No
11. Have you ever used the door lock? Yes  No   
 If yes, then how many times,  
 Only 1  <5  <10  >10   
 Do you have keys of your refrigerator door lock? Yes  No  Lost   
 Do you like to buy refrigerator with child lock without key? Yes  No
12. Do you like Single door frost free refrigerator? Yes  No
13. For interior illumination which would you like to have in your refrigerator?  
 Yellow bulb  LED   
 If you like LED then which colour? Ice blue  Ultra white   
 Pista green  Soft pink
14. Do you like coloured interior? Yes  No  May be   
 If yes, then which colour? Ice blue  Pista green  Soft pink
15. Do you think design of logo attract the buyers for any company? Yes  No
16. Do you think brand image is reflected by the design of logo? Yes  No
17. How do you evaluate the brand image of any company?

18. Logo of which company attract you the most? \_\_\_\_\_



19. Do you like the logo design of whirlpool?    Yes     No

20. Do you think, logo of whirlpool can be better than the present logo?    Yes     No

Suggestion/problems, if any

---

## 4.2.2 Questionnaire results

### 4.2.2.1 Open market survey results

Table 4.1: Result of first survey

Question	Result		Percentage Result	
Breakage of supporting leg while moving or shifting	98/213		46%	
Like metal finish paint	171/213		80%	
Would you like without any flower print	148/213		69%	
Would you like flower print	83/213		39%	
Would you like mat finish paint	164/213		77%	
Which colour would you like to buy	WHITE-14		6.5%	
	RED-3		1.8%	
	PINK-4		1.4%	
	BLACK-14		6.5%	
	DARK GRAY-31		14.5%	
	SILVER GRAY-82		38.4%	
	LIGHT SILVER-31		14.5%	
	DARK SILVER-12		5.6%	
	MAROON-9		4.2%	
	GOLDEN-3		1.4%	
CREAM-10		4.7%		
Hitting of door to the wall while opening	111/213		52%	
External storage space at bottom requirement	155/213		72%	
Ever used door lock	YES-104/213	NO-107/213	49%	51%

if YES, How many times	Only 1+ <5+ <10 = 94		44%	
	>10 = 10		5%	
Like to buy refrigerator with child lock without key	169/213		80%	
Do you like coloured interior	Yes + may be = 169/213		80%	
Do you think design of logo attract the buyers for any company	159/213		75%	
Do you think brand image is reflected by the design of logo	158/213		74%	
Do you like the logo design of whirlpool	YES- 135/213	NO-78/213	63%	37%
Do you think, logo of whirlpool can be better than present logo	191/213		90%	

#### 4.2.2.2 Whirlpool customer survey results

Table 4.2: Result of second survey

Question	Result			Percentage Result		
Lock usage	YES-47/192	NO-145/192		24%	76%	
Purchase with child lock	YES-188/192	NO-04/192		98%	2%	
Vegetable tray capacity	LESS-135/192	SUFF-57/192		70%	30%	
Coloured interior	YES-87	NO-10	MAY BE-95	45%	5%	50%
Bottle space	SUFF-161/192			84%		
Can you purchase new containers like assenary which increase your ref. capacity at some cost as in market	YES-175	NO-6	MAY BE-11	91%	3%	6%

### 4.2.3 Customer Needs as per survey

By this survey we calculate the requirements of the customer. These requirements are not to be confused with limitations; rather they further define and important point of our product. Identifying customer requirement is itself a process, for which we set the three-step method as follows:

1. Collect the data on customer needs was done by asking questions:
  - What are the liking of the customer about the product?
  - What would the improvement required in the product that customer wants?
  - When the customer purchasing the product what are the issues to be considered?

Table 4.3: Customer needs as per survey

Sr. No.	Feature
1.	Bottle Space
2.	Adjustable Bottle Rack
3.	Door Finish and Color
4.	Door Stopper
5.	External Storage Space
6.	Door Lock requirement
7.	Colored interior
8.	New containers for extra covering space
9.	Shelf adjustment
10	Foot stand breakage

2. Classify the needs into a pecking order of primary, secondary and tertiary needs.

The results of steps may end up to a large number of statements. Working with such a long list of inclusive needs is difficult. The main motive of this phase is to structure these necessities in a hierarchical manner. The table will generally contain primary needs, secondary needs and tertiary needs. Each one of which will be categorized by a most important to least important needs. The primary needs are the most general needs that are required for daily routine, while the secondary and tertiary needs put across the needs which are less important for daily purpose. These are arranged in a table in further detail:

Table 4.4: Hierarchy of needs

<b>Primary needs:</b>	<b>Secondary needs:</b>	<b>Tertiary needs:</b>
Containers for covering space	Foot stand breakage	Coloured Interior
Bottle rack adjustment	External storage space	Mat finish or metal finish
Shelf adjustment	Door lock change	
Bottle space		
Door stopper		

### 3. Create an Object Tree:

The above hierarchical list can then be put in a plan tree form, which is a graphical representation of the objectives for the manufactured article or goods. The top-level target in an objective tree, which we signify as a node at the highpoint of the tree, is decomposed or bust down into sub-goals that are at different levels of importance or that contain progressively more feature, so the tree reflects a hierarchical arrangement as it expands downhill.

Table 4.5: Design Alternatives

1. New storage solutions	→	Design new containers for more space utilisation and use the extra space outside the refrigerator
2. Increase in space utilisation	→	Transform the capacity of vegetable tray and bottle rack adjustment
3. Aesthetic improvements	→	Change colour of interior and outer finish
4. Intermediate door stopper	→	Door stopper mechanism to stop the door in b/w two or three stages
5. New design of shelf adjustment	→	Increases shelf shifting ribs or fully adjustable ribs
6. Reengineering of foot stand, lock, door handle	→	Analysis on foot stand, change door lock to child lock without key, make only pocket handle of door

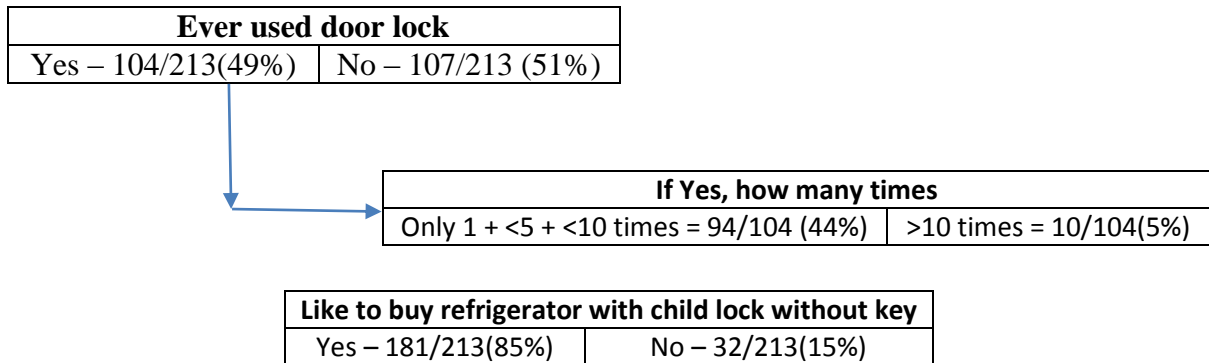
Now we apply engineering methods to satisfy these necessities of the customer. We use cost optimizations and benchmarking techniques for cost reductions. We find the alternative ways to design these requirements we prefer the best possible way which have less cost and highest achievable performance.

### 4.3 Cost reduction of selected features

These some feature modifications based upon the cost reduction and value engineering are discussed below:

#### 4.3.1 Door Lock

Customer survey for door lock usage by all different brands of refrigerator users:



Customer survey by Whirlpool refrigerator users:

Ever used door lock	
Yes – 47/192(24%)	No – 145/192(76%)

Like to buy refrigerator with child lock without key	
Yes – 188/192(98%)	No – 04/192(2%)

#### Important observations for existing design:

1. Cost of present lock is very high.
2. No usage of lock by the customer. Even the keys of the lock are misplaced after few months.
3. Aesthetically not important at front side.
4. Extra tooling cost required to assemble the lock.



Figure 4.1: Existing design of door lock

Cost of existing lock with whole assembly – INR **23.46** per ref.

**Important observations for new proposed design:**

1. Easy to operate.
2. Cost is less of new lock.
3. Proposed design of lock is without key this can't be operated by a small child.
4. It has no effect on the aesthetics of the refrigerator.
5. No extra tooling is required for this new locking system that can be replaced easily at very less cost.

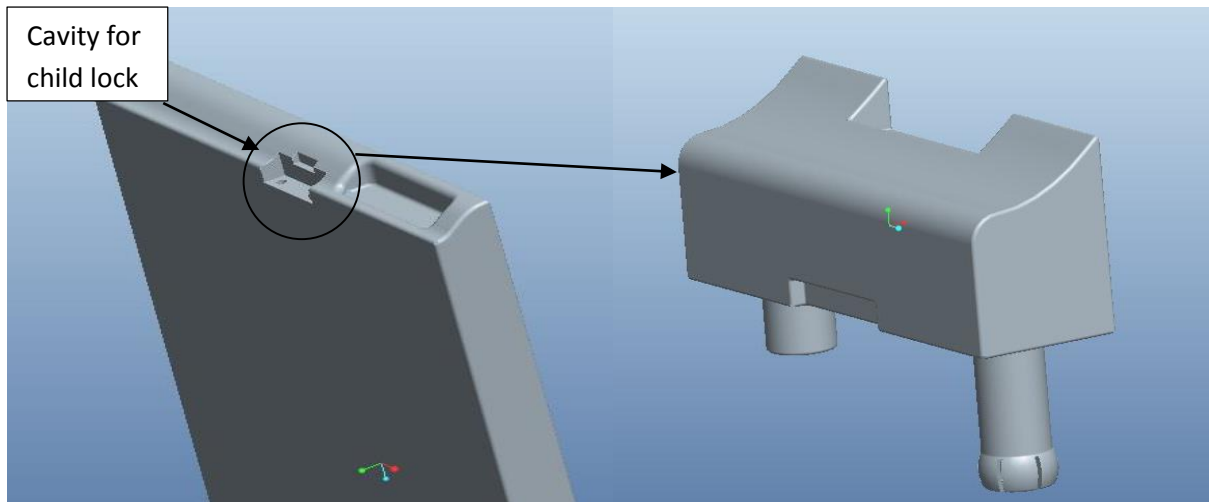


Figure 4.2: Door Lock assembly

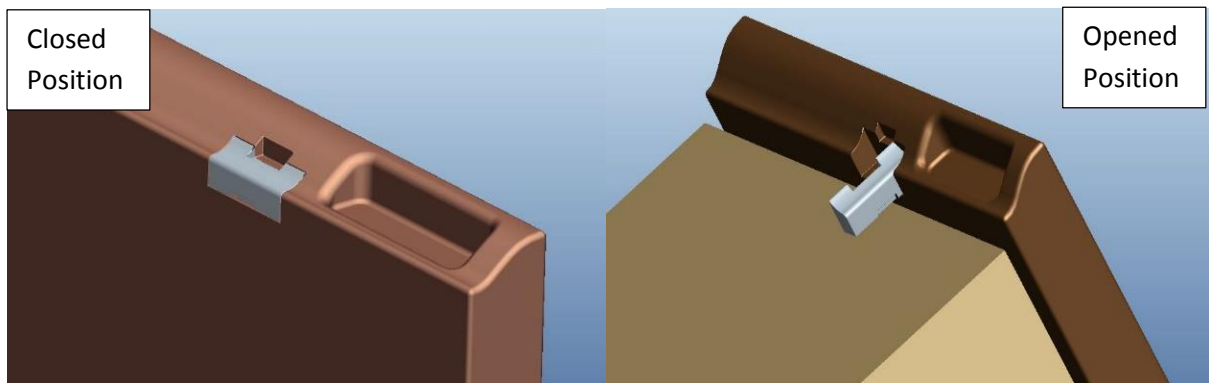


Figure 4.3: Proposed design of new locking system for refrigerator

### 4.3.2 Door Handle

#### Important observations for existing design:

1. Cost of complete assembly is very high.
2. Aesthetically not very important on front side.
3. For small size refrigerators it occupies more front space and require extra tolling to create space in the front designer sheet.
4. Pocket handle at the top of the door can solve our purpose as top left corner of door used by majority of customers in place of existing front handle.



Figure 4.4: Existing door handle

Cost of existing handle of door – INR **58.98** per ref.

**Important observations of new design of door handle:**

1. Handle is at the top of the door.
2. Because of its curved surface it will be gripped from any place and opened easily.
3. Cost of door handle is negligible.
4. Aesthetics are improved at the top of the door by giving different type of pockets for opening the refrigerator.

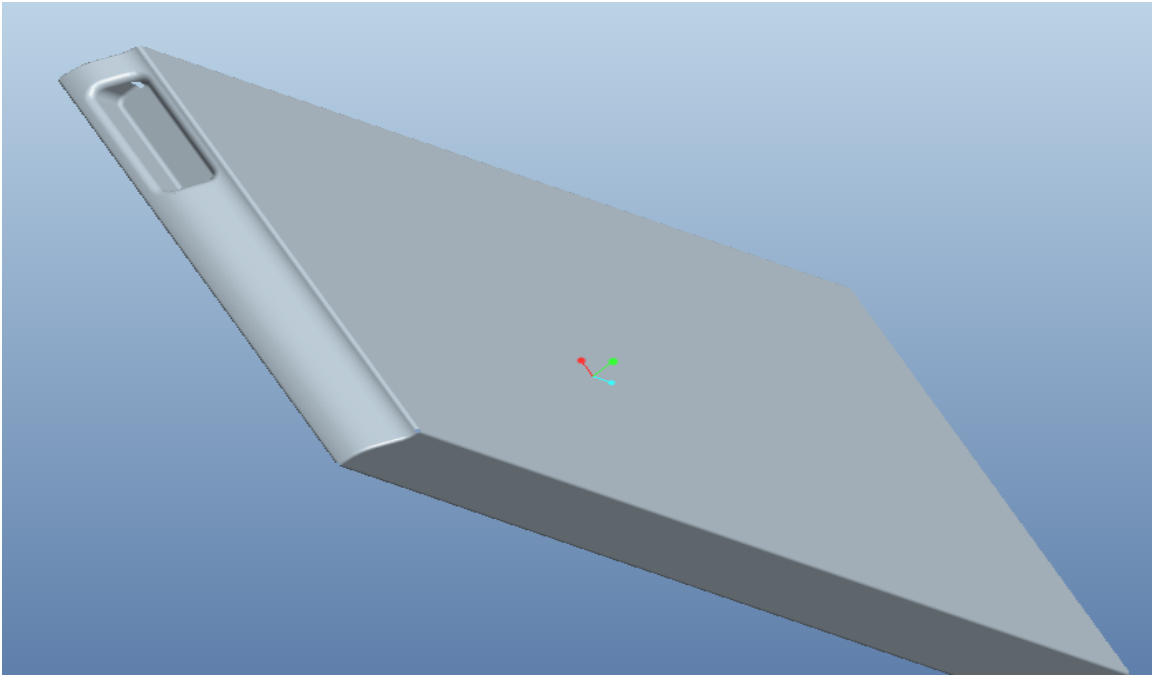


Figure 4.5: New proposed design of door handle

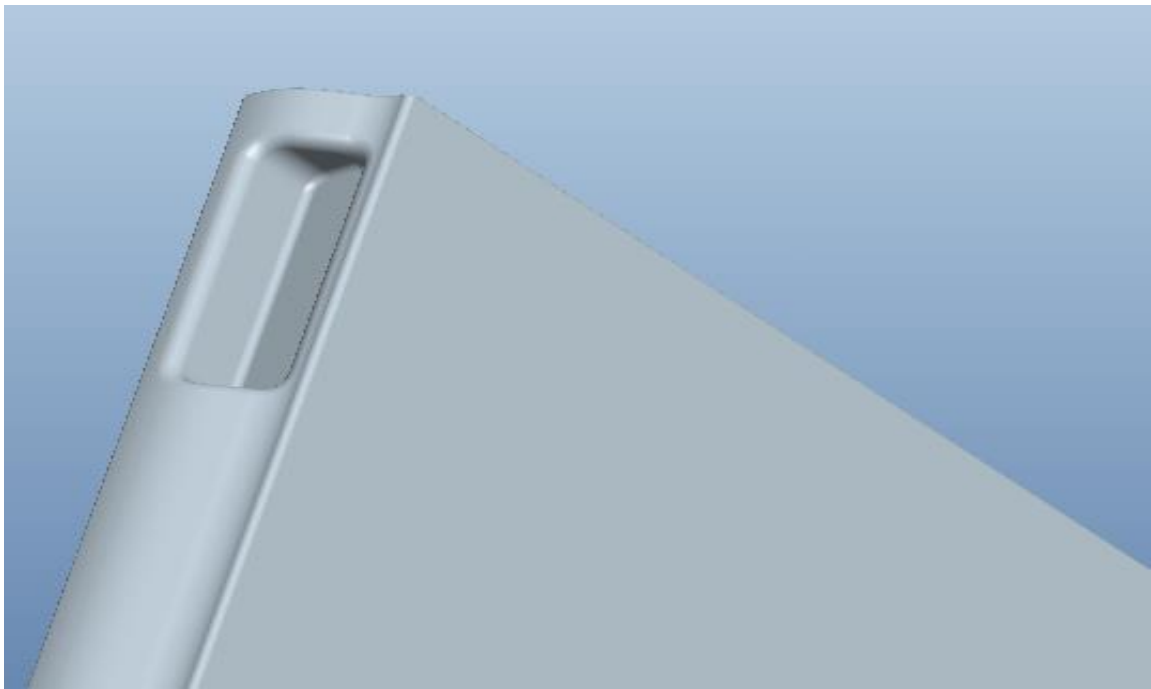
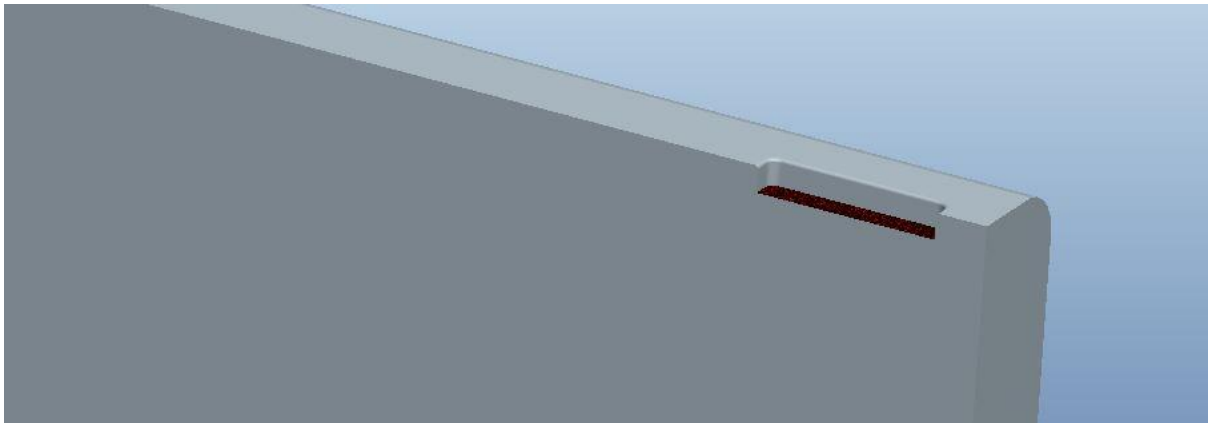
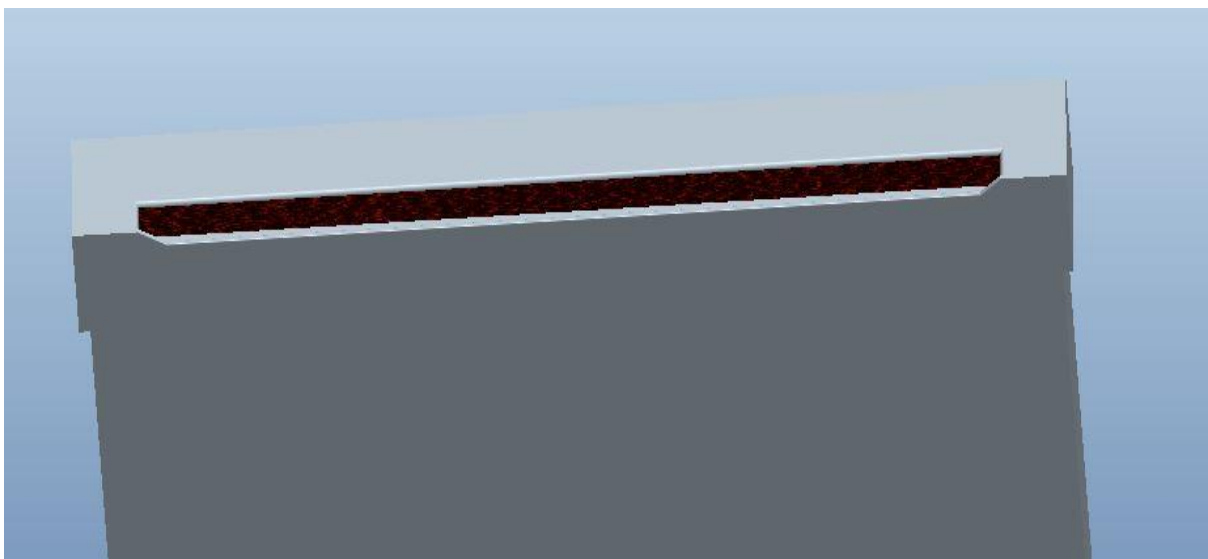


Figure 4.6: Enlarged view of door handle

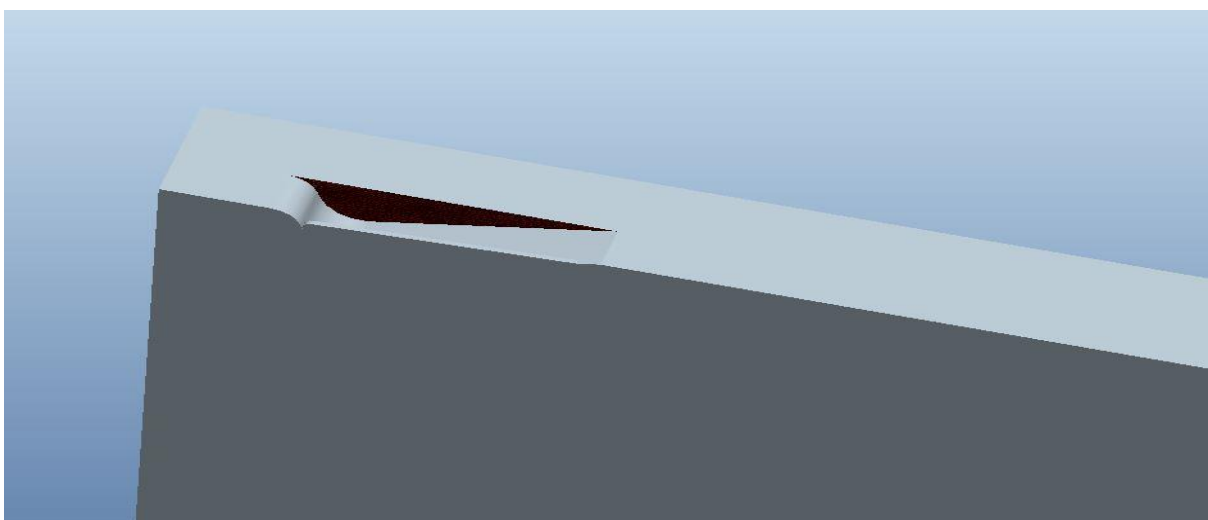
Some other designs of door handle which are made earlier and choose the best from all designs.



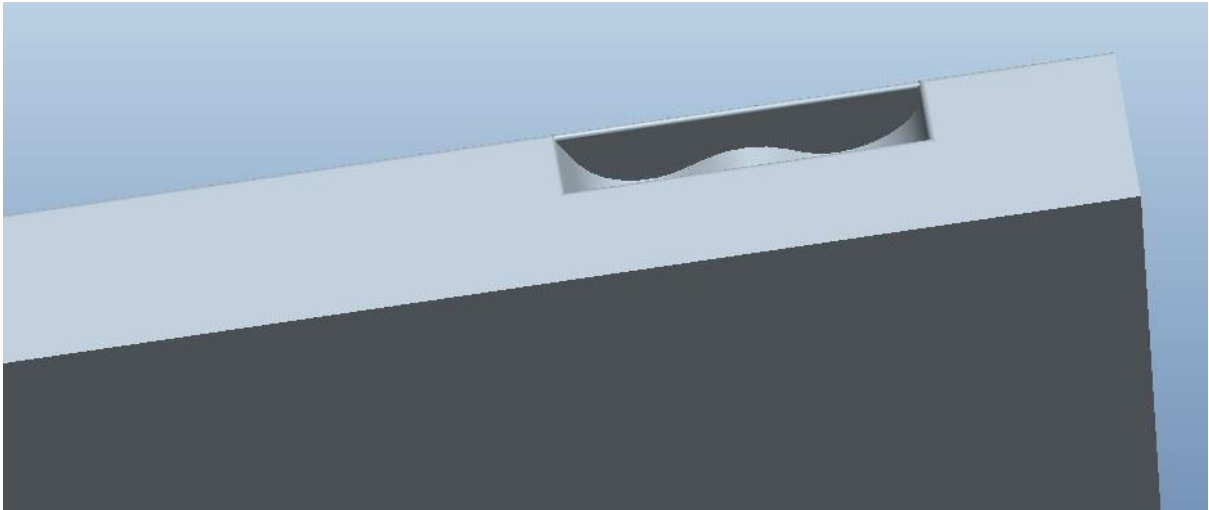
Side pocket handle (a)



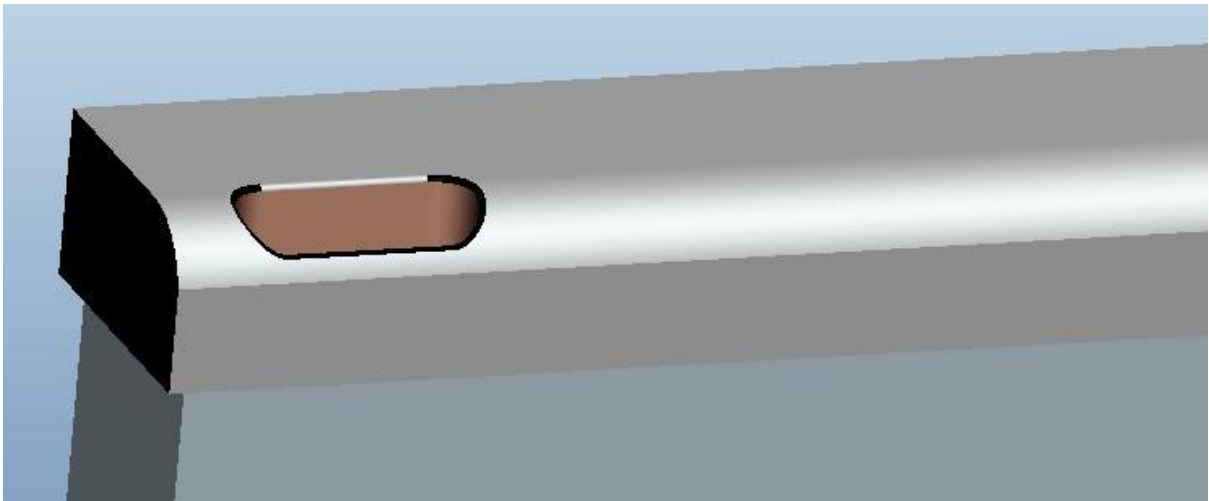
Through pocket handle (b)



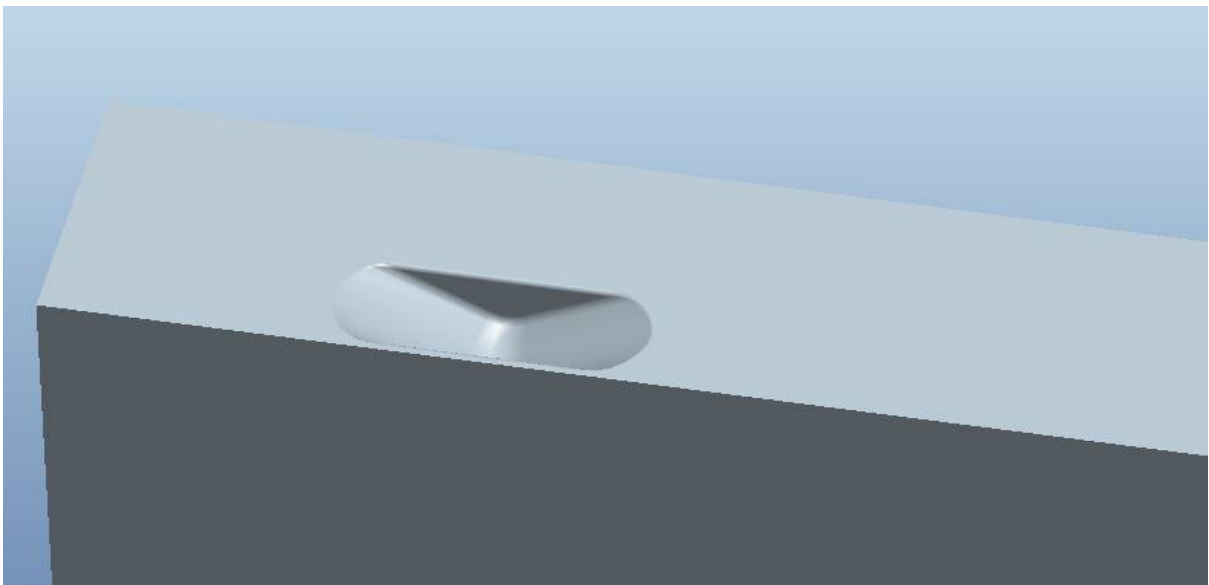
Curved handle(c)



Wave type handle (d)



Round pocket handle (e)



V shape handle (f)

Figure 4.7: Different designs of pocket door handle

### 4.3.3 Bottle Chiller

#### Important observations:

1. The feature of chiller is not a long term desirable feature for customer of this range of refrigerator.
2. Cost of installation is high.
3. Repair and maintenance is cost is high.
4. Occupy 5.85 Litre volume space. Which is more important and can be utilised for more number of bottles.
5. Door of chiller general breaks due to weight of bottles and this can't be replaced easily because of availability and high cost.



Figure 4.8: Bottle chiller

### 4.3.4 Top Hinge Cover

#### Important Observations:

1. Extra material was used on the top hinge cover and size is very large.
2. Cost is to be reduced by some modifications in the design.
3. Aesthetically looks are not so good because this cover up the large area at one corner and height is also large.



Figure 4.9: Existing Top Hinge Cover

**Cost of hinge cover – INR 4.77 per ref.**

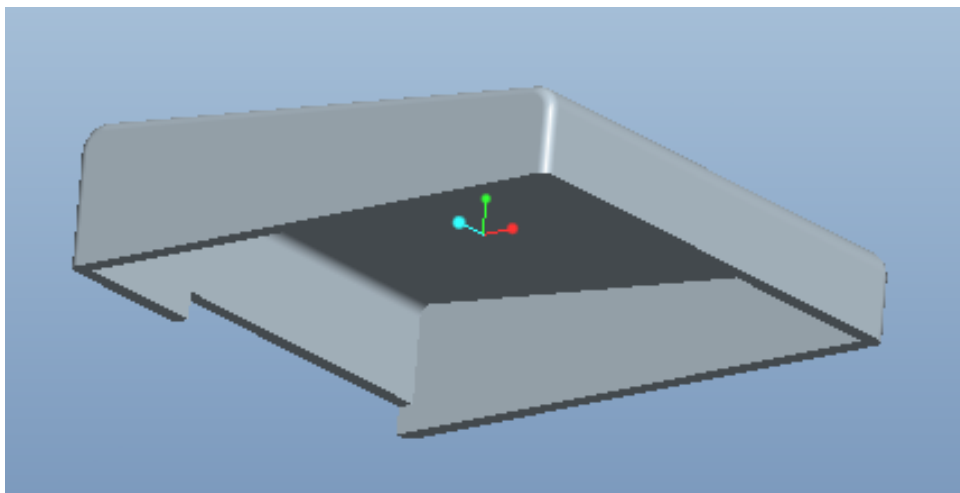


Figure 4.10: Proposed Top Hinge Cover

### 4.3.5 Low Cost, New Age Glass Shelf

#### Important observations in existing Design

1. Existing plastic frame degrade and become yellow after some time.
2. Existing plastic frame reduces the see-through area of shelf and hence give a feeling of tight space.
3. More space wastage in thick plastic frame.



Figure 4.11: Existing Glass Shelf

Cost of glass shelves – INR 131.82 per Refrigerator

#### Important observations for new proposed design:

1. By using frameless glass shelf, the cost of the glass shelf is reduced by INR 7 (approx.).
2. New silicon rubber (or any suitable soft rubber) frame can be used like bumper guard for glass edge. Rubber will work as a protection (similar to existing plastic) and make it safe from slip and breakage.
3. Aesthetics are improved and give more spacious feel by using only glass shelf.
4. High loading capacity (14 kg) even without plastic frame (no compromise with strength of the shelf).

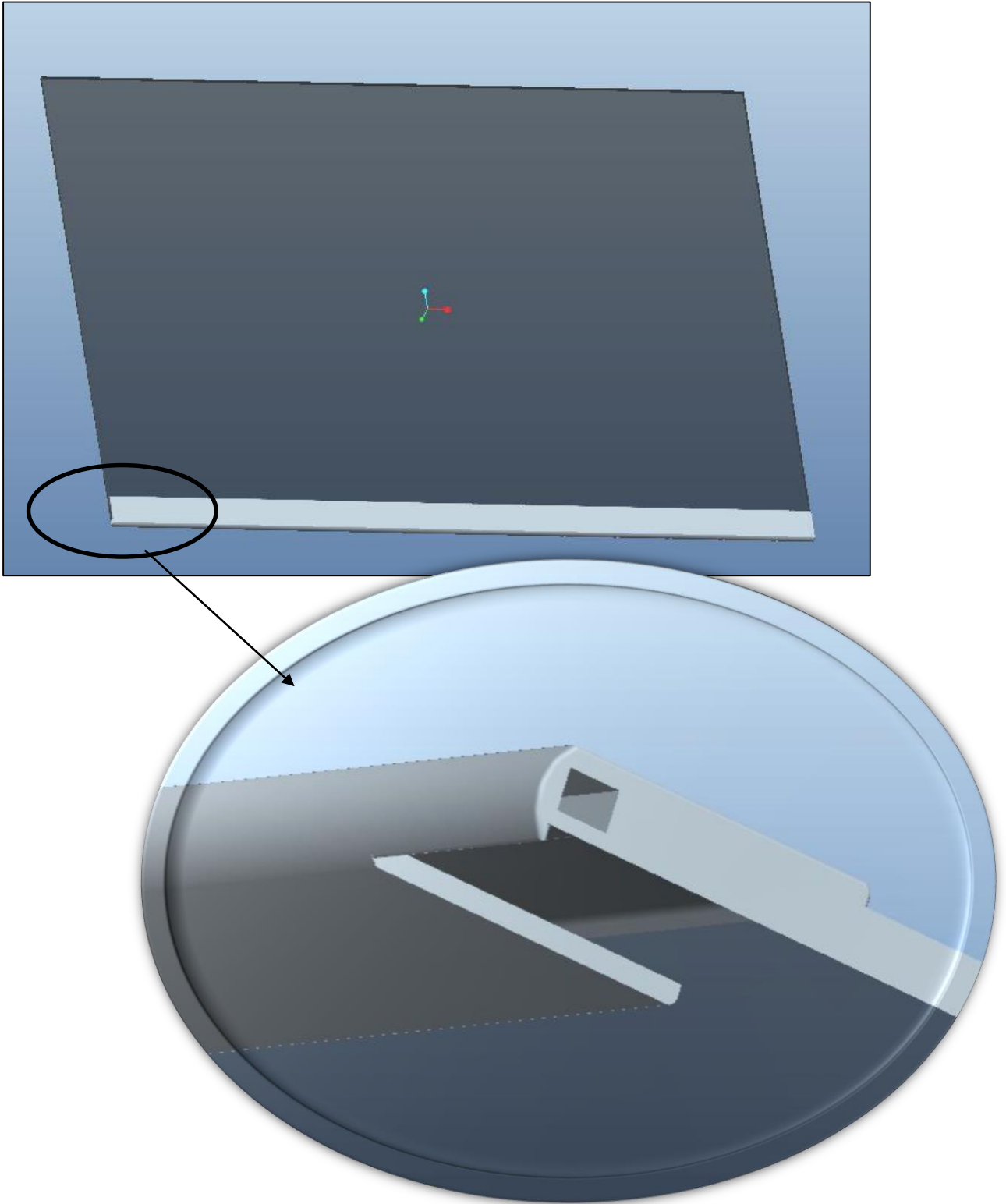
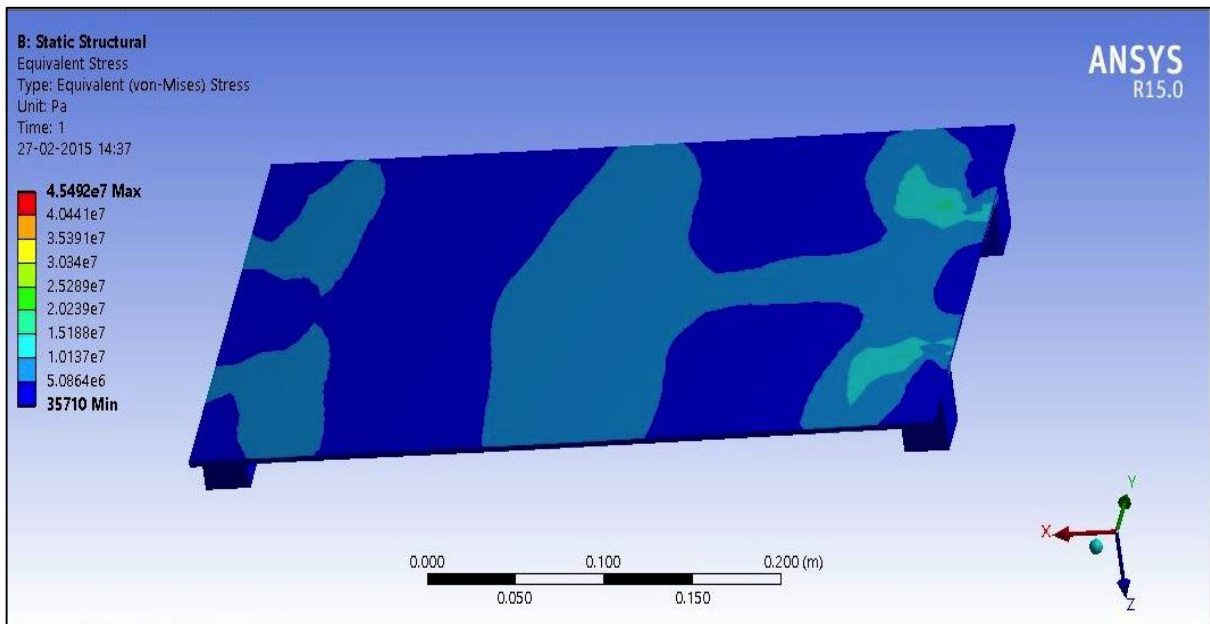
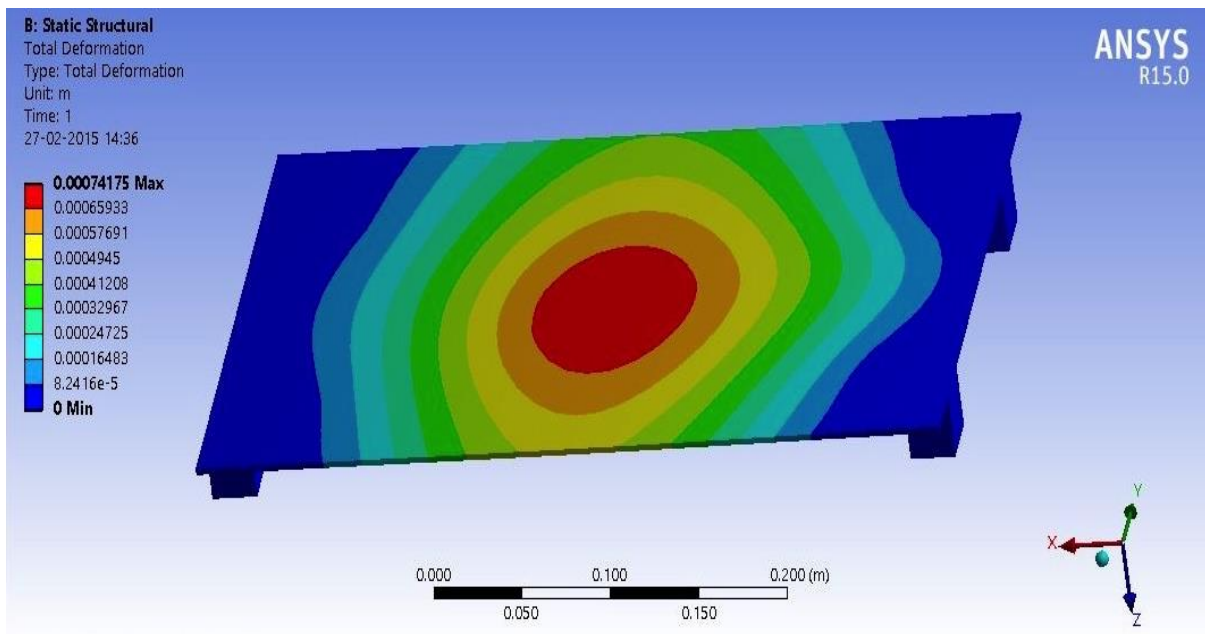


Figure 4.12: New Age Glass Shelf



Equivalent stress on glass frame by load of 14kg  
 (Yield strength -  $2.14 \times 10^8$ )

Figure 4.13: Equivalent stress on glass frame



Total deformation of glass shelf is **0.7mm** on loading **14 kg** on thickness of 3mm glass.

Figure 4.14: Total deformation on glass shelf

## 4.4 Feature analysis and space improvement

Some of features are discussed from value engineering point of view, new feature are proposed which are less in cost, improve overall aesthetics, give more available space for utilization or facilitate the customer with batter usage to increase satisfaction..

### 4.4.1 Tray Adjustment Liner

Important observations for existing design

1. Present cabin consists of shelf supporting ribs protruded within the cabin shell, which creates hindrance to the available free space.
2. Extra support ribs provided for optional adjustment looks anaesthetic.
3. Present design gives limited flexibility for shelf adjustment as per probable need of customer.
4. Calculated space wastage is approx. 4995 cm<sup>3</sup> in available cabin volume.



Figure 4.15: Existing design of refrigerator cabin

### **Important observations of new proposed design:**

1. Newly designed foldable support members.
2. More available space approx. 4995 cm<sup>3</sup>.
3. New design for tray adjustment improve the aesthetics of refrigerator and utilise more of available space.
4. Easily replaceable, as the assembly is separate unit.
5. More flexibility as large no. of shelf shifting options can be provided.
6. New foldable support structure can bear minimum of 28kg weight on shelf.
7. This design is not used by any refrigerator company till date.

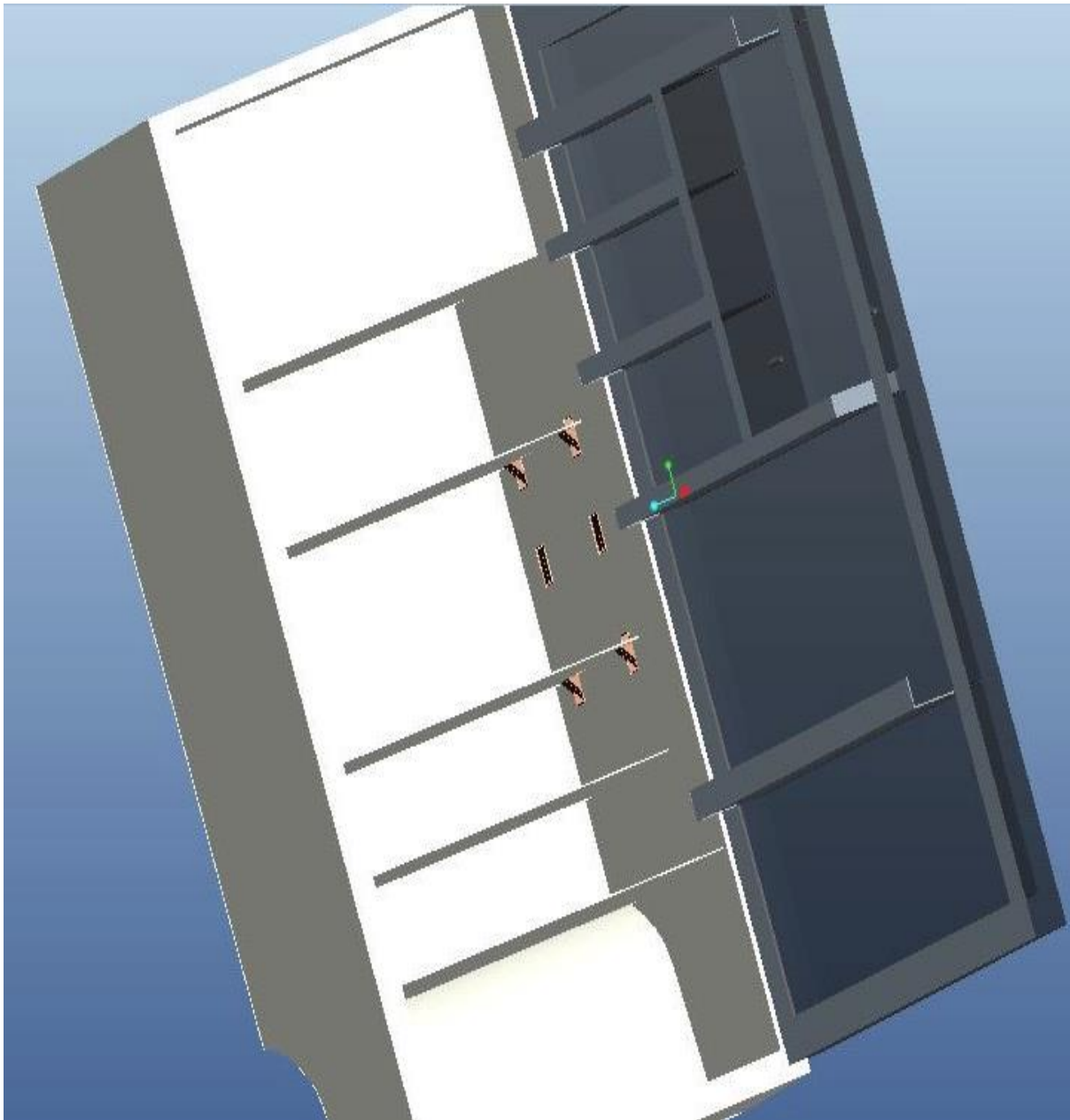


Figure 4.16: New proposed design in cabin

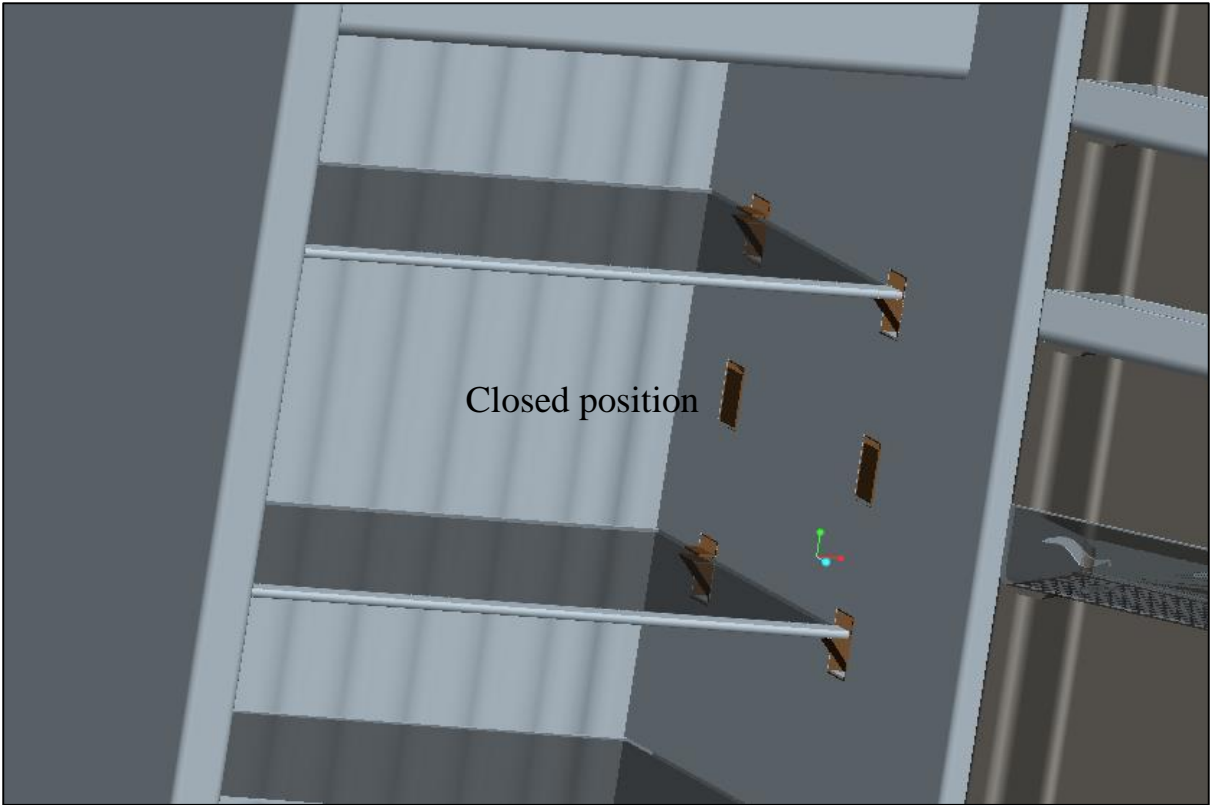
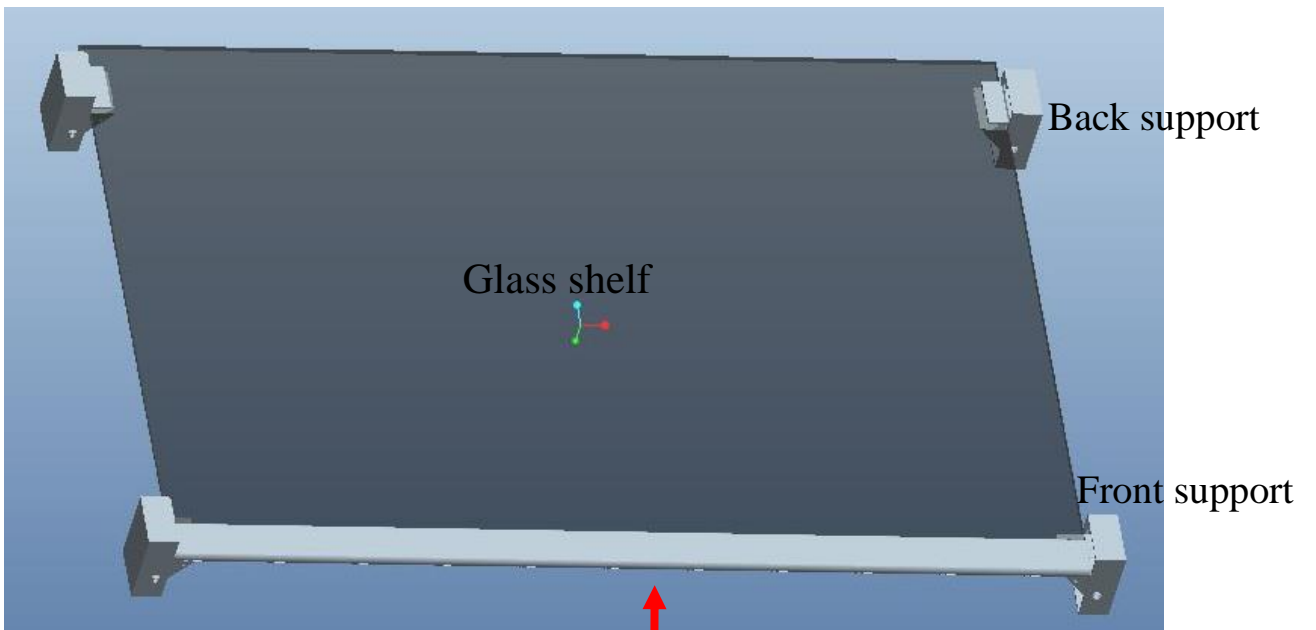


Figure 4.17: Refrigerator interior view



Front view of glass shelf

Figure 4.18: Glass shelf with all supports

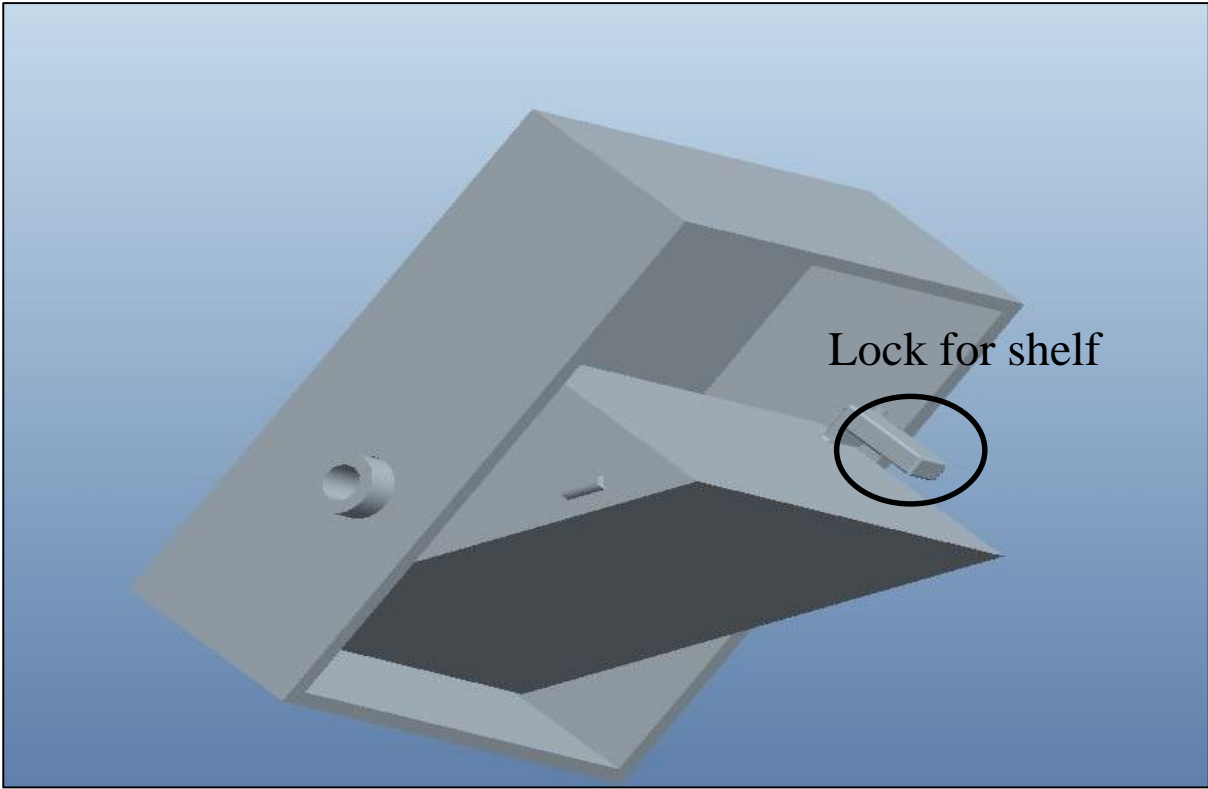


Figure 4.19: Front Foldable Support open position

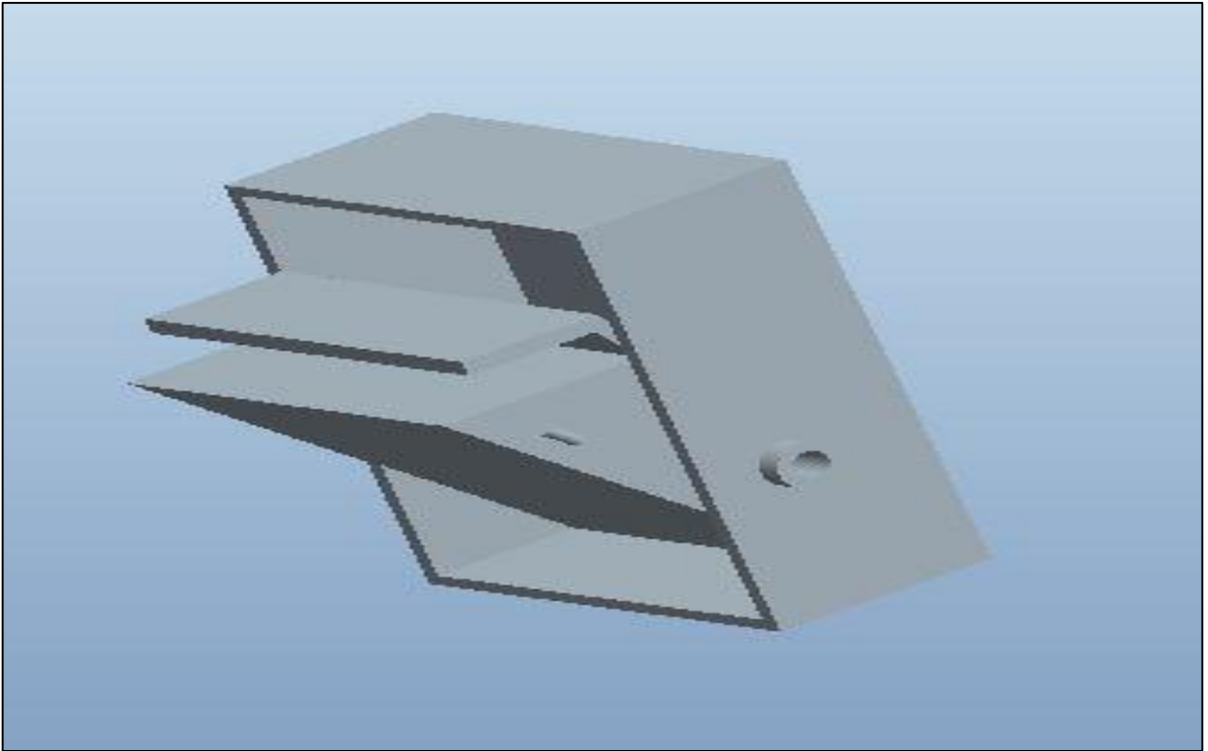


Figure 4.20: Back Foldable Support opened position

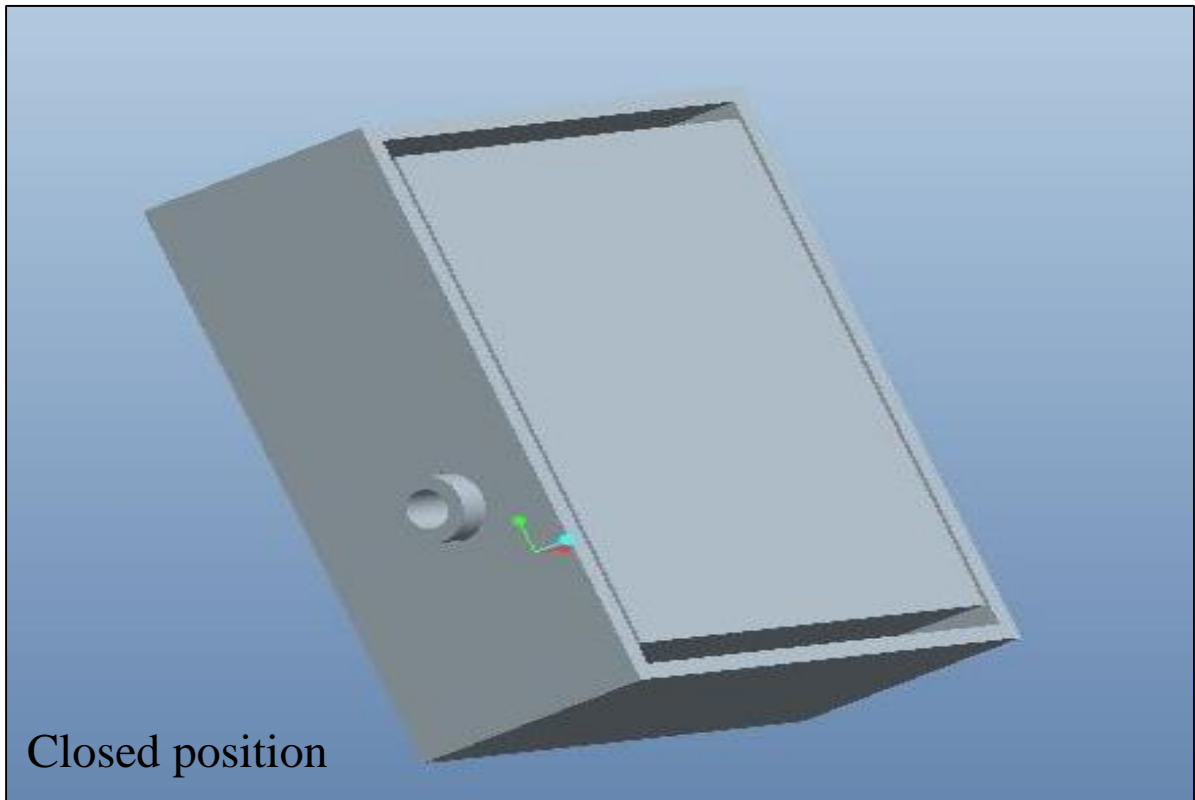


Figure 4.21: Closed Position of support

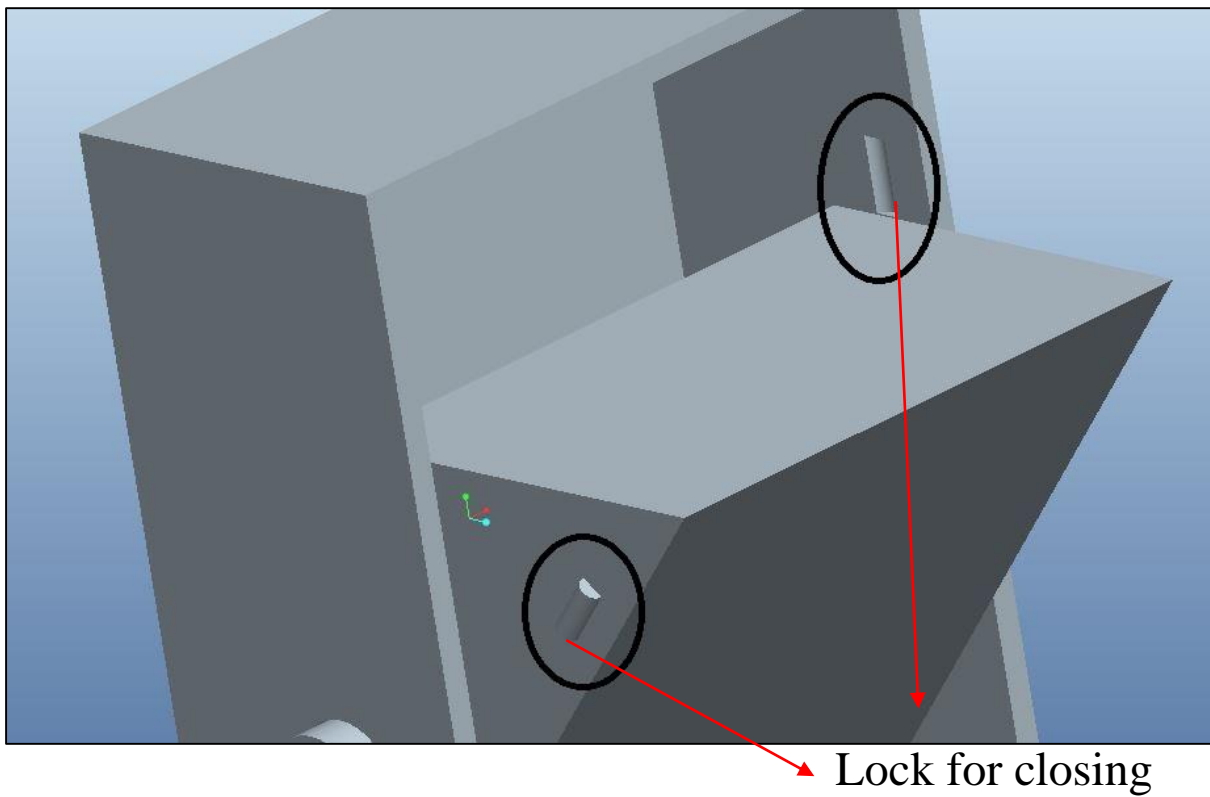


Figure 4.22: Lock for closing the supports

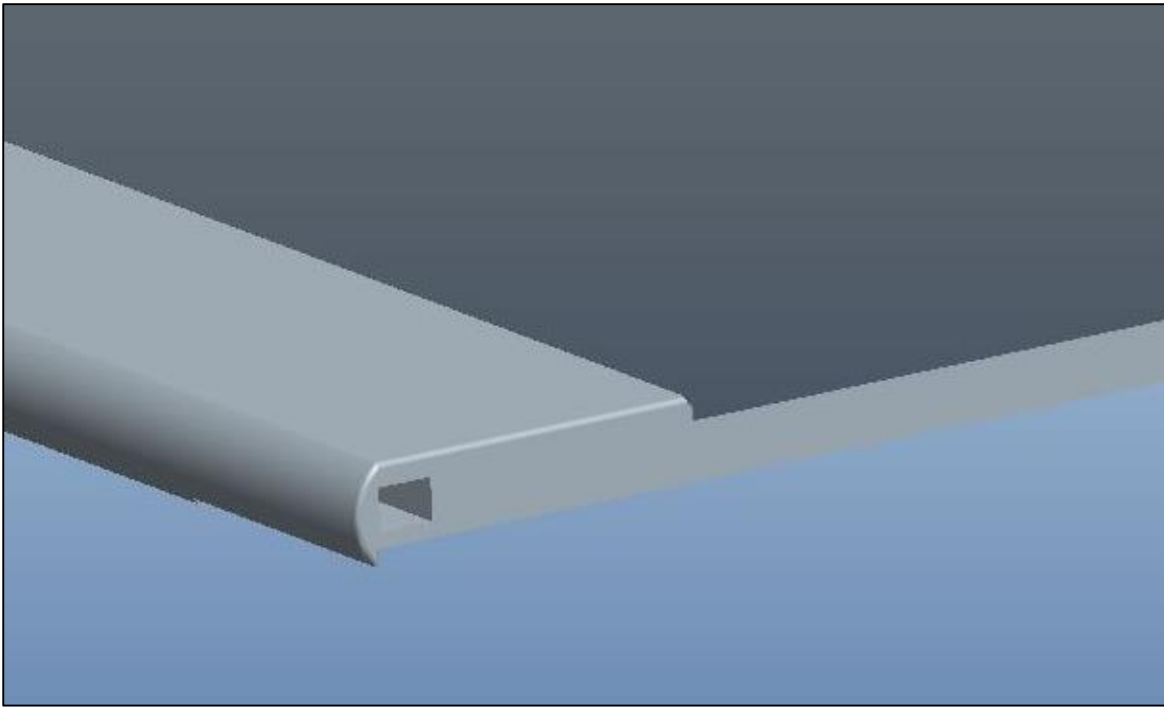


Figure 4.23: Glass Shelf

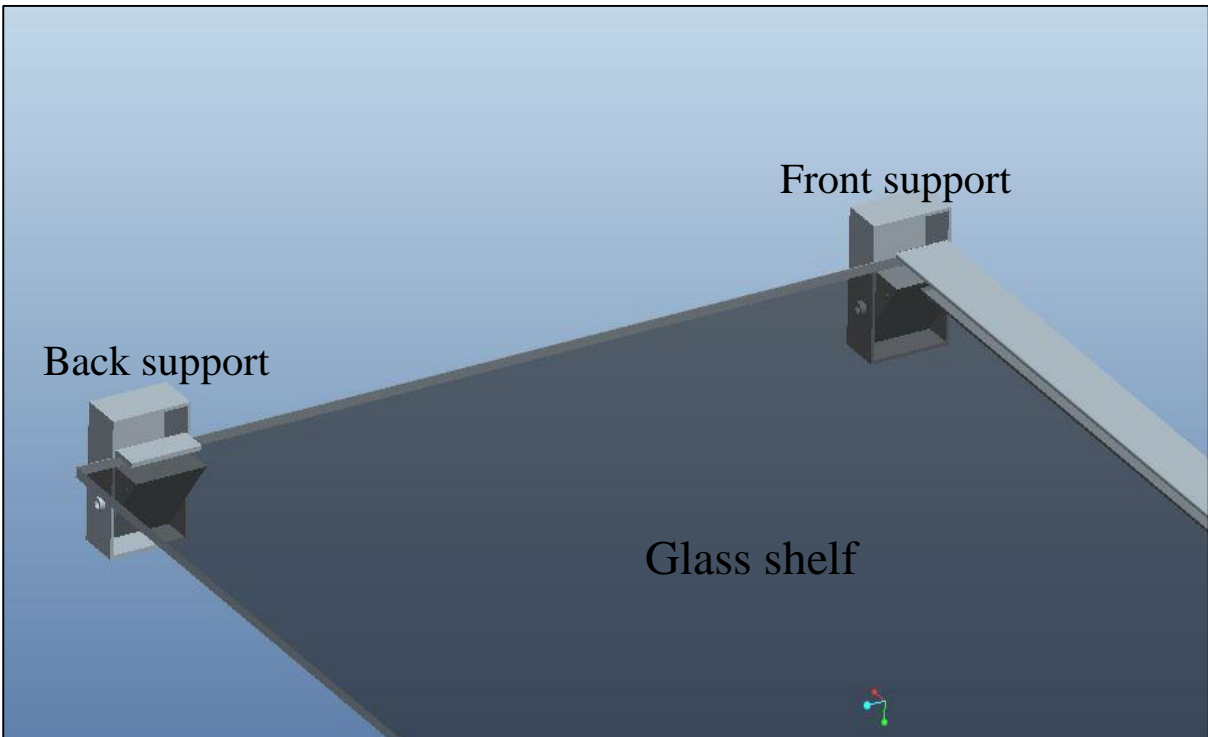


Figure 4.24: Shelf with supports

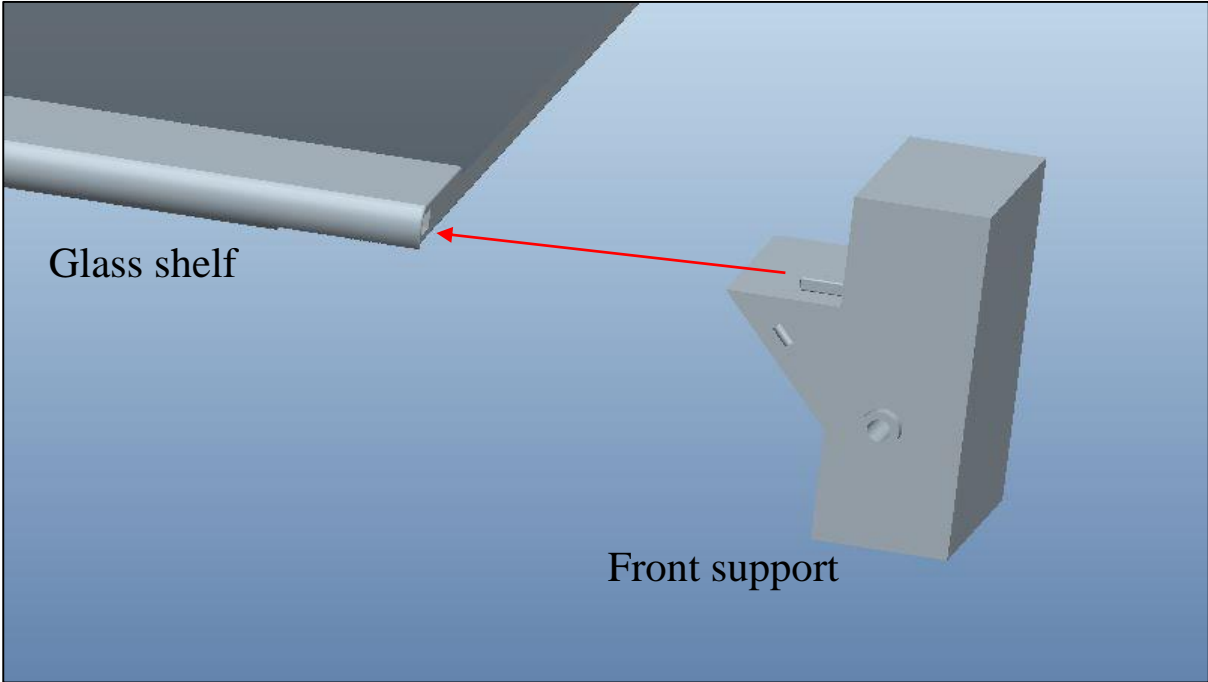


Figure 4.25: Front support fixing

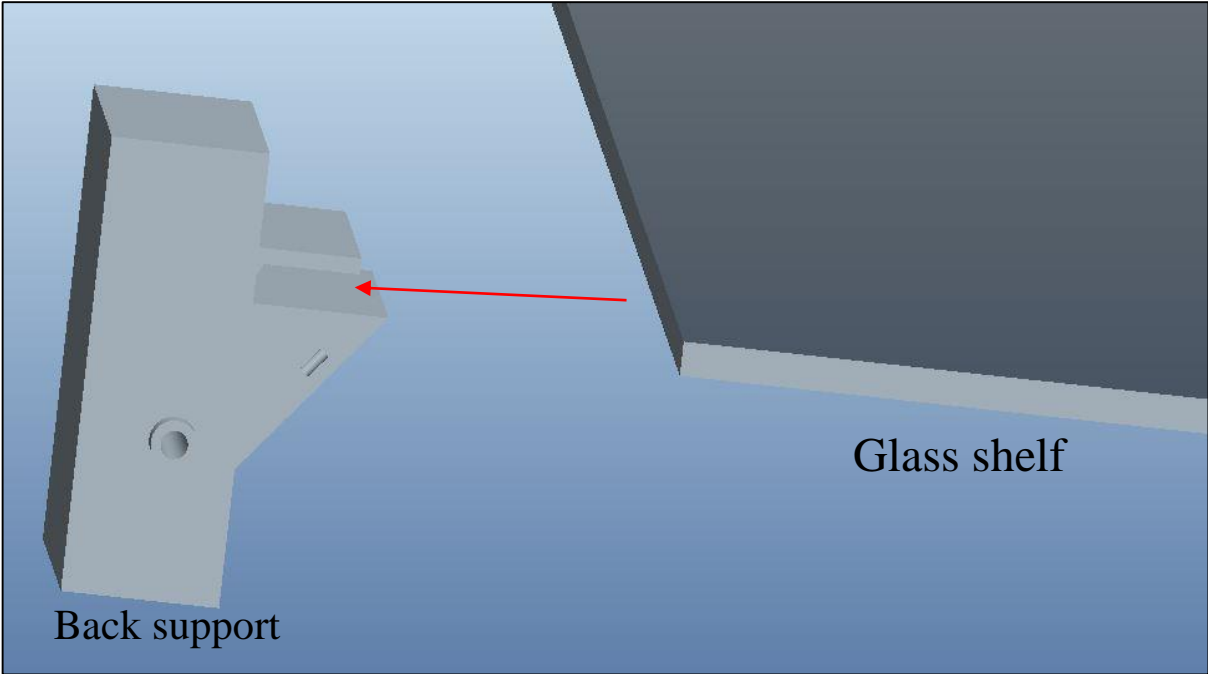
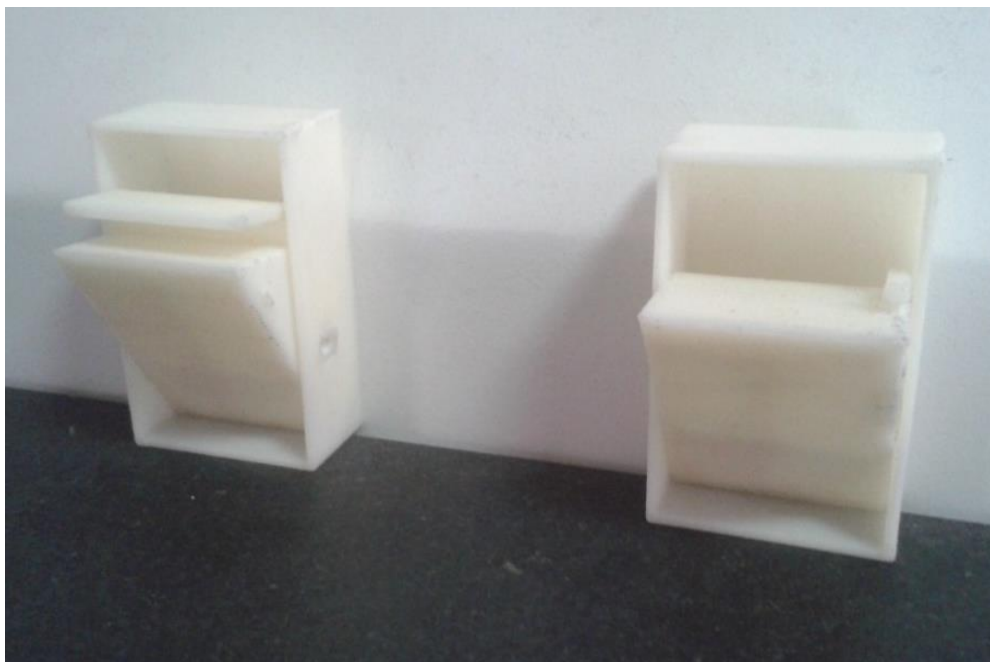


Figure 4.26: Back support fixing

**Prototype of glass shelf supports made by FDM**

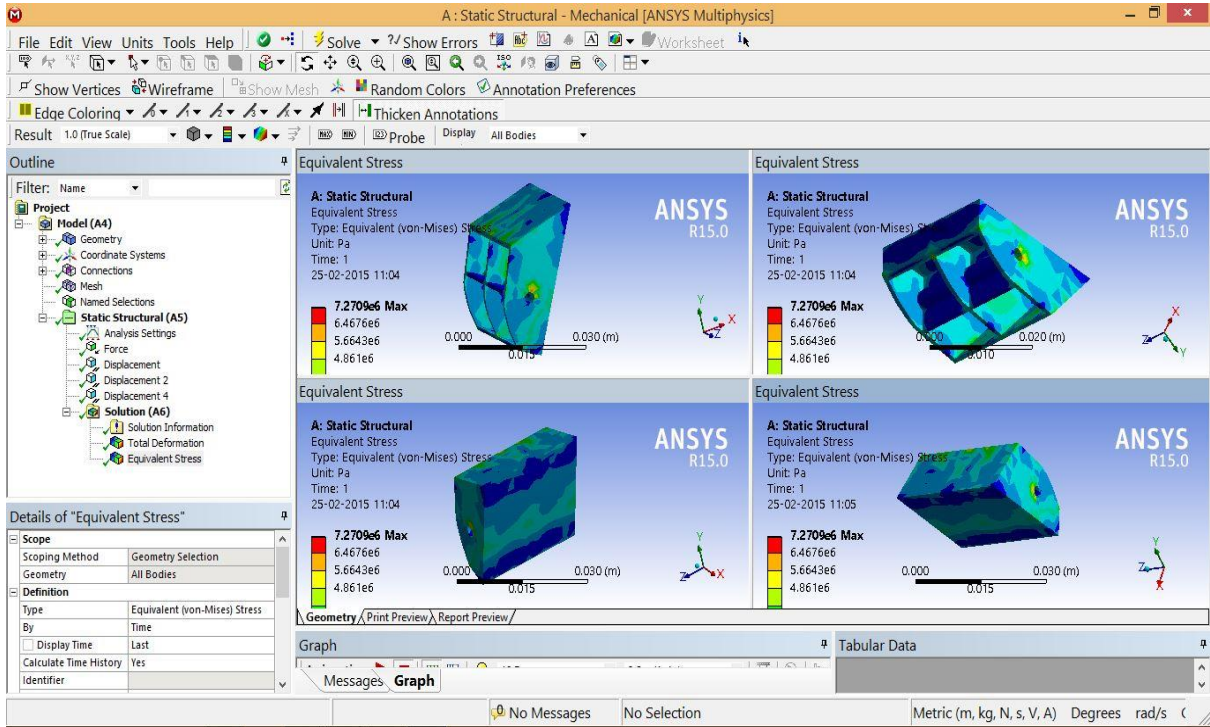


**Closed position (a)**



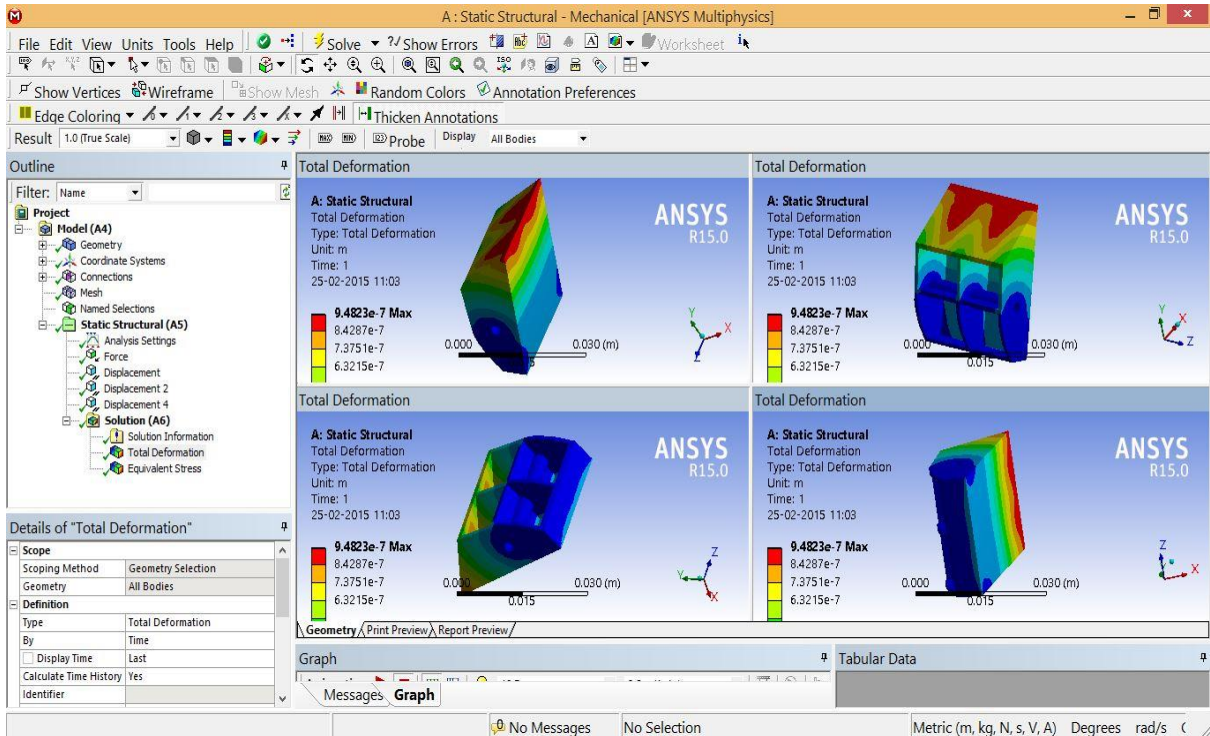
**Open position (b)**

Figure 4.27: Rapid Prototyping Models



Equivalent stress  
(Yield strength- $4.27 \times 10^7$ )

Figure 4.28: Equivalent stress on tray liner



Total deformation by load of 7kg on surface

Figure 4.29: total deformation on tray liner

Other designs for glass shelf adjustment which are not suitable for aesthetics and strength of the glass shelf in the refrigerator

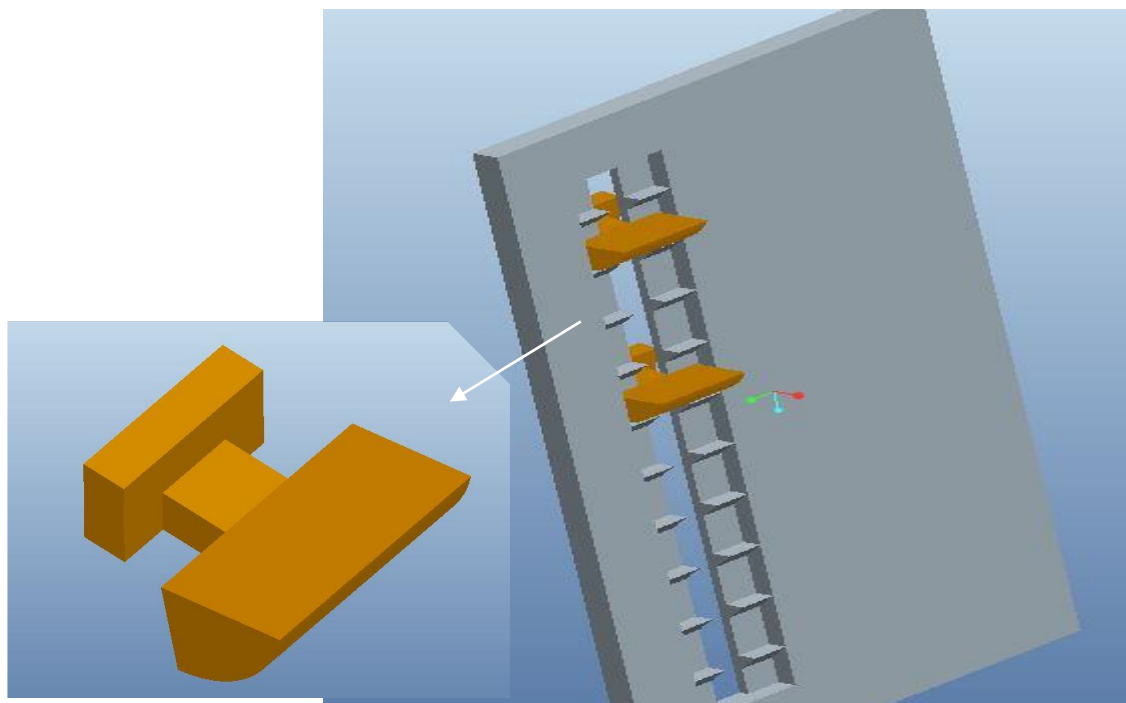
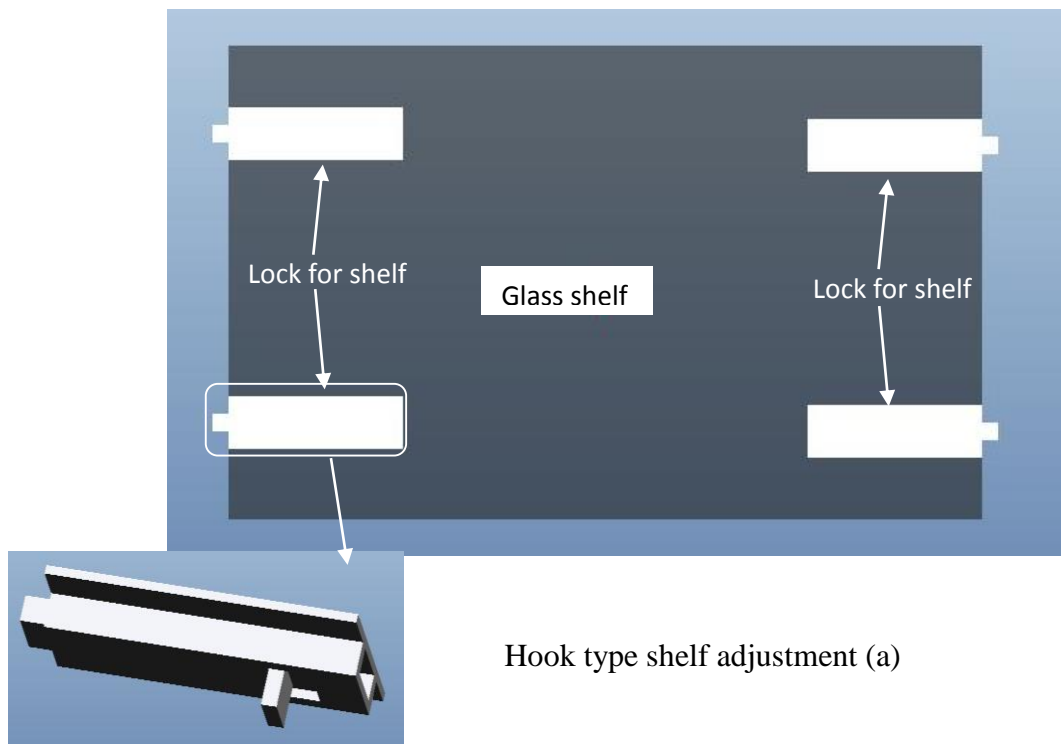


Figure 4.30: Other designs for tray adjustments

#### 4.4.2 Door Stopper for Intermediate Stops (Top hinge)

In current design, door is free to move within its work envelop. During opening we have to hold it for few seconds to stabilize it at any angle. Most of the time momentum of door is high due to bottles and other materials placed in the door. It will hit the nearby objects or wall if present. Although probability of door hit depend upon the location of refrigerator & nearby object but if present then probability of door hit is very high. According to the survey report from the refrigerator users, 52% customer said that this problem is faced by them in daily routine when they put some large size of things like milk container in the refrigerator because both of the hands are busy to grip that container and door open to its full opening position and hit to some object placed nearby.



Figure 4.31: Existing door hinge

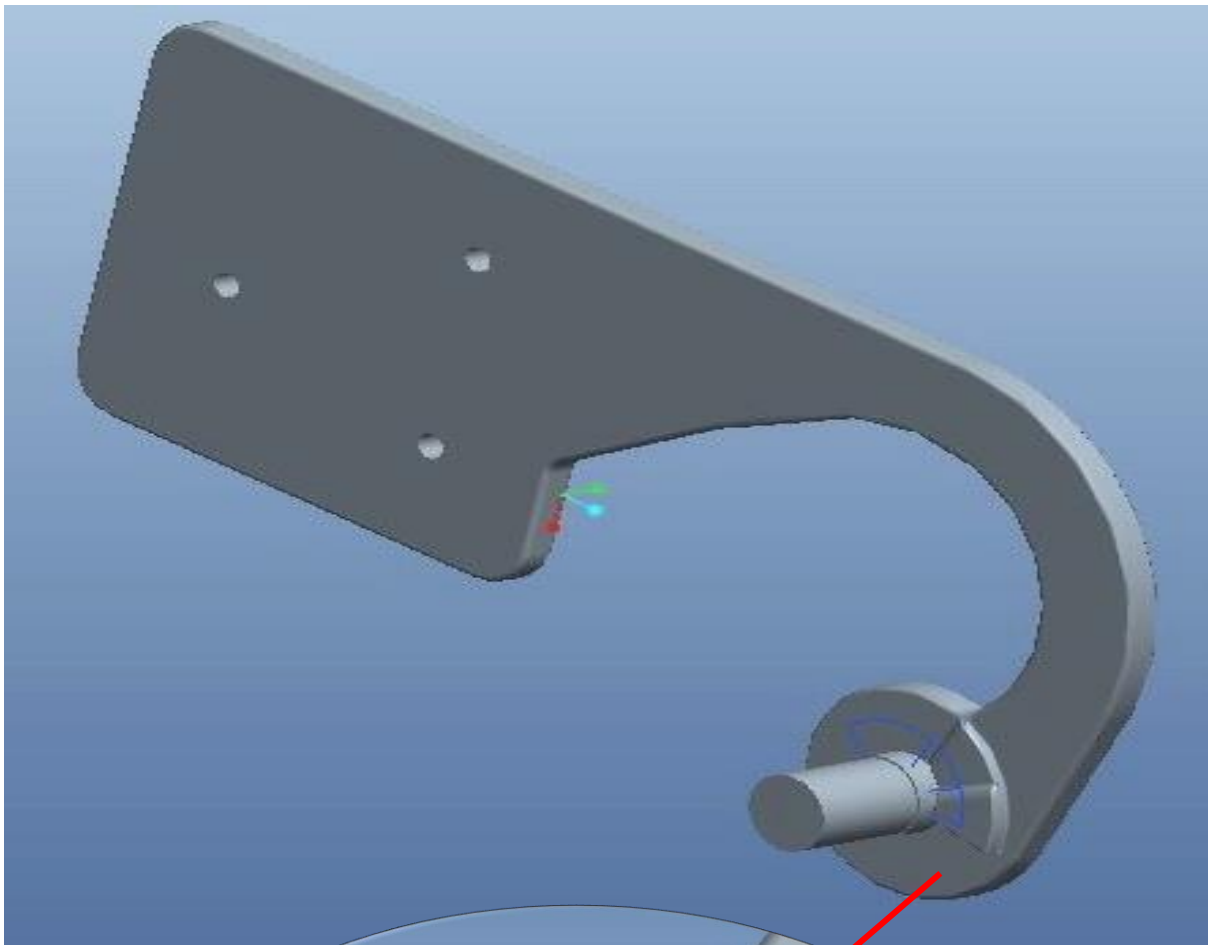
#### Survey report from refrigerator users

<b>Hitting of door while opening</b>	
<b>Yes – 111/213(52%)</b>	<b>No – 102/213(48%)</b>

#### Important observations for proposed design-

1. In proposed design, incremental ramps offer intermediate stops at the designed opening angles.
2. This will give two stops to the door. First is at 70° and second is at 110°.
3. Closing of door is easy (as in old design) and continuous without any stop.
4. Design advantage is more while cost variation is very less.
5. This design is not used by any refrigerator company till date.

## New Door Stopper Top Hinge Design



Path for spring loaded ball

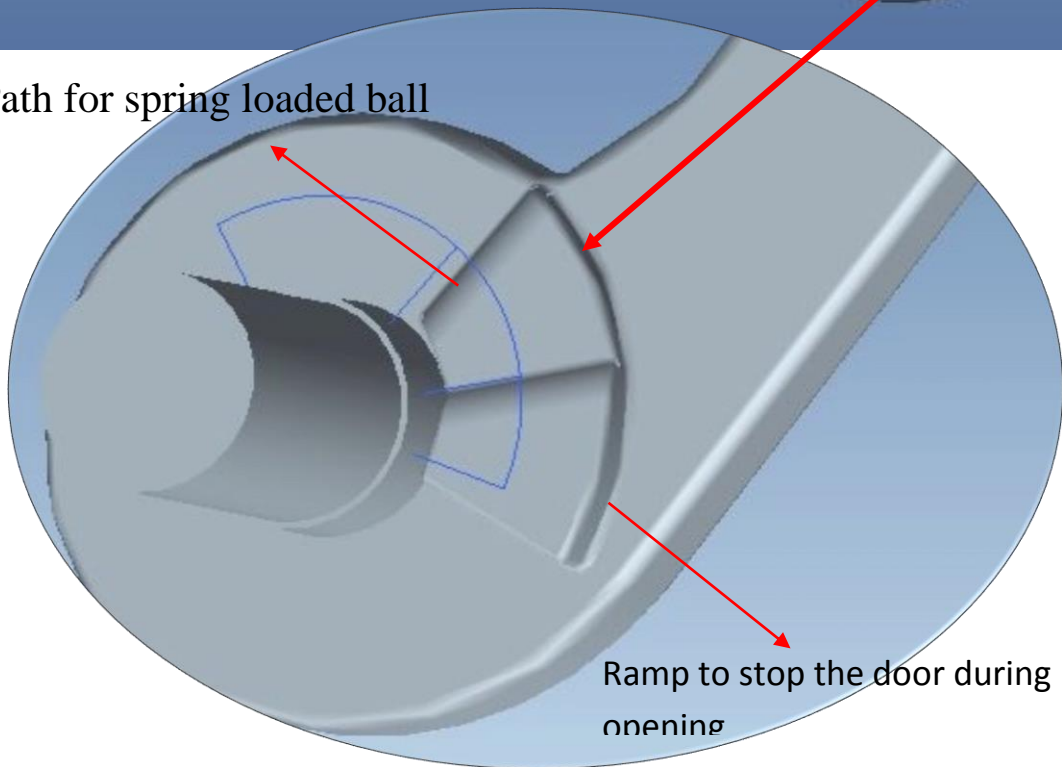


Figure 4.32: New proposed top hinge design

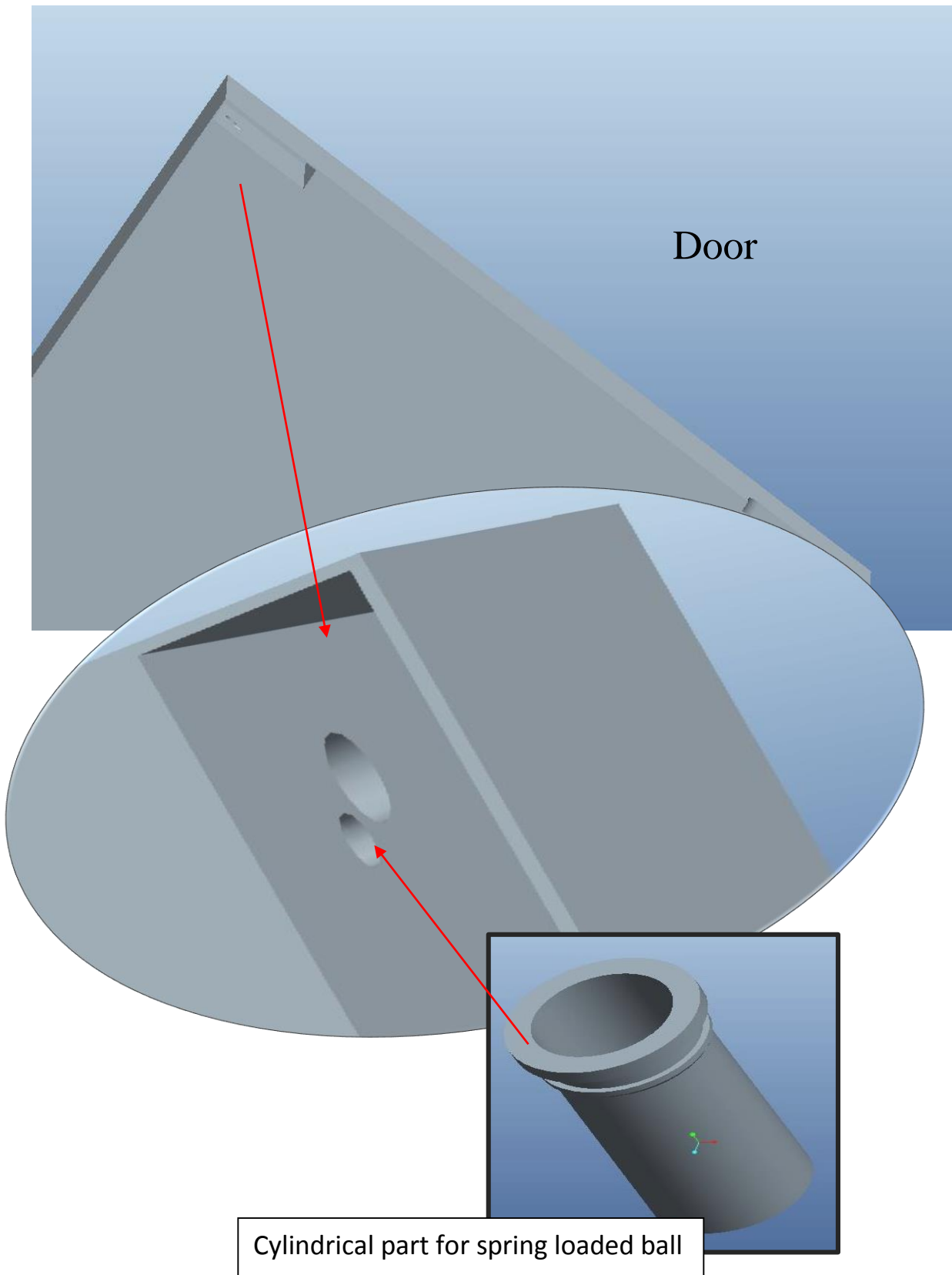


Figure 4.33: Internal parts for this hinge in refrigerator

## Prototype of top hinge made by FDM

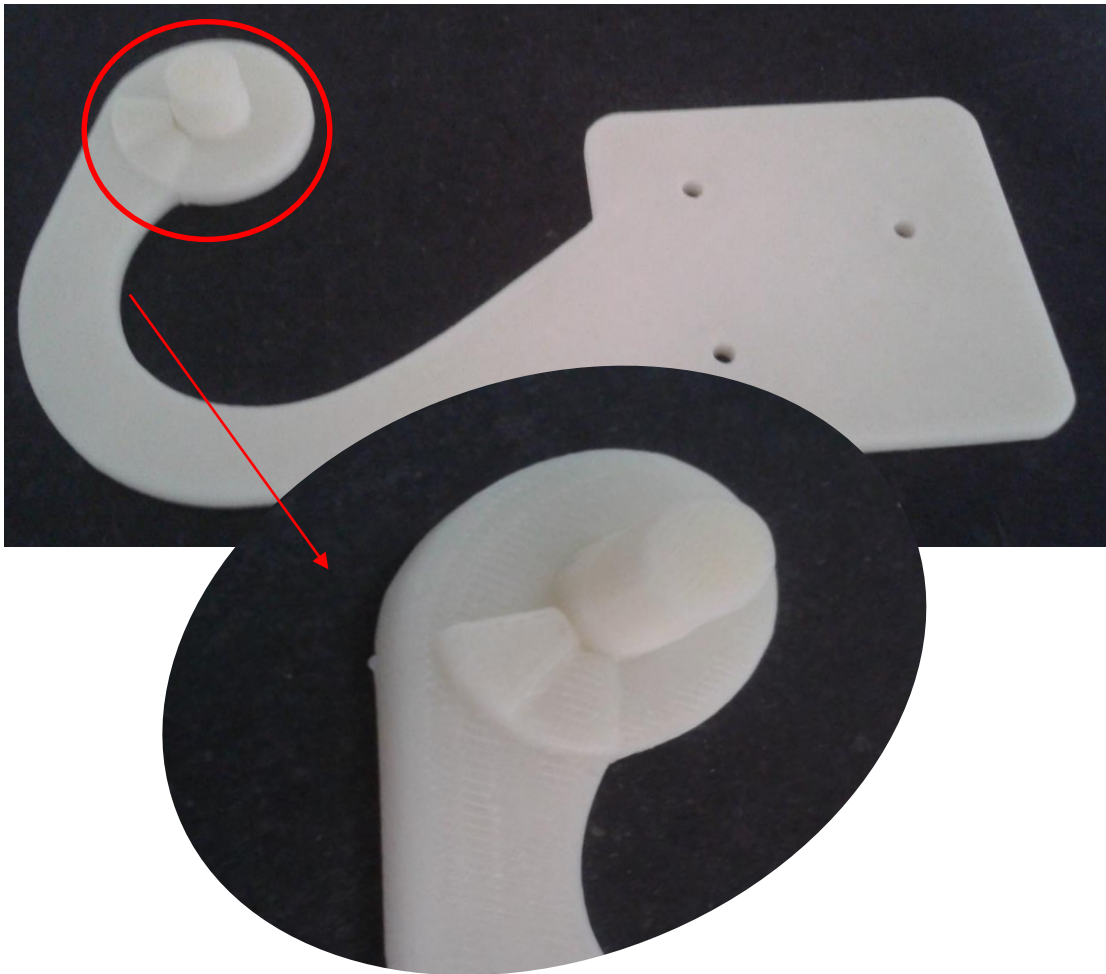


Figure 4.34: Rapid prototyping models of top hinge

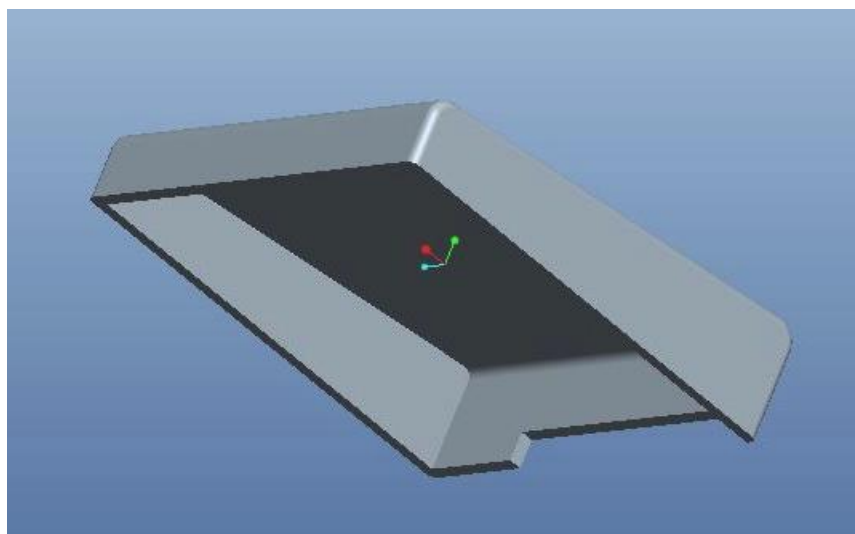


Figure 4.35: Top hinge cover

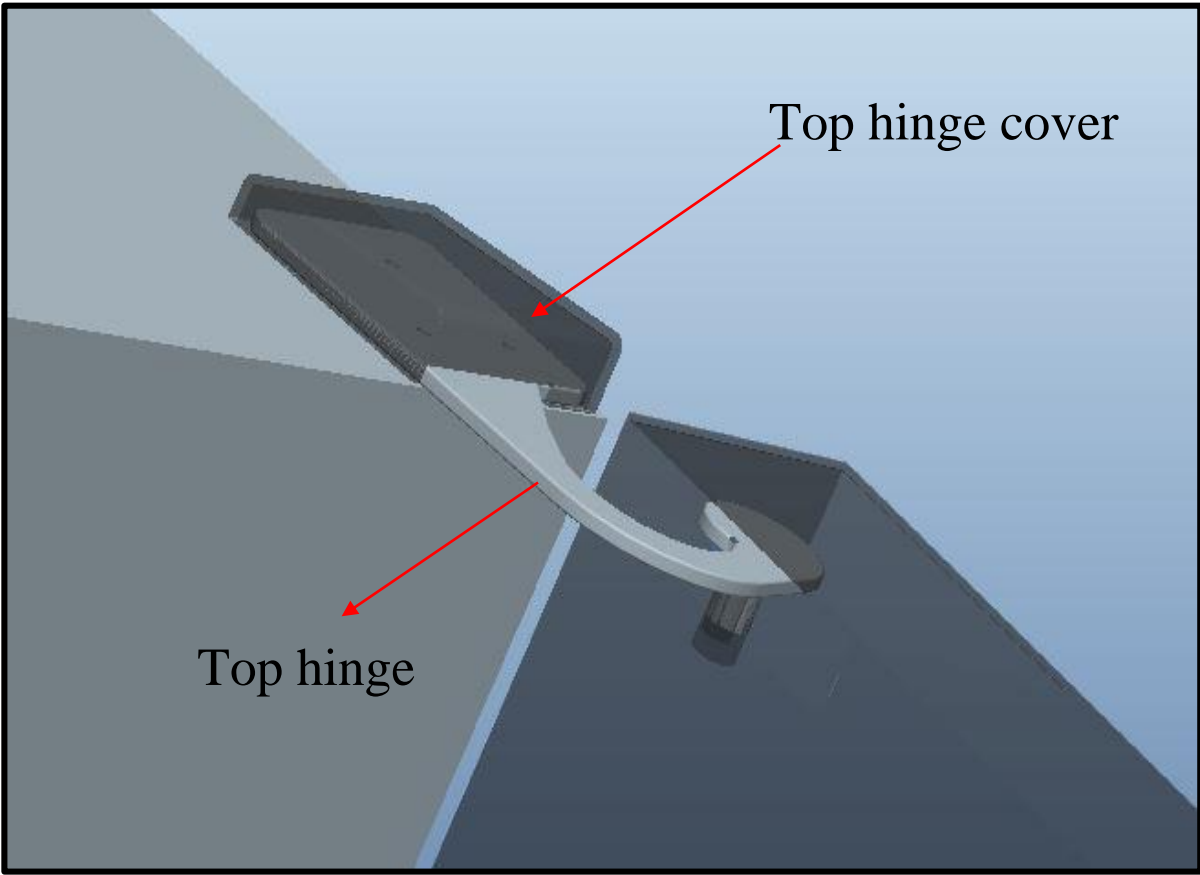


Figure 4.36: Top hinge with cover on model



Figure 4.37: Top view of model with tip hinge

### 4.4.3 Improved Base Support

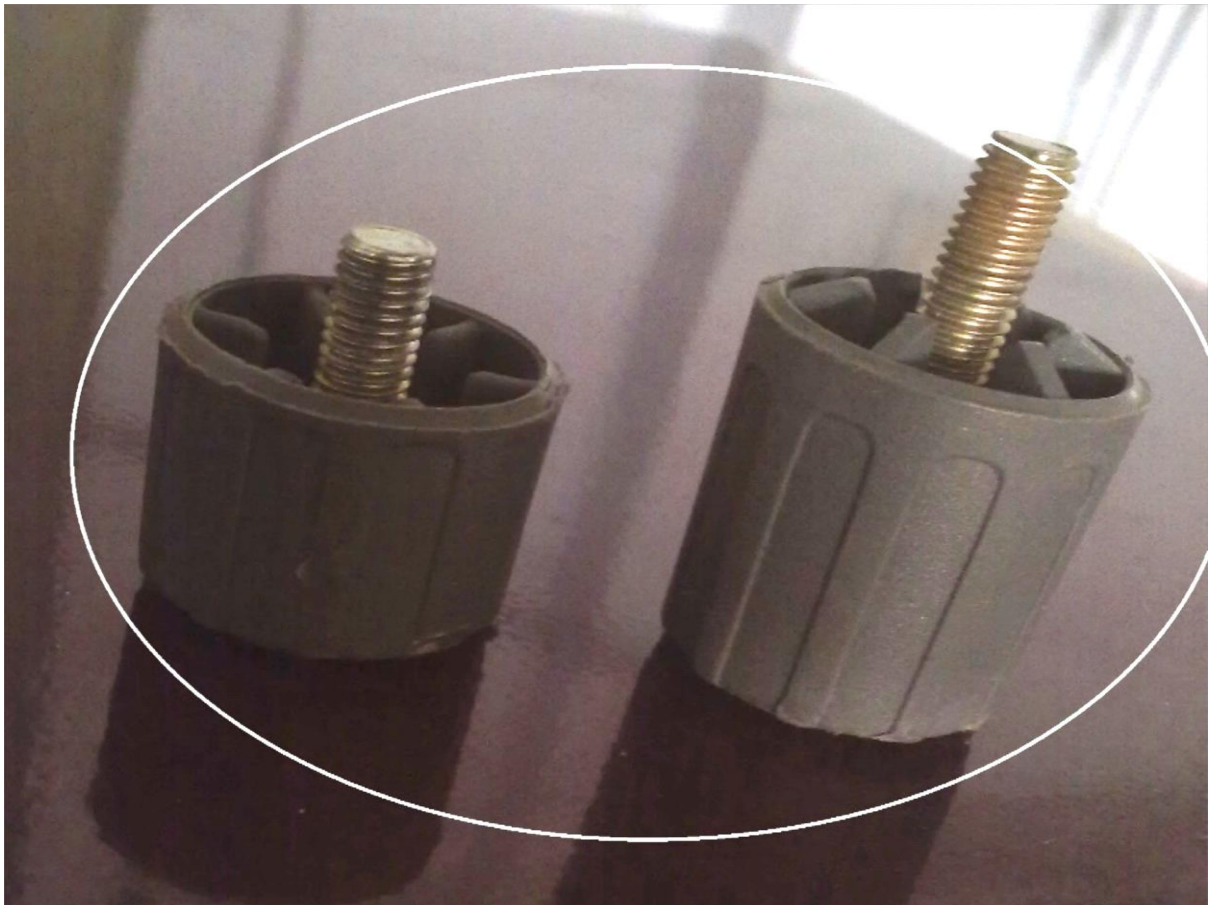


Figure 4.38: Existing Base Support

Survey report from general refrigerator users

<b>Bend/Breakage of supporting leg while moving or shifting</b>	
<b>Yes – 98/213(46%)</b>	<b>No – 115/213(54%)</b>

Survey report from Whirlpool refrigerator users

<b>Bend/Breakage of supporting leg while moving or shifting</b>	
<b>Yes – 42/192(22%)</b>	<b>No – 150/192(78%)</b>

#### **Important observations-**

1. Breakage of legs (base support as shown in fig.) while shifting or moving refrigerator.
2. Old design have very less contact area at holding point.
3. Threads on small diameter (steel bolt) offers high stress concentration during sudden jerk.
4. Bending strength of new part is high.
5. Material saving in new design.

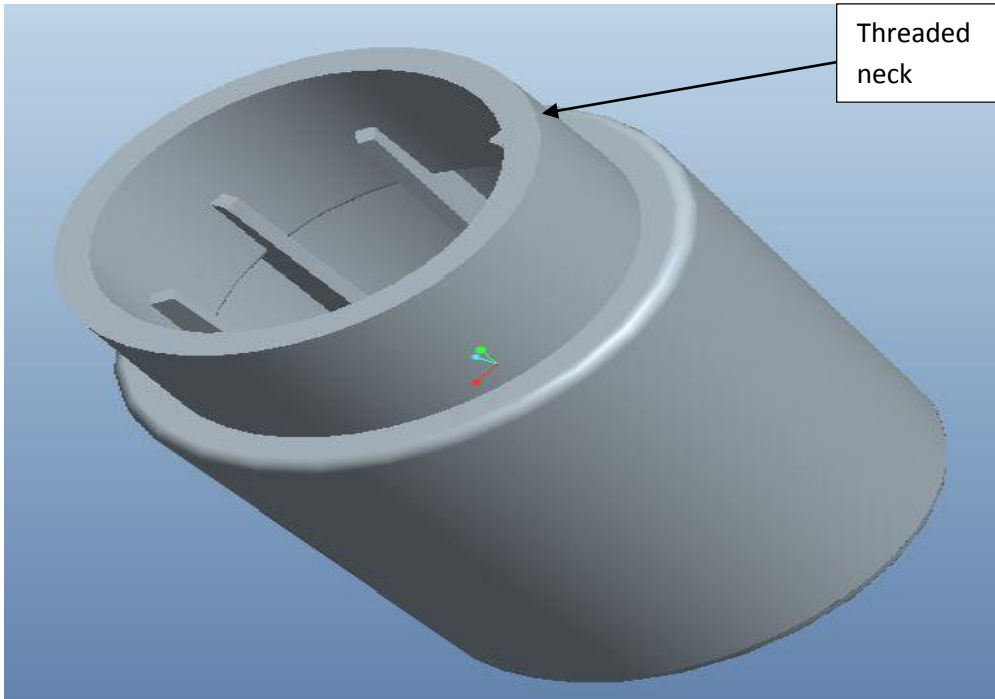


Figure 4.39: New proposed base support

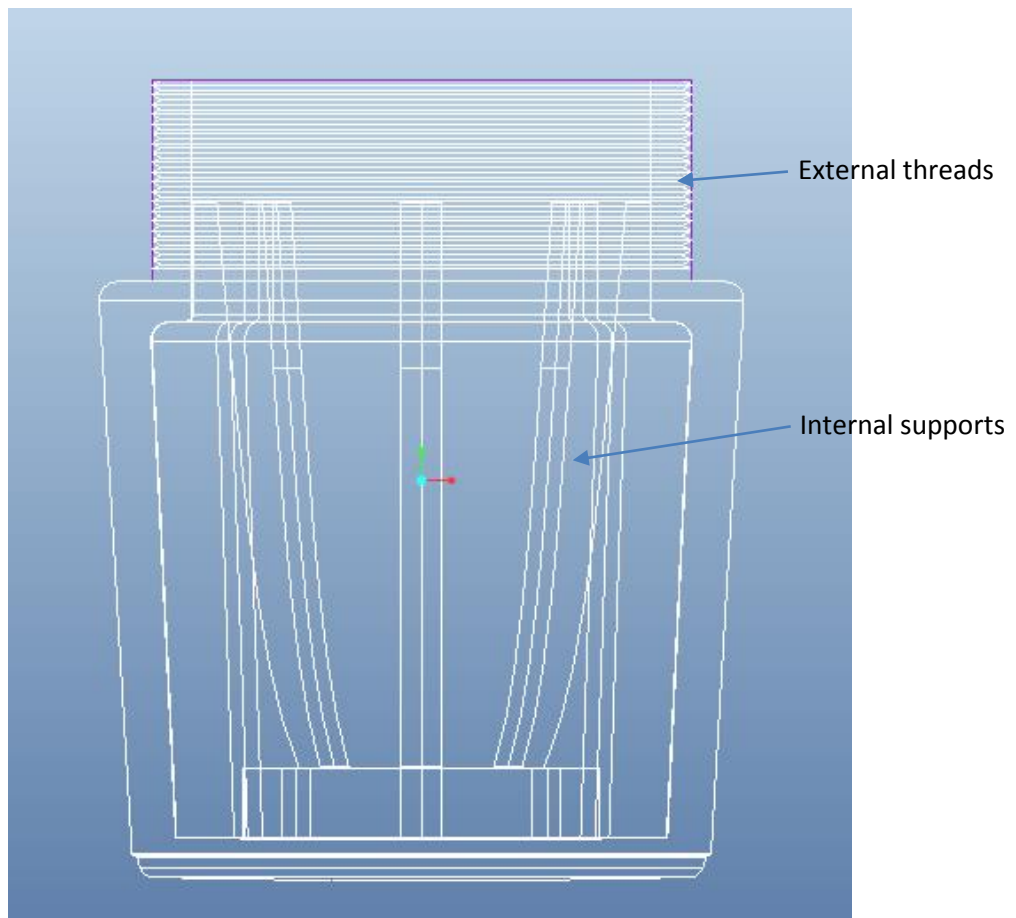


Figure 4.40: New Proposed internal design of base support

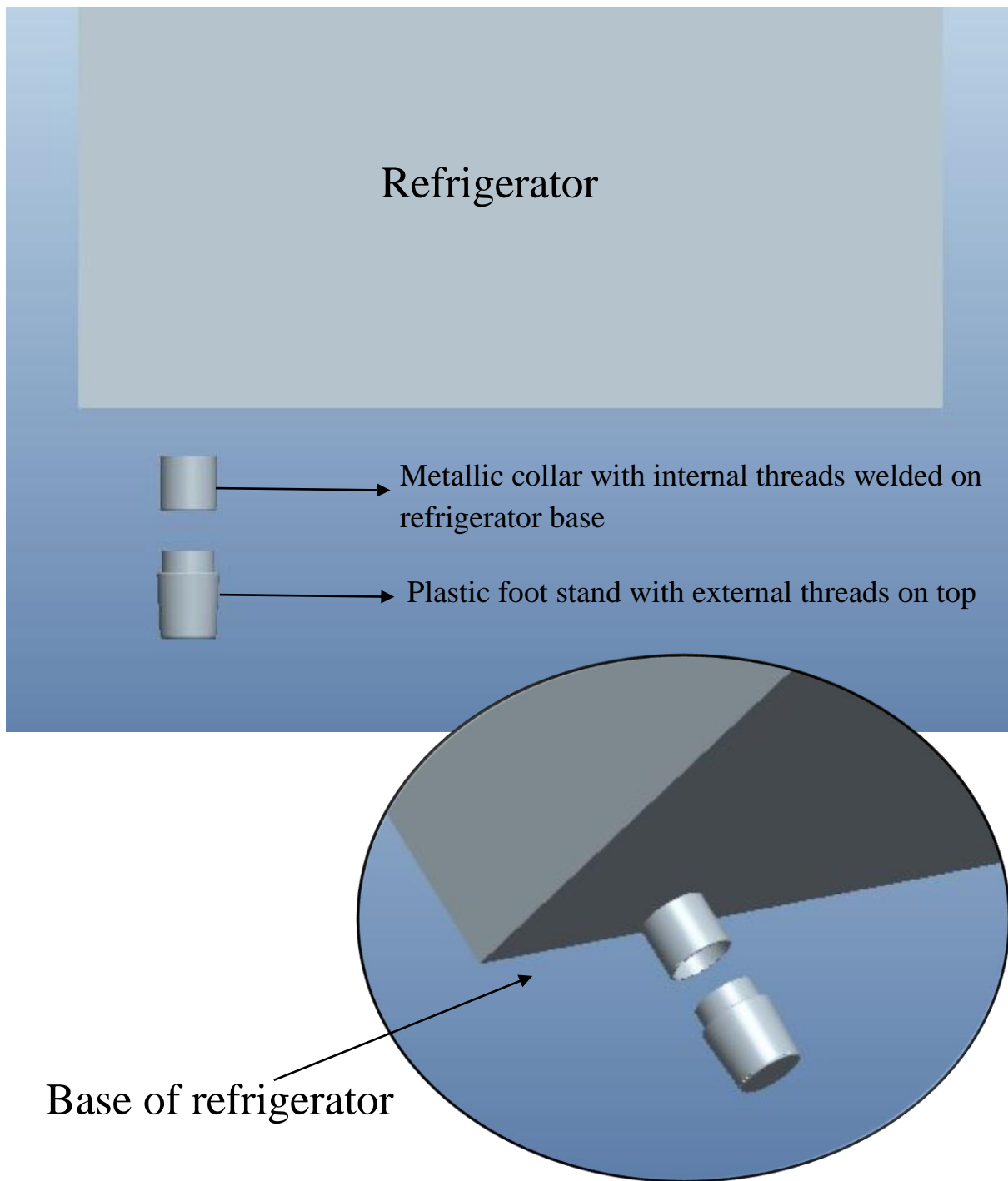
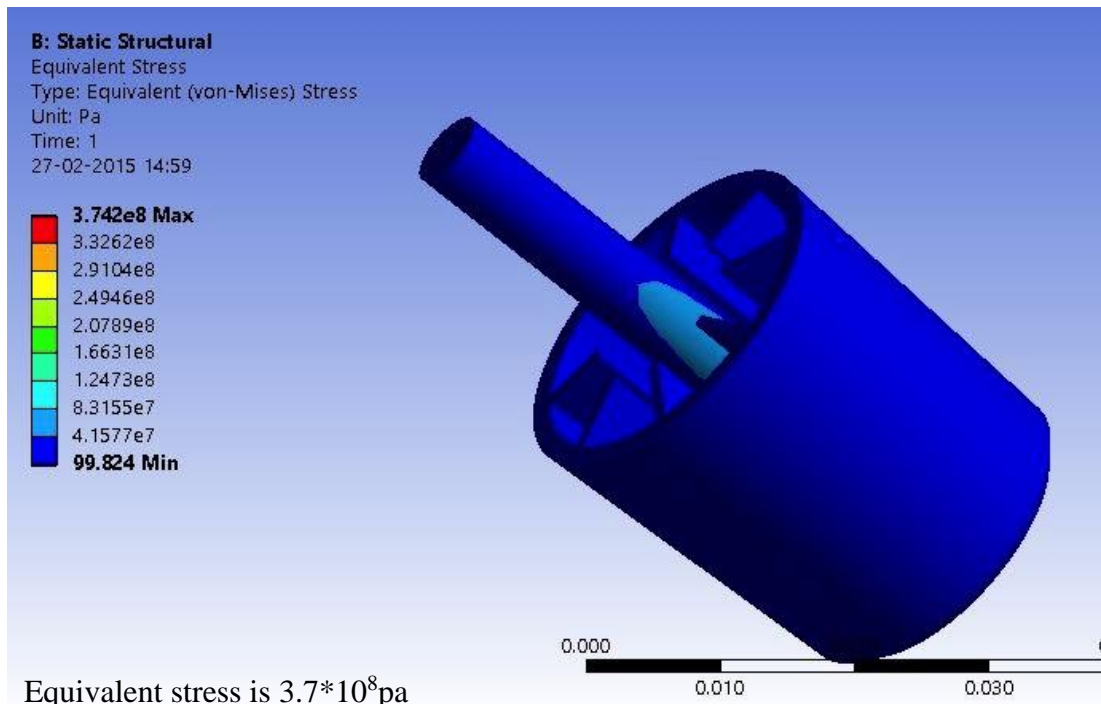


Figure 4.41: Full view of model with base support

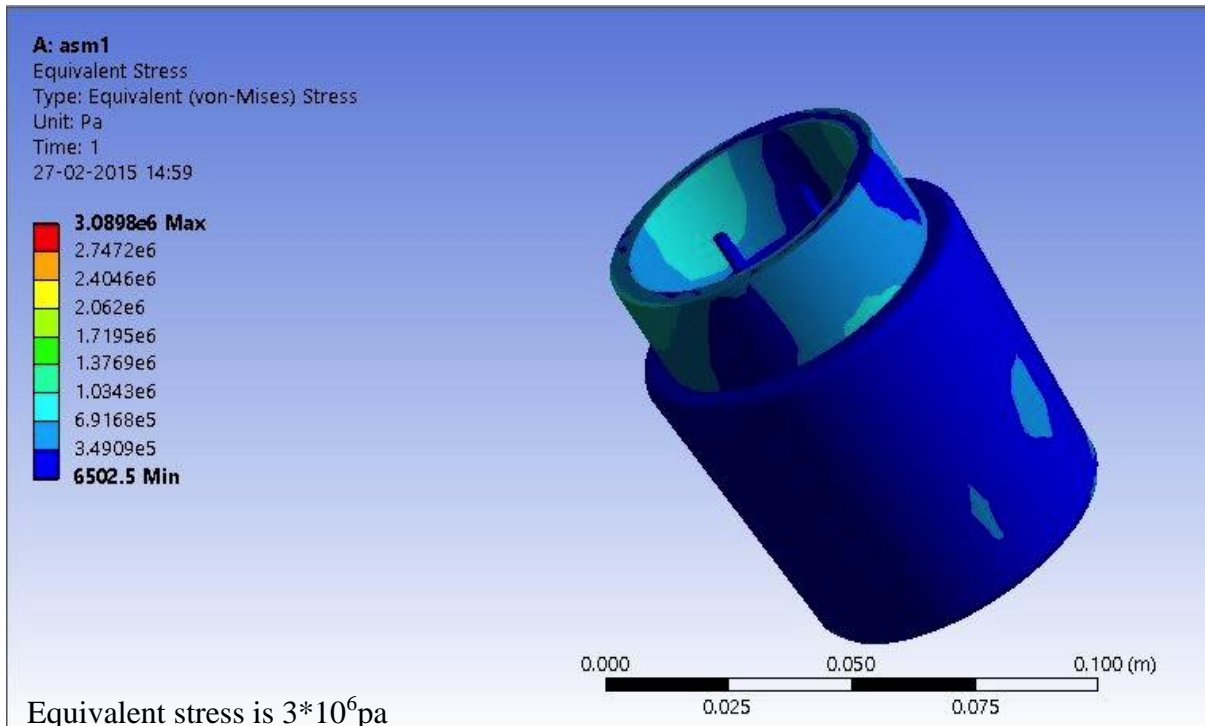
## Old Design



Equivalent stress is  $3.7 \cdot 10^8$  pa  
(Yield strength- $1.03 \cdot 10^9$ )

Figure 4.42: Equivalent stresses on existing design

## New Design



Equivalent stress is  $3 \cdot 10^6$  pa  
(Yield strength- $1.03 \cdot 10^9$ )

Figure 4.43: Equivalent stresses of new design

## Old design

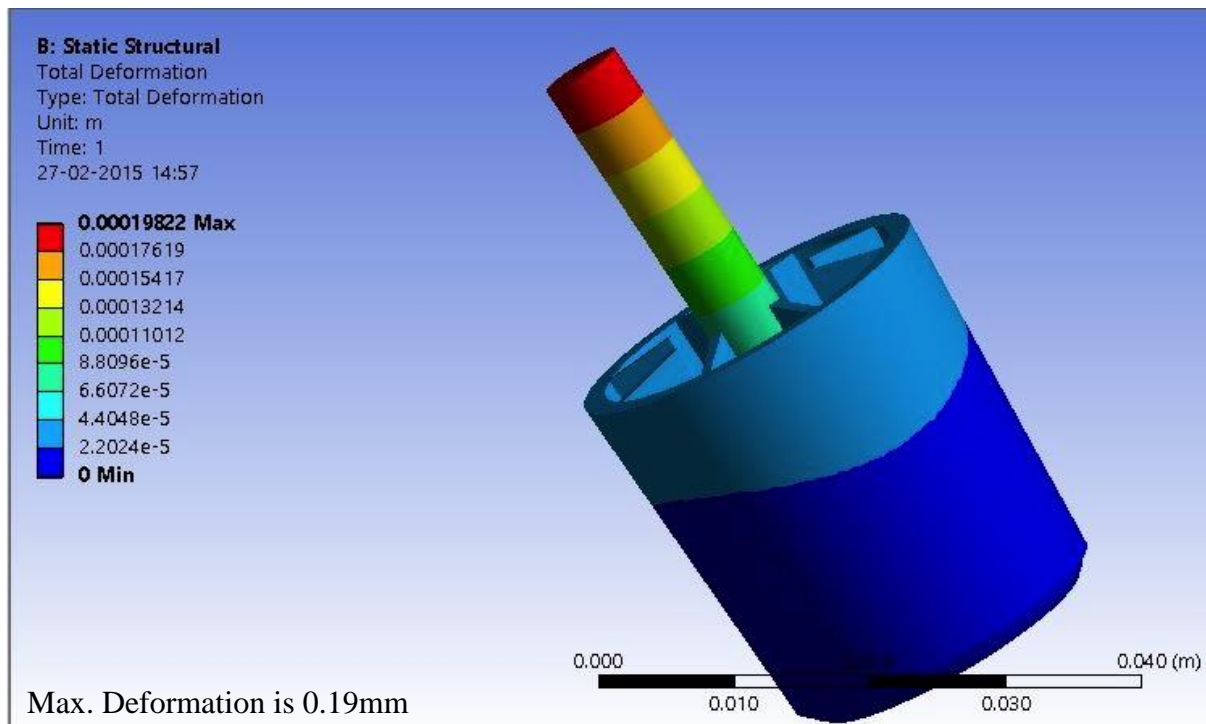


Figure 4.44: Maximum deformation on existing and new proposed design

## New Design

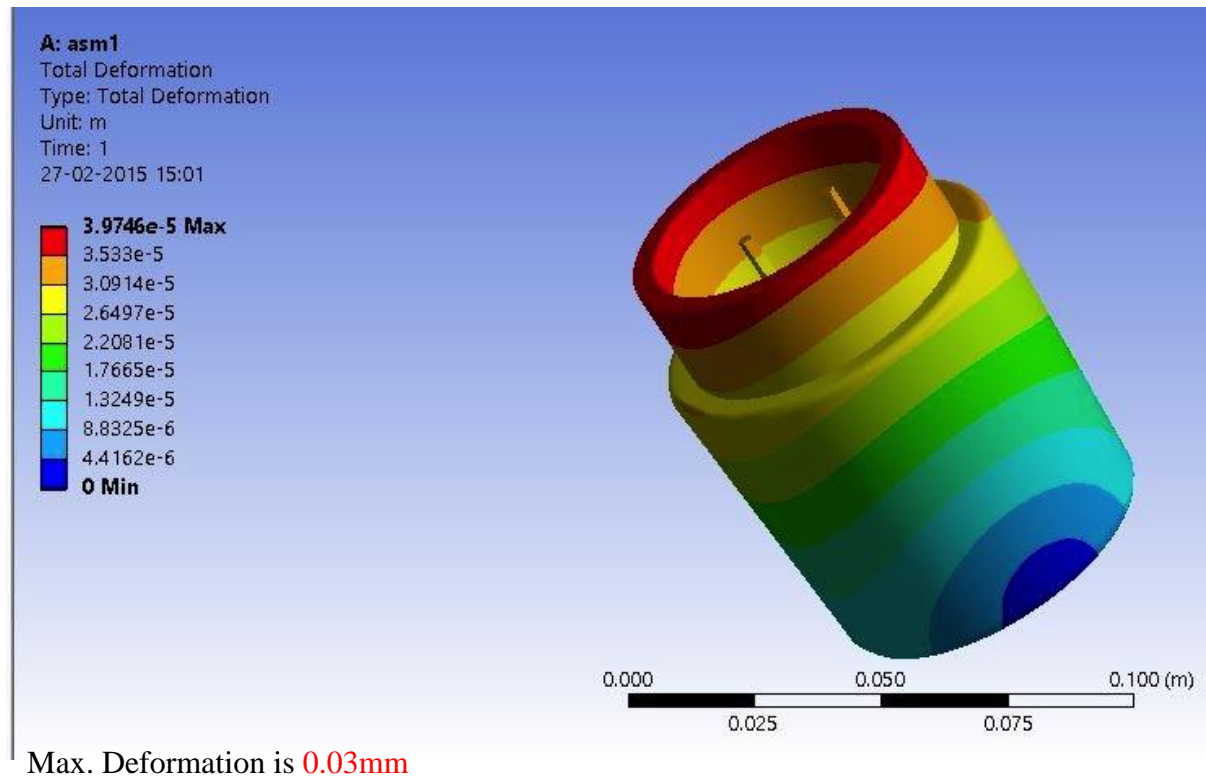


Figure 4.45: Maximum deformation new proposed design

#### 4.4.4 Bottle rack improvements



Figure 4.46: Existing Design of door

## Important observations of existing design

1. In existing design, more space wastage on the base of tray due to extruded ribs.
2. Strength of tray is less for big bottles.
3. Wastage of space and material at corners used for tray support and fixture.
4. Fillets at corners and extruded tray supports, occupy significant space in the door.

## New tray design

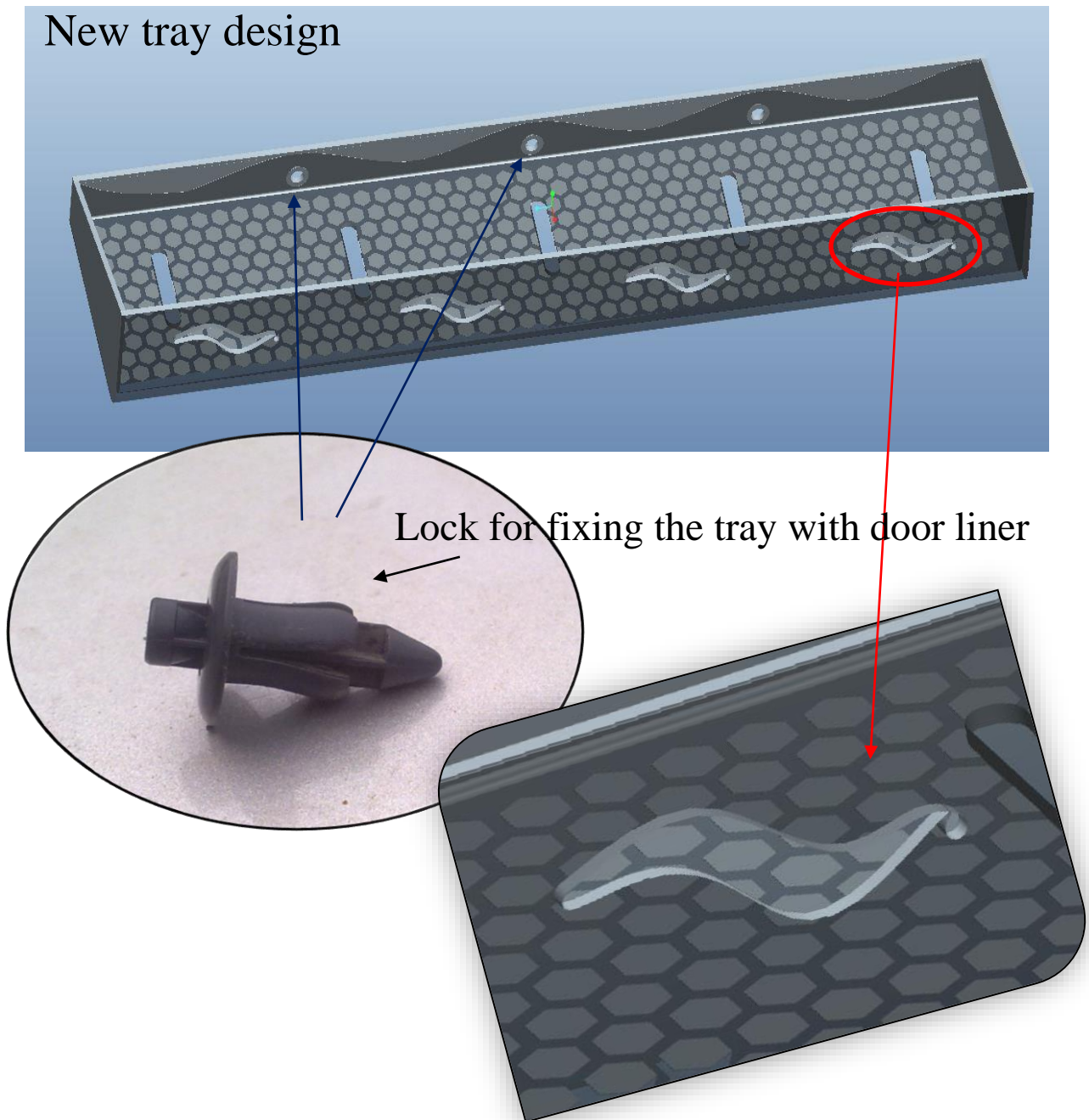
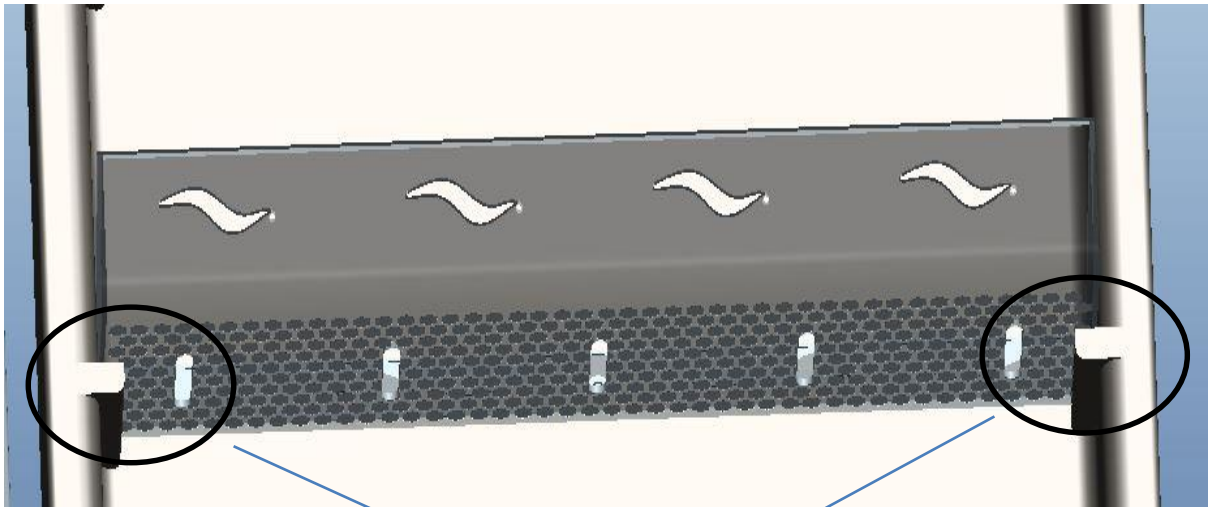


Figure 4.47: New tray design



Bottom support for tray

Figure 4.48: Front view with bottom supports

Locks for back support

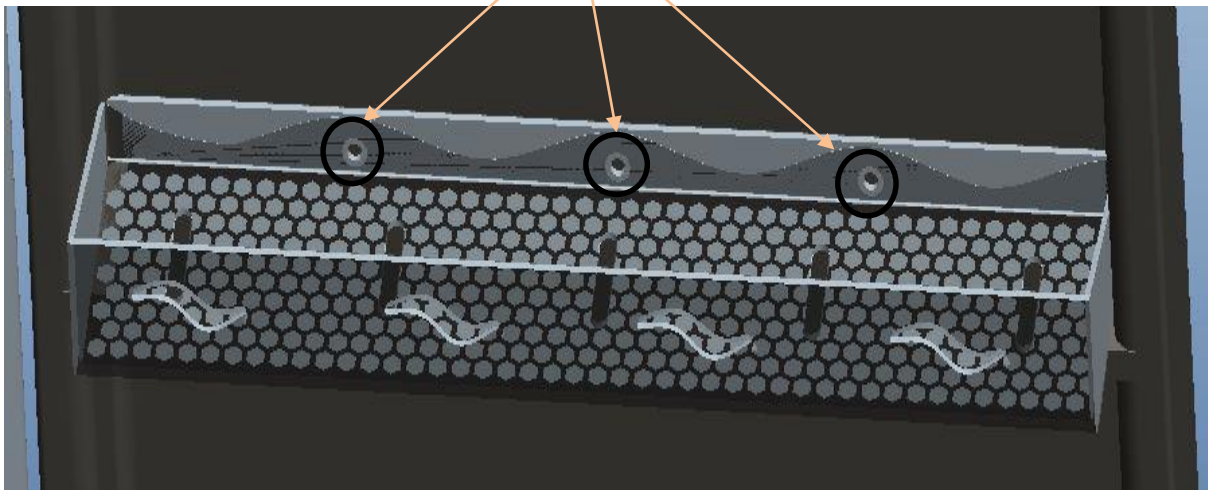


Figure 4.49: Front view with back supports

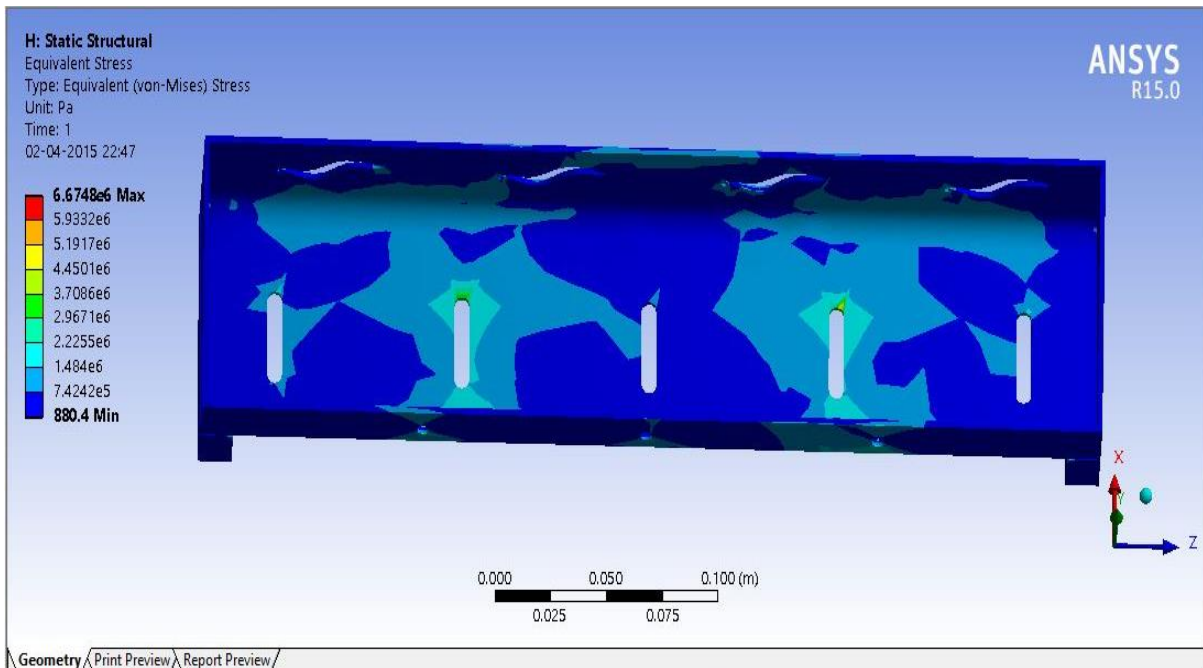


Figure 4.50: Equivalent stress of bottle rack by loading of 12kg weight

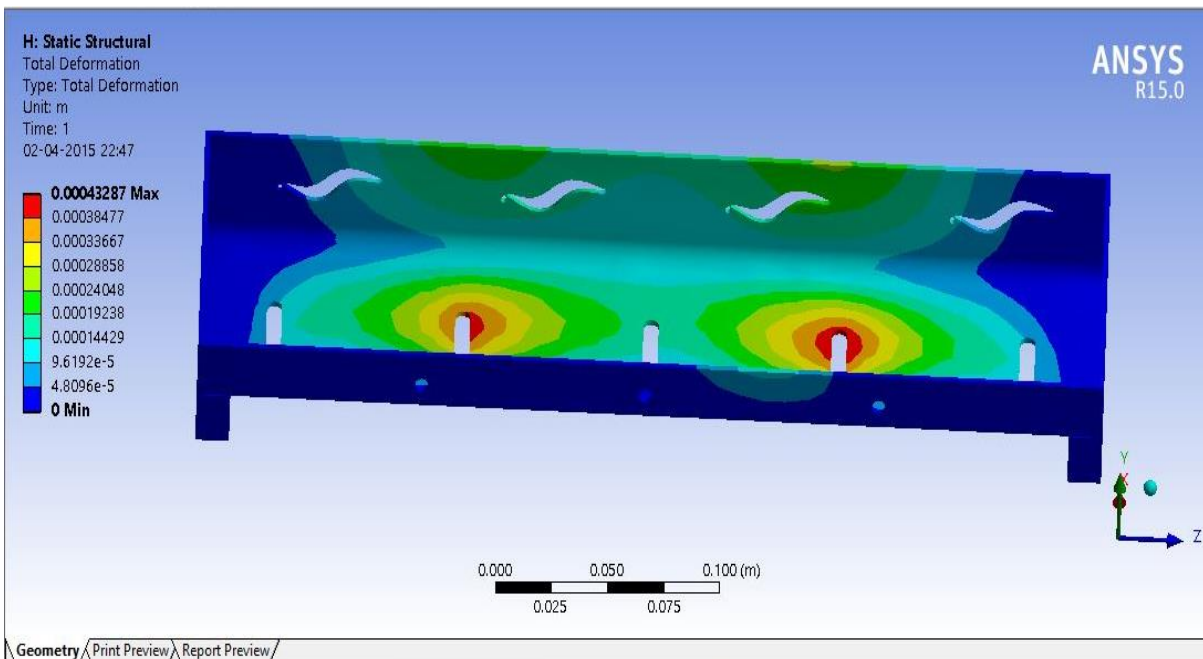


Figure 4.51: Total deformation on rack by loading 12kg weight is 0.4mm

## Features of New Proposed Design

- 1.Strength of bottle rack is improved enough to bear the load of about 12 kg.
- 2.Improved aesthetics, having more flat space at base and corners by removing extruded parts from the door of refrigerator.
- 3.Difference between cost of new bottle rack and old frame is very less.
- 4.Improved locking system is proposed for bottle tray bearing good strength and easy assembly.
- 5.New design facilitates improved space utilization i.e. 3717 cm<sup>3</sup>, which is 12% of existing door capacity.

### 4.4.5 Rearrangement of shelves and bottle rack improvements



Figure 4.52: Existing Design of refrigerator



Figure 4.53: Front view of new designed cabin

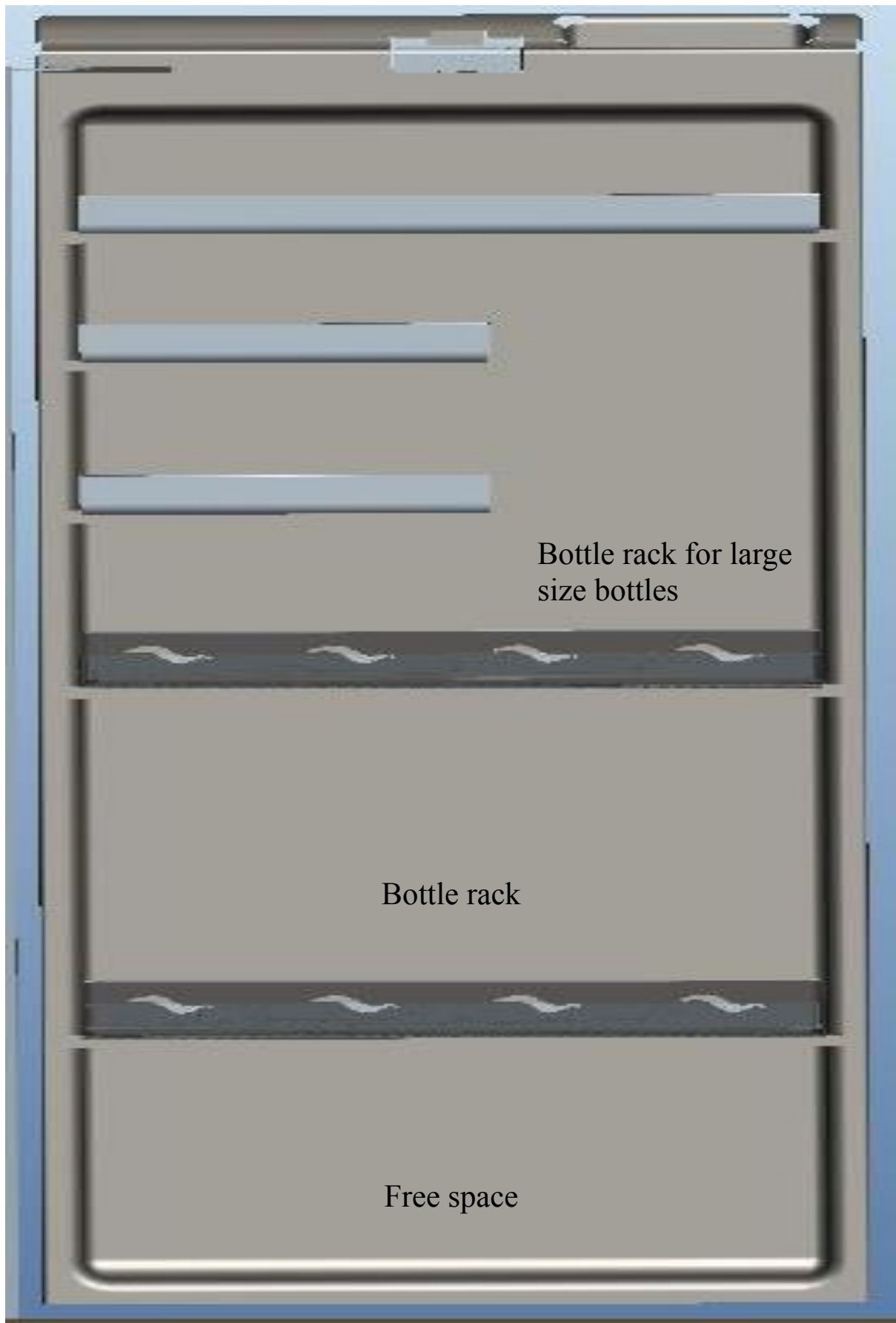


Figure 4.54: Front view of new designed door

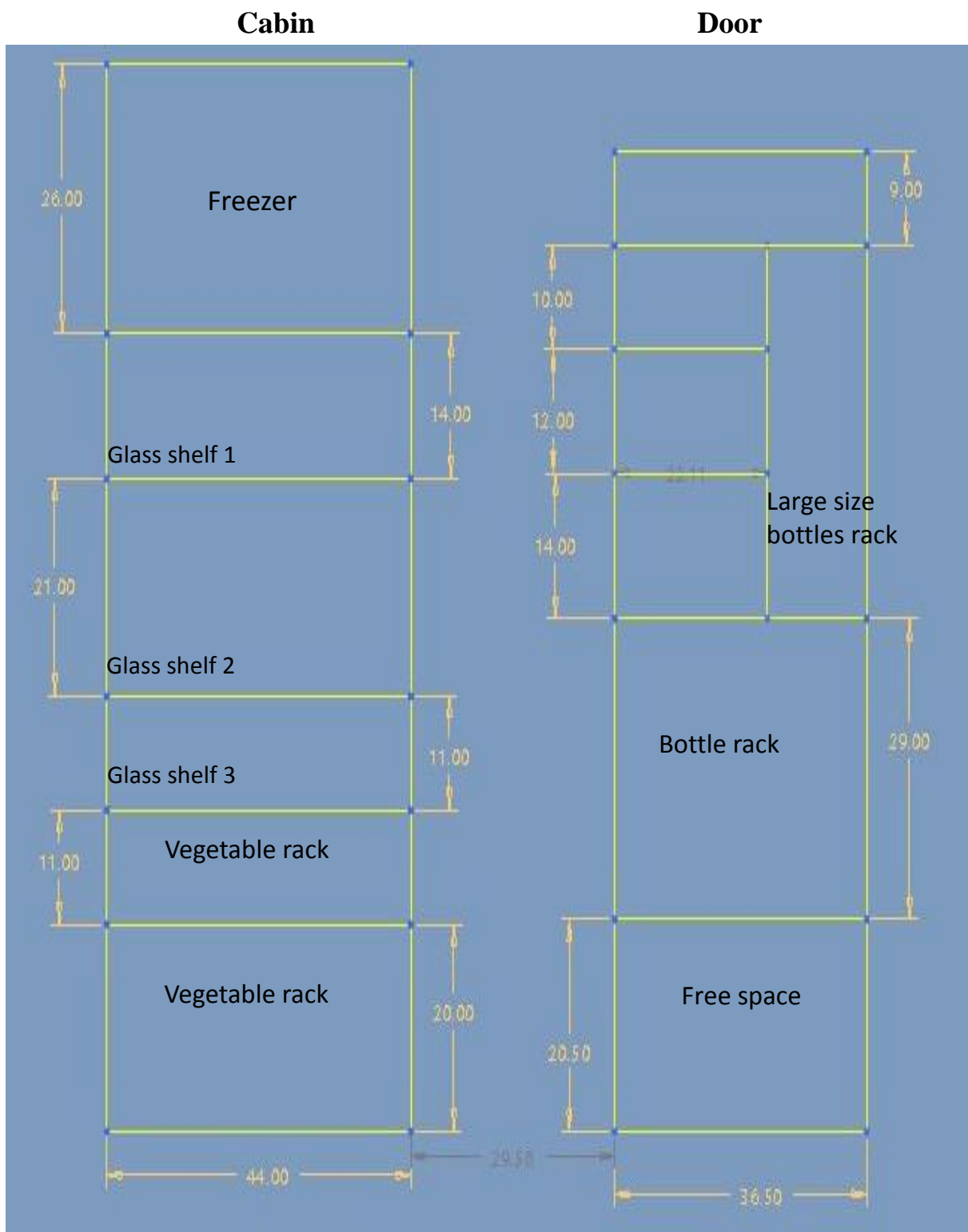


Figure 4.55: New proposed design dimension

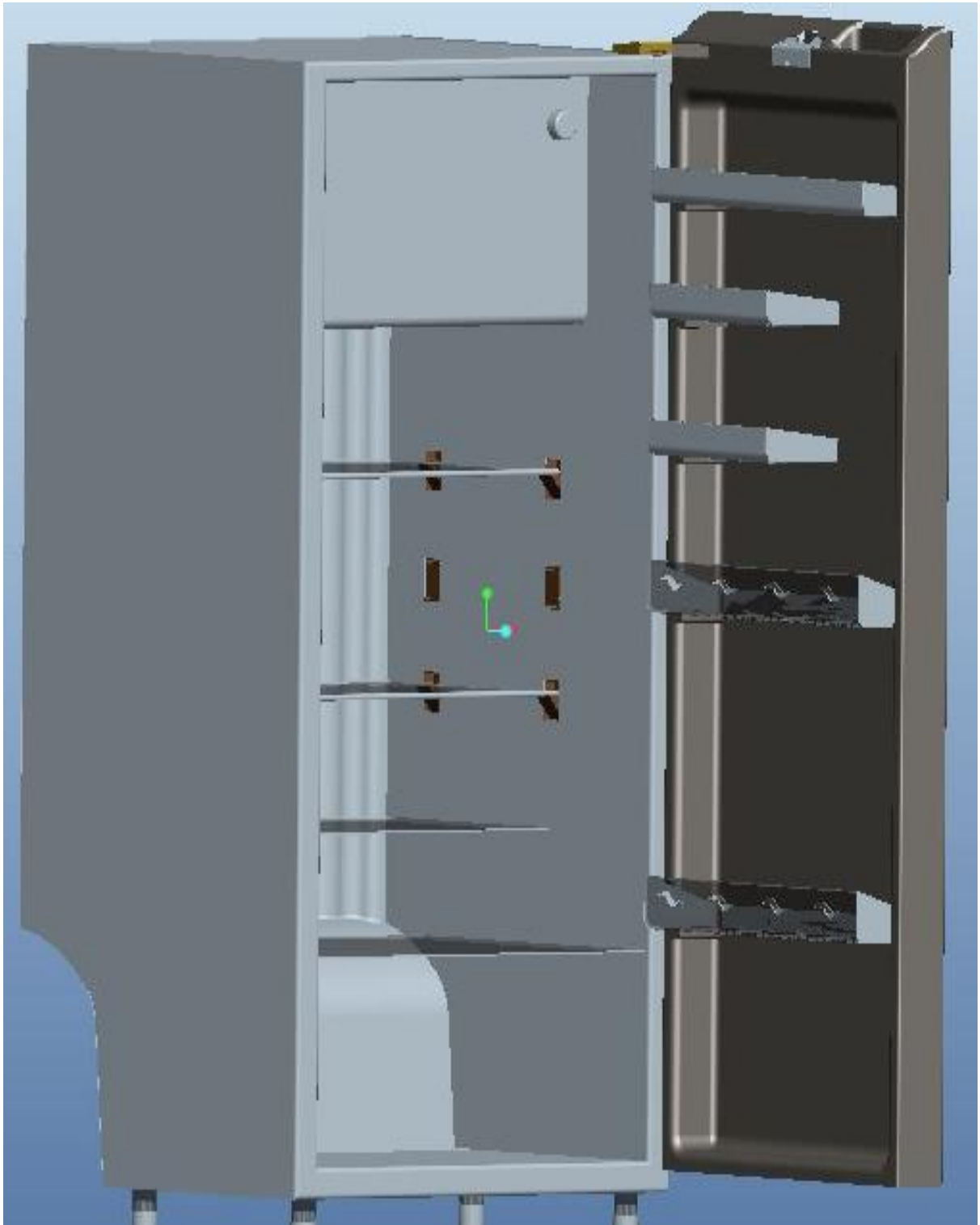


Figure 4.56: Full view with all modifications

## Chapter 5- Result and Discussion

**1. Door lock-** New door lock is designed based on the customer survey. The lock of the refrigerator is not used by any user and key is also misplaced so lock without key is designed.

<b>Feature</b>	<b>Improvement</b>
<b>Door lock</b>	a. INR 21.56 cost reduced b. 0.162 Space improved c. Aesthetics improved d. Easy operated & without key

**2. Door handle-** Door handle cost is very high so can be replaced with new design. Which is easy to use with improved aesthetics

<b>Feature</b>	<b>Improvement</b>
<b>Door handle</b>	a. INR 58.98 cost reduced b. Aesthetics improved

**3. Bottle chiller-** This is not a long term desirable feature and due to breakage, its replaceable cost is very high so this feature is removed.

<b>Feature</b>	<b>Improvement</b>
<b>Bottle chiller</b>	a. INR 101 cost reduced b. 5.85L Space improved

**4. Glass shelves-** Aesthetics are very important in the interior of refrigerator. So design of glass shelf is change hence see through glass area is increased.

<b>Feature</b>	<b>Improvement</b>
<b>Glass shelf</b>	a. INR 7 cost reduced b. Aesthetics improved c. improvement in strength

**5. Top hinge cover-** Excess material is used in this feature. So by using new design, the extra material is reduced and save cost.

<b>Feature</b>	<b>Improvement</b>
<b>Top hinge cover</b>	a. INR 3.77 cost reduced

**6. Tray adjustment liner-** High wastage of space in this feature in existing design that space is utilised by new design that have high strength and aesthetically improved.

<b>Feature</b>	<b>Improvement</b>
<b>Tray adjustment liner</b>	<ul style="list-style-type: none"> <li>a. 4.995L Space improved</li> <li>b. High strength</li> <li>c. High loading capacity</li> <li>d. more flexibility for shifting</li> <li>e. Easily replaceable</li> <li>f. Aesthetics improved</li> <li>g. new design till date</li> </ul>

**7. Door stopper (Top hinge) -** Door of the refrigerator of hit nearby items when it is fully opened automatically. In the new design, ramps are used to stop the door at some angles. This design is not used by and company till date

<b>Feature</b>	<b>Improvement</b>
<b>Door stopper</b>	<ul style="list-style-type: none"> <li>a. Ramps to stop door</li> <li>b. Cost variation is very less</li> <li>c. New design till date</li> </ul>

**8. Base support-** When refrigerator is moved its base supports are bend down or break. To remove this cause, we make a new design with cost saving.

<b>Feature</b>	<b>Improvement</b>
<b>Base support</b>	<ul style="list-style-type: none"> <li>a. Bending strength is high</li> <li>b. Material saving or cost reduction</li> </ul>

**9. Bottle rack improvements-** When large size of bottles are placed on the bottle rack, the cracks are produced on it and break after some time. For this proper utilisation, we made a new design with high load capacity.

<b>Feature</b>	<b>Improvement</b>
<b>Bottle rack</b>	a. strength is high b. Space utilisation 3.717L c. Aesthetics improved

## Result summary

### **Comparison between existing design and new proposed design**

<b>Existing Design</b>	<b>New Proposed Design</b>
a. As the distance between the glass shelves of cabin is more than sufficient.	a. Distance between the glass shelves of cabin is reduced to optimum.
b. Extruded ribs at the door reduces the see-through area and hence provide a feeling of tight space.	b. Ribs are removed in new design and hence provides more space usage.
c. Door trays covers more space and also causes material wastage at the corners.	c. More space utilisations using less tray material.
d. Lacks in Aesthetics.	d. Improved aesthetics having more space.
e. Simple door tray design.	e. Improved door tray design.
f. Some extra features (bottle chiller, door lock, door handle) utilise more space which also effects the cost of the refrigerator.	f. Unnecessary features are removed.
g. Vegetable tray capacity is less.	g. Increased vegetable tray capacity.
h. Door is free to move with its working envelop while opening.	h. Incremental ramps offer intermediate stops at the designed opening angles.

## Chapter 6- Conclusion

The Improvement in space utilisation on door is  $9567\text{cm}^3$  i.e. 31% on door of the refrigerator and Improvement of space utilisation in cabin is  $4995\text{cm}^3$  i.e. 3% in cabin of the refrigerator. Aesthetics are improved as per customer feedback and the unnecessary features (**bottle chiller, door lock, door handle**) are removed which affects the cost of the refrigerator. With these all improvements the cost of INR 192 approx. is reduced per refrigerator. New designs of **Tray adjustment liner, Door stopper, Top hinge cover, Door lock, Glass shelf, Bottle rack, Door handle** are proposed for product improvement at the same or reasonable cost.

## Future Scope

The feature improvement can also be studied for double door frost free refrigerator.

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