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DESIGN OF A MODULAR KITCHEN FURNITURE

Abstract: *The kitchen was one of the most important rooms in the past; even if the initial houses had one room with multiple functions, in time, the kitchen got separated from the other rooms, it begins to have a certain purpose, and a well-established function. Experiencing an impressive evolution throughout the ages, the kitchen manages to become indispensable in all homes. Nowadays we see kitchens equipped with high-performance home appliances, efficient materials for furniture, easy to clean; we can also see various kitchen furniture designs, from old kitchens, which preserve a traditional tint, to eccentric and colourful kitchens with a futuristic design. If the house has ample space, then there is a large market for this kind of kitchen furniture, but what if we lack it?*

Key words: *design, modularity, simulation, furniture, kitchen*

INTRODUCTION

In Europe we already have the space-saving trend; through ingenious ways, designers manage to turn a very small area in rooms with various functions, or change a piece of furniture in one with multiple functions [1].

After researching the market, I observed that in most European countries there is a problem with the living space, especially in urban areas where the apartments dominate [2].

Inspired by this space saving trend [3] I thought of a convertible kitchen, that can be transformed according to the needs of the owner; such a kitchen could be used in small areas or studio apartments where the owners have a single room.

My idea is to create a practical kitchen furniture which may be reduced to a cuboid, easily transforming your space. If, for example, you live in a studio, a convertible kitchen furniture might help you organize the space in an ingenious way.

By ordering and having the proper size of these areas, experienced designers can make full use of storage space, thus coming up with a perfect setup for any type of functional kitchen, while also including accessories and special mechanisms to provide comfort and functionality.

We must also take into consideration the allocated budget; the economic factor has a direct impact on the practical and durable parts of the kitchen furniture, as well as the aesthetic qualities.

The ideal kitchen furniture must fit your personal style and living space, respond to your personal needs, ensure comfort and facilitate specific activities.

Beyond the advantages or disadvantages of a particular type of kitchen furniture, the design is conditioned by the architectural frame.

Simulation solutions help design engineers reduce the inherent risk that comes with innovation and get their products to market faster with less physical prototyping, decreasing costs.

These simulations allow us to visualize any deformation happening on a specific area, thus helping us decide on the final design.

Taking this step allows us to see the behaviour of objects in 3D without spending resources to make a physical prototype; this involves costs reduction if we were to talk of a product which is being sold on the market.

The main advantage of this simulation is that it allows us to change the kitchen design furniture according to our needs and preferences, and helps us see the weak points of the object, thus being able to save material.

Because the project is still in the prototype phase, I will present in this article the simulation analysis for the most important parts of the modular kitchen furniture.

2. CHARACTERISTICS OF THE MODULAR KITCHEN FURNITURE

This specific piece of furniture should cover four areas:

- the cooking area (hood, electric hob, oven and/or microwave);
- the cleaning zone (Corian sink, trash, dish drier);
- storage facilities (assigned according to needs).

In the figure below you can see the overall design of furniture, with separate areas.

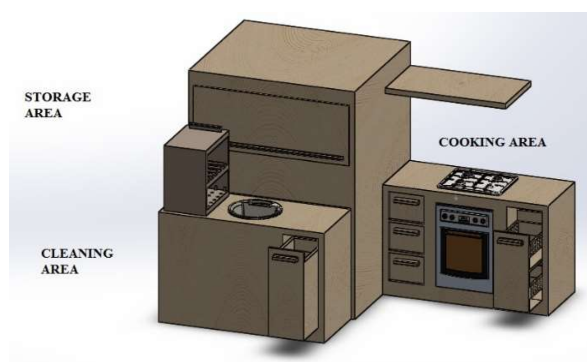


Fig. 1 The division of the modular furniture.

If we want to save space when we are not using the kitchen, we can close it and reduce it to a cuboid shape (fig. 2).

Fig. 2 Modular furniture-saving space mode.

I chose to use quality materials for the furniture, even if in economic terms it shows a higher cost, however, this material guarantees a much longer lifespan of the furniture.

- **M.D.F.** – the most commonly used material in the manufacturing of kitchen and bathroom furniture because it has a density between 530 and 800 Kg/m^3. The advantages of M.D.F. (fig. 3) furniture are: fast execution; a wide range of colours; you can execute various types of furniture regardless of shape and size; the average lifespan is high.

We will use the waterproof variant of M.D.F. with a thickness of 10 mm.

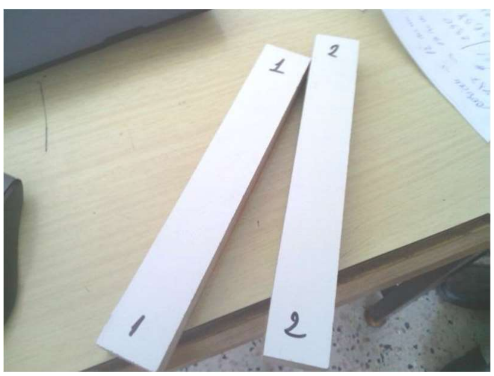


Fig. 3 M.D.F. sample.

- **Corian® DuPont** – is a solid surface material, non-porous, homogeneous, and composed of ± 1/3 acrylic resin (also known as PolyMethyl MethAcrylate or PMMA) and ± 2/3 natural minerals. These minerals are composed of aluminium trihydrate (ATH) derived from bauxite ore from the extracted aluminium.

We will use Corian® (fig. 4) sheets of 930 x 3658 mm with an 19 mm thickness.

3. MODULAR KITCHEN FURNITURE DESIGN

We will go through each module of furniture, where I will explain how it will be designed and ways of obtaining these modules.

The extension of the bottom modules is done with wheels (currently there are a lot of wheel designs for furniture that facilitates its movement) and with sliding systems located behind the furniture, which may be hidden by using some boards, or MDF plates.

Fig. 4 Corian® sample.

- **The cooking area** (fig. 5) – in which we find a stove, an oven, extendible hood, and a small storage space.

Fig. 5 Module 1.

I created the technical drawings (fig. 6) for this piece, to help us cut the M.D.F. sheets.

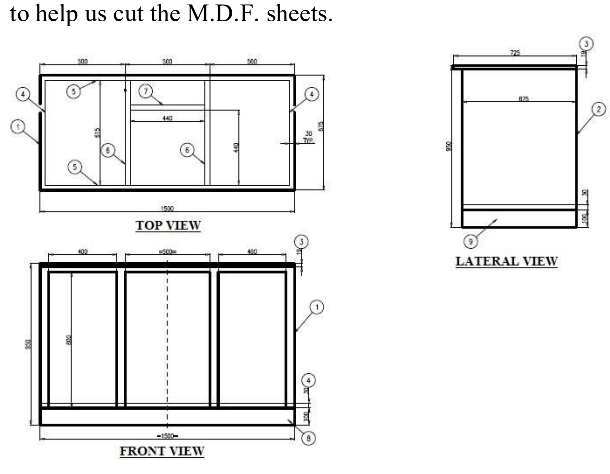


Fig. 6 Technical drawing for Module 1.

Position 1 represents the front plate with cut-outs for oven and two storage spaces, position 2 are two furniture side plates, position 3 is the Corian counter top of 19 mm thickness, positions 4, 5, 6 and 7 are a metal frame that supports the entire structure on which are mounted eight wheels, 6th and 7th positions were made to support an oven, and positions 8 and 9 are baseboards, which covers the running system.

- **Cleaning area** (fig. 7) – where we have a sink, drier vessels that is extending out of the top and a locker where you can attach the trash.

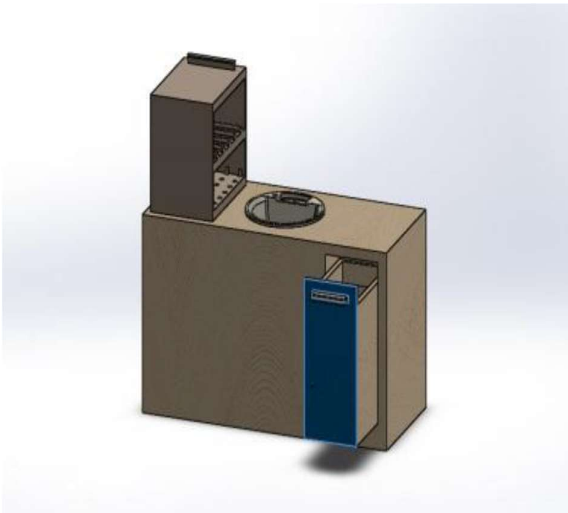


Fig. 7 Module 2.

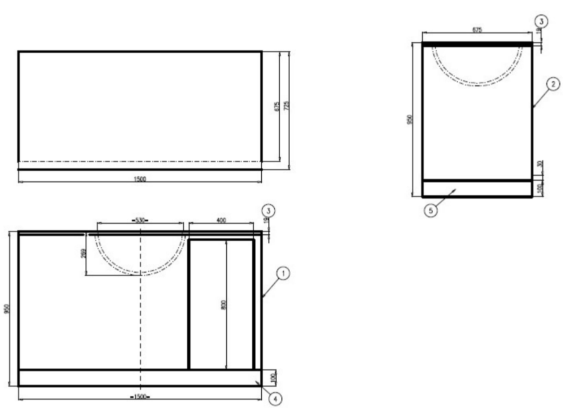


Fig. 8 Technical drawing for Module 2.

In fig. 8 we can identify the position 1 as M.D.F. front sheet with one cut for drawer where we can introduce a garbage accessory which can be purchased from companies that produce bins which can be integrated in a furniture, position 2 are two side plates, position 3 is a Corian kitchen countertop which is used also for sink, and positions 4 and 5 are baseboard covering the running system. Although in this image doesn't appear the metal frame used at module 1, it is also used in module, except that it doesn't present additional ribs as the previous one, this angle being mounted only on the module extremities.

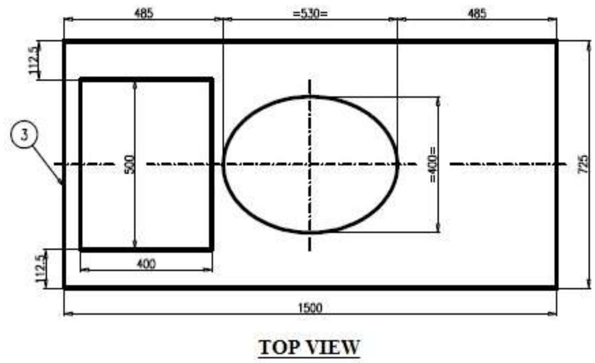


Fig. 9 Module 2-Top View.

In fig. 9 we can see where the sink is positioned and the cut for the drier used for plates.

4. FURNITURE HARDWARE

To facilitate expansion of the furniture I have chosen the wheel solution, in addition to maintain the direction of expansion I opted for sliding rails to guide the gradual exit from the furniture module.

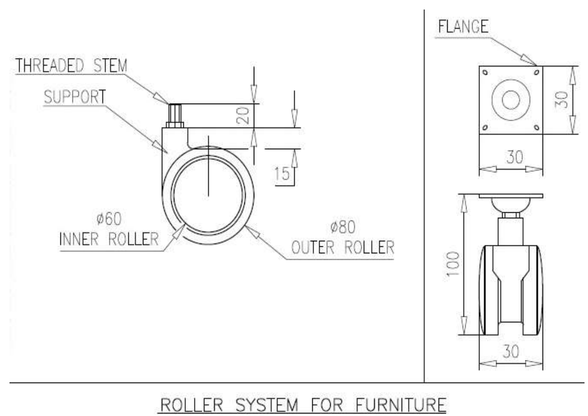


Fig. 10 Wheels for cabinets

I chose simple wheel (fig. 10) that can support a weight of 70 kg, it can be sale with or without brakes, but in our case I opted for those without brakes, the furniture is heavy and doesn't allow movement of the countertop when we lean on it. The wheels are made of ABS plastic and nylon, the support is made of zinc and the plate that is used like a flange is made of steel.

For the storage space located above the sink I chose for the Liftit HL used for one-piece folding doors (fig. 11). This system shows a vertical opening, is used for folding doors made of wood or with aluminium frame. The hardware features has a damping system for closing and is made of steel, it has a masking system.

We will use the sliding system (fig. 12) with balls for the two modules with a rail width of 76 mm and a load up to 227 kg. It must be mounted behind the furniture module in its extremities. The material which is made from is steel.

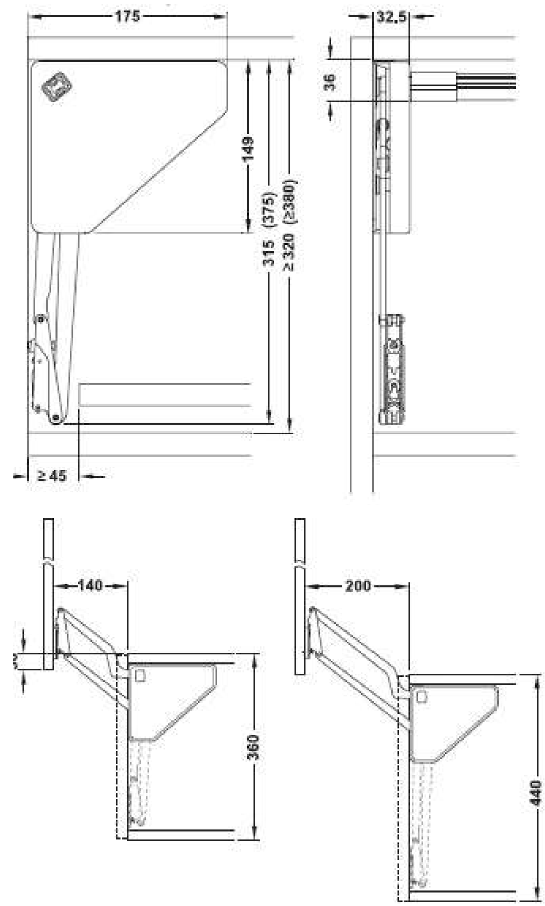


Fig. 11 Liftit HL System

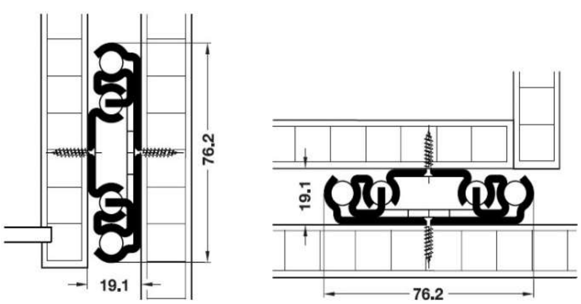


Fig. 12 Sliding system

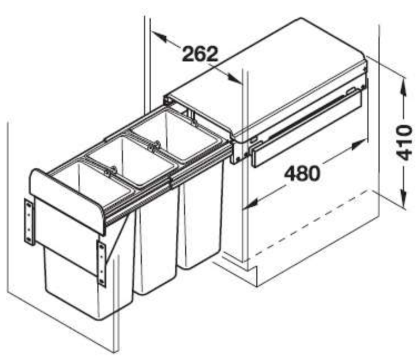


Fig. 13 Trash accessory for kitchen furniture

For the trash space I have chosen a kitchen accessory as in figure 13, it can be purchased and fitted inside the drawer (fig. 14).

The modules will be expanded by using handles located on the side of the furniture (fig. 15).

Fig. 14 Furniture front view

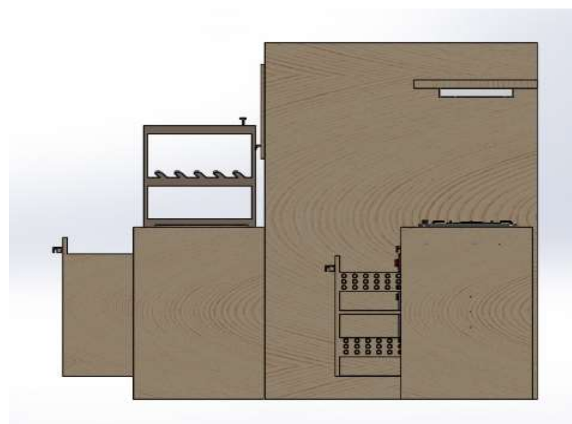


Fig.15 Furniture lateral view (handles positioning)

5. MANUFACTURING METHODS

The M.D.F. boards will be cut using CNC machines, using the technical drawings. After being cut it moves to the painting process and finally the process of edging. After being prepared it will give holes for locking systems and / or sliding system depending on case.

Sink with countertop will be obtained from a single sheet of Corian, because it has the advantage of being deformed at high temperature, and with a special adhesive we can glue two plates of Corian and after that polish them, thus making the contact between the two plates undetectable.

The sink will be made by using a metal mould.

6. SIMULATION ANALYSIS

The parts analysed will be:
- the cooking area;
- the cleaning area (with the dish drier).

These are the most exposed essential parts of the kitchen furniture.

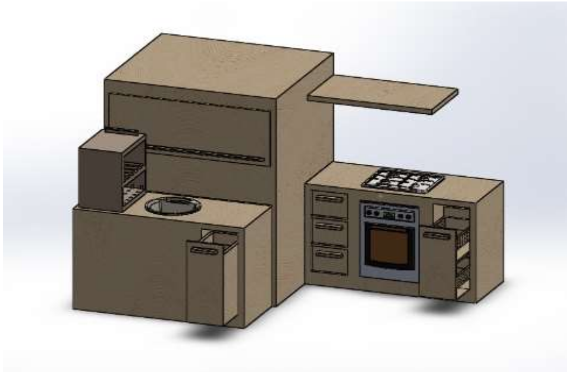


Fig. 16 The modular kitchen furniture design

In figure 16 we can see the General Assembly of the modular kitchen, made by using the software SolidWorks and to create continuity I used SimulationXpress for this study.

6.1 Module furniture designed for cooking area

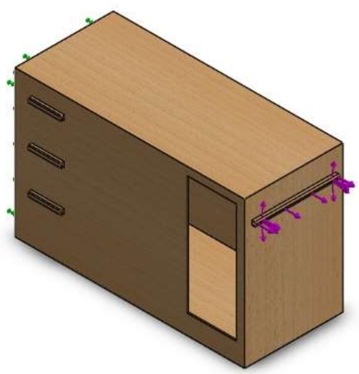


Fig. 17 Modular furniture- force applied

For this model I made two simulations one with a force of 1000 N, figure 17, applied on the right handle, the one that help us expand the furniture module, and another simulation with a distributed force that applies a pressure of 1000 N on the furniture countertop.

To run the simulation I inserted the following data presented in Table 1.

Table 1

Cooking area model information

Model Reference type	Characteristics
Document Name and Reference	**Solid body** *Mass:11.6312 kg* *Volume:0.0726996 m^3* *Density:159.99 kg/m^3* *Weight:113.986 N*
Material Properties	*Name: Balsa* *Model type: Linear Elastic Isotropic* *Yield strength: 2e+007 N/m^2*
Fixture/ Load	*Entities: 1 face* *Type:Fixed Geometry*
Load name Force 1	*Entities: 3 face(s)* *Type:Apply normal force* *Value: -1000 N*

Stress results for this simulation can be seen in figure 18, where we can observe the minimum value 4.6142 N/m^2 (Node: 6090) and maximum value of 5.01673e+006 N/m^2 (Node: 10662). The blue zone represents the non-exposed areas and the red zone represents the most affected one.

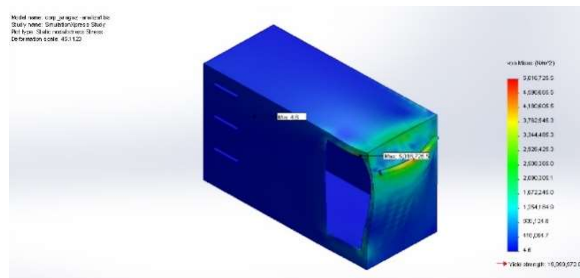


Fig. 18 Stress results for cooking module

Displacement results for this simulation can be seen in figure 19, where we can observe the minimum value 0 mm (Node: 1069) and maximum value of 3.55851 mm (Node: 6819).

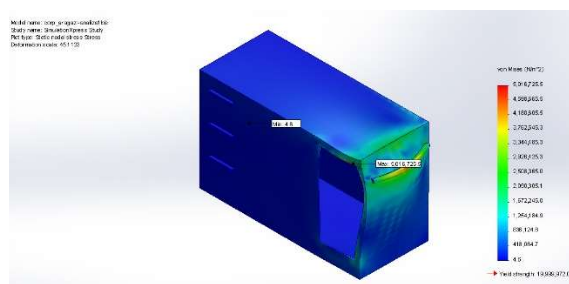


Fig. 19 Displacement results for cooking module

The factor of safety for this force simulation is minimum 3.98666 in node 10662 and maximum 4.33444e+006 in node 6090 which means the object is safe, also because the force applied is high.

In figure 20 we can see the deformed shape of the furniture piece.

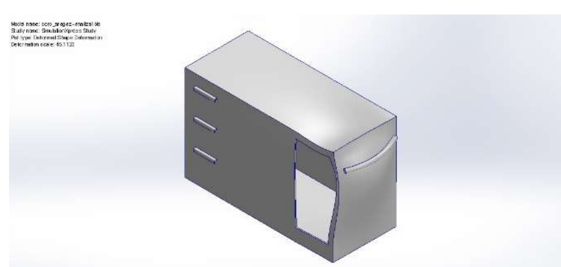


Fig. 20 Deformed shape

For the distributed pressure of 1000 N, we can see the distribution of fixture and loads in figure 21, the main characteristics remain the same as in Table 1.

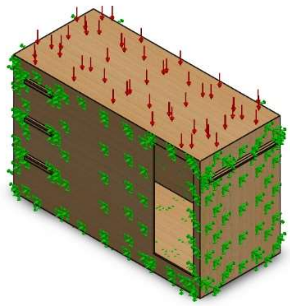


Fig. 21 Fixture and Loads distribution for Pressure simulation

Stress results for this simulation can be seen in figure 22, where we can observe the minimum value 0.000480489 N/m^2 (Node: 15656) and maximum value 358547 N/m^2 (Node: 14039).

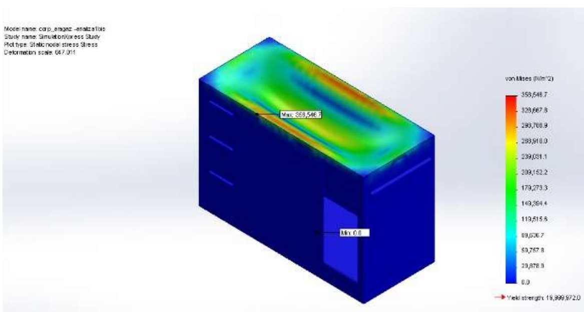


Fig. 22 Stress results for cooking module – pressure force test

Displacement results for this simulation can be seen in figure 23, where we can observe the minimum value 0 mm (Node: 1035) and maximum value of 0.248064 mm (Node: 13921).

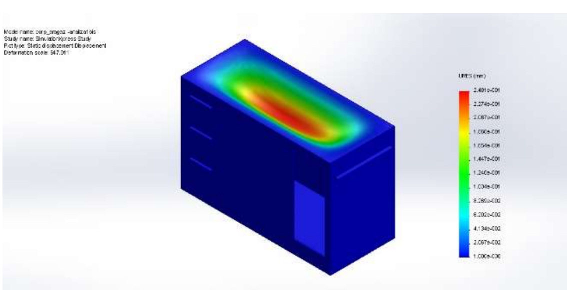


Fig. 23 Displacement results for cooking module – pressure force test.

The factor of safety for this force simulation is Minimum 55.707 in node 140392 and Maximum 4.16242e+010 in node 15656 which means the object is safe.

In figure 24 we can see the deformed shape of the furniture piece in case of force pressure applied.

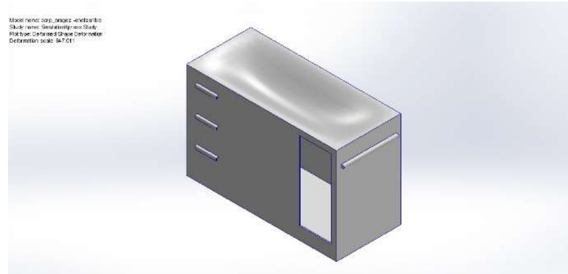
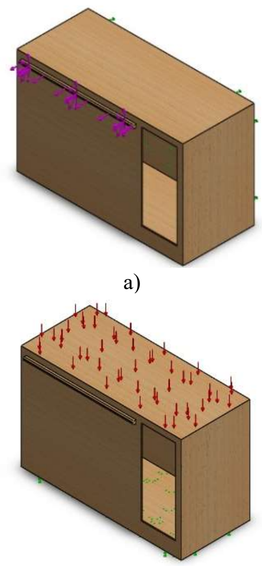


Fig. 24 Deformed shape – pressure force test.

6.2 Module furniture designed for cleaning area

I adopted the same approach for this piece of furniture; the data used being the same with the one from Table 1. In figure 25 we can see the distribution of force/loads for all cases.



a)

b)

Fig. 25 Forces applied: a) Case A; b) Case B.

Stress results for this simulation can be seen in figure 26 a, b where we can observe:

- Case A: the minimum value 0.579683 N/m^2 (Node: 12250) and maximum value 1.323e+006 N/m^2 (Node: 15501) ;
- Case B: the minimum value 2.97643 N/m^2 (Node: 9000) and maximum value 554098 N/m^2 (Node: 1918).

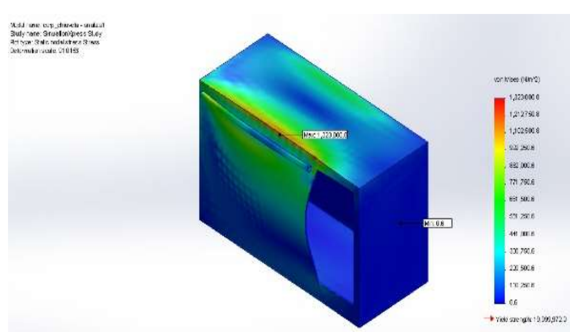


Fig. 26 a) Stress results. Case A

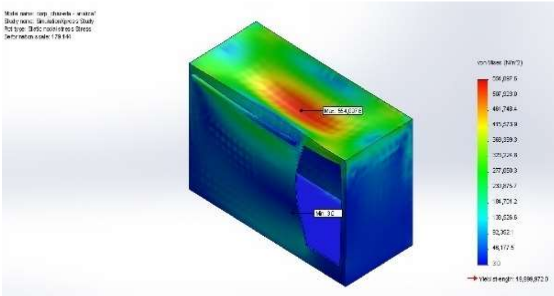
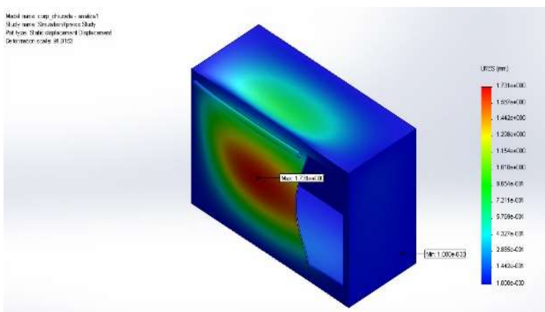


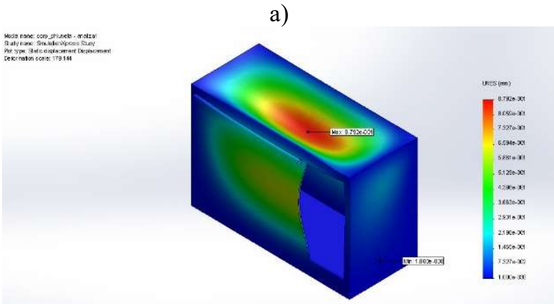
Fig. 26 b) Stress results. Case B

Displacement results for this simulation can be seen in figure 27, where we can observe:

- Case A: the minimum value 0 mm (Node: 1379) and maximum value 1. 73075 (Node: 7762) ;
- Case B: the minimum value 0 mm (Node: 1035) and maximum value 0.879185 mm (Node: 4726).



a)



b)

Fig. 27 Displacement results: a) Case A; b) Case B

For this piece of furniture the safety factor will be:

- Case A: the minimum value 15.1171 (Node: 15501) and maximum value 3.45016e+007 (Node: 12250);
- Case B: the minimum value 36.0947 (Node: 1918) and maximum value 6.71945e+006 mm (Node: 9000).

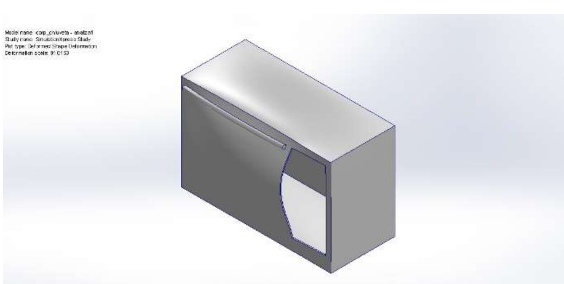


Fig. 28 a) Deformed shape: Case A

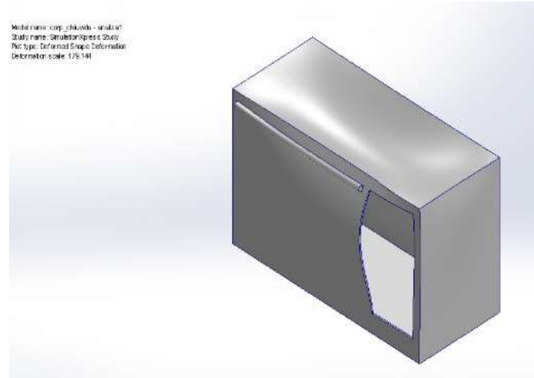


Fig. 28 b) Deformed shape: Case B

6.3 Dish drier simulation analysis

To run the simulation for this particular object we need the data presented in Table 2.

Table 2

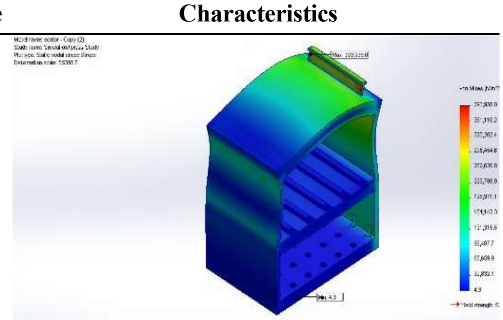
Dish drier design

Model Reference type	**Characteristics**
Document Name and Reference	**Solid body** *Mass:335.467 kg* *Volume:0.0435672 m^3* *Density:7700 kg/m^3* *Weight:3287.58 N*
Material Properties	*Name: Balsa* *Model type: Linear Elastic Isotropic* *Yield strength: 6.20422e+008 N/m^2* *Tensile strength: 7.2382e+008 N/ m^2*
Fixture/ Load	*Entities: 1 face* *Type:Fixed Geometry*
Load name Force 1	*Entities: 3 face(s)* *Type:Apply normal force* *Value: -1000 N*

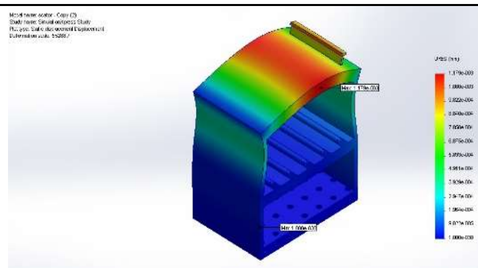
In Table 3 we can see the study results.

Table 3

Dish drier – Study results

Type	**Characteristics**
STRESS	 Min: 4.28609 N/m^2 (Node: 1978); Max: 393938 N/m^2 (Node: 24064).

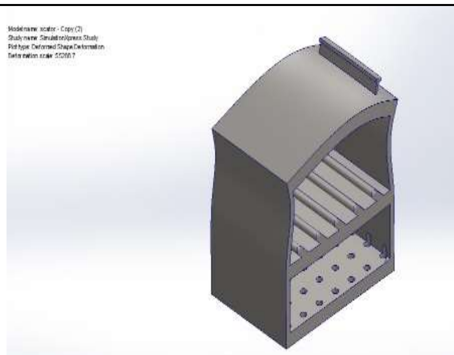
DISPLACEMENT



Min: 0 mm (Node: 5);

Max: 0.00117863 (Node: 24209).

DEFORMATION



Factor of Safety:

Min 1574.92 (Node: 24064);

Max 1.44752e+008 (Note: 1978).

7. IMPROVING A DESIGN USING SIMULATIONS

After testing the original model we can modify its design in various ways; for example in order to increase the resistance I chose primarily to change the handle and position it in the central part, so when we apply a force to expand the drawer, this force is equally distributed.

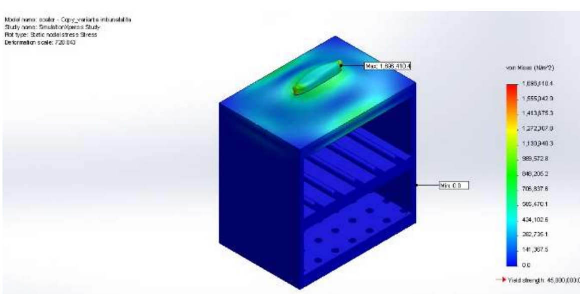


Fig. 29 Stress result for the new design of dish drier.

As we can see in figure 29, the new design shows a higher stress resistance and has no critical areas.

In addition, I opted for changing the material with an acrylic resin, specifically Corian, this choice presenting a good resistance characteristic and it also offers an advantage from an esthetic point of view.

In figure 30 we see that the highest tension is on the handle, but we need to consider that the force applied for this test was 1000 N, in reality we won't apply such a high force on a drawers handle.

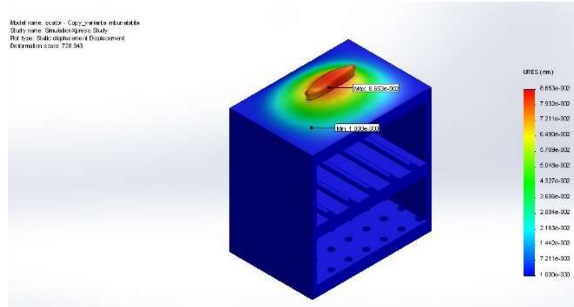


Fig. 30 Displacement results for the new design.

Regarding the thickness of the drawer, we could not achieve significant changes since the sheets of this type of material come in standard dimensions and cutting them will raise the costs, which is not an economical solution for a producer.

We have to note that all connections between assembly components have been considered ideal.

8. CONCLUSION

This approach brings innovative and technical ideas in the field of kitchen furniture; by trying to test all the object designs in a way which lets us decide on the optimal solution for what we want to reflect.

The furniture design is a compromise between functionality and aesthetic appearance; using software simulations can show us the weak points of our creation and afterwards we can improve our ideas in an economical way, before materializing the product.

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