SAPIENZA
UNIVERSITÀ DI ROMA

Department of Mechanical and Aerospace Engineering

Master of Science in Mechanical Engineering

Course of

Advanced Methods in Mechanical Design

Under the Guidance of

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Assignments Report

submitted by

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Assignment 1 - Concept Design of a Tea Brewing Machine

Please develop the workflow arriving to the evaluation of concepts and the selection of the possible best, starting from the voice of customers here reported, analysing the state of the art, developing the List of Requirements (LoR), the Sequential Functional Analysis (SFA), the Tree Functional Analysis (TFA), the morphological matrix aggregating at least 3 concepts and evaluating them through the Quality/Cost Diagram

Tea Brewing Machine - Voice of customers

- This product should furnish brewed tea or just hot water to the user, after the input of power, cold water and tea (possibly in both forms of leaves and bags)
- It has to have a pot able to store and serve the freshly brewed tea
- It should be programmable, and it should maintain as much as possible the temperature of the brewed tea
- It should have 1 or more storage compartments for tea leaves and/or bags.
- It has to have the possibility to control tea temperature and concentration during the brewing process.
- It has to have interface for controlling the process and to communicate to the user possible missing ingredients.
- It has to be gorgeous, fashioning, and possibly light and limited in terms of volumes.
- It could be used in houses and/or in little offices.
- It must respect standards of safety, of compatibility with food treatment.
- The parts to be interfaced with users need to be ergonomic, safe.
- The system must consent the ordinary maintenance, and easy cleaning operations.

Assignment 1

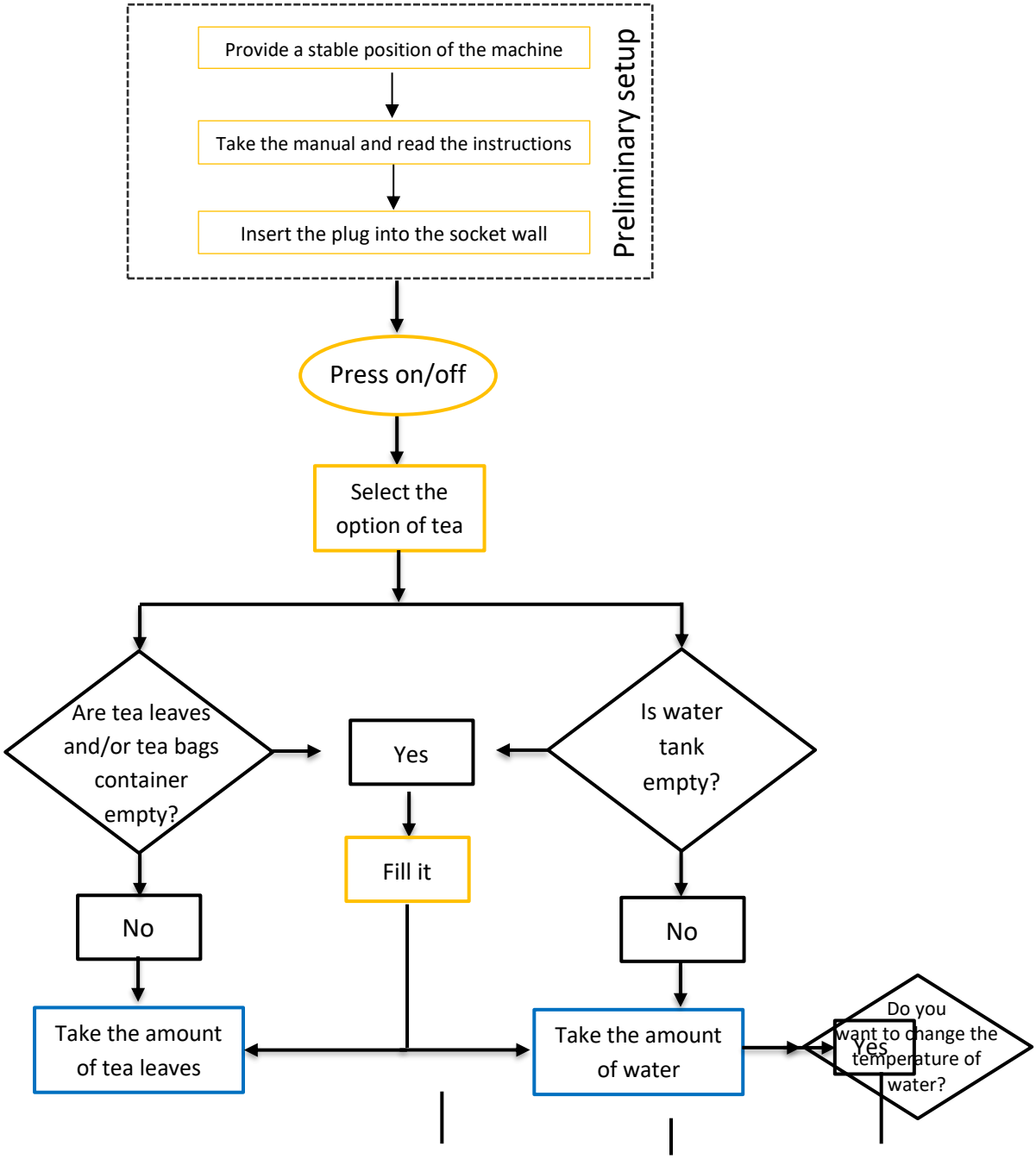
- It could have the possibility of imputing/saving/finding information about the kind of tea and the best values to brew each specific one.
- The designer should also take care about the relative positioning of the parts and compartments, and also of the systems of water/tea/leaves/bag motion.

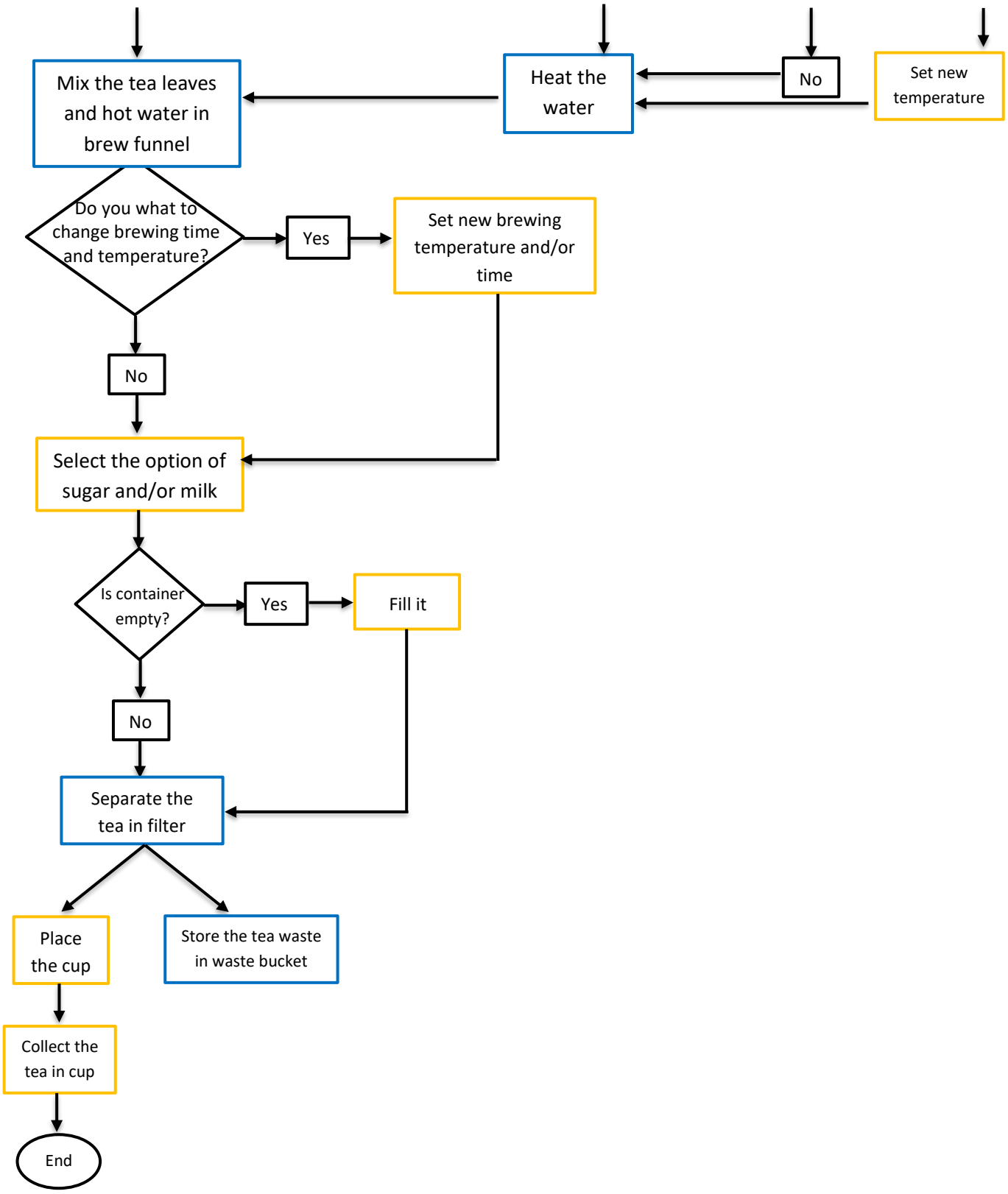
Table – List of Requirements for a tea brewing machine

External Properties	Detailed Description
Performances and Functionalities	Dimension of machine (size)
	Capacity of water tank
	Number of containers
	Capacity of containers
	Ability to select different types of tea
	Inserting space for water tank and containers
	Allow to set temperature of water
	Allow to set brewing time and temperature
	Size of cup
	Allow to manually operation
	Allow to store the used tea leaves/ bags (waste)
	Allow backside opening of machine
	Allow machine-user interaction
	Input of power
Ergonomics	User interface easy to be understand
	Easy to operate • Manually • Automation
	Suitable to use in houses and offices
	Ability to save previous input data/information
	Easiness to be cleaned
Aesthetics	Good perception • Material • Flexible design
	Light in weight
	Colour
Safety	Avoiding unexpected usage
	Avoiding electrical failure
	Avoiding sharp edges
	Allow stable positioning
	Compatibility of food treatment
	Avoiding functional error
	Avoiding over heating
Reliability and Maintenance	Reliable to automatic usage
	Reliable to user interaction
	Resistance of electrical devices
	Easiness to be maintained

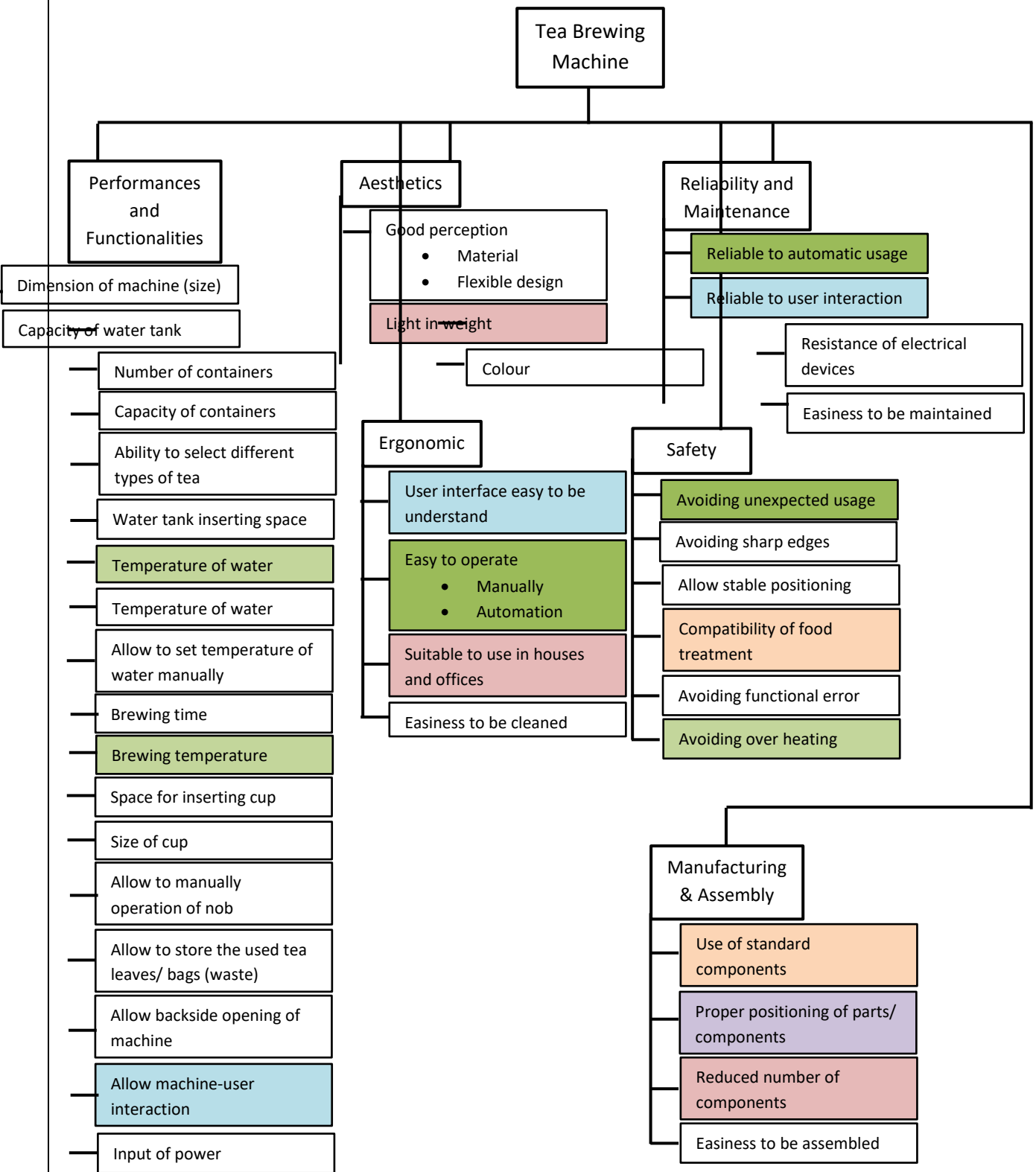
	General cleaning of machine
Manufacturing & Assembly	Use of standard components
	Proper positioning of parts/ components
	Reduced number of components
	Easiness to be assembled
Standard and laws	To be checked
Costs	Manufacturing cost

Sequential Functional Analysis of a tea brewing machine

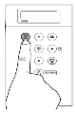
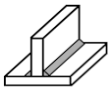
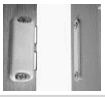



Mix the tea leaves and hot water in brew funnel
Heat the water
No
Set new temperature
Do you what to change brewing time and temperature?
Yes
Set new brewing temperature and/or time
No
Select the option of sugar and/or milk
Is container empty?
Yes
Fill it
No
Separate the tea in filter
Place the cup
Store the tea waste in waste bucket
Collect the tea in cup
End
User
Machine

Tree Functional Analysis of a tea brewing machine



Morphological Matrix

Function	Actuators																	
		E	S	A	R	C		E	S	A	R	C		E	S	A	R	C
How to use	User manual 	4	4	4	5	4	Video Guideline 	5	5	5	4	5	Technician explanation 	3	4	3	2	2
Stability of machine	4 feet 	5	5	4	5	5	2 feet 	4	4	4	5	5	Flat surface 	4	4	5	5	3
Machine user interaction	Touch screen 	5	4	5	4	3	Buttons 	5	5	4	3	4	Voice assistant 	3	3	4	3	3
Assembly of components	Screw 	4	4	3	5	5	Joints 	5	4	5	4	3	Glue 	5	5	5	3	4
Body Material	Plastic	5	4	5	4	5	Alloy	2	4	3	3	4	Stainless steel	5	5	4	5	4
Power supply	Plug 	4	5	4	5	5												
Position of water tank	Vertical	5	5	4	5	4	Horizontal	5	4	5	4	4						
Position of container	Vertical	5	5	4	5	4	Horizontal	5	4	5	4	4						
Container material	Food grade plastic	5	5	5	4	5	Steel	3	4	3	4	3						
Cup material	Food grade plastic	5	5	5	4	5												
Open/close of backside of machine	Handle with lock 	4	3	4	2	3	Push and pull 	4	5	5	4	5	Handle with magnet lock 	3	5	5	5	4

1 Non-sufficient
2 Sufficient
3 Good
4 Very good
5 Excellent

E = ERGONOMICS
S = SAFETY
A = AESTHETICS
R = RELIABILITY
C = COST

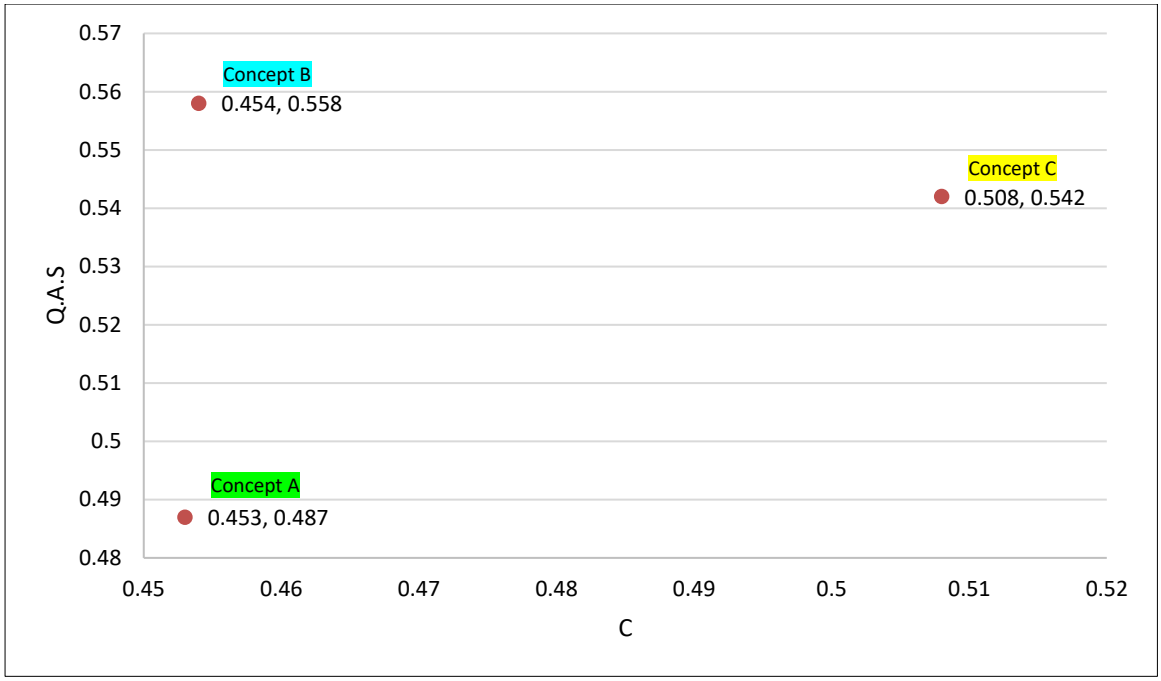
Concepts

I choose three concepts to evaluate.

Concept A	Concept B	Concept C
User Manual	User Manual Video guideline	User Manual, Technician explanation
Flat surface	4 feet	4 feet
Buttons	Touch screen Buttons	Touch screen Voice assistant
Screw Joints	Screw Joints	Screw Joints
Plastic	Plastic	Alloy
Plug	Plug	Plug
Vertical Horizontal	Vertical Horizontal	Vertical Horizontal
Vertical Horizontal	Vertical Horizontal	Vertical Horizontal
Food graded plastic	Food graded plastic	Food graded plastic Steel
Food graded plastic	Food graded plastic	Food graded plastic
Handle with magnet lock	Push and pull	Handle with lock

Concept A is the expensive one, concept B is the one with the highest quality and concept C is a compromise between the two.

	E	S	A	R	Q	Q_{MAX}	1/C	Q.A.S
A	64	63	63	63	253	520	0.453	0.487
B	76	74	70	70	290	520	0.454	0.558
C	72	72	70	68	282	520	0.508	0.542



As we noticed, concept A has higher price and low quality while concept B has similar expensive but the higher quality. Concept C is the compromises among both concepts A and B.

Assignment 2 - Parametric Design of a Stool and related Family of Parts

Please develop the parametric design of a stool and a set of variants through the generation of a family of parts.

The family of parts must include.

a) 1 stool for houses
b) 1 stool for children
c) 1 stool for bar and restaurants (to be fixed on the floor)
d) 1 stool with footrest

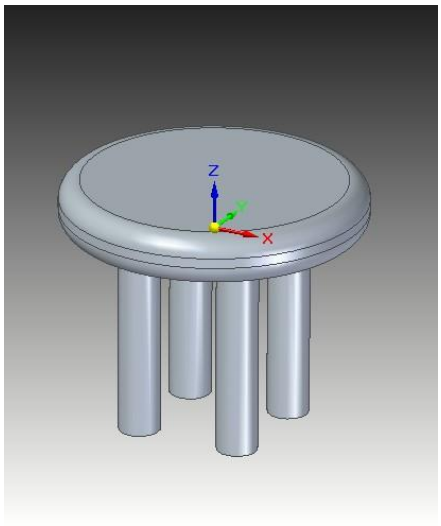
The starting model to populate the family must be defined parametrically in accordance with these requirements:

1. Safety factor of 2
2. Loads related to the 50% percentile of European population – gender male (see appendix) for all cases, except b) in which you can assume 20 kg.
3. Define the most appropriate formula for the sizing criterion of the most solicitated section, considering that it is under compression. Use this consideration also for finding the most suitable type of section.
4. Feel free to select materials, shape of the seat and footrest according to ergonomics and total weight. Unique requirement: single part, not assembly.

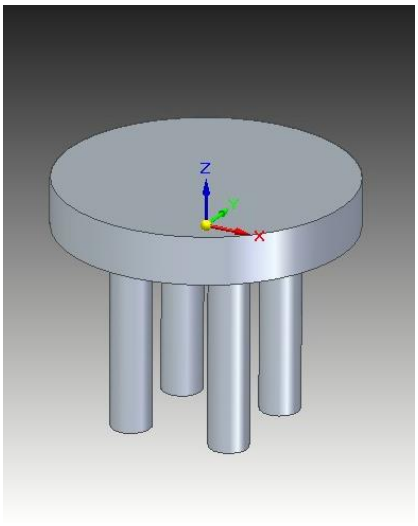
Design Model of Stools

- Always design a model part in Transition to Ordered modelling environment.
- Made Four elements in Family of Parts and done design according to requirements.
- **Stool for Children (House)** :

In this I made seat of circular shape by Extrude feature and then designed leg of table with Extrude. I wanted to make four leg stool so I used feature Pattern to make a pattern of extruded leg.



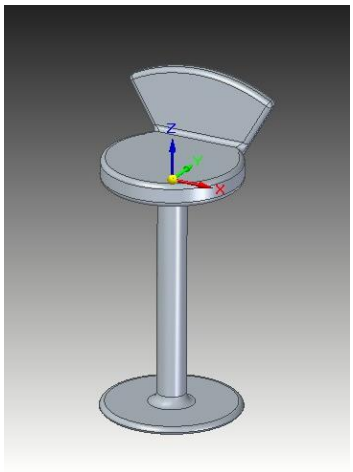
Stool for Children



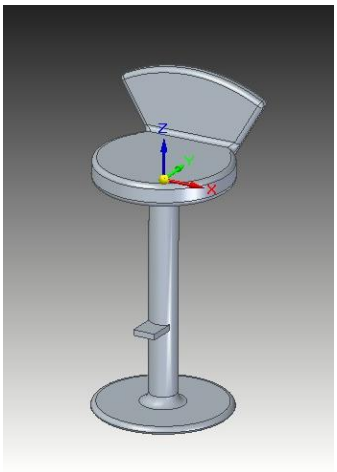
Stool for House

- **Stool for Bar (with Footrest)** :

In this I made seat of circular shape by Extrude feature and then designed leg of table with Extrude. I designed a circular base with Extruded feature. To give nice look of stool, I made a low back stool by Extrude and Cut features. I done radius edges by Round feature.



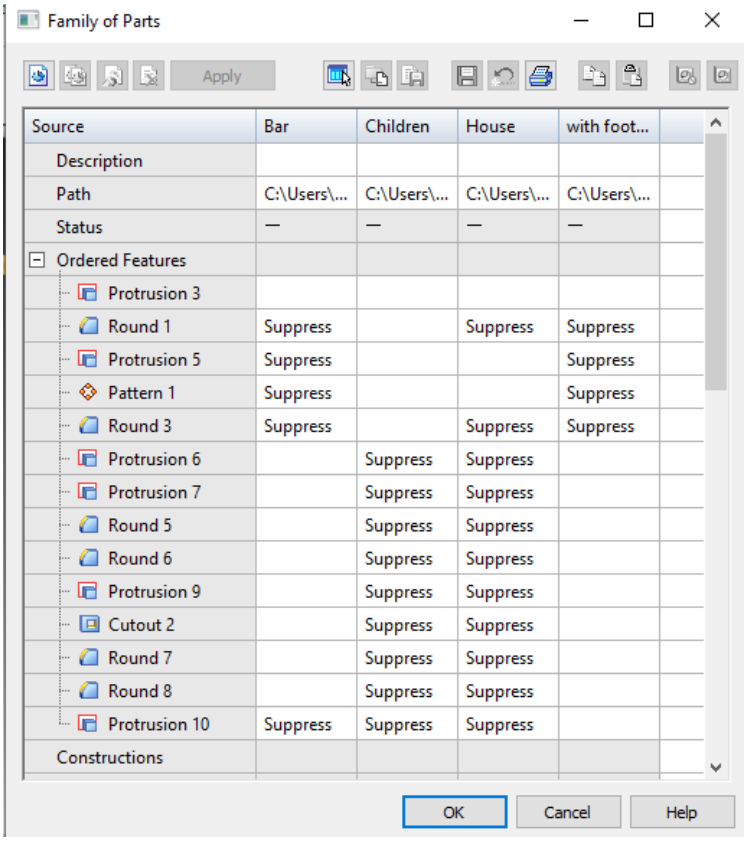
Stool for Bar



Stool with Footrest

Table of Family of Parts

This table shows all features of design used in different family of part. It also shows a suppression feature in each part.



Source	Bar	Children	House	with foot...
Description				
Path	C:\Users\...	C:\Users\...	C:\Users\...	C:\Users\...
Status	—	—	—	—
Ordered Features				
Protrusion 3				
Round 1	Suppress		Suppress	Suppress
Protrusion 5	Suppress			Suppress
Pattern 1	Suppress			Suppress
Round 3	Suppress		Suppress	Suppress
Protrusion 6		Suppress	Suppress	
Protrusion 7		Suppress	Suppress	
Round 5		Suppress	Suppress	
Round 6		Suppress	Suppress	
Protrusion 9		Suppress	Suppress	
Cutout 2		Suppress	Suppress	
Round 7		Suppress	Suppress	
Round 8		Suppress	Suppress	
Protrusion 10	Suppress	Suppress	Suppress	
Constructions				

Table of Variables

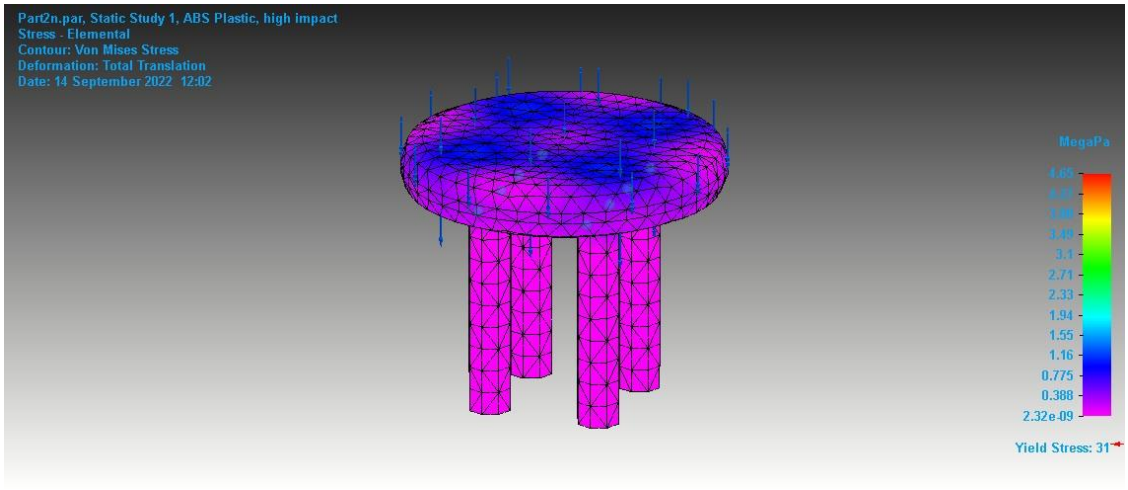
I linked the diameter of seat and height of leg with Excel sheet. In Excel sheet, I used formula for height of stool for children and house is equal to diameter multiplied two by third(D*2/3). Height of bar (with footrest) stool is equal to diameter multiplied five by third(D*5/3).

Type	Name	Value	Units	Rule	Formula	Range	Expose	Exposed Name	Comment
Dim	V428	30.00	mm						
Dim	ExtrudedProtrusio	1.50	mm						
Dim	V551	6.00	mm						
Dim	Height2	50.00	mm	Paste Link	@'C:\Users\D			Height2	
Dim	Round_3_Radii1	1.00	mm						
Dim	Height	20.00	mm	Paste Link	@'C:\Users\D			Height	
Dim	Diameter	30.00	mm	Paste Link	@'C:\Users\D			Diameter	
Dim	ExtrudedProtrusio	5.00	mm						
Dim	Round_1_Radii1	2.00	mm						
Dim	Round_5_Radii1	2.00	mm						
Dim	Round_6_Radii1	1.00	mm						
Dim	V2790	8.00	mm						
Dim	V2791	8.00	mm						
Dim	ExtrudedProtrusio	15.00	mm						
Dim	ExtrudedCutout_2	12.00	mm						
Dim	Round_7_Radii1	1.00	mm						
Dim	Round_8_Radii1	1.00	mm						
Dim	V3706	93.51	°						
Dim	V3986	15.00	mm						
Dim	V3993	0.50	mm						
Dim	V3999	0.50	mm						
Dim	V4001	1.30	mm						
Dim	ExtrudedProtrusio	9.50	mm						
Var	PhysicalProperties	0.000	kg/mm^3	Limit		[0.000 kg/m		Density	
Var	PhysicalProperties	0.990		Limit		(0.000;1.000]		Accuracy	
Var	V703	4.000		Limit		[1.000;)			

Stress Section Analysis

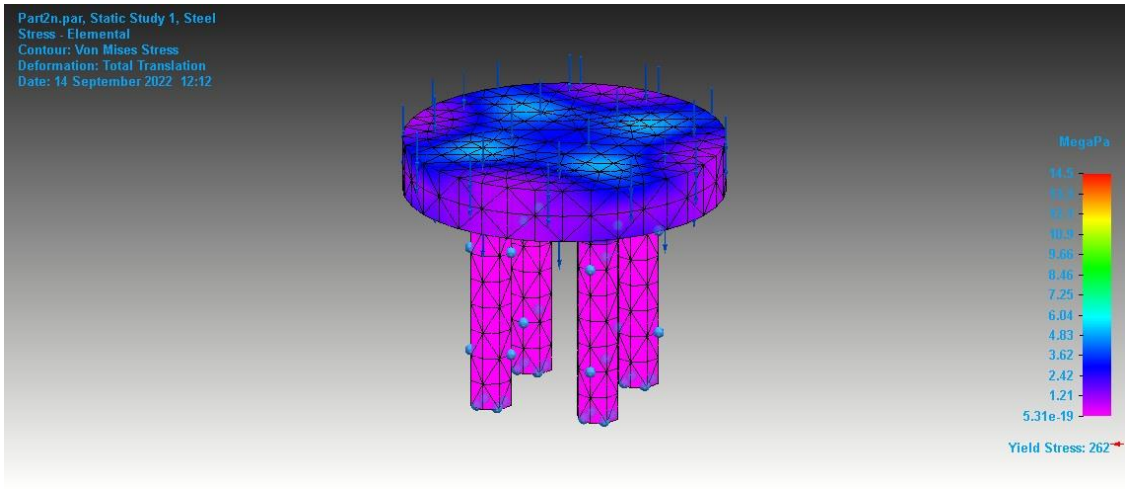
- Stool for Children:

  - Material : ABS Plastic, high impact
  - Force : 196200 mN



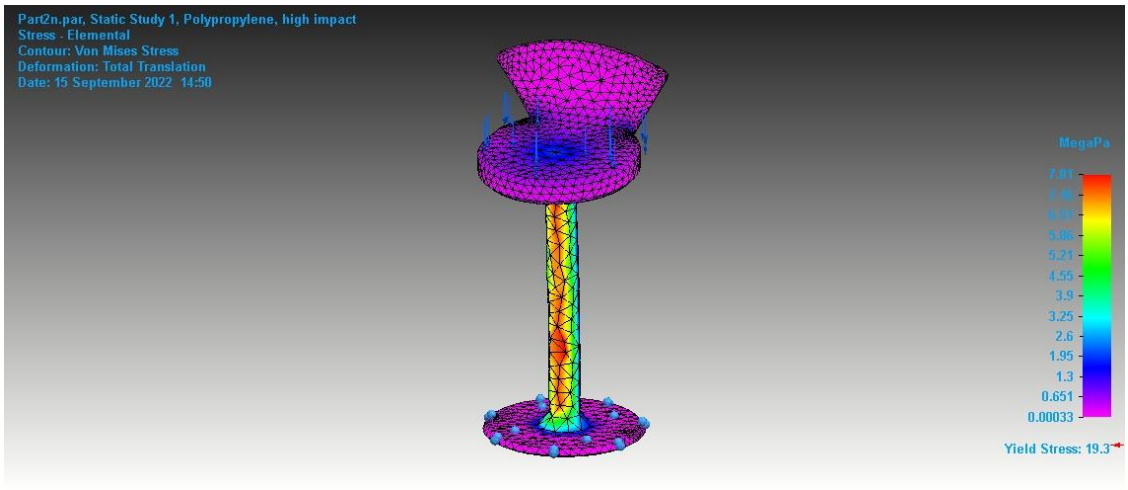
- Stool for House:

  - Material : Steel
  - Force : 490500 mN



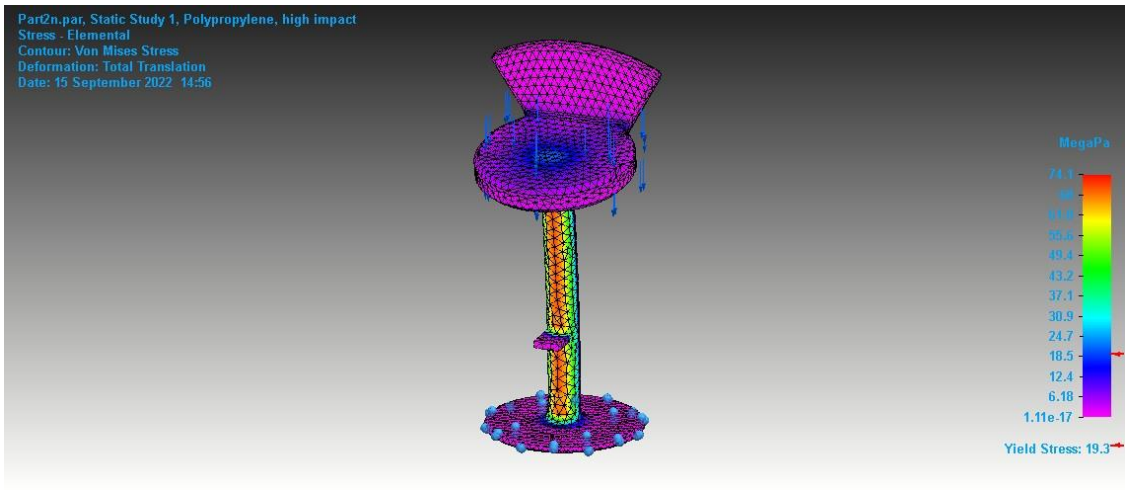
- Stool for Bar:

  - Material : Polypropylene, high impact
  - Force : 735750 mN



- Stool for Bar:

  - Material : Polypropylene, high impact
  - Force : 735750 mN



Assignment 3

Steps for the Design of Surface

- First of all, I imported step file of **setpoints** for assignment in Solid Edge.
- Create **Keypoint Curve** by joining these points which is as per image (a).
- I defined **cross section points** to draw section A, section B, and section C as shown in image (b).

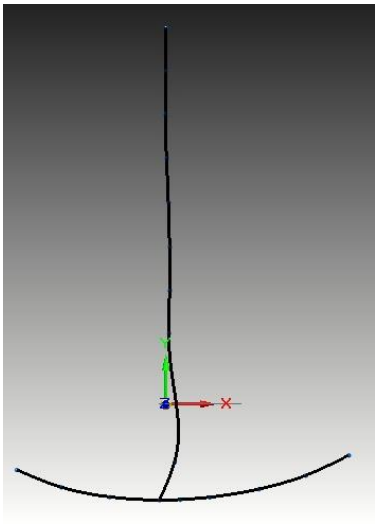


Image (a)

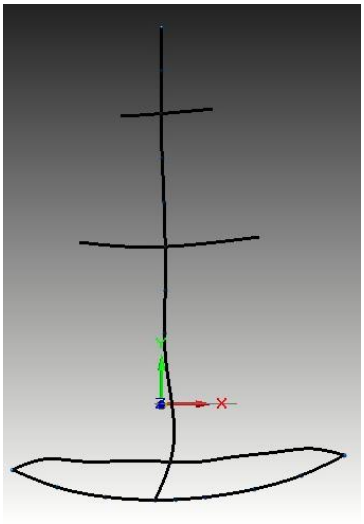


Image (b)

- Create another **Keypoint Curve** to join the network as shown in image(c).

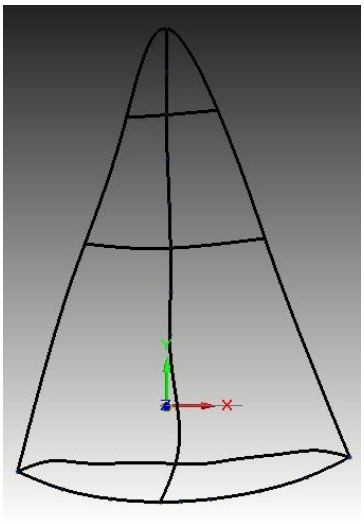


Image (c)

- Making surface within outer closed boundary with **Bounded** feature and then select **Bounded - Guided Curve Step** to define the path curve of surface.
- Final surface is ready as per image (d).

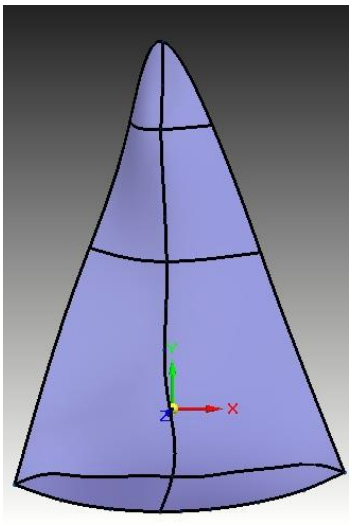
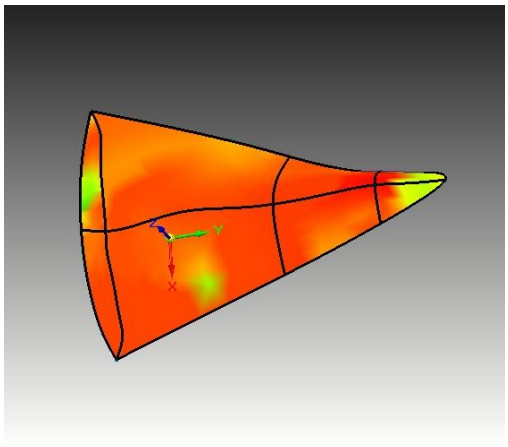
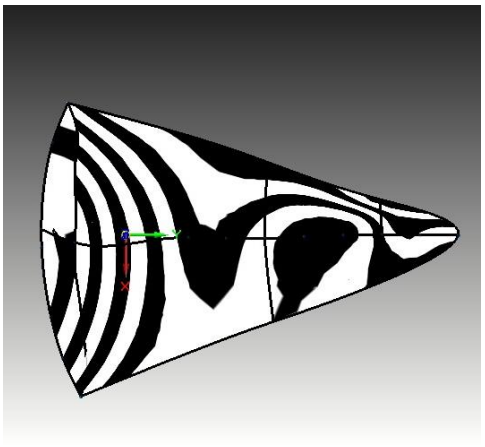


Image (d)

Curvature Analysis

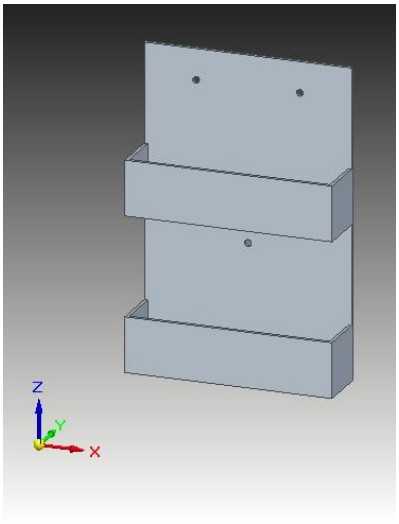


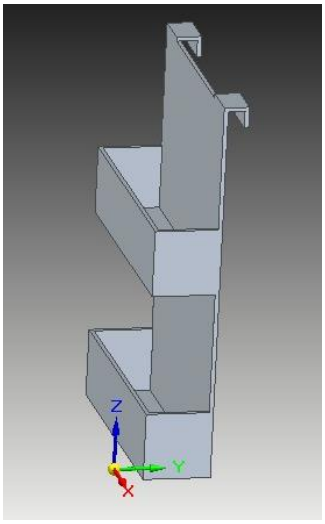


Assignment 4 – FEA and TO of a showercaddy

Model of Geometry

- Software used : Solid Edge 2022



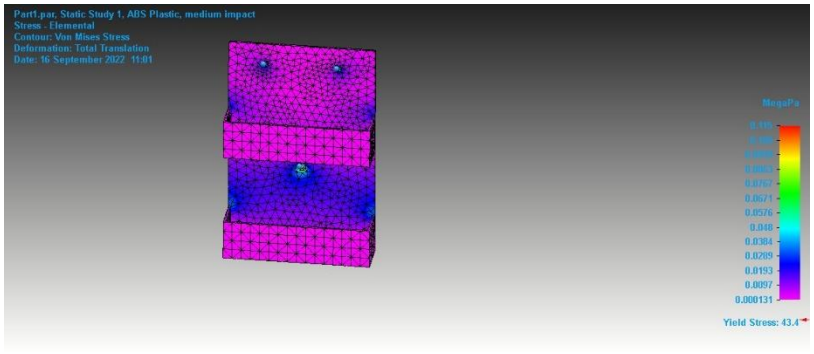


FEA of Geometry in SolidEdge

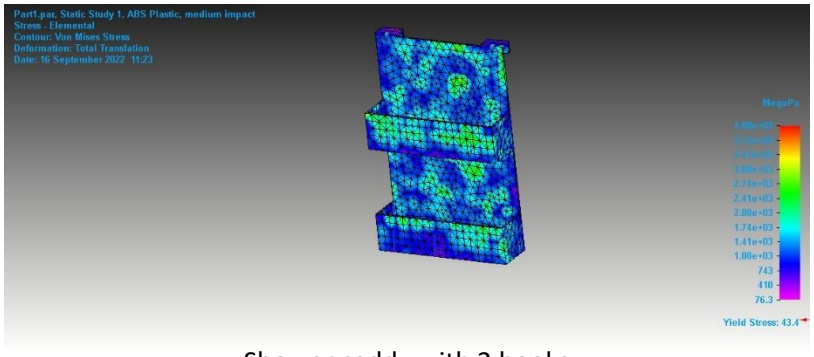
- Material : ABS Plastic, medium impact

Case A: Forces distributed on the shelves horizontal facets

- Force : 14715 mN



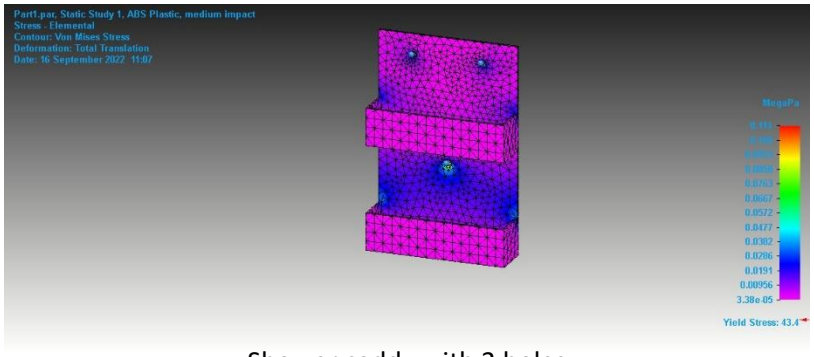
Shower caddy with 3 holes



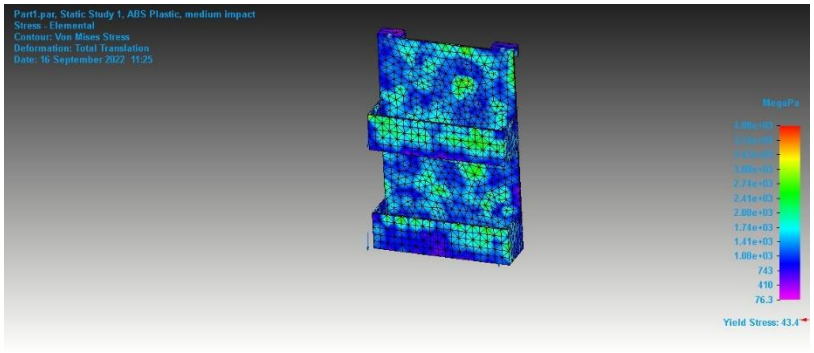
Shower caddy with 2 hooks

Case B: Forces localized on a corner of each shelf

- Force : 3678.75 mN on each corner



Shower caddy with 3 holes

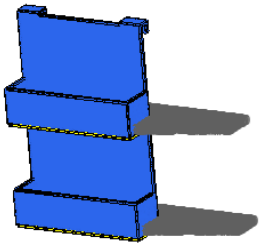


Shower caddy with 2 hooks

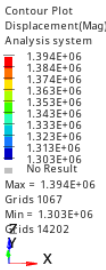
FEA and TO of Geometry in HyperWorks

Case A: Forces distributed on the shelves horizontal facets

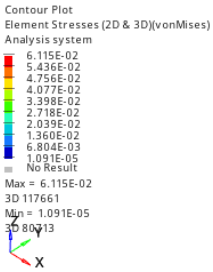
- Shower caddy with 2 hooks

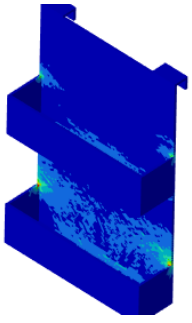


Model

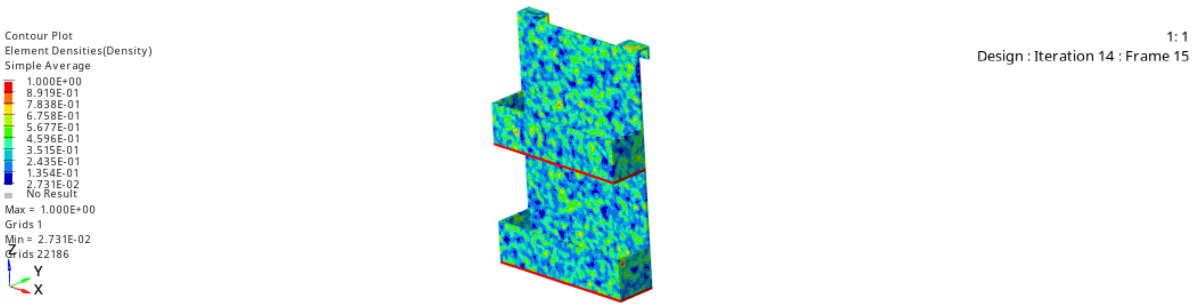


Displacement Analysis



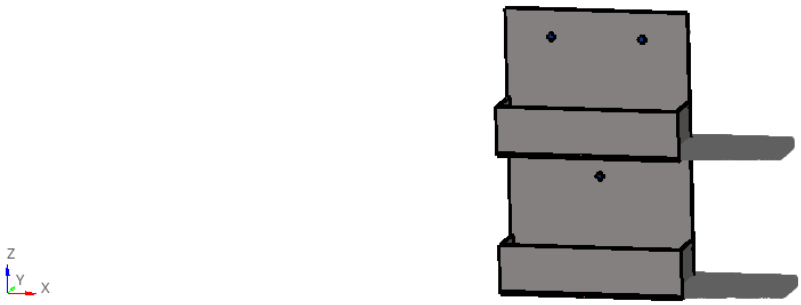


Element Stress Analysis

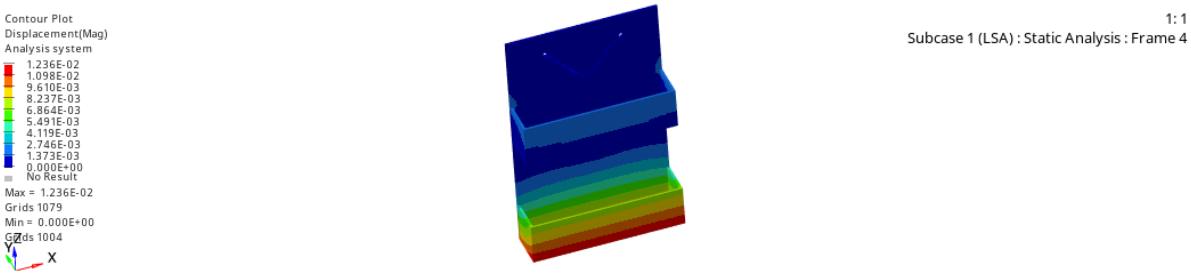


Topological Optimization

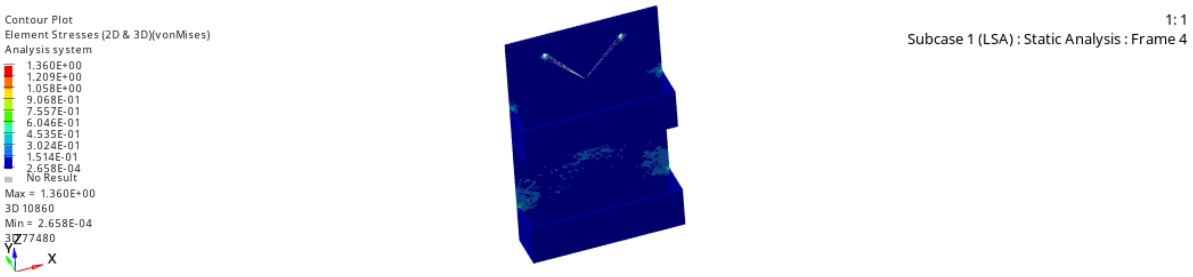
- Shower caddy with 3 holes



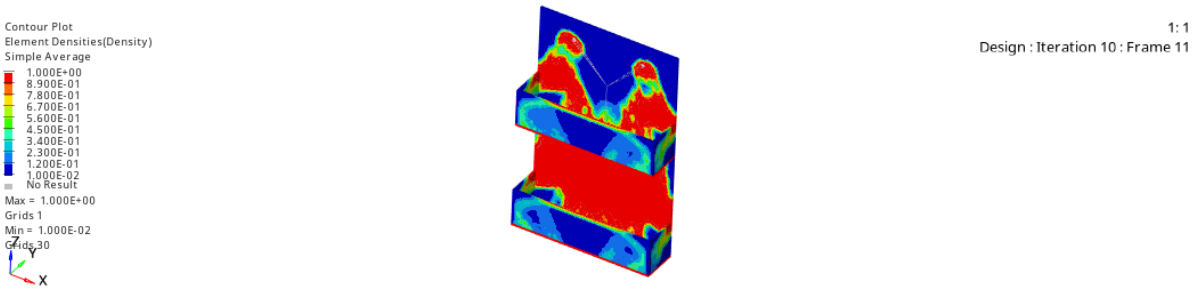
Model



Displacement Analysis



Element Stress Analysis

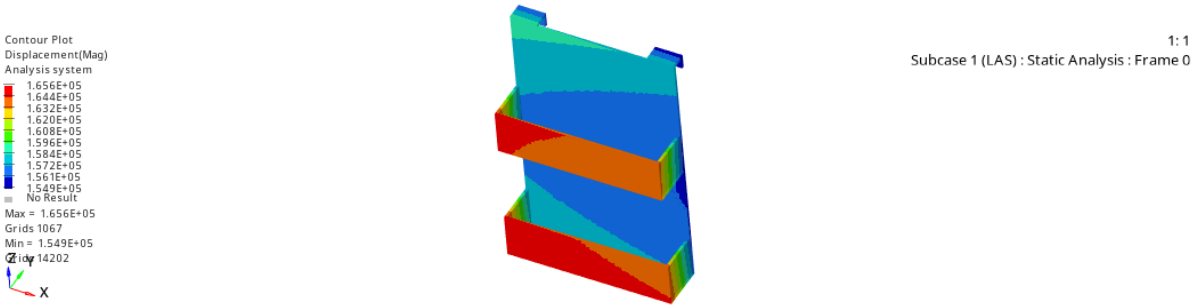


Topological Optimization

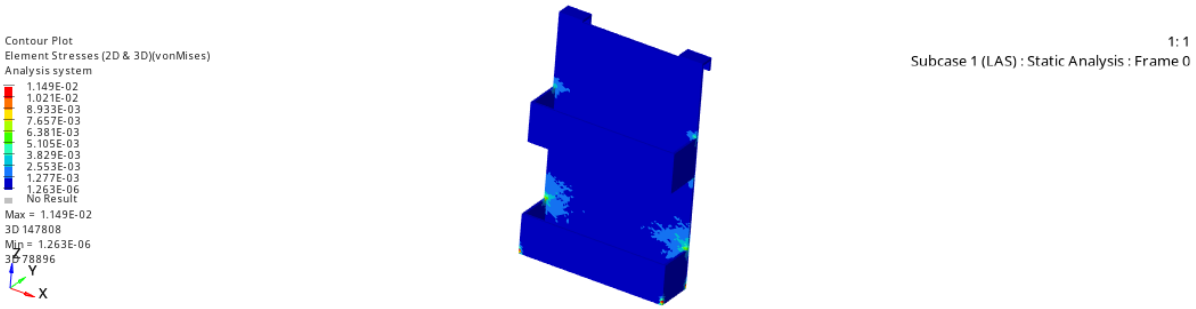
Case B: Forces localized on a corner of each shelf

- Shower caddy with 2 hooks

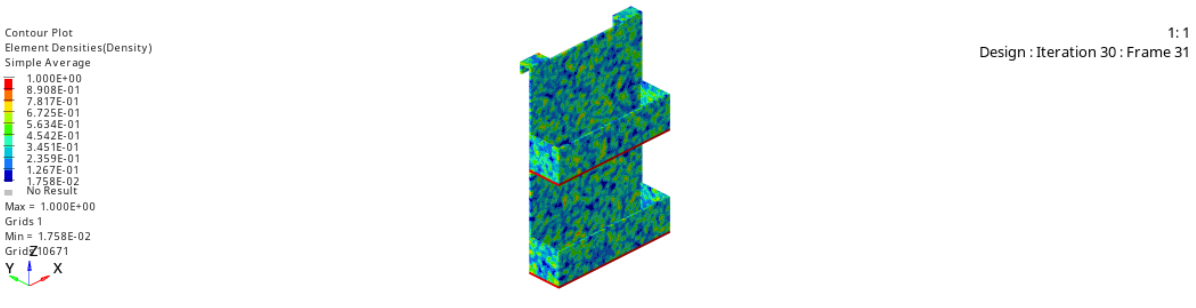
Model



Displacement Analysis

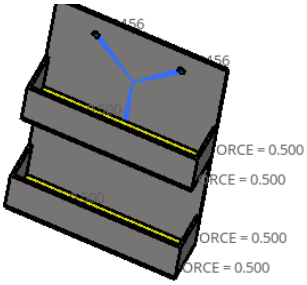


Element Stress Analysis

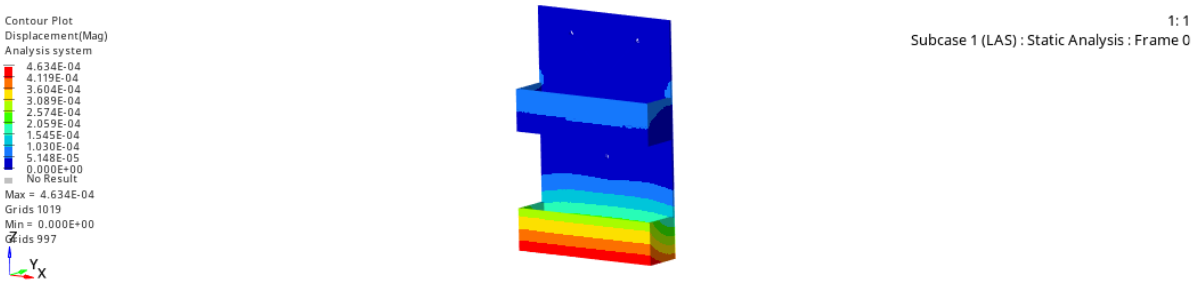


Topological Optimization

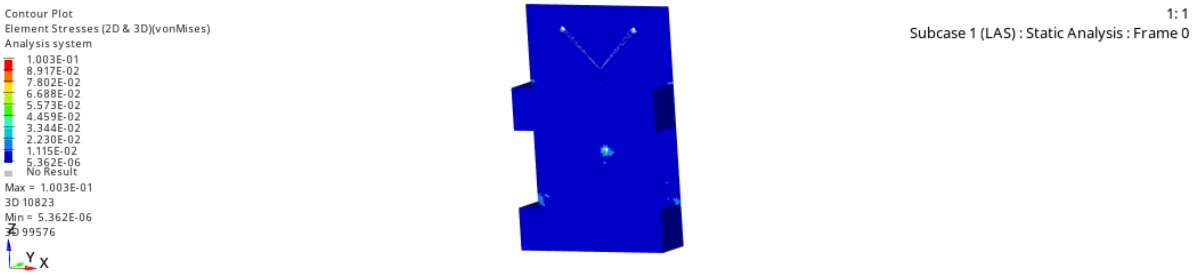
- Shower caddy with 3 holes



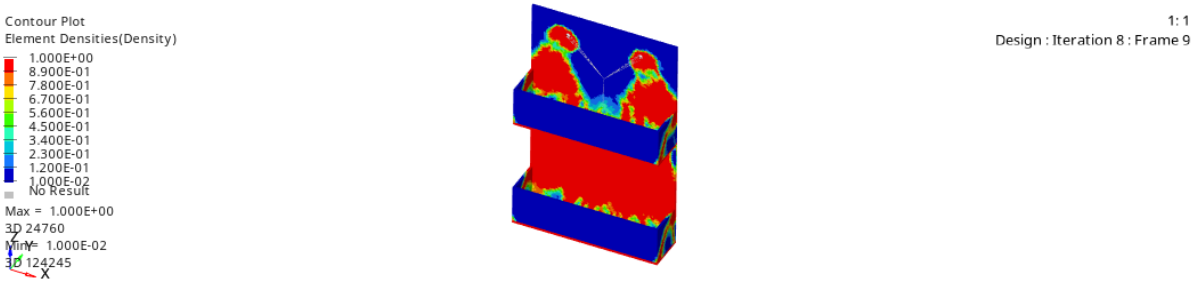
Model



Displacement Analysis



Element Stress Analysis



Topological Optimization