COMPUTER AIDED DESIGN AND ANALYSIS (UME411)

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CREATING AN OPTIMUM DESIGN FOR A BOTTLE USING CREO 6.0

Presented To

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EXECUTIVE SUMMARY

The purpose of this report is to design and optimize a water bottle using CREO 6.0 software. Firstly, we have modelled the initial design of bottle using various features like SWEEP, SHELL etc. The base of bottle is kept elliptical **(30 x 50 mm**) and height **220 mm** (with cap and tolerance). We defined the VOLUME measure to know the capacity of the vessel.

Since the initial volume of the bottle was 428.176 ml, we had to optimize the bottle to make volume equal to **500 + 5 ml** (5 ml for tolerance and cap).

BMX module of CREO allows us to define our own features for analysis.

THICKNESS PARAMETER was assigned with initial value of 1.1 mm and was used in shell command.

Sensitivity analysis was done for 7 different dimensions to know the effect of dimensions on the volume measure of the model.

Dimension	Current Value	MIN. Value	MAX. Value
D20	60.0 mm	54.0 mm	66.0 mm
D4	70.0	63	77
D3	16	14.4	17.6
D7	23.0	20.7	25.3
D8	280.0	252	308
D9	65.0	58.5	71.5
D13	60	54.0	66.0

After that optimization was done with the GOAL of minimising the mass and design constraint that VOLUME Measure should be equal to 505 ml. The optimized model had a volume of 505.065 ml.

CREO SIMULATE:

The bottle was to be made of glass so material assignment was done with density 2.5 g/cm^3, Poisson's ratio 0.22, E = 70 GPa, Tensile strength 160 MPa, Compressive strength 1000 MPa.

Next, displacement constraint was added on the elliptical base since it was to be

assumed that bottle is lying on a surface in real world and thus translational movement in all directions were fixed.
Atmospheric pressure of **101 KPa** was applied on the outer of the bottle and a **400 KPa** pressure inside the bottle which was the pressure exerted by the fluid on bottle in real world.

Static analysis was done:

- The analysis show the model max as 53.9387MPa and model minimum as 0.03873 MPa.
- Error estimate: 0.9% of 53.9387MPa.
- Mass of bottle **1.086533e-04 TONNE.**

Since the stress should not exceed by **40 MPa** (FOS = 4) on the bottle, optimization for the stress was required.

Global sensitivity analysis was done to known the impact of changing THICKNESS PARAMETER with Maximum von misses stress on model.

Finally optimization was done with constraint that max_stress_vm less than 40 MPa and variable was taken as THICKNESS

VARIABLE	CURRENT	MINIMUM	INITIAL	MAXIMUM
THICKNESS	1.1 mm	0.8 mm	0.9 mm	1.6 mm

RESULT OF OPTIMIZATION:

- Final thickness came **1.30734 mm**.
- Max stress came out **40.0052 MPa.** (satisfied within tolerance)
- Total mass of bottle: **1.2972e-04 TONNE**

TABLE OF FIGURES

ABSTRACT

Prototype making of an initial concept of product plays a vital role in production cost of a product. Nowadays, to lower the cost of prototype we simulate the models of prototype rather than again and again making prototypes since it will add up in the cost of developing it.

CREO SIMULATE Enhance your product design with simulation and analysis to reduce costly physical prototyping while increasing your products' durability, reliability, and safety. It helps us to analyse the various other properties of model such as stresses induced, pressure applied and helps us to optimize our model in context with these properties which cannot be performed in CREO PARAMETRIC.

The aim of this project is to design an optimized bottle with the following features:

- The capacity of the bottle should be 500 ml.
- It should have minimum mass and a resist a stress of at least 40 MPa.

CREO Simulate is a multi-discipline CAE (Computer Aided Engineering) tool with which you can simulate the physical behaviour of a model and understand and improve the mechanical performance of your design. You can directly calculate stresses, deflections, frequencies, heat transfer paths, and other factors, showing you how your model will behave in a test lab or in the real world.

BMX MODULE (CREO):

BMX is the ultimate in feature based parametric modelling through which we create features that ensure changes to geometry and update the rest of your model.

GETTING STARTED

I. DESIGNING THE BOTTLE:

CREO 6 is a powerful tool for modelling 3D shapes and assemblies. Base of the bottle is taken elliptical of 30*50 mm and total height of bottle 220mm (200 mm for fluid, 10 mm for cap and 10 mm for clearance)

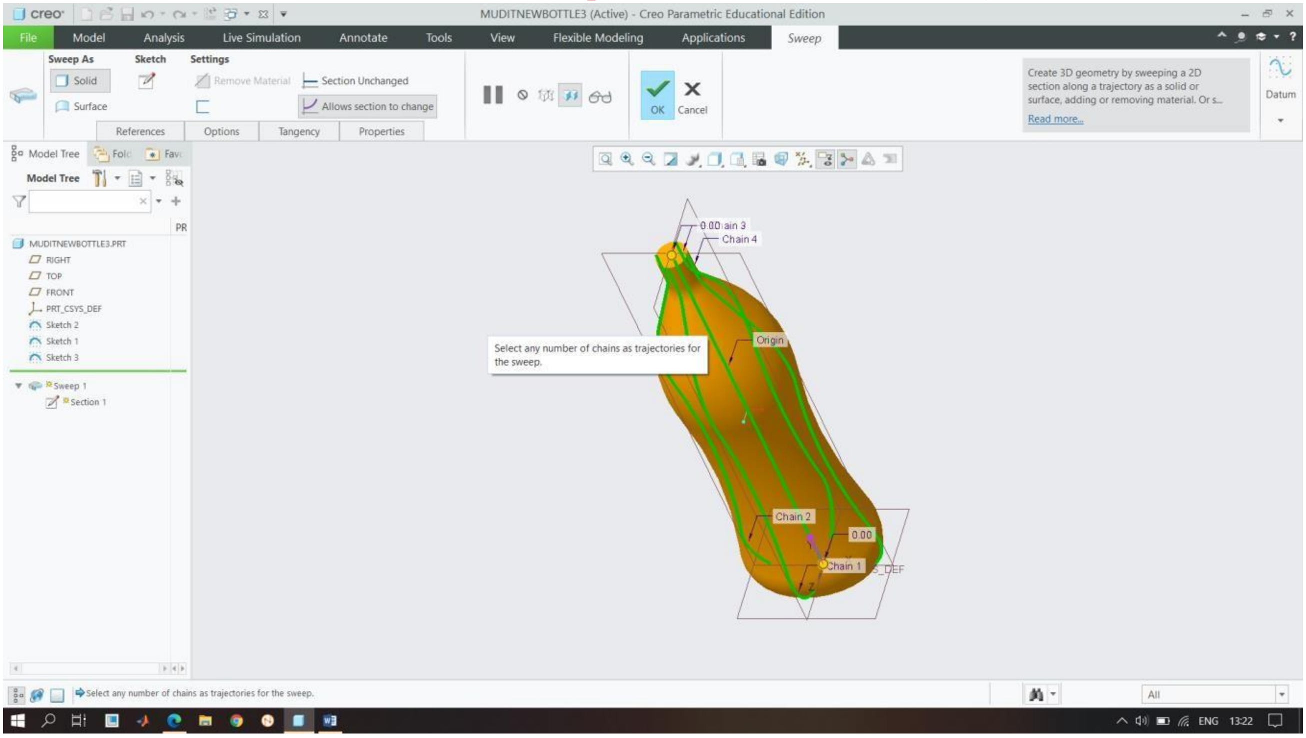


Fig 1.SWEEP feature application

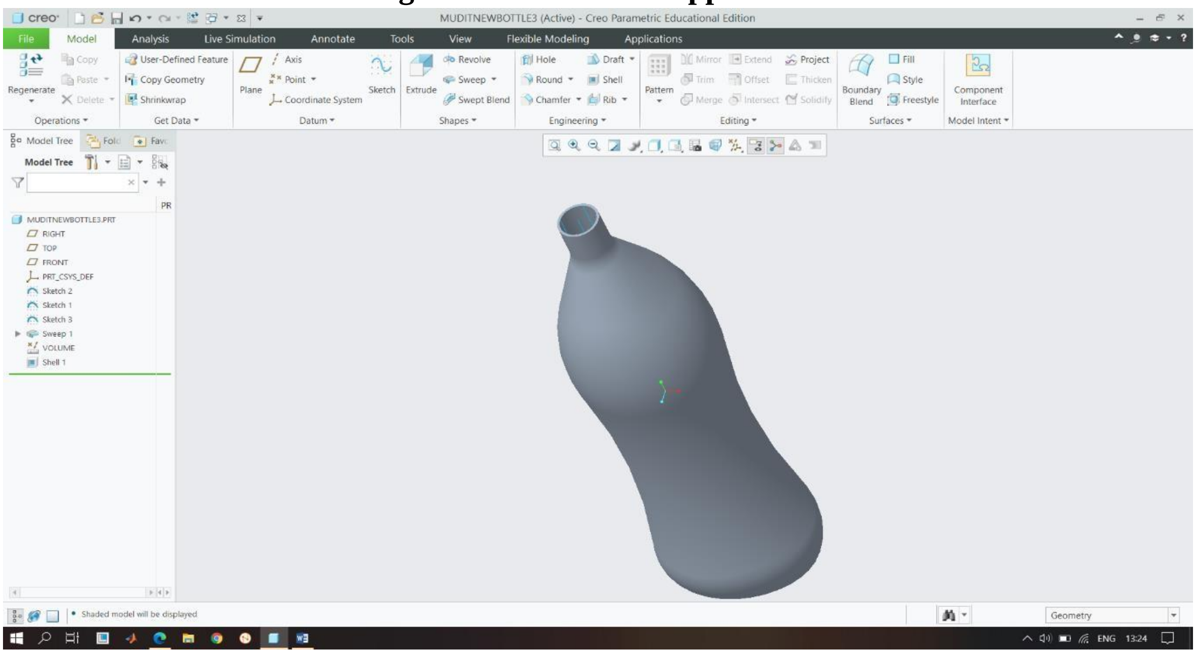


Fig 2. Initial Bottle Design

NOTE: The shell feature should be applied towards the outer bountary so that the volume of bottle does not change while applying shell feature.

II. CREATING THE VOLUME AND MASS FEATURE:

BMX module under CREO parametric allows user to define its own features for analysis and optimization of various parts or assemblies in 3D. Volume feature will give us the volume inside the bottle and will later act as a design constraint for volume optimization.

It can be created easily by MEASURE button under analysis tab. Initial volume is **428176.00** mm3.

Similarly we can assign the MASS feature. Initial mass is 1.0043156e-04 TONNE**.**

NOTE: The volume feature created should be dragged just above the SHELL in the model tree so that it gives the volume inside the vessel.

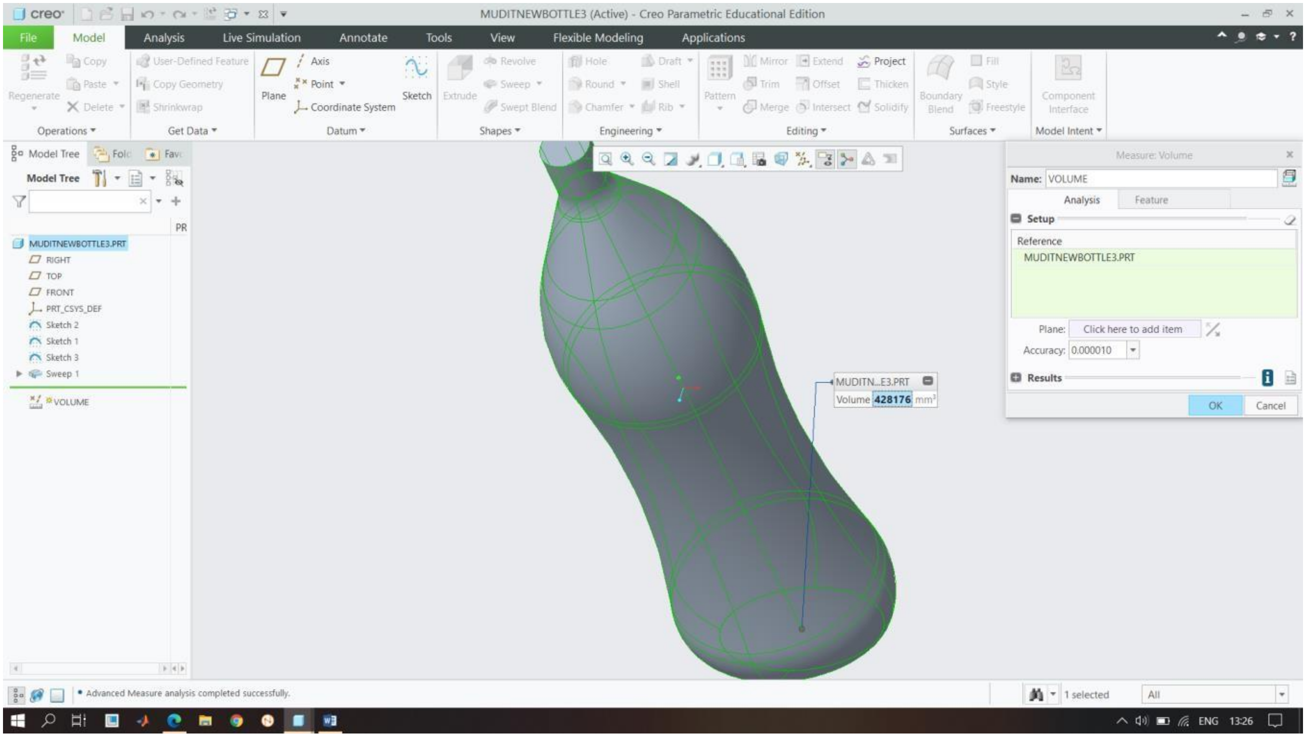


Fig 3. Initial Volume of Vessel

III. ADDING RELATIONS AND PARAMETERS:

Since bottle is made using SWEEP command, for having the symmetry of the bottle we need to define some relations for it. We can define Relations thorough relations button under MODEL INTENT menu.

We have to add a Parameter THICKNESS for the thickness of the Vessel and define it in SHELL command thickness input with initial value of 1.1 mm as shown in Fig 4.

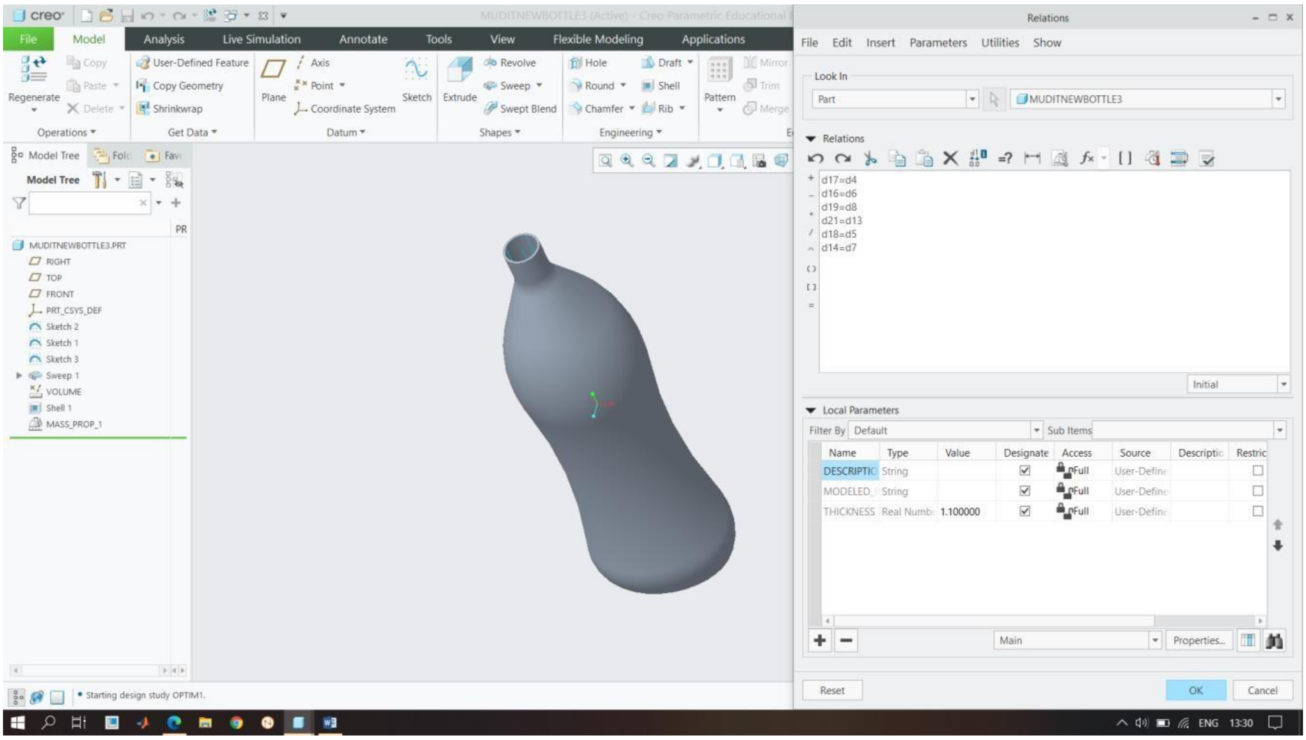


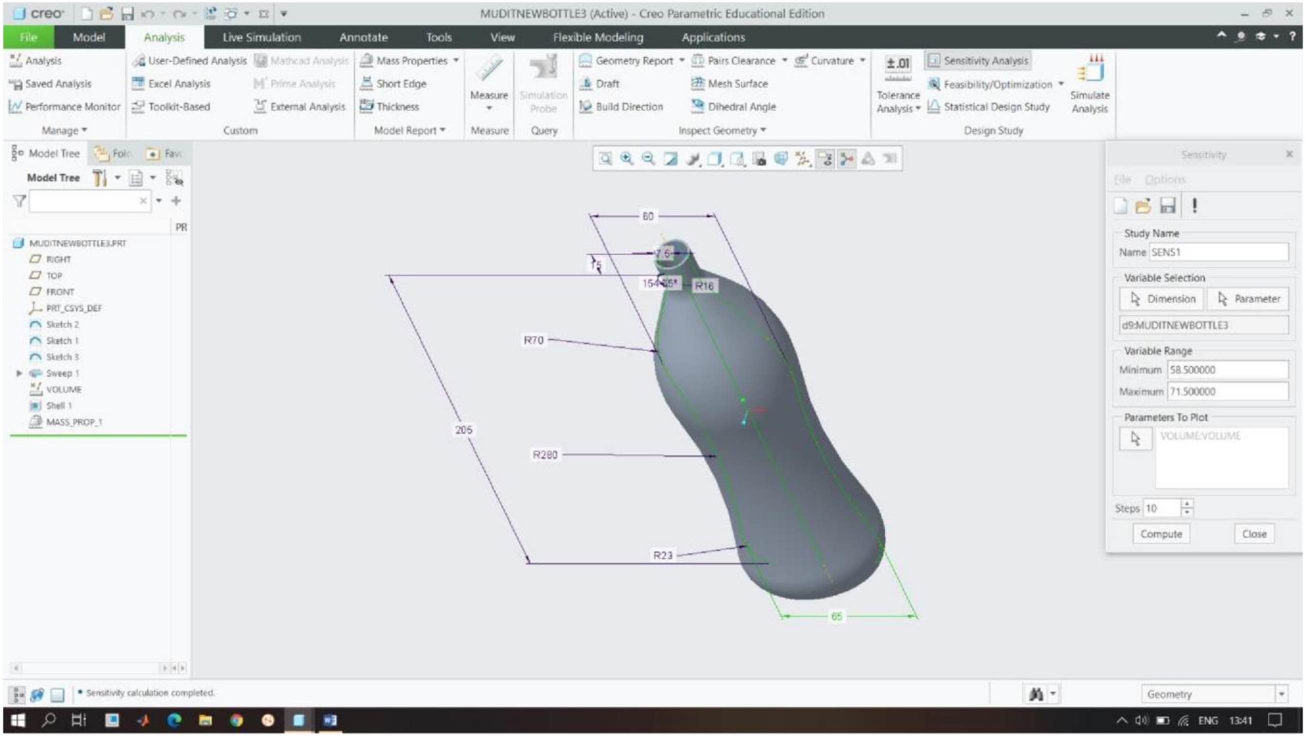
Fig 4. Relations and Parameters

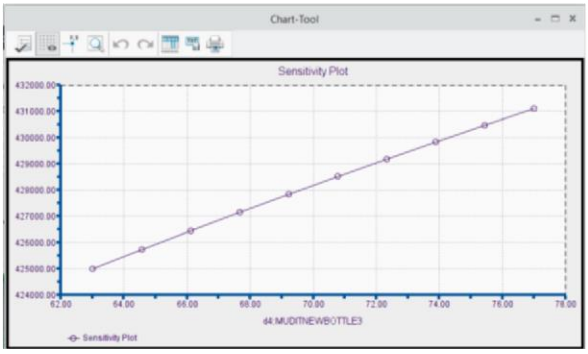
IV. SENSITIVITY ANALYSIS:

Sensitivity analysis allows you to analyse how various measured quantities (parameters) vary when a model dimension or an independent model parameter is varied within a specified range. The result is a graph for each selected parameter showing the value of the parameter (VOLUME) as a function of the dimension.

Fig 5. Sensitivity analysis setup

Dimension	Current Value	MIN. Value	MAX. Value
D20	60.0 mm	54.0 mm	66.0 mm
D4	70.0	63	77
D3	16	14.4	17.6
D7	23.0	20.7	25.3
D8	280.0	252	308
D9	65.0	58.5	71.5
D13	60	54.0	66.0





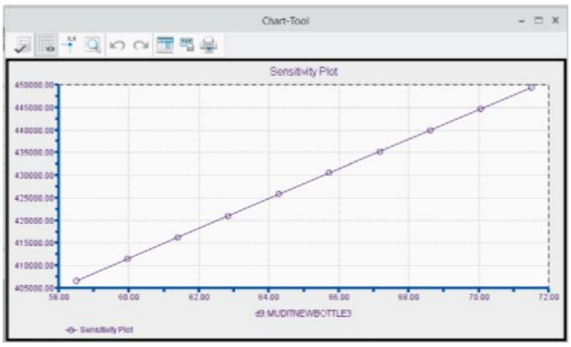


Fig 6a. Graph of D4

Fig 6b. Graph of D9

Fig 6c. Graph of D8

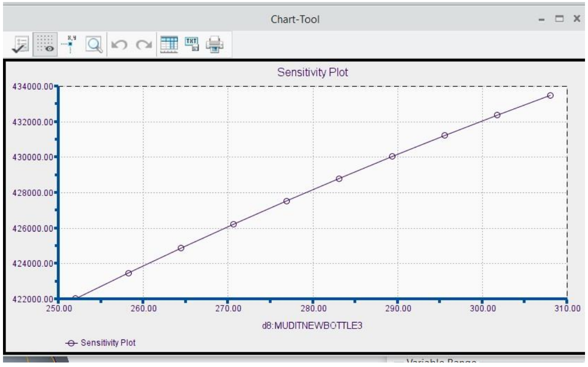
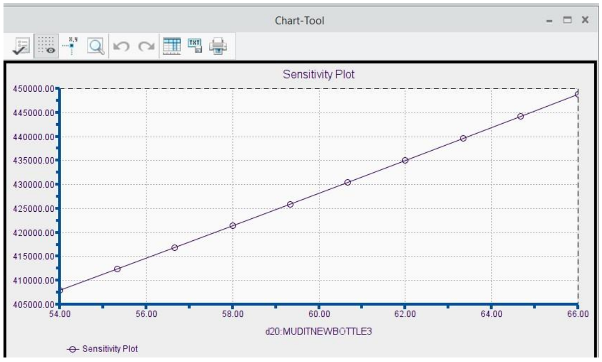


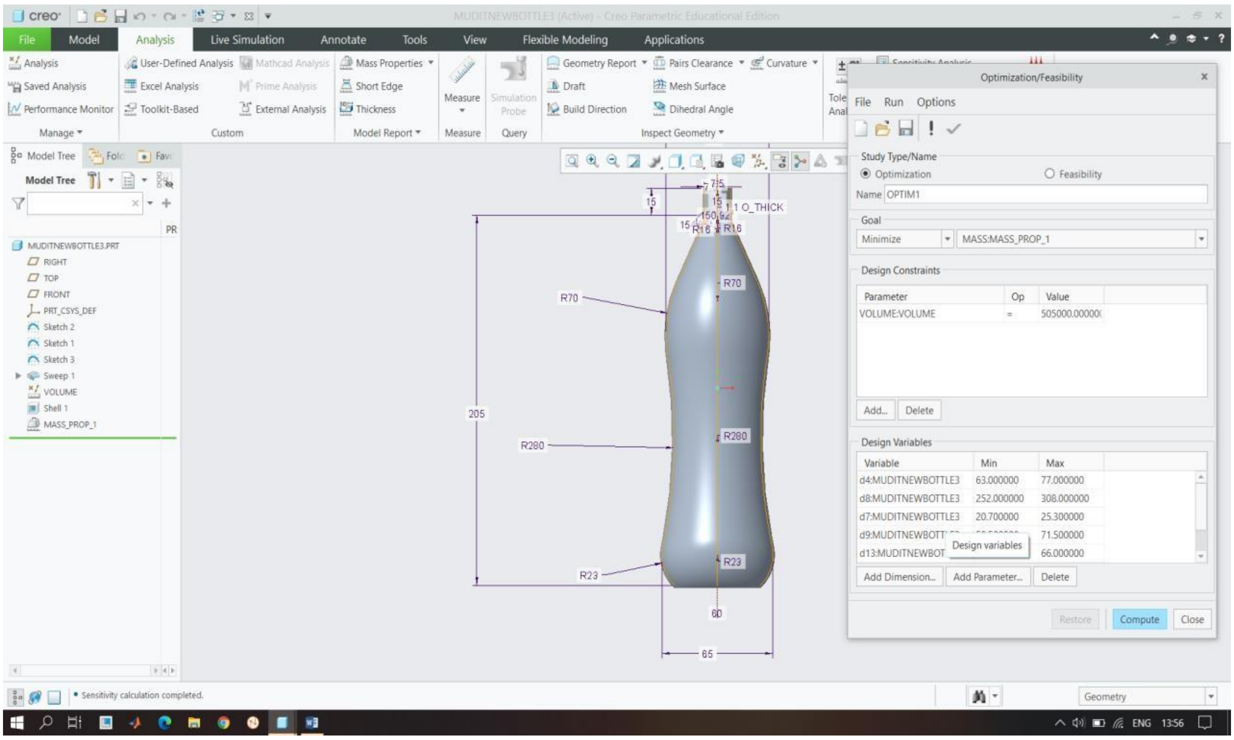
Fig 6d. Graph of D20



V. OPTIMIZATION OF VOLUME:

the arrow next to **Feasibility/Optimization**. Click

constraint and minimising the mass.



Feasibility and optimization studies allow you to have the system compute dimension values that cause the model to satisfy certain user-specified constraints. To access a feasibility or optimization study, click **Analysis** and then click
Feasibility/Optimization and select the type of study from the dialog box.

OPTIMIZATION is done for making the volume of vessel 505 ml by giving a design

NOTE: **I have taken DESIGN CONTRAINT VOLUME equal to 500+5 ml where 5ml is for the volume of clearance (10 mm) and cap (10 mm).**

Fig 7. Optimization setup

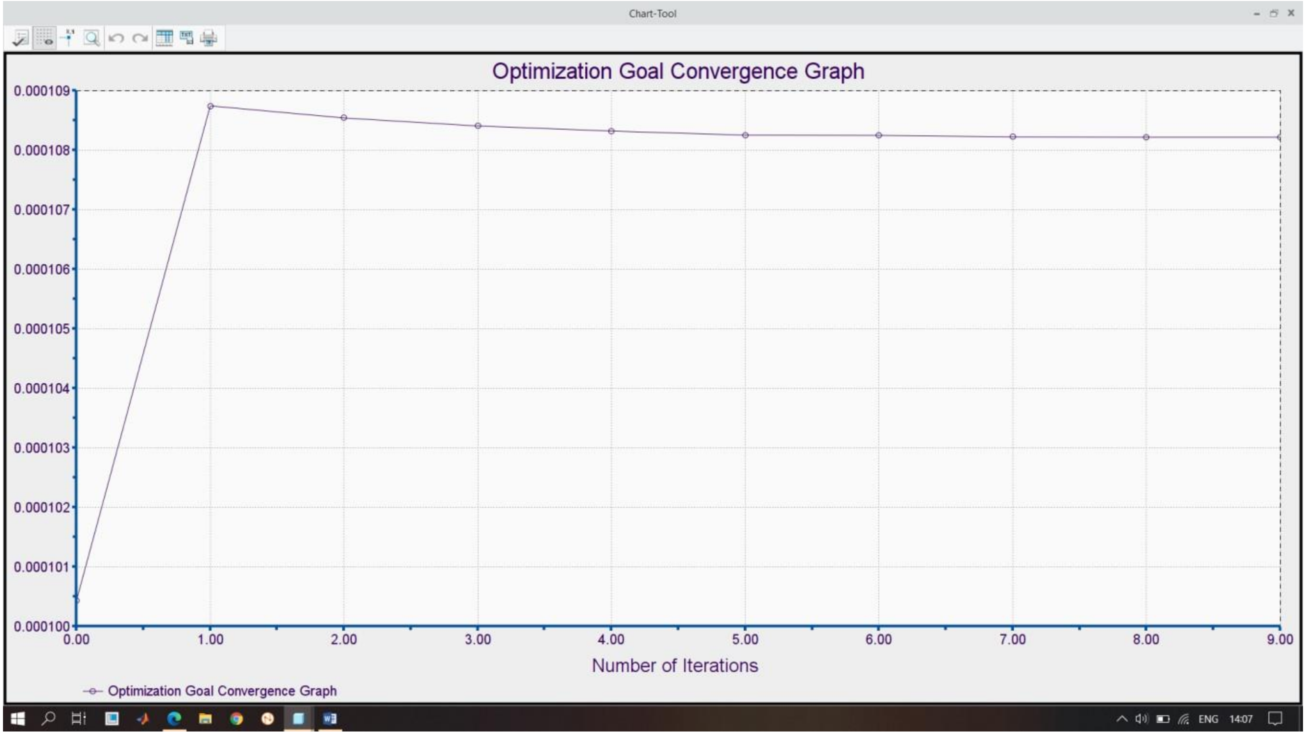


Fig 8. Optimization Graph (GOAL)

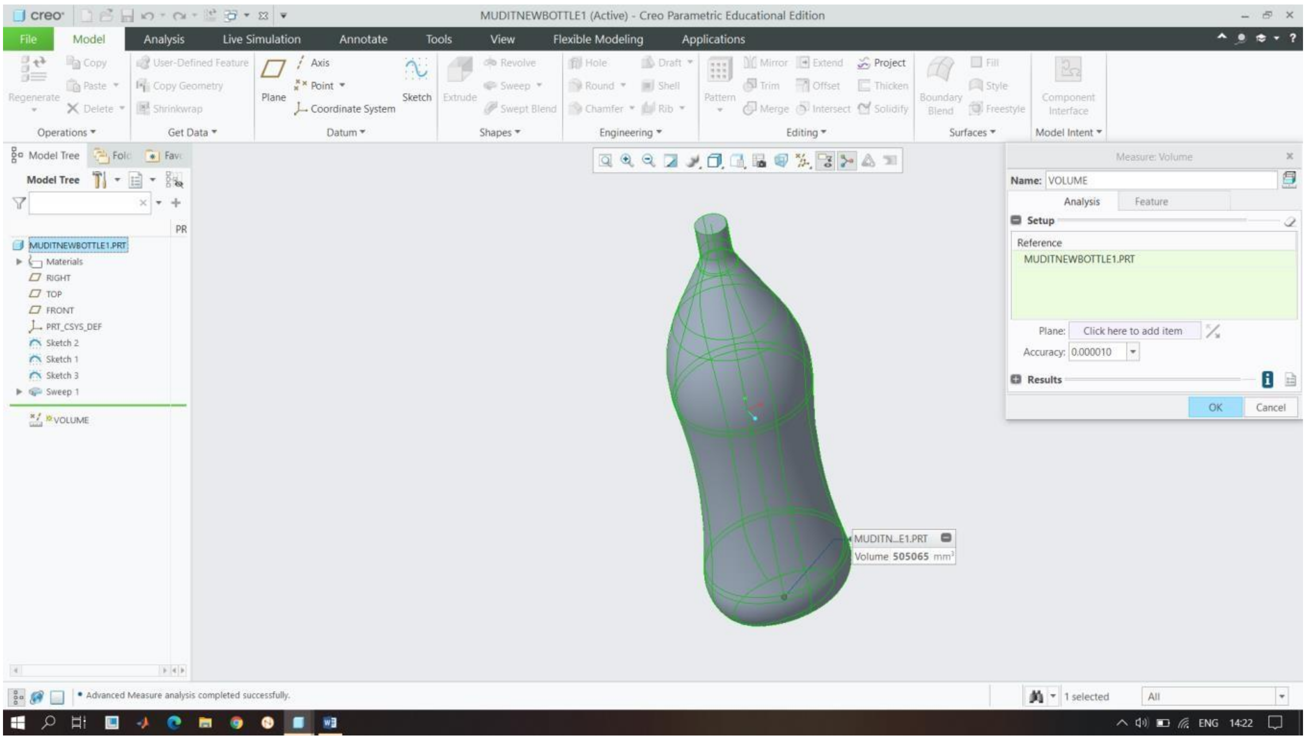


Fig 9. Final model (volume= 505.065 ml and mass = 1.0865111e-04 TONNE)

NOTE: The optimization curve is increasing because initial volume of bottle was less than 505 ml. (501 ml till 200 mm from bottom of model)

GETTING STARTED WITH SIMULATE

The CREO family of simulation software and capabilities lets you perform simulations on your products throughout the development process, helping reduce physical prototyping costs, design cycle times, and analysis department backlog. When you resolve basic design problems earlier, the analysis department can focus on higher-level issues when they get your prototype. The result is an optimized product developed at lower cost and taken to market earlier.

To start the SIMULATE, click on the simulate button under applications tab in CREO Parametric.

I. MATERIAL ASSIGNMENT:

The bottle is to be made of Glass, of density 2.5 g/cm^3, Poisson's ratio 0.22, E = 70 GPa, Tensile strength 160 MPa, Compressive strength 1000 MPa.

Material assignment can be done using MATERIAL ASSIGNMENT button under material tab.

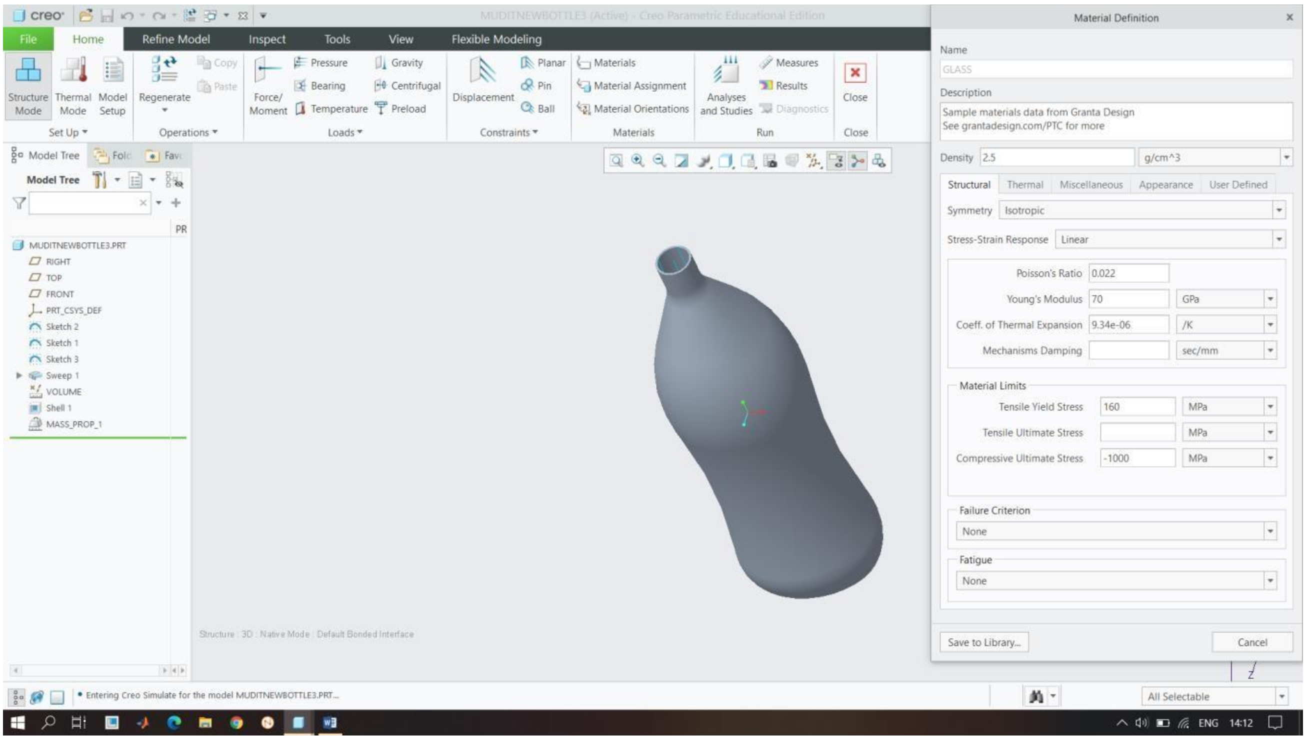


Fig 10. Material assignment

II. CREATING LOAD CONSTRAINTS:

While defining constraints for a Structure model, your goal is to fix portions of the model geometry so that the model cannot move, or can move only in a predetermined way. Your model's constraints, along with its loads, provide the software with the realworld conditions that it uses as the basis for analysis.

The elliptical base of the bottle is to be fixed i.e. it should no displace and it can be done using displacement constraint by selecting fixed option.

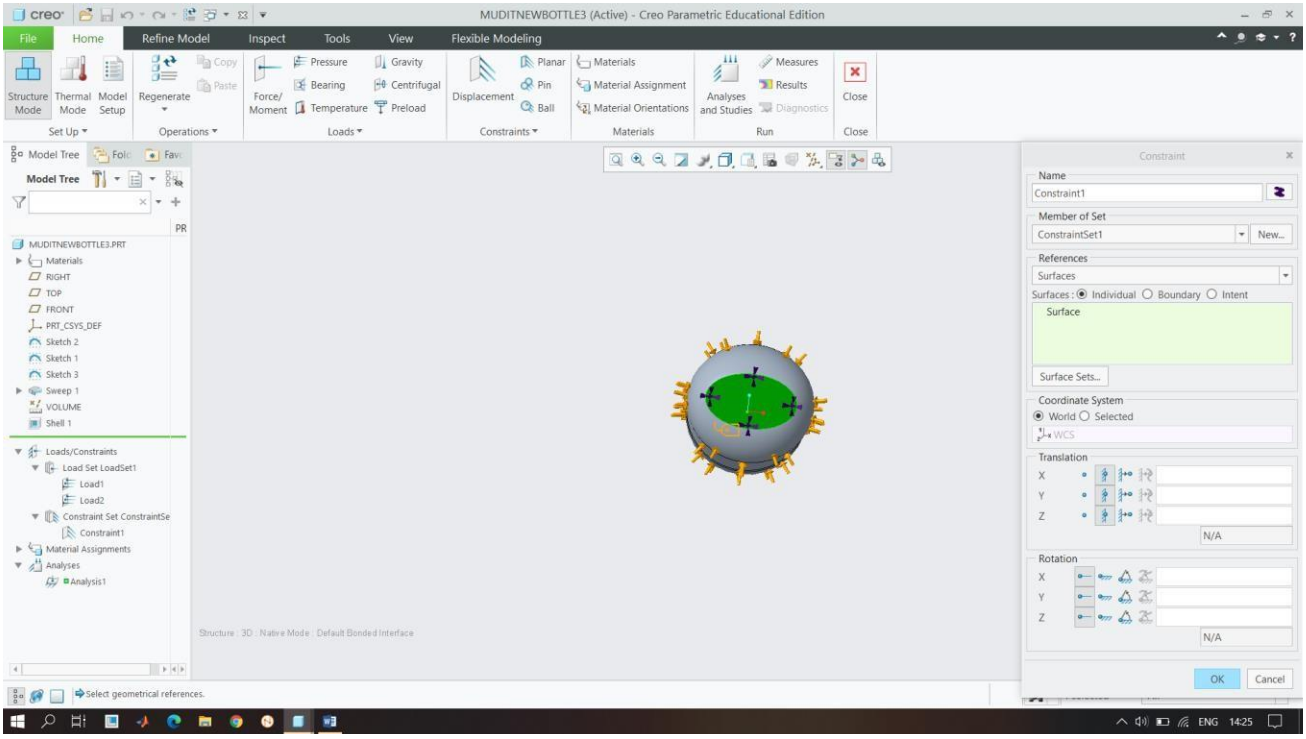


Fig 11. Displacement constraint

III. CREATING PRESSURE LOADS:

CREO Simulate simulates the behaviour of your model under loads you define when performing standard analyses and sensitivity studies for your model. Your model's optimal shape and mass can also depend on the loads you define. You can define loads on your model through the ribbon user interface or the Model Tree.

The atmospheric pressure outside the bottle is assumed to be 101 KPa which will be applied on the outside boundary while pressure inside the vessel is 400 KPa when filled with fluid will be applied on inside surface of the vessel.

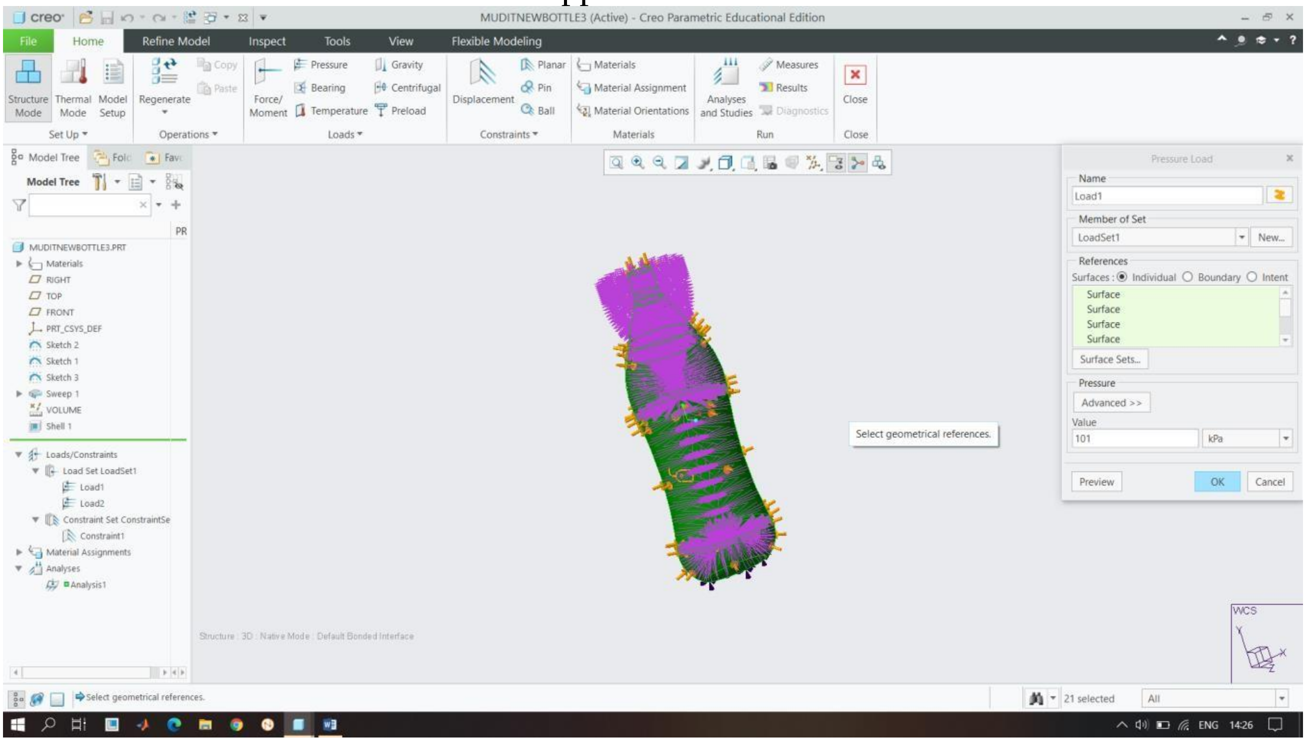


Fig 12. Applying atmospheric pressure (101 KPa)

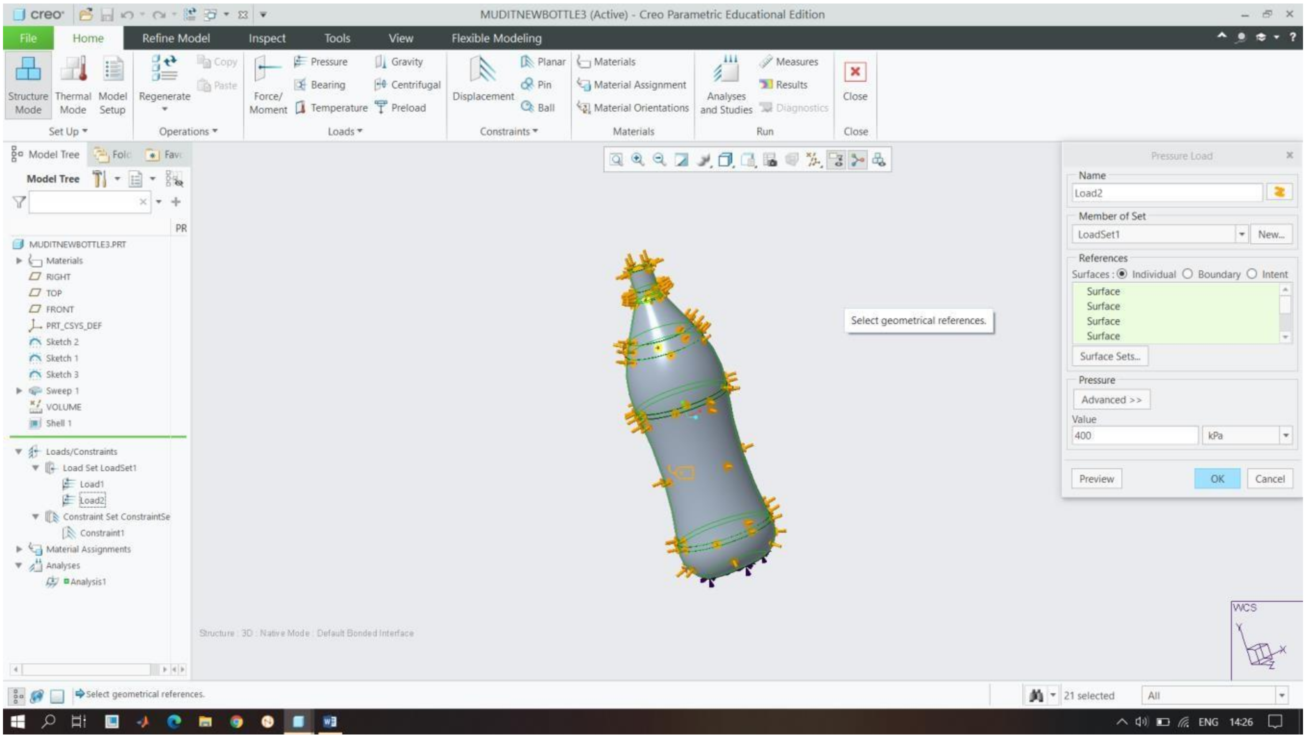


Fig 13. Applying inside pressure load (400 KPa)

RUNNING THE ANALYSIS

Use CREO Simulate Analyses and Studies to create and manage analyses. For FEM mode analyses, see About FEM Analysis and About Running FEM Analyses and Generating Output Decks. It provides vast range of analysis to the users according to their needs.

A. STATIC ANALYSIS:

In a static analysis Creo Simulate calculates deformations, stresses, and strains on your model in response to specified loads and subject to specified constraints.

- Click Home > Analyses and Studies. The Analyses and Design Studies dialog box opens.
- Click File > New Static. The Static Analysis Definition dialog box opens.
- Select the constraint set 1 and load set 1 check box.

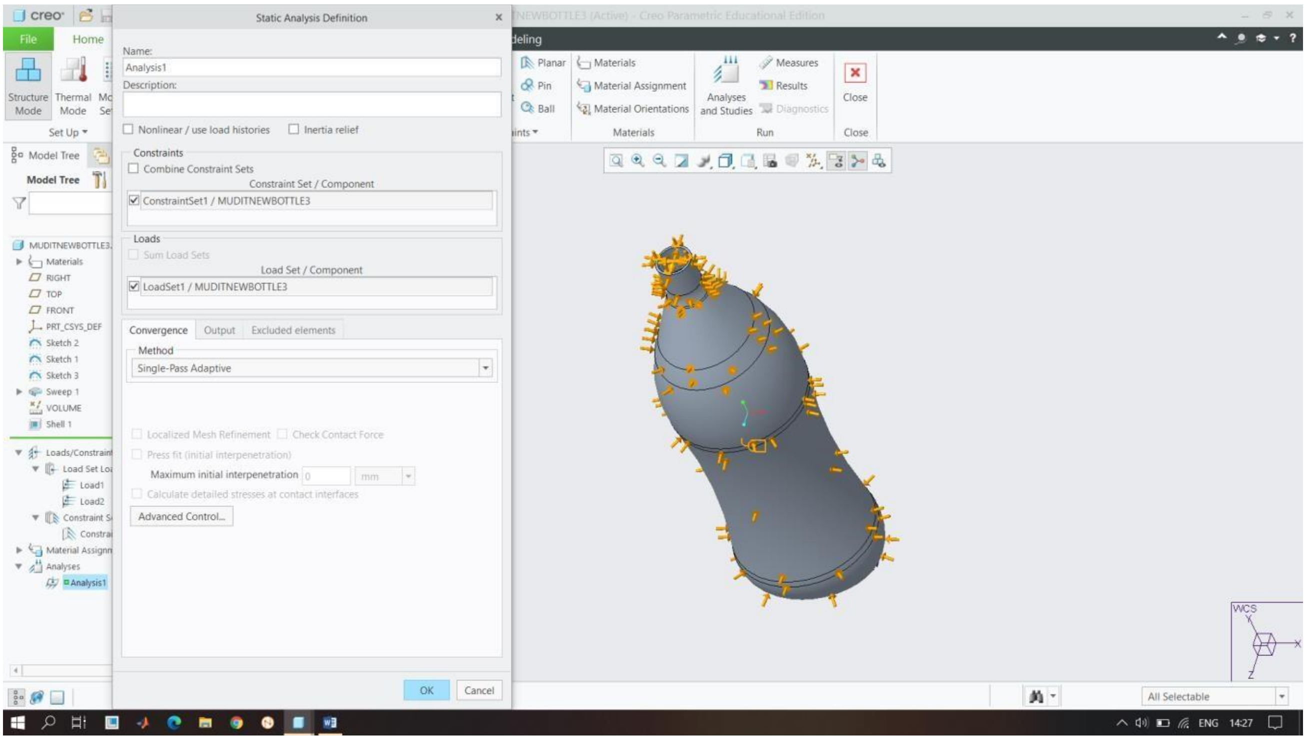


Fig 14. Static analysis setup

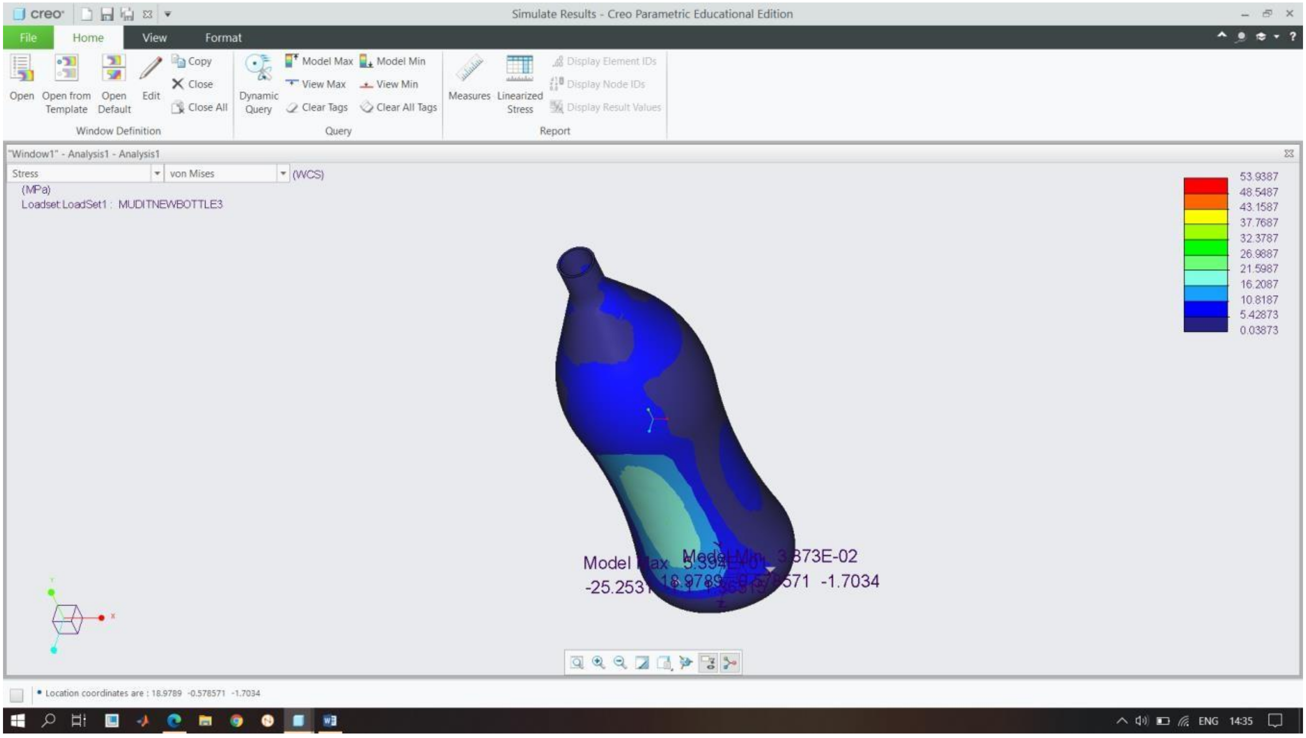


Fig 15. Initial stress contour plot

B. REVIEW RESULT:

To review any result in SIMULATE, we must create a new result window. The 3 attribute we need to select are Quantity, Location and Display.

- The analysis show the model max as 53.9387MPa and model minimum as 0.03873 MPa.
- Error estimate: 0.9% of 53.9387MPa. Mass of bottle **1.086533e-04.**

OUR AIM IS TO GET THE MAX. STRESS LESS THAN 40 MPA SINCE FACTOR OF SAFETY IS 4 (160/4 MPA).

NOTE: I have attached a .txt log file in the zip folder named ‘STATIC ANALYSIS1’.

GLOBAL SENSITIVITY ANALYSIS

In a global sensitivity study, Creo Simulate calculates values for all measures that are valid for the analyses included in study. The software specifically calculates the changes in your model's measures when you vary a design variable over a specified range. We are taking THICKNESS PARAMETER for showing the changes is von misses stress with thickness of bottle by defining the RESULT SET for the analysis.

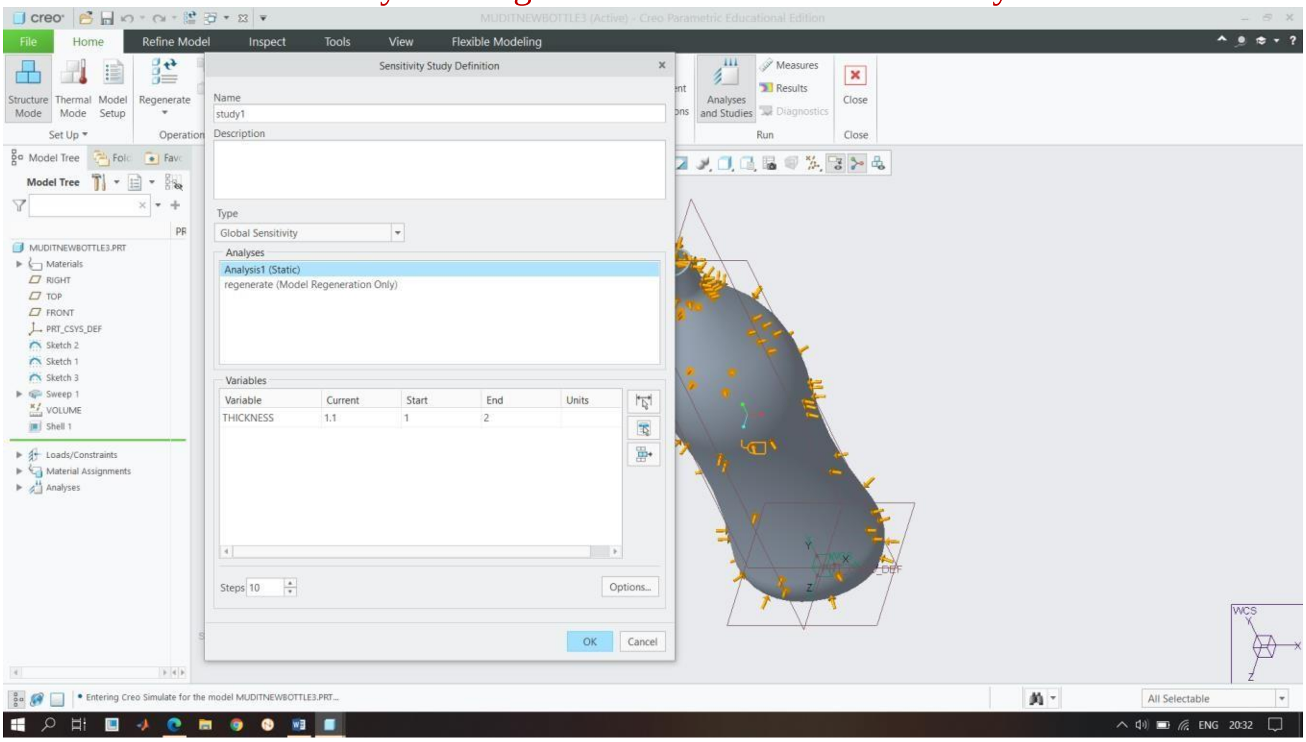


Fig 16. Global Sensitivity analysis setup

Fig 17. Stres_vm vs Thickness graph

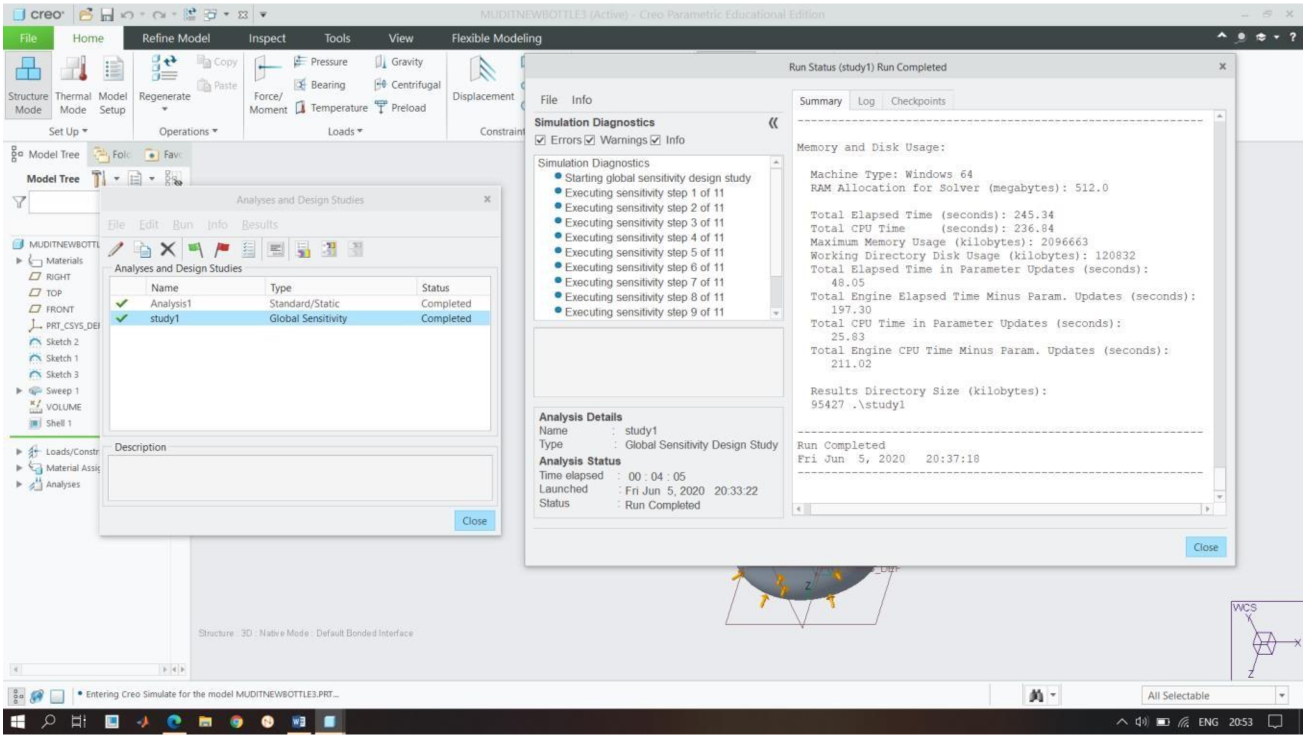


Fig 18. Log summary of global sensitivity analysis

RESULT REVIEW:

- As the thickness increases the Max. Stress decreases.

- Attached a .txt log file in zip folder named 'GLOBALSENSITIVITY ANALYSIS'.

OPTIMIZATION

An optimization design study adjusts one or more variables to best achieve a specified goal or to test feasibility of a design, while respecting specified limits.

- Click **File** > **New Optimization Design Study**. The **Optimization Study Definition** dialog box opens.

- We have to add a design limit that max_stress_vm less than 40 MPa.
- Add THICKNESS PARAMETER in variables window.
- Minimise the total_mass.

VARIABLE	CURRENT	MINIMUM	INITIAL	MAXIMUM
THICKNESS	1.1 mm	0.8 mm	0.9 mm	1.6 mm

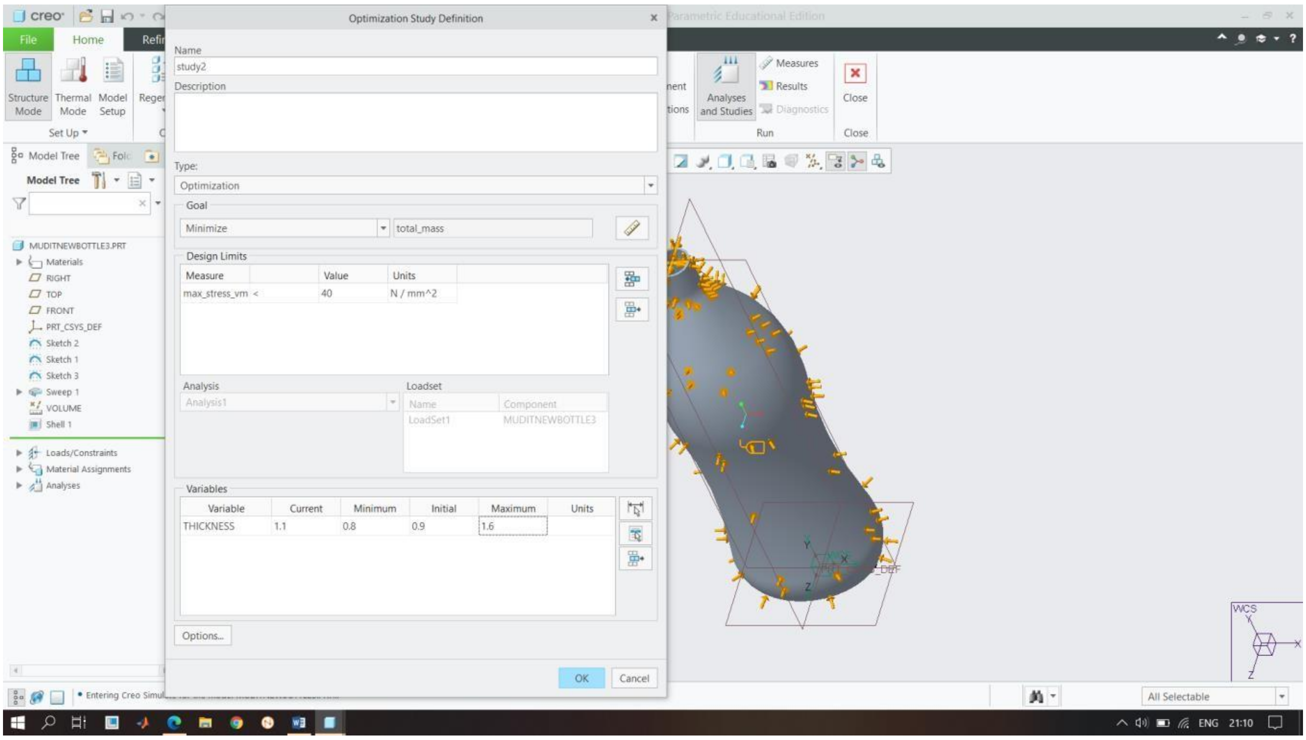


Fig 19. Optimization study setup

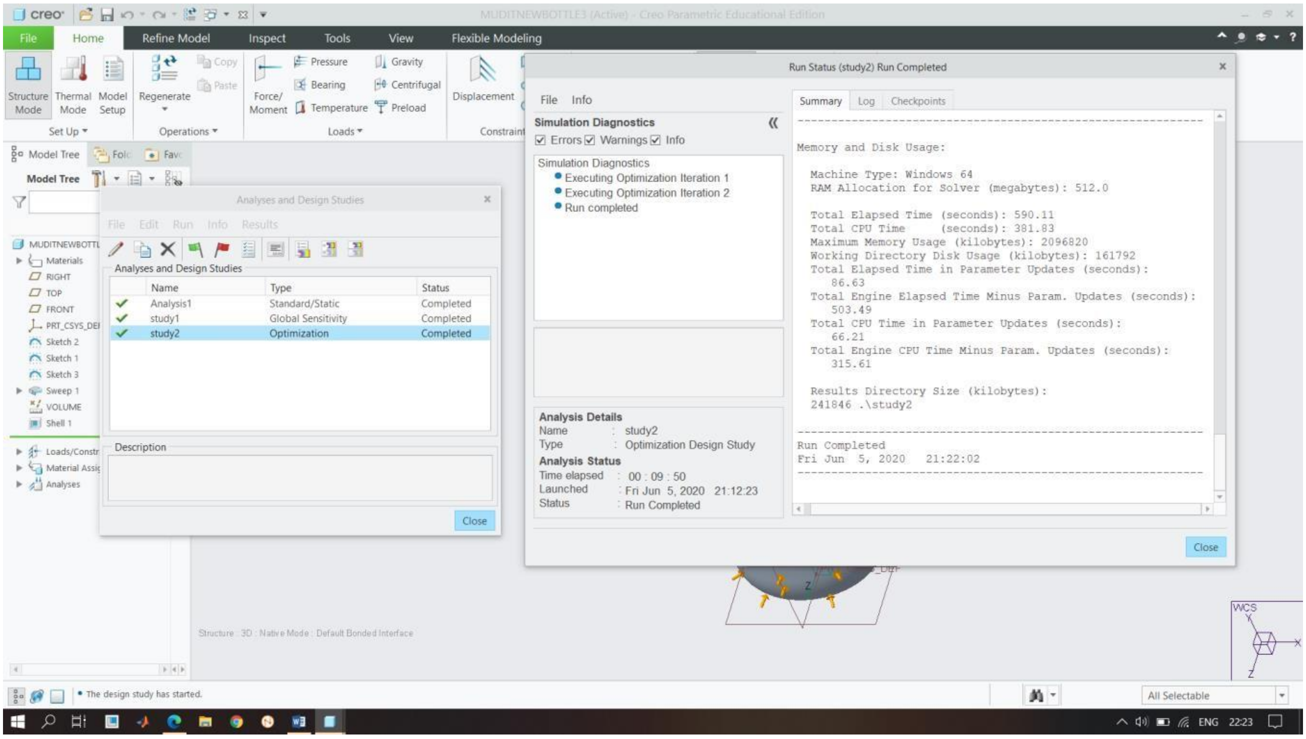


Fig 20. Optimization completed (Iterations: 2 Thickness: 1.30734 mm)

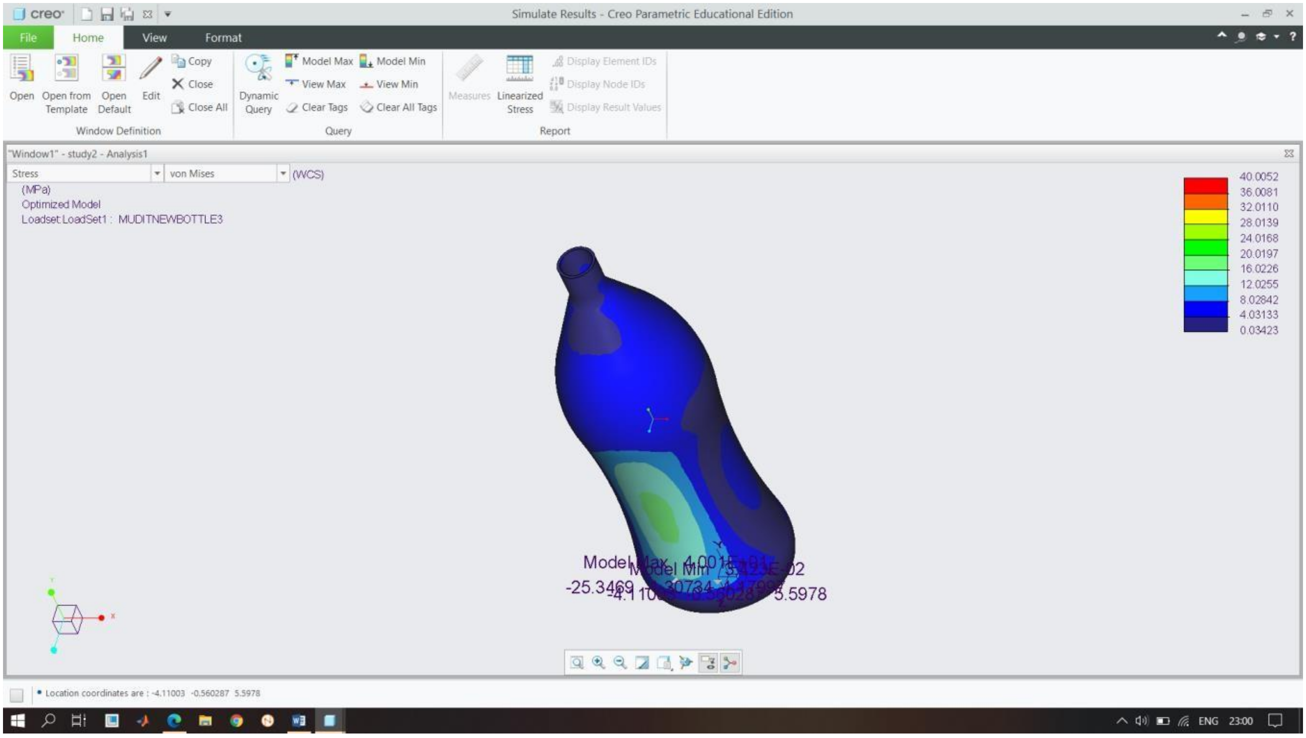


Fig 21. **Final stress contour plot**

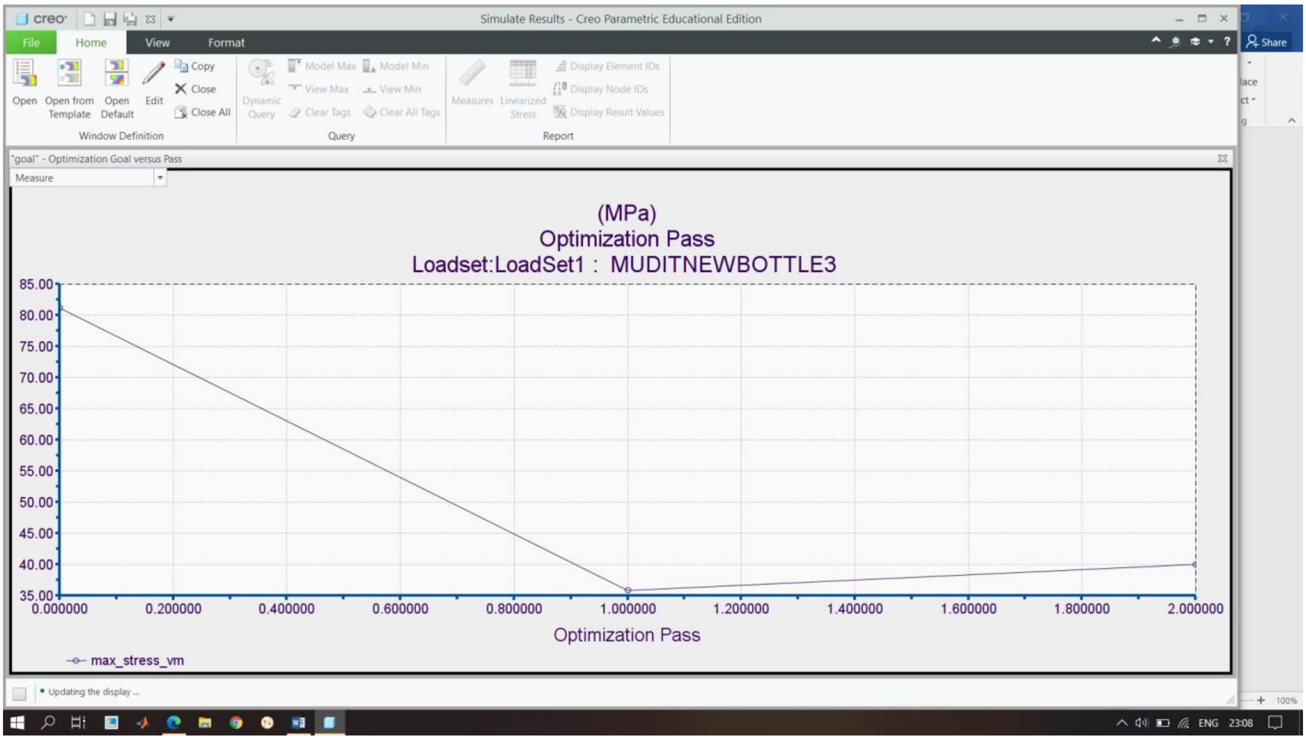


Fig 22.Vm_stress vs Optimization passes

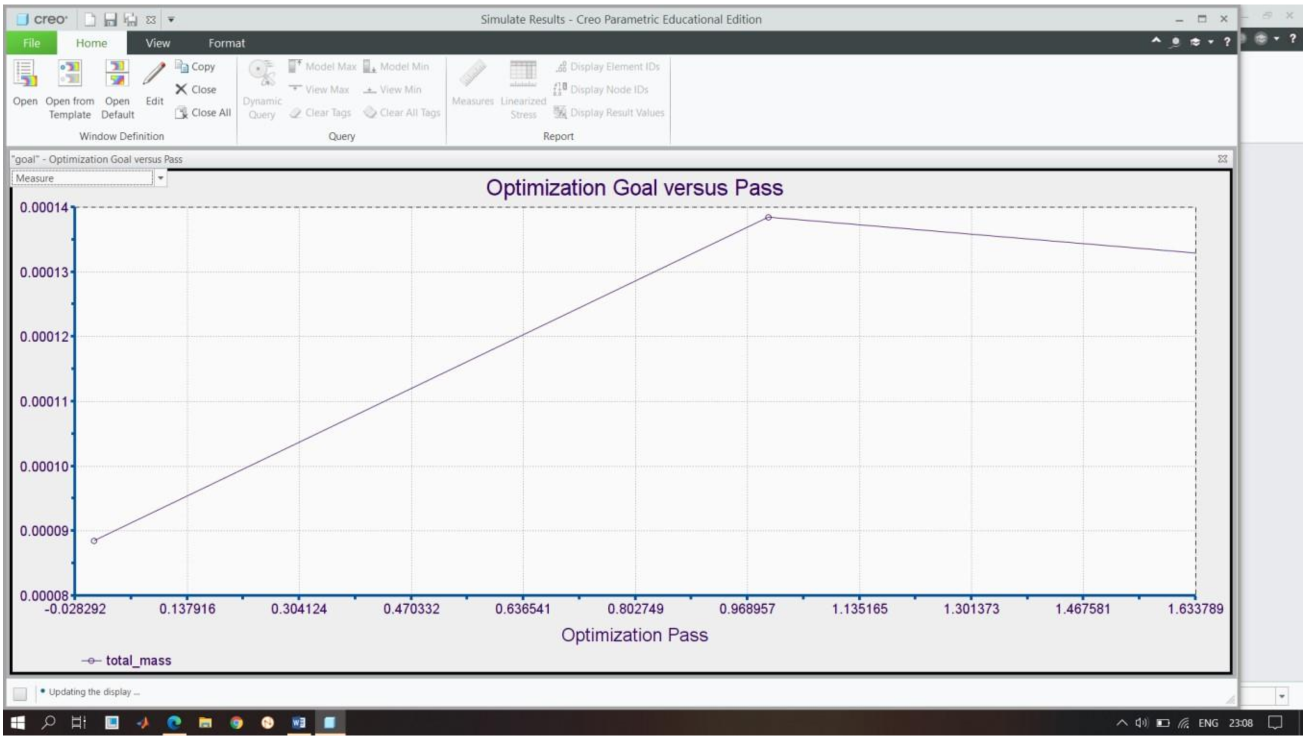
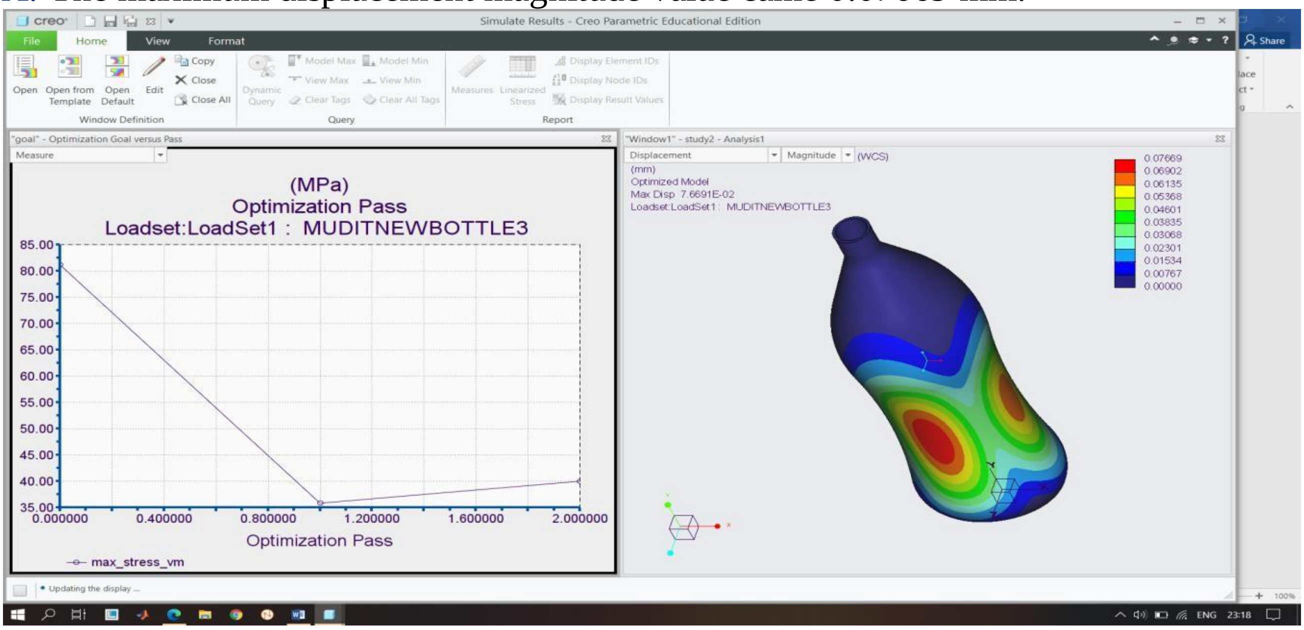


Fig 23.Total_mass vs Optimization passes

RESULT

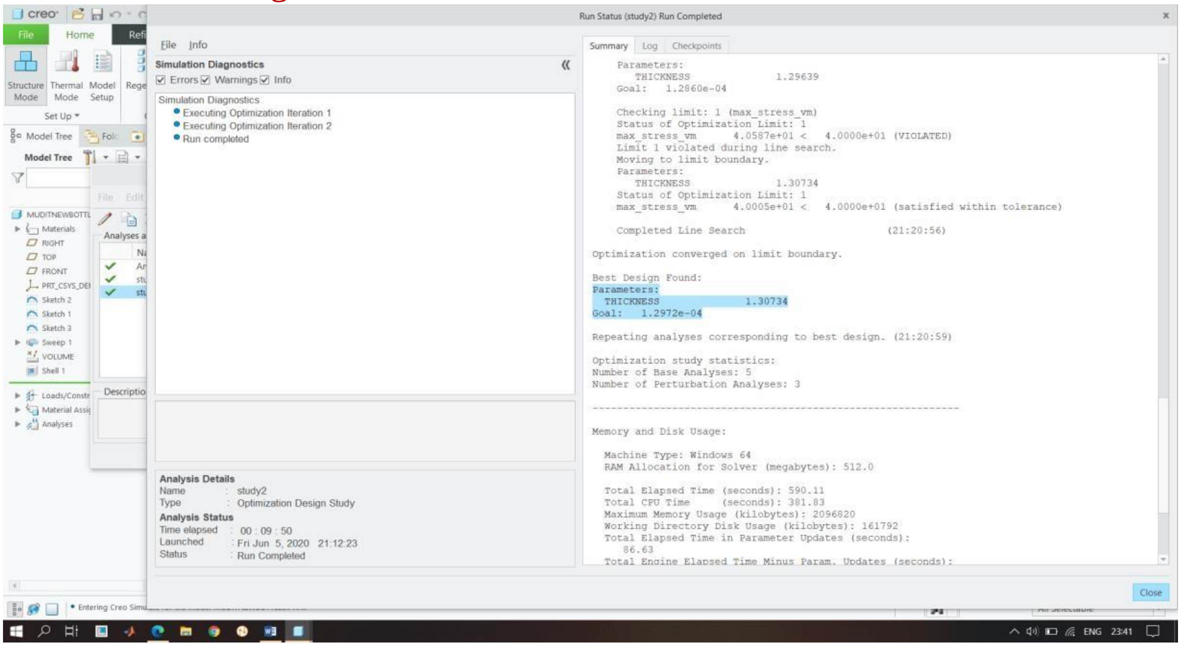
A. The maximum displacement magnitude value came 0.07669 mm.



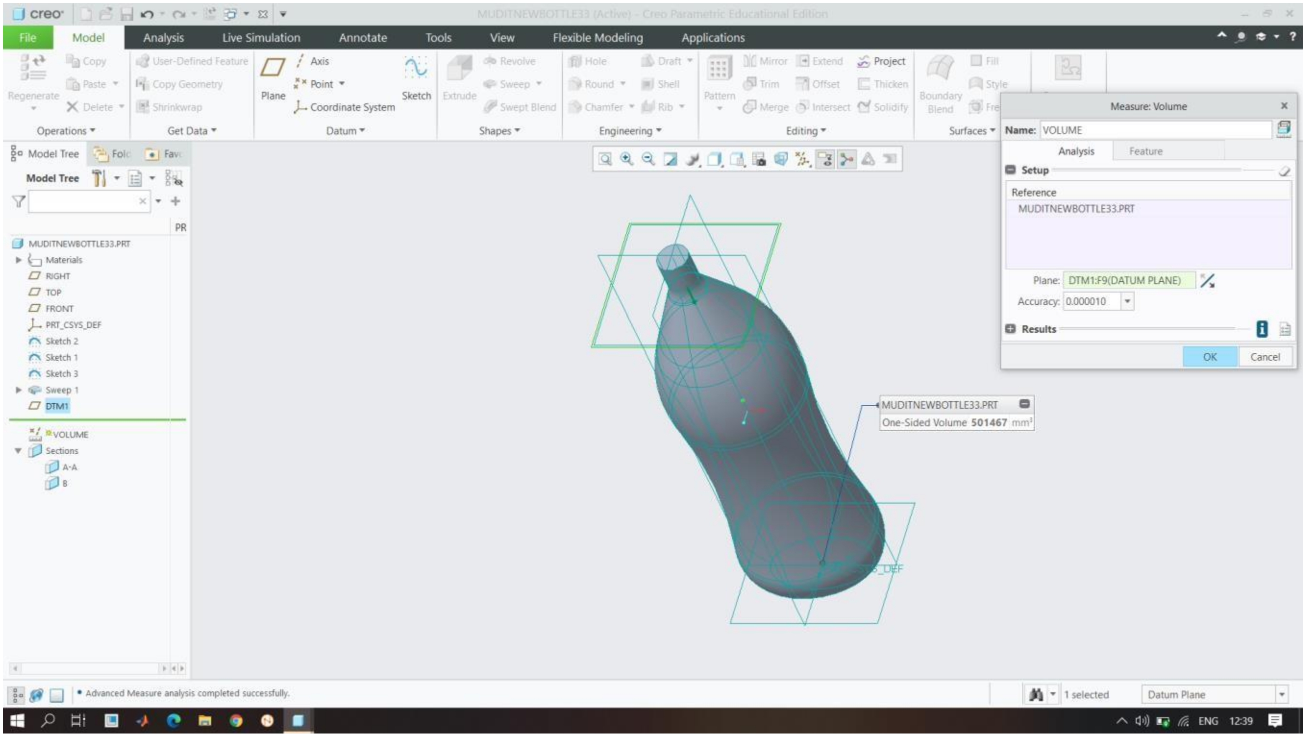
B. The maximum von misses stress after optimization is 40.0052 MPa (satisfied within tolerance) which was earlier 53.9387MPa. Percentage decrement: 25.832102%.

C. The initial mass of the bottle was **1.086533e-04 TONNE** and after optimization it is 1.2972e-04 TONNE. Percentage increment: 19.388%

D. The final thickness after optimization came out to **1.30734 mm** which was earlier 1.11 mm. Percentage increment: 18.849%.



E. The volume of bottle till 200 mm height was found to be 501 ml which is under tolerance limit.



CONCLUSIONS

A. During this project, it was concluded that the Stress induced in bottle is dependent upon the Thickness of the bottle under compressive loading as shown during Global sensitivity analysis. In fig 17, we can see that how stress decreases as thickness increases.

B. We were able to optimize the bottle to hold 500 ml of fluid in it by changing the 7 different design dimensions.

C. During the volume sensitivity analysis, we concluded that in some cases as the dimension is increased, volume also increases BUT in some, we saw a decrement in volume by increasing the dimension.

D. By the end of the project, we were able to minimise the total mass of bottle in context to that Vm_stress total should be less than 40 MPa.

LEARNINGS

- The production cost of a product also depends on the expenditure done on developing the prototype. CREO SIMULATE aims to decrease the cost of prototyping a model by testing and analysing out model with real world situations like loads, constraints and all.

- Through this project I was able to learn about various features of CREO simulate which will help me in future for designing purpose in my mechanical engineering career.

- I want to appreciate that the faculty given us no boundations and we were free to design bottle of any shape and it really made me to brainstorm to another level.

❖ Learnings:

- Learned about SWEEP and SHELL commands and its applications. ▪ About various loads that can be applied on a model.
- Constraints that as present in real world and how to implement them.