2026 Journal of Engineering, Technology and Social Sciences
Jurnal Kejuruteraan, Teknologi dan Sains Sosial
Volume 12 Special Issue: GTiMME
International Conference on Green Technology in Mechanical and Marine Engineering

STRUCTURAL OPTIMIZATION OF THE SMARTPHONE HOLDER ANCHOR VIA CATIA V5 SIMULATION

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ARTICLE INFO

Article history:
Received
14 July 2025
Received in revised form
18 September 2025
Accepted
03 October 2025
Published online
02 January 2026

***Keywords**:*
Phone Holder, CATIA V5, 3D design, FEA, stress, ABS Material, Optimization, Material Selection, Cost Reduction.

ABSTRACT

The use of smartphones in daily life is increasing, making phone holders a necessity for various activities such as watching videos, answering video calls, or using them while working. This study focuses on the design and structural optimization of the smartphone holder anchor using CATIA V5 software. This project involves 3D drawing, finite element analysis (FEA), as well as design optimization and material selection. The main components, namely the 'anchor' and were analysed under static loads to study the stress and displacement response. The analysis results showed that the ABS material used was able to withstand the maximum applied stress, and the optimized design successfully reduced the mass without compromising the structural strength. This material reduction also had a positive impact on the overall production cost. This study proves that through a simulation and optimization approach, efficient and cost-effective designs can be achieved in the development of everyday products such as phone holders.

1. Introduction

The rapid pace of technological advancement has transformed how people use digital devices, particularly smartphones. This reliance has driven demand for companion accessories like the smartphone holder, which has evolved from a simple stand to a highly engineered product (Kumar & Sharma, 2021). To create efficient and lightweight yet structurally sound phone holders, designers are turning to innovative technologies and optimization strategies.

Consumer product design has greatly benefited from Computer-Aided Design (CAD) software, with CATIA V5 being a popular choice for its robust 3D design and simulation capabilities. While extensively used in the automotive and aerospace industries, CATIA's adaptability makes it suitable for consumer product development (Desai & Patel, 2020). Its simulation applications allow users to evaluate 3D models under various loading conditions.

A critical component of product validation is Finite Element Analysis (FEA), a numerical technique used to test a product under different loads. FEA helps designers predict stress, strain, and displacement to identify potential failures and ensure structural integrity. For products like smartphone holders, which endure repetitive use, FEA ensures the final product meets durability and safety standards (Desai & Patel, 2020).

Design optimization is another key aspect, refining a product to achieve the best performance with minimal resources. For smartphone holders, this often means reducing weight and material while enhancing strength. This process involves defining objectives (e.g., minimizing mass) and constraints (e.g., maximum stress) which are analyzed using optimization algorithms (Singh et al., 2020), ensuring the design is structurally sound, cost-effective, and environmentally responsible.

Material selection heavily influences a product's performance and cost. For thermoplastic products like phone holders, Acrylonitrile Butadiene Styrene (ABS) is frequently chosen for its balance of strength, rigidity, and impact resistance. It is lightweight, easy to fabricate via injection molding, and performs well under both static and dynamic loads, making it ideal for portable accessories requiring moderate mechanical performance (Zhou & Lu, 2018). Its low cost also supports the economic feasibility of mass production.

The application of simulation-driven design and material optimization allows companies to innovate and produce high-performance consumer products more rapidly. By analyzing the stress and displacement on key components like the phone holder's "anchor," engineers can identify where excess material can be removed without compromising structural integrity. Combining ABS with an optimized structural design can lead to a notable reduction in mass, improving material efficiency and lowering production costs. This shift towards simulation-based engineering also aligns with the modern manufacturing emphasis on cost-efficiency and sustainability.

In competitive markets, companies strive to reduce costs without sacrificing quality. Using tools like CATIA V5 and FEA empowers designers to make data-driven decisions that align engineering performance with business objectives. Reducing material content not only lowers costs but also lessens environmental impact, aligning with global sustainability goals (Rahman et al., 2021). Ergonomics also plays a crucial role. An ergonomic study has emphasized the need for smartphone holders that support natural hand and head positions, reduce strain, and adapt to various uses like desk work or video conferencing (Lee & Kim, 2019). Integrating ergonomic principles ensures the product is not only mechanically optimized but also user-friendly.

In conclusion, the design of smartphone holders now incorporates sophisticated engineering tools. The use of CATIA V5 for 3D modeling, FEA for stress analysis, and design optimization ensures products are both efficient and effective. The selection of materials, particularly ABS plastic, is crucial in achieving desired performance. By adopting a simulation-based and optimization-driven approach, engineers create innovative, cost-effective, and user-centric products that meet the demands of modern consumers. This multidisciplinary method, combining mechanical analysis, materials science, ergonomics, and cost efficiency, shows how even simple products benefit from advanced engineering.

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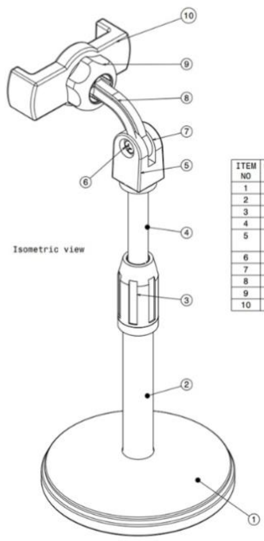
2. Methodology

This study employed a systematic design and analysis approach using CATIA V5 software to develop and optimize a smartphone holder anchor. The methodology can be divided into four main stages: 3D modelling, finite element analysis (FEA), design optimization, and material selection.

2.1 3D Modelling

The initial design phase involved creating a 3D model of the smartphone holder anchor using CATIA V5. The software was chosen for its advanced capabilities in mechanical design and parametric modeling (Dassault Systèmes, 2020). Detailed dimensions and geometric constraints were defined to ensure ergonomics and functional compatibility with common smartphone sizes. The Anchor, designated as item number 8 (refer Figure 1 below), is a crucial component that serves as the pivot pin for the phone holder's tilting joint.



ITEM NO	QUANTITY	PART NUMBER	DESCRIPTION
1	1	PART-01	BASE
2	1	PART-02	POLE 2
3	1	PART-03	SOCKET
4	1	PART-04	POLE 1
5	1	PART-05	ANCHOR HOLDER
6	1	PART-06	SCREW
7	1	PART-07	NUT
8	1	PART-08	ANCHOR
9	1	PART-09	LOCK NUT
10	1	PART-10	BRACKET

Figure 1. Smart Phone Holder 3D drawing details (Anchor item number 8)

2.2 Finite Element Analysis (FEA)

The structural performance of the anchor component was analyzed under static loading conditions using the integrated FEA module in CATIA V5. Loads were applied to simulate realistic conditions such as the weight of a smartphone and forces exerted during use. Stress distribution and displacement patterns were evaluated to identify potential failure zones (Hearn, 1997).

2.3 Design Optimization

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Based on the FEA results, the design was refined by introducing structural modifications aimed at reducing mass while maintaining strength. Design optimization techniques such as topology optimization and parameter tuning were applied to achieve material efficiency (Yang & Chen, 2019). The performance of each iteration was validated through reanalysis in CATIA.

2.4 Material Selection

ABS plastic was selected as the construction material due to its favourable mechanical properties, including good impact resistance and manufacturability (Callister & Rethwisch, 2020). The material's yield strength was compared with the maximum stress observed in the FEA to ensure structural integrity under operational loads. The reduced mass also contributed to a lower production cost, demonstrating the economic viability of the optimized design.

2.5 Analysis on Anchor

Material = ABS
Yield strength = 1.85e+007N/m^2
There is distribution force acting on negative Y direction (200g – weight of the phone) F= 1.96 N.
Mass of the anchor is estimated at 0.006249 kg based on software calculation based on Figure 2.

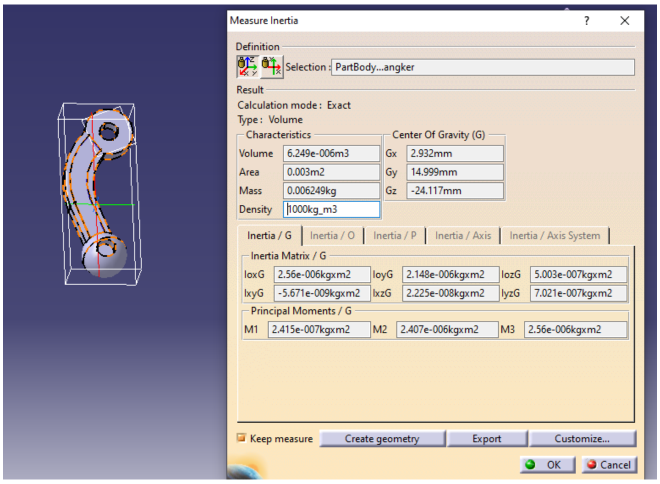

Figure 2. Estimated mass of initial anchor

2.5.1 Mesh size by default 3.856mm

From Figure 3, the finite element model was initially generated using the default mesh size of **3.856 mm**. A coarser mesh reduces the number of elements and nodes, leading to faster computation, but may compromise the accuracy of the results, especially in regions with high stress gradients.

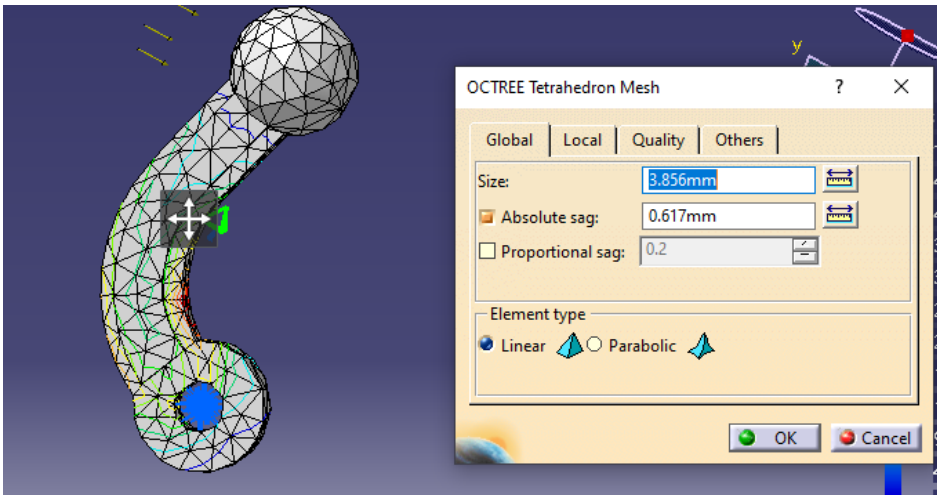

Figure 3. Mesh Sizes was set to default 3.856mm

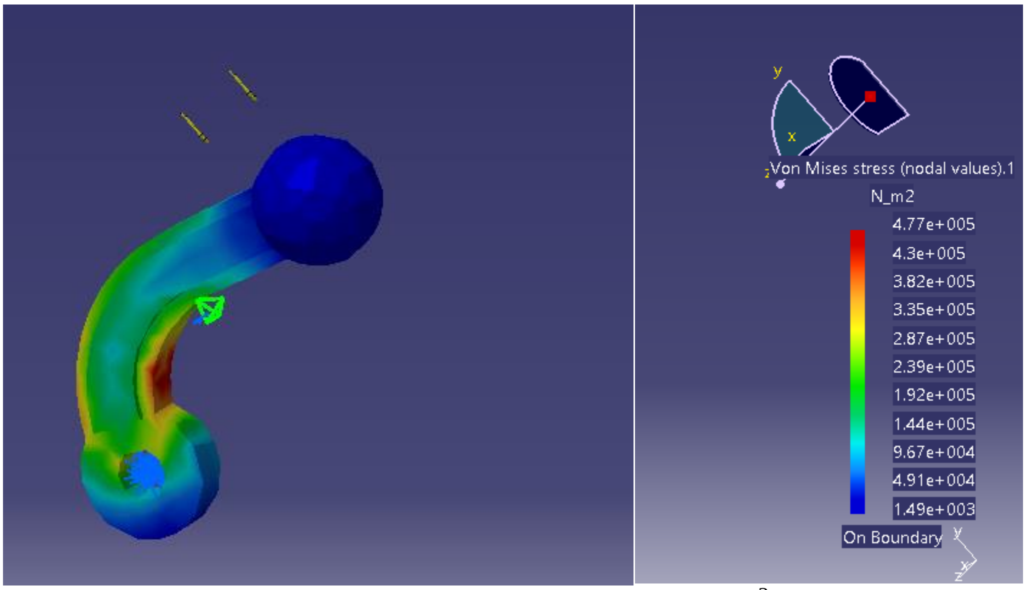

Figure 4. Von Mises Stress of 4.77e5 N/m^2

With the default mesh size in *Figure 2.3*, the maximum Von Mises stress obtained is 4.77×10^5 N/m². The stress contours are relatively smooth due to the coarser discretization, which may underestimate localized stress concentrations. The maximum displacement recorded for the default mesh is 0.0893 mm. From figure 2.4, the displacement value is slightly lower compared to the refined mesh case, reflecting that a coarse mesh tends to smoothen deformation prediction and may not fully capture localized deflections.

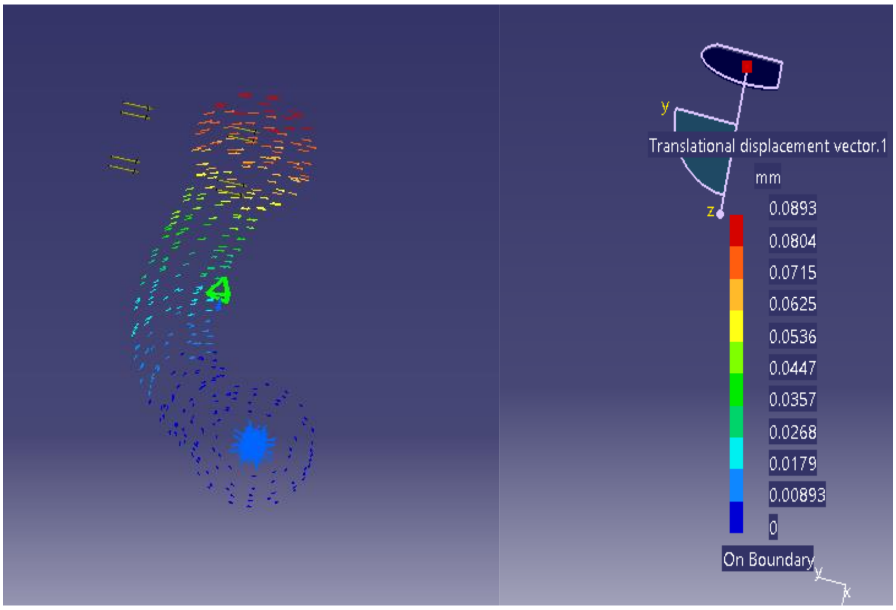

Figure 5. Maximum Displacement of 0.0893mm

2.5.2 Mesh size changes to 1.5mm

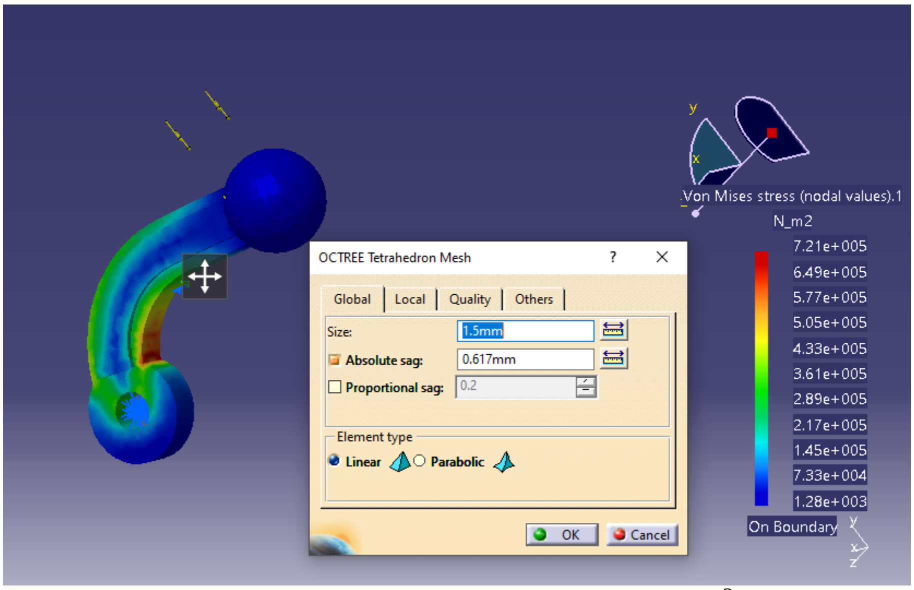

Figure 5. Von Mises Stress of 7.21e5 N/m^2

The Von Mises stress contour obtained with a refined mesh size of 1.5 mm shows a maximum stress value of 7.21 × 10^5 N/m^2 in Figure 5. The stress distribution indicates that the mesh refinement captures localized stress concentration more accurately, ensuring better reliability of the simulation results.

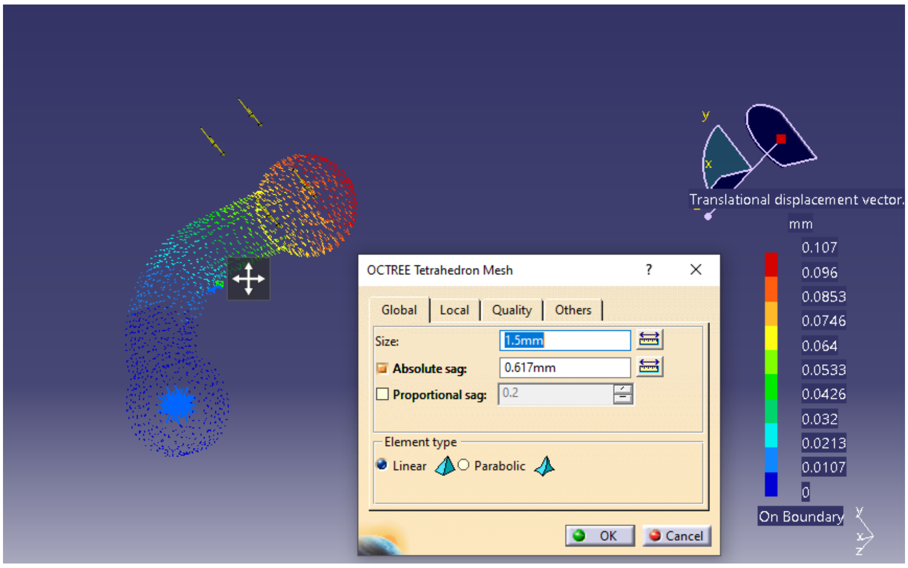

Figure 6. Maximum Displacement of 0.0893mm

In the Figure 6, the displacement contour for the same mesh size records a maximum deflection of 0.107 mm. This small displacement demonstrates that the structure maintains good stiffness under the applied loading conditions, with deformation localized in areas of reduced rigidity.

2.5.3 Mesh size = 0.5mm

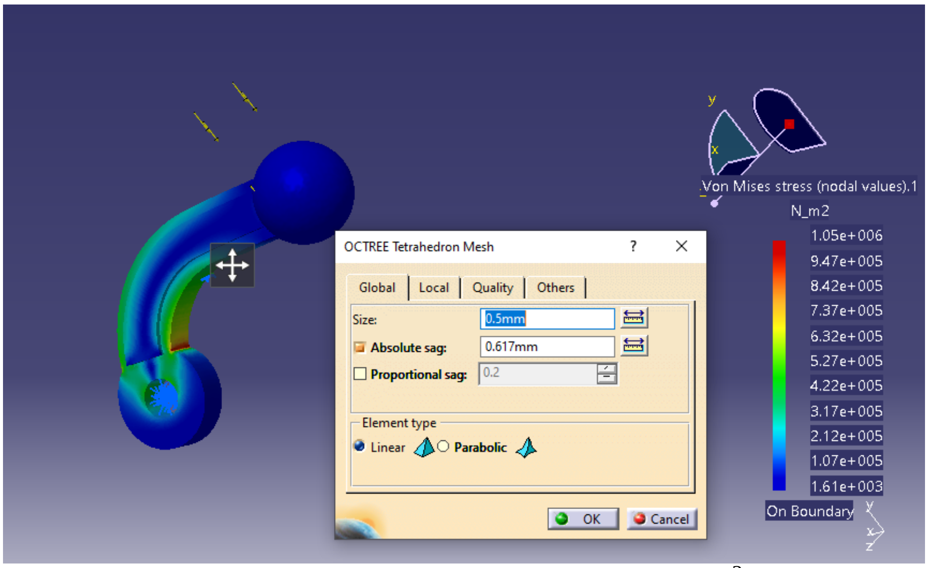

Figure 7. Von Mises Stress of 1.05E6 N/m^2

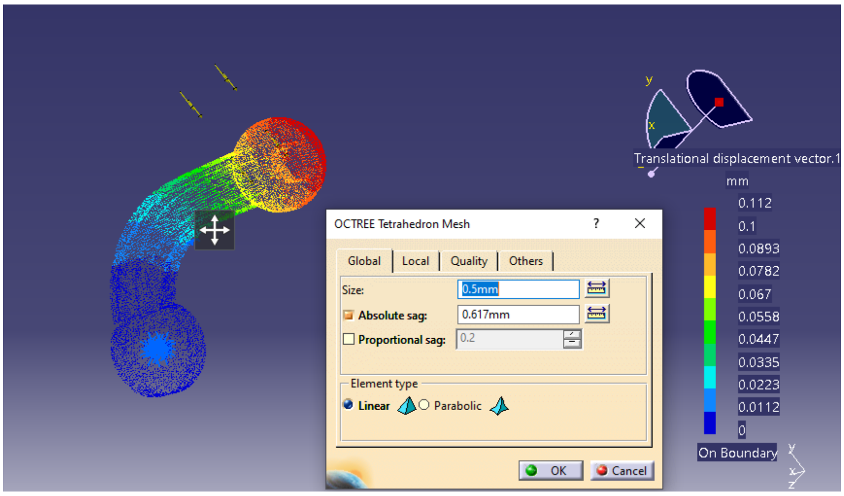

Figure 8. Maximum Displacement of 0.112mm

2.6 Design Optimization

2.6.1 Reduce the material by punching holes inside the solid part (Anchor)

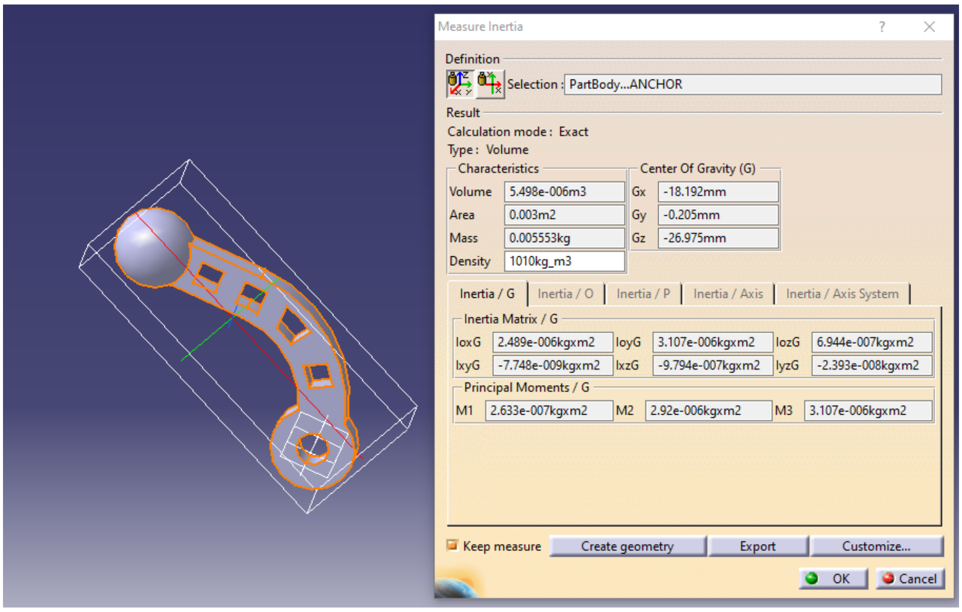

Figure 9. Anchor design optimization by material reduction

Based on Figure 10, design optimization is carried out by reducing the material in Anchor design. Mass of the part after optimization is 0.005553kg. The reduction mass after optimization is calculated by:

$$\boldsymbol{mass\ of\ initial\ design - mass\ of\ optimization\ part = mass\ reduction}$$
$$\boldsymbol{0.006249\ kg - 0.005553\ kg = 0.000696\ kg}$$

If production cost for one piece of anchor is RM0.80, after optimization we can save material and cost by 0.696 g/piece and RM0.09/piece. If the production volume 1000 pieces per day, we can save RM90/day equal to RM2700/month.

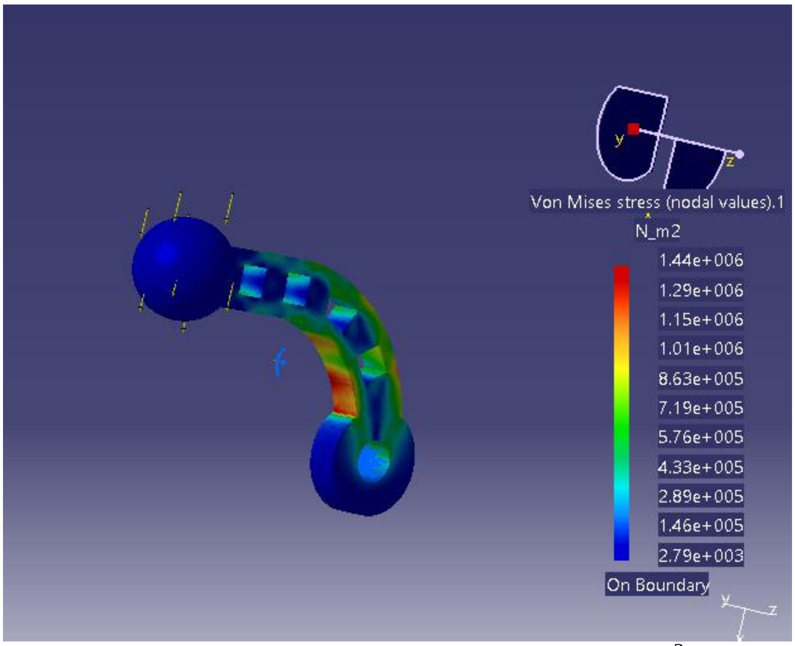

Figure 10. Von Mises Stress of 1.44E6 N/m^2

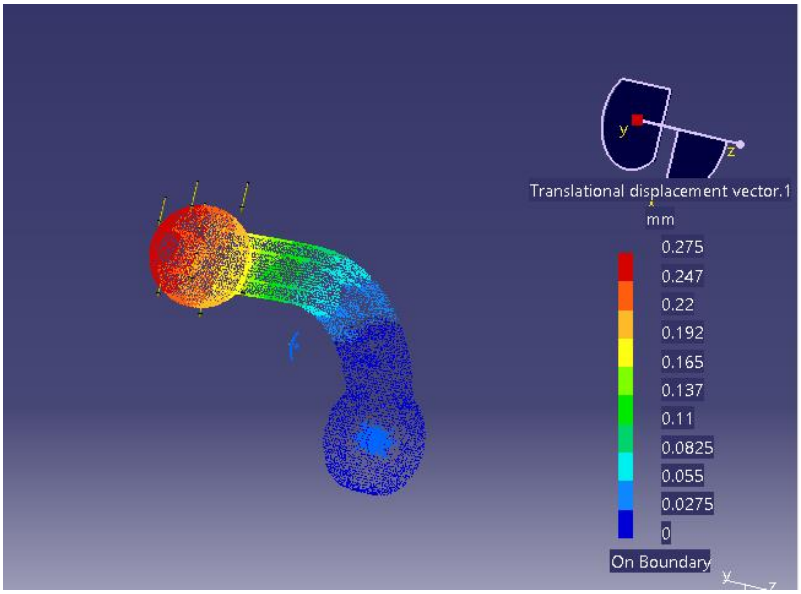

Figure 11. Maximum displacement of 0.275mm

The anchor design optimization faced no failure since the yield strength of 1.85E7N/m^2 was bigger than the Von Mises Stress of 1.44E6 N/m^2.

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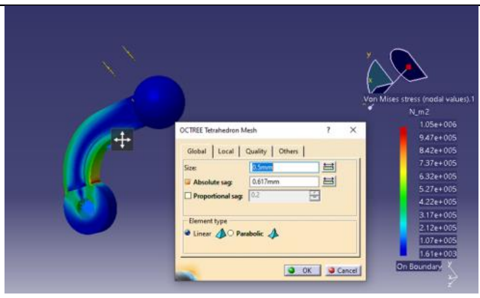
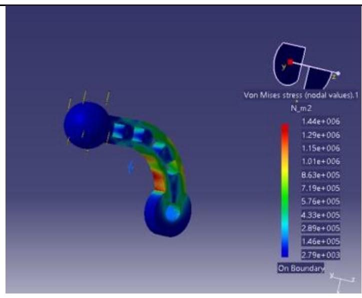
3. Result and Discussion

Table 1. Results of different sizes of mesh using static analysis

Mesh sizes (mm)	Von Mises Stress (N/m^2)	Deformation (mm)
3.856	4.77E5	0.089
1.500	7.21E5	0.107
0.500	1.05E6	0.112

Table 1 shows a summary of the results from the static analysis performed on the Anchor part. Three different mesh sizes were selected to observe the difference in results for Von Mises Stress and deformation. The Anchor part faced no failure because the yield strength of 1.85E7 N/m² was greater than the Von Mises Stress for all mesh sizes, confirming the baseline design's structural soundness according to fundamental mechanics principles (Hearn, 1997).

Table 2. Comparison before and after optimization

	Before optimization	After optimization
Design		
Von Mises Stress (N/m^2)	1.05E6	1.44E6
Weight (kg)	0.006249	0.005553
Strength to weight ratio (N/m^2/kg)	1.68E8	2.59E8

Interestingly, in the Table 2, the optimization led to a slight increase in the maximum Von Mises stress, from 1.05E6 N/m² to 1.44E6 N/m². This is an expected trade-off; as material is removed, the remaining structure must bear a higher load concentration. However, the final stress value of 1.44E6 N/m² is still less than 8% of the ABS plastic's yield strength of 1.85E7 N/m² (Callister & Rethwisch, 2020), providing a substantial safety factor of over 12. The maximum displacement of 0.275 mm is minimal and poses no risk to the component's function.

The most significant outcome is the 54% improvement in the strength-to-weight ratio, which increased from 1.68E8 to 2.59E8 N/m²/kg. This metric is a critical indicator of structural efficiency, demonstrating that the optimized design is substantially stronger for its given weight.

3.1 Economic Impact and Cost Savings

The material reduction translates directly into significant economic benefits. With a mass savings of 0.696 grams per piece and a production cost of RM0.80 for the original part, the optimization yields a cost saving of RM0.09 per unit. For a production volume of 1,000 pieces per day, this equates to daily savings of RM90, or approximately RM2700 per month. This highlights how engineering optimization, when combined with cost-conscious manufacturing strategies like Material Flow Cost Accounting, can directly enhance profitability and reduce environmental impact through more efficient material use (Rahman et al., 2021).

4. Conclusion

A static structural analysis of the smartphone holder anchor was successfully conducted using CATIA software. The study evaluated the component's performance under anticipated loading conditions. As the mesh size was refined, results showed a consistent increase in both Von Mises stress and displacement values, confirming improved solution accuracy with finer meshing—an expected trend in finite element analysis. The component was modeled using Acrylonitrile Butadiene Styrene (ABS), a common thermoplastic known for its impact resistance and durability. The simulation results demonstrated that the maximum Von Mises stress remained significantly below the material's yield strength, indicating that the ABS anchor would not experience plastic deformation under the given load case.

Additionally, an optimization phase was conducted, aiming to reduce mass without compromising the structural integrity of the design. The optimized model achieved a notable decrease in mass while still ensuring mechanical safety, with stress and displacement values remaining within acceptable limits. Overall, the analysis confirmed that the optimized smartphone holder anchor meets both performance and safety requirements while also contributing to material efficiency and cost-effectiveness.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the author(s) used OpenAI's ChatGPT to assist in improving the readability and language of the text. All content generated by ChatGPT was subject to thorough review, editing, and revision by the author(s) to ensure its accuracy, completeness, and alignment with the research objectives. The author(s) take full responsibility for the integrity and content of the published work. This declaration complies with ICGESD 2025 guidelines on the use of generative AI in scientific writing.

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