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DESIGN AND ANALYSIS OF THE COMPONENT OF GLASS CLEANING ROBOT USING GENERATIVE DESIGNING MODULE

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ABSTRACT

Cleaning window glasses at high altitudes presents unique challenges due to architectural complexity and safety concerns associated with human labor at great heights. To tackle this problem, the proposed work on comprehensive research to develop an adaptable and efficient glass-cleaning robot. The design has been developed using Autodesk Fusion 360 and to make the robot cost-effective and compatible it is to optimize the robot's parts in terms of various factors like stress, mass, etc. The material selection with the optimized mass will be justified using the same software by the generative design module. It keeps the analysis and optimizes the parts efficiently, which increases the effectiveness and affordability of these robots

Keywords: Generative Design, Stress And Material Analysis, Mass And Volume Optimization, Autodesk Fusion 360.

I. INTRODUCTION

Modern city landscapes are characterized by the useful resources of towering skyscrapers and difficult architectural designs. While these systems show off human innovation, in addition, they present unique annoying conditions, especially inside the protection and cleaning of their substantial glass facades [1]. The cleaning of windows on excessive upward thrust buildings has been a daunting and risky project, with protection troubles paramount in such operations. Human exertions at extreme heights are not always handiest highly priced however additionally fraught with inherent danger [2].

To overcome such conditions the design of a glass-cleaning robot is made which can climb any type of building, minimizing the risk of human life as it can be controlled from a distance with the help of a mobile application and can be automated as well. The cleaning process provides a clean and hygienic way of cleaning the tall building glasses.

This paper covers a certain part of the design of the glass-cleaning robot. The design is about a part that has been made to its best possible structure through the help of the generative designing technique. It talks about the stress analysis and the different factors on which the strength of the part depends. In this paper, we discuss a critical part that underpins the development of the glass-cleaning robot [3]. Its results are given on the basis of a detailed study of generative design using Autodesk fusion 360 [4]. Multiple factors have been taken into account before finalizing which type of material will be the best for the component. Factors such as maximum global displacement, volume-is-to-mass graph, the stress handling capacity of the material for that type of component, and much more.

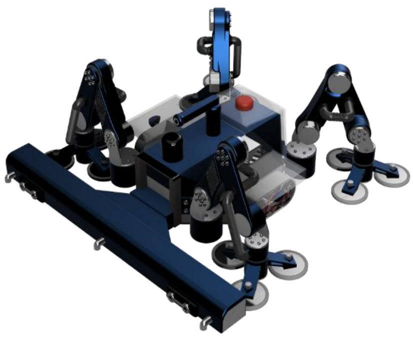

Figure 1: Robot design

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II. METHODOLOGY

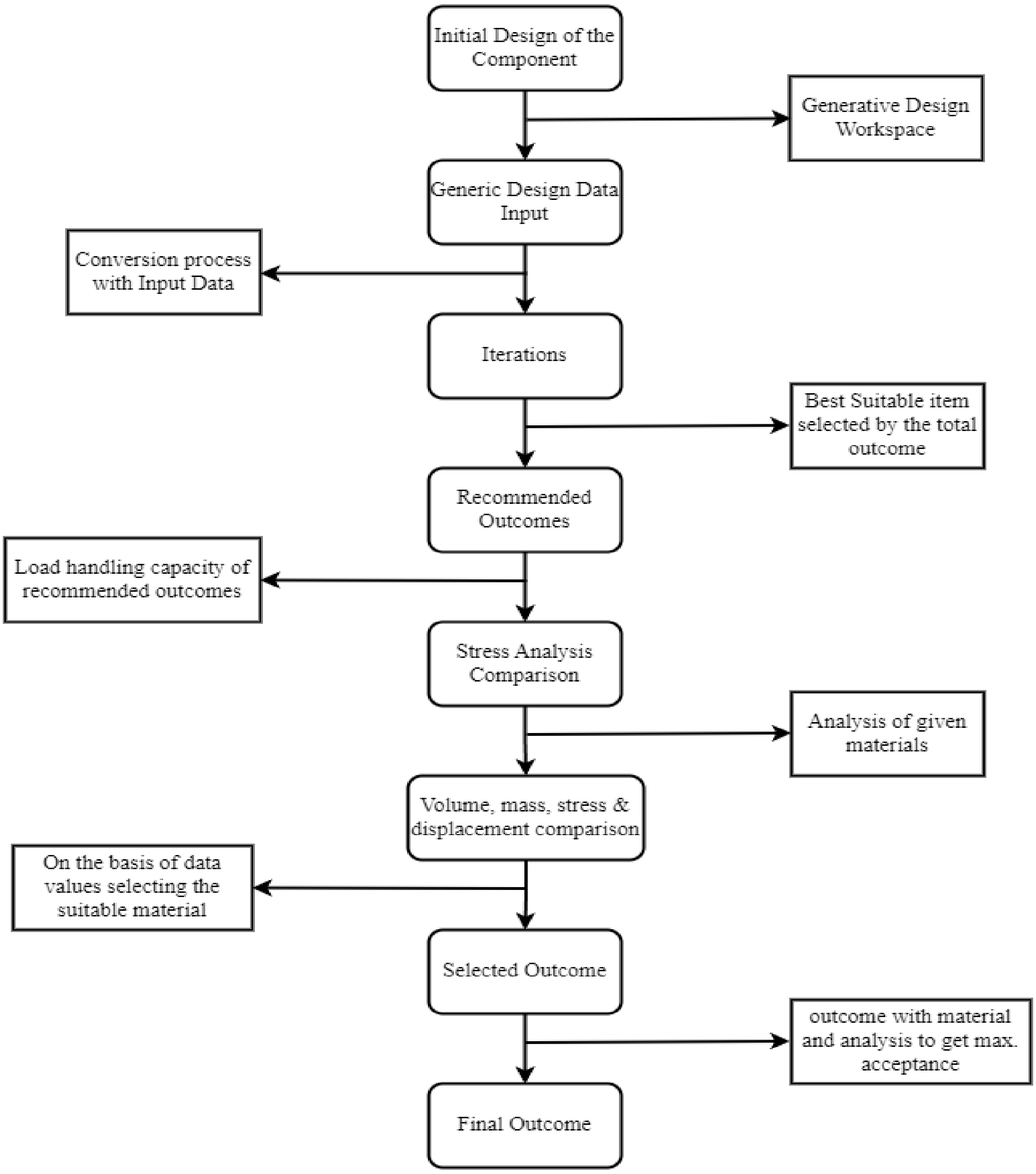

Figure 2: flowchart for the selection of outcome.

Figure 2, shows a flowchart of how the selection of an outcome is done. It starts with the initial design of the component, which then goes to the generative design workspace of the Autodesk Fusion 360. Then the generic design input data is given, which moves towards the conversion process with the given input data. With the help of multiple iterations, the given initial design is now converted into the generative design model. Now among the 18 outcomes the best 4 suitable items are selected for the further process. Through this process, the best outcomes are recommended by the software itself on the basis of input data. After getting the recommended outcomes, next comes the load handling capacity of the recommended outcomes through the process of stress analysis of different materials on different recommended outcomes. Now, the analysis of the material is done based on volume, mass, maximum displacement global, and stress and compared with each other to find out the best one. Then based on the values of the previous process an outcome from recommended is selected. Now the selected outcome is the one, which gets the maximum acceptance, and then that outcome becomes the final outcome for the generative design for that component [5]. Finite element analysis have been recommended by previous researchers on structural components which can be done in future work [6] [7].

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Brief Description

The main reason for the optimization of this part is to make a mass-optimized component with the required strength and load capacity which will minimize the weight, and manufacturing cost and maximize the efficiency.

The component_1 is the name of one of the parts of the robot and is attached with gears in the conveyor belt assembly to stabilize the movement of the motor as shown in figure 3.

This part is attached as per the gear wheel position but it should be optimized in terms of various aspects, before optimization it needs to have proper input data while optimizing in generative models like structural load, gravity, and other simulating input data which is used during the analysis. With the help of the analysis, this paper came to the solution that the values to provide are gravity-9.8 m/sec, Load capacity-800 N [8].

In this context, this work has been optimized using a generative design module present in the software Autodesk fusion 360. The final suitable result of the design and the solution for part optimization has been discussed in the result and discussion section.

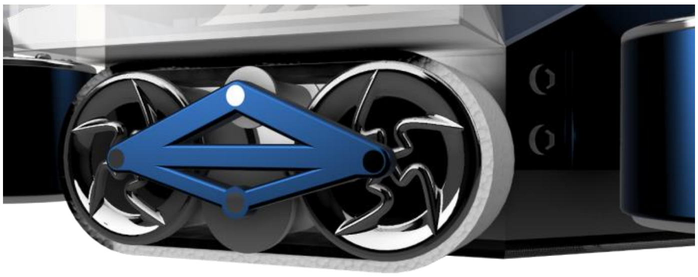

Figure 3: Component (in blue color) on which generative design is implemented.

III. RESULTS AND DISCUSSION

To effectively generate and explore a variety of design options in the context of generative design, a number of essential design parameters and criteria must be specified within the software. In order to meet the demand for lightweight yet highly effective products in the market, generative design frequently focuses on reducing mass while increasing stiffness. To maximize the effectiveness and performance of a product, these goals are necessary.

Safety is a crucial factor in the generative design workspace because it helps to ensure that the created designs adhere to safety regulations. The case study that is being presented has mass reduction as its main goal, with a specified factor of safety limit set at 2. This means that while aiming for mass reduction and increased stiffness, the generated designs must maintain this safety threshold.

This generative design workspace's incorporation of manufacturing processes during the design phase is one of its distinguishing characteristics. The software offers a number of manufacturing processes, each with its own benefits and factors to take into account. Unrestricted manufacturing, additive manufacturing, three- and five-axis milling, two-axis cutting, and die casting are some of these techniques. Unrestricted manufacturing typically results in designs with high performance and low weight, though their complexity may make manufacturing them more difficult. On the other hand, advanced capabilities for producing intricate and lightweight prototypes are provided by additive manufacturing, like 3D printing.

Specific parameters must be defined for additive manufacturing, including orientation (e.g., +X, +Y, +Z, -X, -Y, and -Z directions), overhang angle (often set at 45 degrees as a default), and minimum thickness. In order to achieve the desired design outcomes and manufacturability, these parameters are essential [9].

The selection of materials, in addition to manufacturing techniques, is a crucial component of generative design. The environment determines materials' suitability, the desired physical and chemical characteristics of the final product, and the chosen manufacturing process. Varieties of materials are available in the generative design workspace for consideration. These materials are Aluminium, Steel, Aluminium ALSi10Mg, Carbon Fibre Reinforced Polymers (CFRP), Titanium, Aluminium ALSi10Mq, and Stainless Steel for the case studies that are presented.

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The choice of materials is an important step in ensuring the product has the desired performance and functionality and can withstand the environment in which it is to be used. Overall, generative design combines these design standards, production techniques, and material selections to optimize product designs for mass reduction and improved performance, satisfying the market's demand for light, efficient products.

Component used for the holding of gears of the conveyor belt:

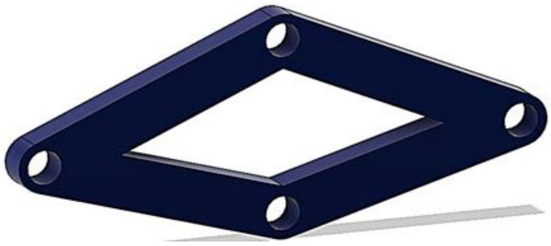

Figure 4: Initial design.

Figure 4, is the initial design of the component that was used in the design of the robot.

Figure 5: Preserved geometry.

Figure 5, consists of those shapes that won't change while processing to generative design.

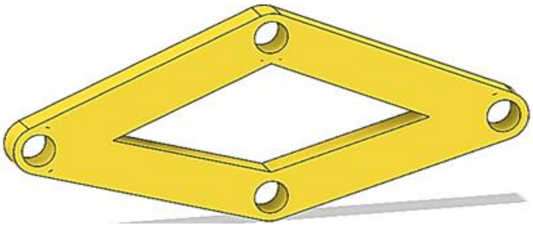

Figure 6: Starting shape.

Figure 6, is the shape that is going to be optimized with the help of generative design.

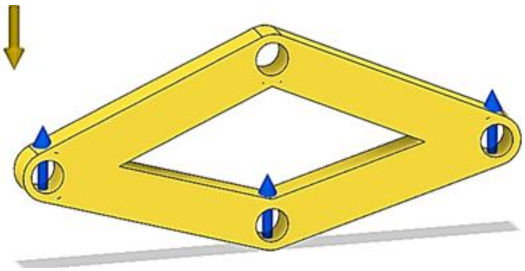

Figure 7: Structural load.

Figure 7, shows the load that the holes will stand up to approx. 80 kg of weight in the opposite direction of gravity (9.8 g).

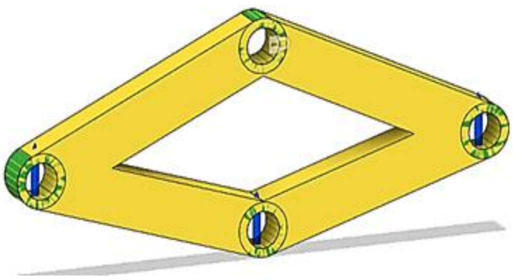

Figure 8: Structural constraint.

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Figure 8, shows a lock that will not move, as it is permanently attached to the main body while the rest of them are attached to the wheels of the conveyor belts.

Specific criteria and parameters were used in the generative design process described here to optimize the design of a structure capable of withstanding a given pressure while reducing mass and volume. The first step involved maintaining the geometry of four cylinders at their ends so that they would not change during the optimization procedure.

The component to be optimized in terms of mass and volume while maintaining strength to withstand the specified pressure was designated as the starting shape, which represented the remaining body. Except for the topmost cylinder, all of the other cylinders were subjected to a structural load of 800 N (80 kilograms), which reflected the need for the geometry to be preserved in order to withstand the applied pressure.

As it is permanently connected to another component of the design, the topmost cylinder was chosen as the structural constraint, essentially locking it in place to prevent movement.

The design goals were straightforward: to reduce mass while maintaining a safety factor of 2, which required that the developed designs withstand a load of 1600 N or twice the applied magnitude [10] [11].

The process also considered manufacturing considerations, including cost estimation based on a production volume of 2 units. It was possible to use various manufacturing processes, such as additive manufacturing, milling, and unrestricted manufacturing.

Because different materials have different physical properties, materials were important in the generative design. Steel, Stainless Steel, Titanium, Aluminum, and CFRP (Carbon Fiber Reinforced Polymers) were all potential material options that the software took into account when generating designs.

The generative design process produced 18 designs by adhering to these carefully chosen criteria and parameters. The final selection, however, was made in accordance with standards that give priority to minimum mass, reduced volume, and maximum stress-sustaining capacity, while also considering safety considerations. Outcomes 13, 10, 17, and 14 were chosen as the top four recommended designs following a thorough evaluation. These designs are the best options for the intended application because they satisfy the strict requirements for mass reduction, volume optimization, and stress resistance.

Now, based on the available data of the above available designs, selecting the best four recommended designs, which are provided to us based on minimum mass and volume with maximum stress sustaining capacity and factors of safety.

These are the best ones: outcomes - 13, 10, 17, and 14 (recommended).

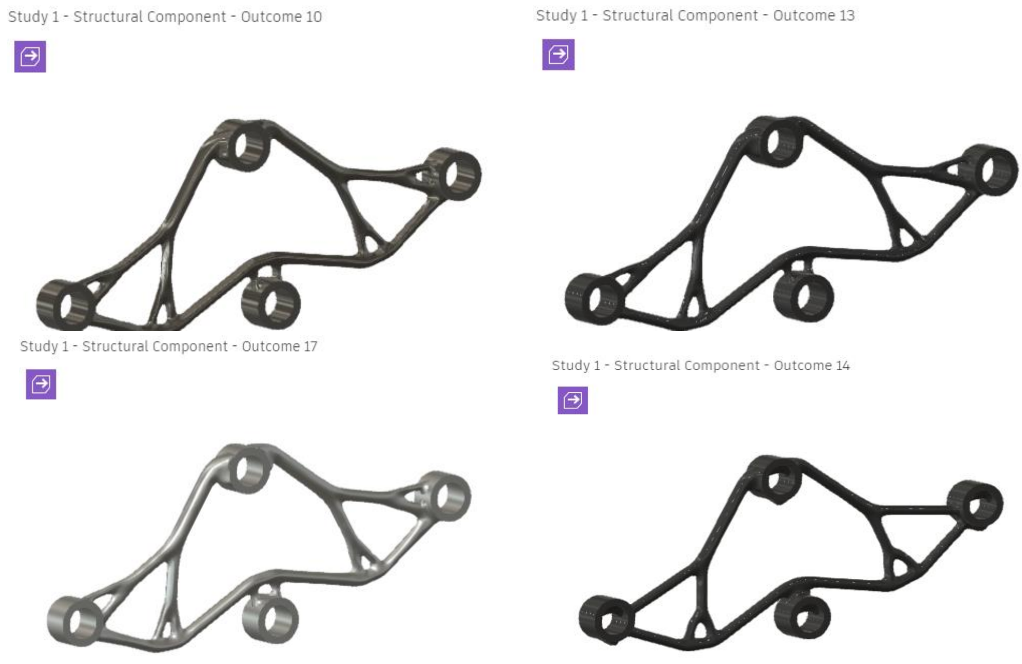

Figure 9: Structural components of different materials.

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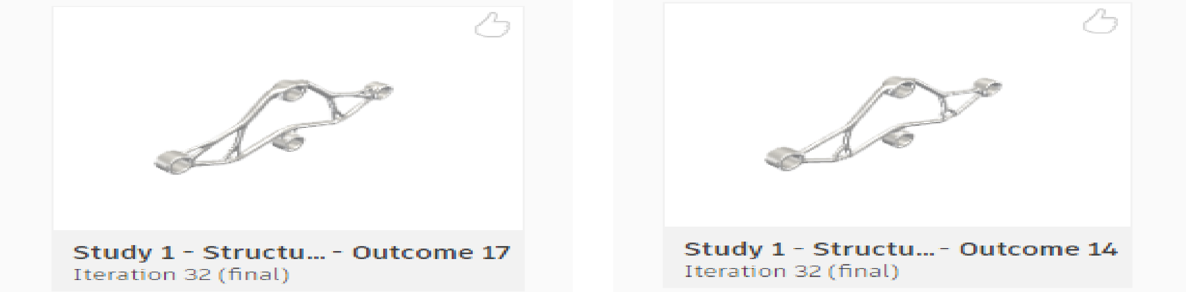
Figure 9, shows the structural component of different materials when implemented on the component.

Table 1. Comparison of four recommended outcomes.

Properties	Outcome -13	Outcome -10	Outcome -17	Outcome -14
Recommendation %	91.25 %	85.247 %	80.47 %	78.883%
Material	CFRP	Titanium	Aluminium ALSi10Mg	CFRP
Manufacturing method	Unrestricted	Unrestricted	Unrestricted	Addictive
Volume(mm^3)	7661.641	7933.886	8534.076	8301.378
Mass(kg)	0.011	0.036	0.023	0.012
Max von Mises stress(MPa)	150	137.8	120	150
Max displacement global (mm)	0.211	0.253	0.318	0.188

Figure 10 & 11, shows the brief description of the four recommended outcomes – 13, 10, 17, 14.

Figure 10: Brief description of outcome-13 & 10.



Properties (Outcome 17)

Status	Converged
Generative model	Generative Model 1
Material	Aluminum AlSi10Mg
Orientation	-
Manufacturing method	Unrestricted
Visual similarity	Group 2
Production volume (pcs.)	-
Piece part cost	
Range (USD)	-
Median (USD)	-
Fully burdened cost	
Range (USD)	-
Median (USD)	-
Volume (mm^3)	8,534.076
Mass (kg)	0.023
Max von Mises stress (MPa)	120
Factor of safety limit	2
Min factor of safety	2
Max displacement global (mm)	0.318

Properties (Outcome 14)

Status	Converged
Generative model	Generative Model 1
Material	CFRP
Orientation	Z+
Manufacturing method	Additive
Visual similarity	Group 3
Production volume (pcs.)	-
Piece part cost	
Range (USD)	-
Median (USD)	-
Fully burdened cost	
Range (USD)	-
Median (USD)	-
Volume (mm^3)	8,301.378
Mass (kg)	0.012
Max von Mises stress (MPa)	150
Factor of safety limit	2
Min factor of safety	2
Max displacement global (mm)	0.188

Figure 11: Brief description of outcome - 17 & 14.

Outcome-13 Iterations:

In Generative design, the design is optimized w.r.t mass [12] and volume, Here are the iterations showing how the generative designing function works in reducing the mass and volume of the designed object.

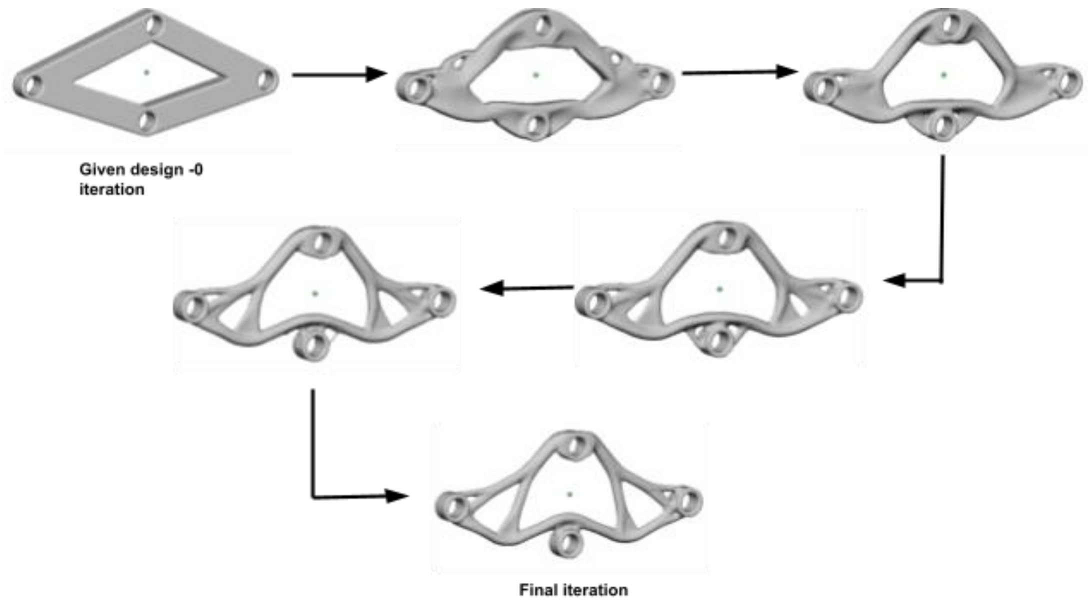


Figure 12: Iteration process of the component.

Figure 12, shows the Iteration process through which the component has gone to get the final Iteration

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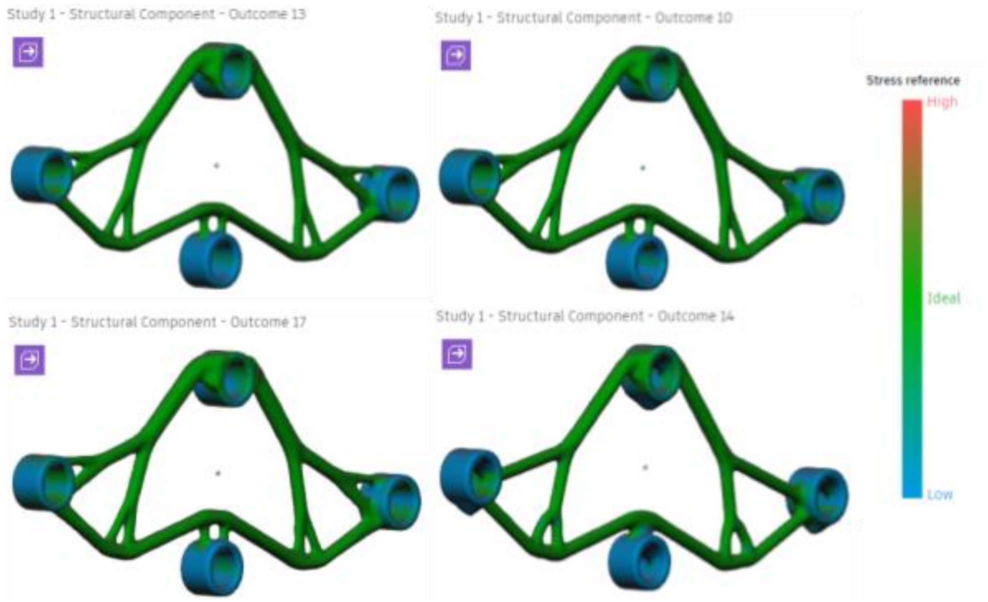

Figure 13: Stress view of the four recommended outcomes.

Figure 13, shows the stress level of the component when different materials are used, in which red shows a high-stress level, green shows an ideal stress level, and blue shows a low-stress level [13].

Graphs on mass, volume, Stress, and displacement for different materials based on recommended four outcomes:

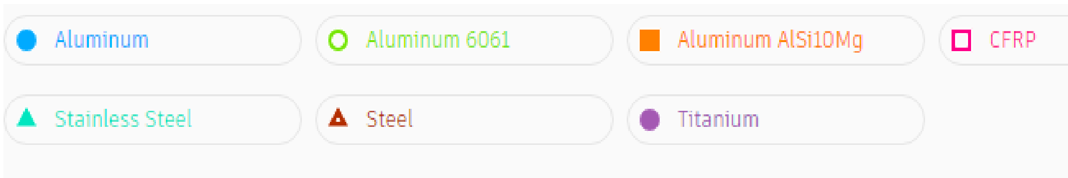

Figure 14: Symbols keys of graphs.

Volume to Mass Graph:

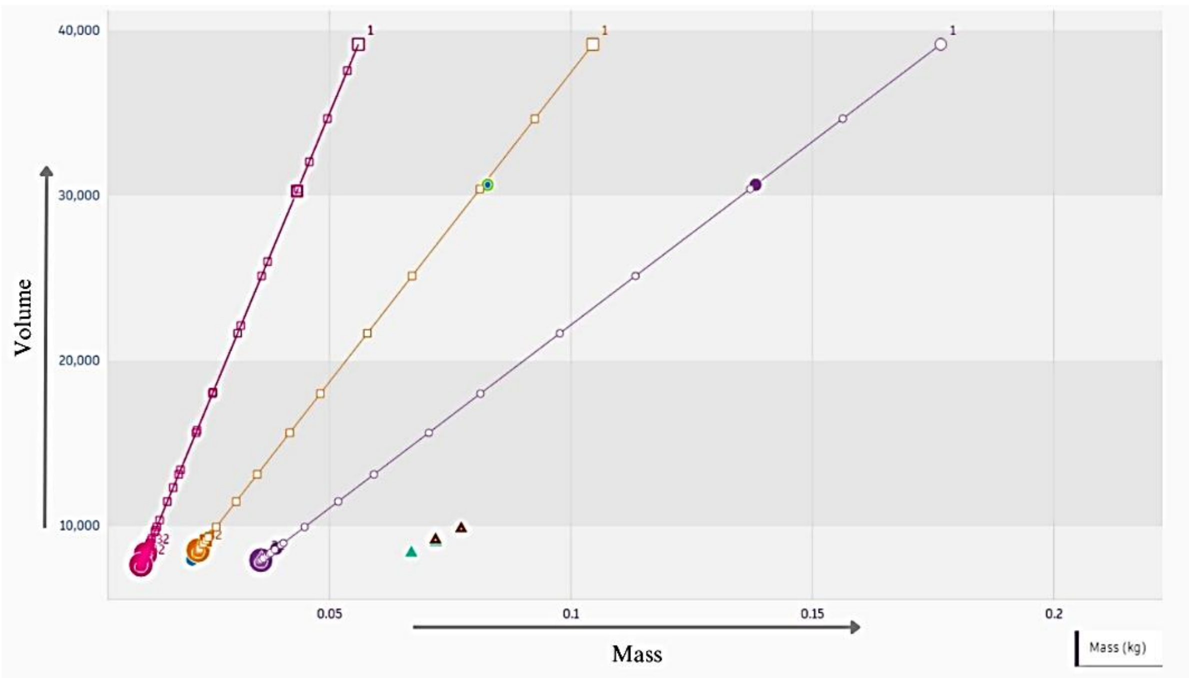

Figure 15: Volume versus mass graph.

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MEx von Mises stress to mass graph:

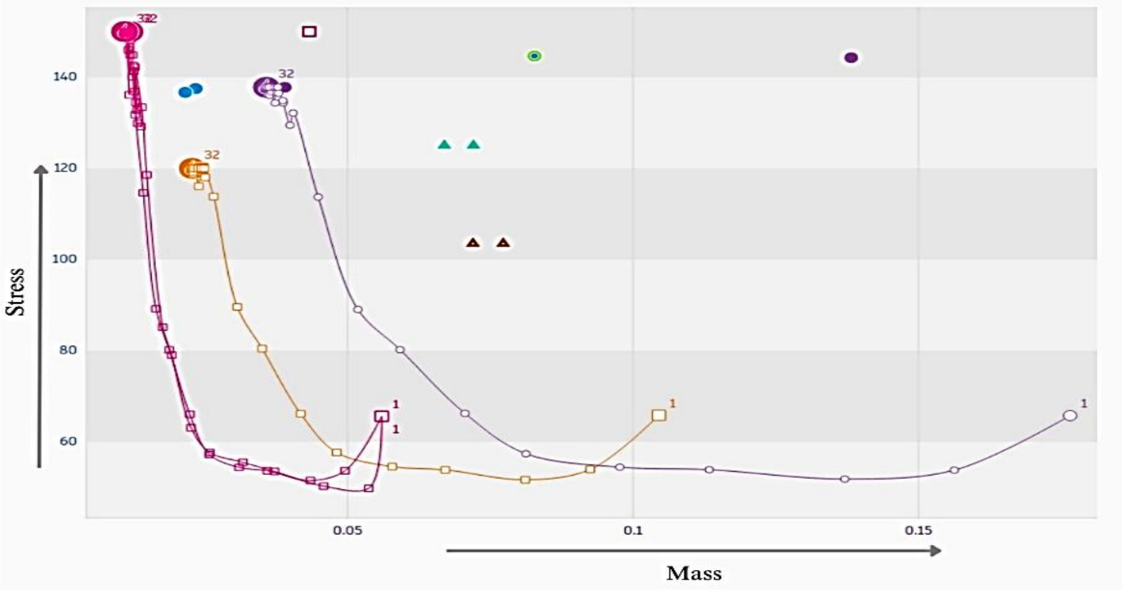


Figure 16: Stress versus mass graph.

Max displacement global to mass graph:

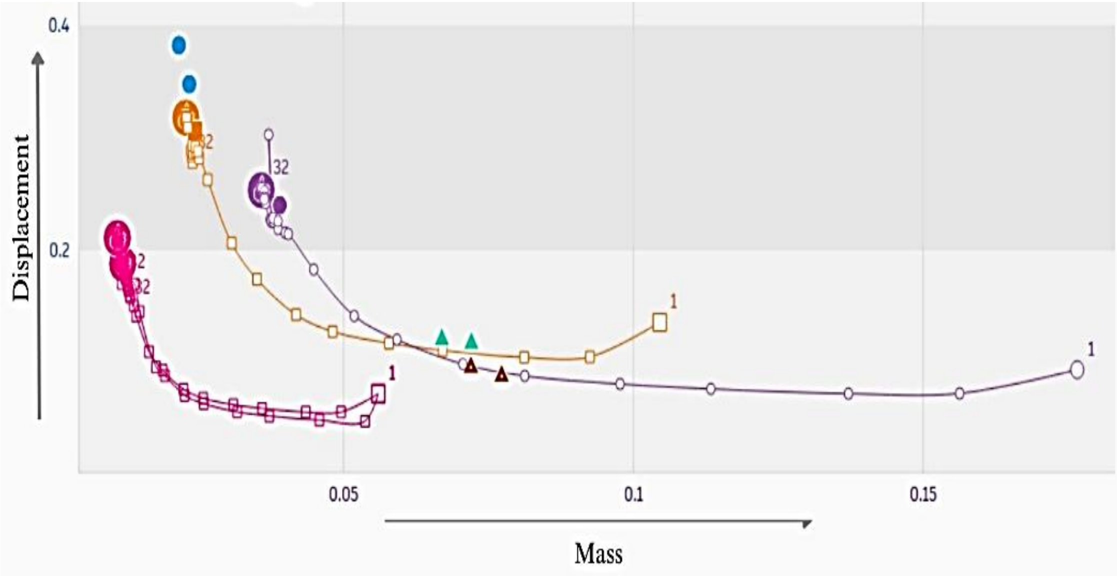
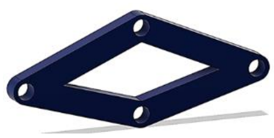
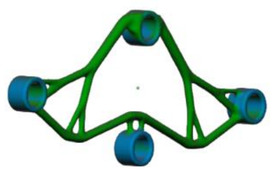


Figure 17: Displacement versus mass graph.

In Figure 15, it can be seen that the CRFP has the lowest volume-is-to-mass in comparison to all the other materials used. Figure 16, shows that the stress-handling capacity of CRFP is the best among all the other materials that are used. While Figure 17, shows the maximum displacement global of CRFP is best as per use.

Table 2: Final selected outcome table.

Parts Name	Main Design	Selected Generative Design	Stress Analysis Design
Component-Outcome-13			

IV. CONCLUSION

In this work, one important component of glass cleaning robot has been optimized using generic design module available in Fusion 360. In this module, stress-strain analysis, volume vs mass, stress vs mass and strain vs mass have been compared for all possible options. Outcome-13 is selected which is made up of carbon fiber [CFRP] and is recommended with 91.25 % because it requires a minimum volume of 7661.641 mm^3, mass= 0.011 kg, Displacement= 0.211 mm with a maximum stress bearing capacity of 150 MPa which is best among all its alternatives.

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