SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Generative Design of Electric Vehicle Additive Manufacturing (EVAM) Suspension Rocker

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Electric vehicles are becoming a more popular choice in recent years, with an increase of 40% in 2022 (Powell, 2023). In general, these vehicles are comparatively more sustainable compared to the conventional combustion engine, simply because they do not produce harmful carbon emissions. Additionally, most vehicle charging stations use renewable energy. Similarly, manufacturing has continually been improving by creating a smaller carbon footprint through using eco-friendly materials.

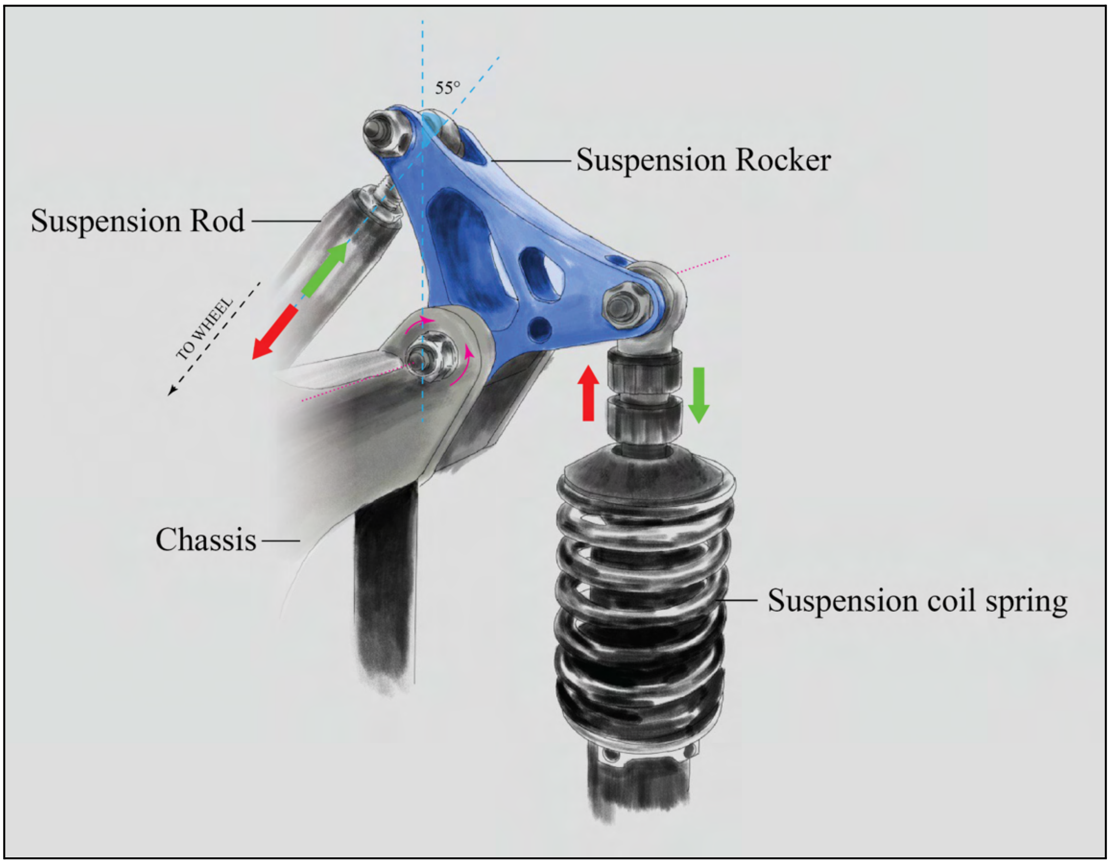
At the forefront of design and innovation, Singapore University of Technology and Design (SUTD) is manufacturing components for their electric vehicle project, known as Electric Vehicle Additive Manufacturing (EVAM). As the name suggests, they employ fabricating methods such as Selective Laser Melting (SLM), Fused Deposition Modeling (FDM), Multi Jet Fusion (MJF) and Stereolithography (SLA).

In this project, we will be exploring the use of generative design tools to propose practical solutions that can promote material and energy savings. We will be focusing on the Electric Vehicle Additive Manufacturing (EVAM) suspension rocker.

Methodology

Firstly, we had to understand the load constraints of the EVAM rocker. For this, we needed to map out the component's function within the mechanism of the system, which has been drawn out in Figure 1.

Figure 1
Illustration of the EVAM Rocker Mechanism



The purpose of this mechanism is to stabilize the control of the vehicle and increase comfort in the vehicle (Universal Technical Institute, 2021). This can be illustrated in the stages of motion when the vehicle travels over a bump.

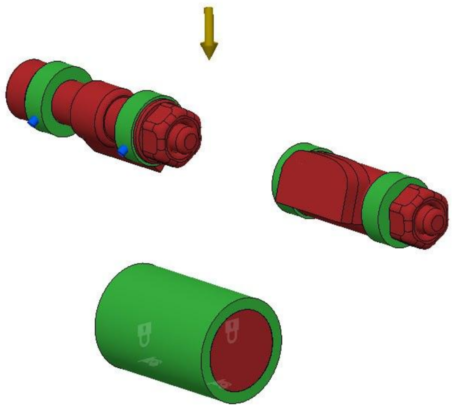
In the first stage when the wheel first hits the bump, there is an upward force on the wheel of the car. This pushes the suspension rod upwards at a 55 degree angle to the vertical. Through the rocker, the force is translated to a downward force onto the coil spring. This first stage is illustrated using the green arrows.

The second stage is when the wheel fully travels over the bump. The suspension coil spring exerts a force back on the rocker. The rocker translates the force back onto the suspension rod, which pushes the wheel back into the ground. This maximizes the contact of the tires with the ground, so that traction can be kept, and the driver will not lose control of the car. This is illustrated by the red arrows.

Within these two stages, the rocker translates the directions of the forces. This is illustrated by the pink arrows, as the rocker rotates about the axis (pink dotted line).

Loads and Constraints

Figure 2
Illustration of loads and constraints



Next, we needed to interpret our force analysis from Figure 1 into the generative design software that we would be using, which is *Autodesk Fusion 360*. A generative study was created as seen in Appendix A.

The generative study requires preserve geometries and obstacle geometries. The preserve geometries are the structures that will hold pins that are attached to the suspension rod, coil spring, and main chassis. Meanwhile the obstacle geometries are for these pins to go through. The component is then sandwiched by two more obstacle geometries so that its width does not increase.

The design of mechanical systems often requires the use of constraints to achieve the desired motion or behavior. In the case of the rocker and connector bearing support, a pin constraint and a fixed constraint were used according to the specifications provided in the design information. The fixed constraint was applied to the largest hole in the rocker to prevent any movement while allowing it to act as a hinge, while the pin constraint was applied to the bearing support to prevent deformities in the radial and axial directions.

The pin constraint on the bearing support allowed for movement in response to the force being applied on the other hole by the pushrods, while preventing undesirable deformities. The pushrods were found to be exerting a load of 5000N at an angle of 55 degrees from the vertical, which required careful consideration of the constraints to ensure proper function of the system.

By using textbook constraints and following the design information, the system was able to achieve the desired motion and withstand the applied forces. The proper use of constraints is essential in mechanical design to ensure safe and reliable operation of the system.

Materials

In order to generate design alternatives for evaluation, we decided to vary the material of the generative design study. We narrowed down the materials down to Aluminium AlSi (10Mg), Cobalt Chrome, Inconel 718, Stainless Steel 17-4 PH, Titanium 6Al-4V, from the Fusion 360 Additive Material Library. We chose Inconel 718 and Stainless Steel 17-4 PH from their other variants of Inconels and Stainless Steels because both materials have better properties in general, in terms of yield and tensile strength, density and cost.

We are aiming to settle for materials that have the highest yield and tensile strength, lowest density in order to minimize its weight contribution to the vehicle, and lowest cost for better manufacturing. Although Inconel 718 has lower ultimate tensile strength than its other 2 variants (Inconel 625 and Inconel 718 plus), it also has the lowest density and highest yield strength, whilst being cheaper. The Stainless Steel that we picked (Stainless Steel 17-4 PH) has lower density, higher yield, and higher tensile strength as compared to its alternative (Stainless Steel AISI 304) in the Fusion 360 Additive Material Library (Ansys Granta, 2019, 2). Since we are designing a rocker for a formula 1 themed electric vehicle, although Stainless Steel 17-4 PH is more costly, the benefits of the material being light and strong exceeded the drawback of the cost of the material.

From there, we performed a Life Cycle Assessment (LCA) on these materials to assess and understand the environmental impacts in each stage of the material's life cycle. This is important in order to be inline with the project's goal of sustainable design. In this case, we focused on the mass of carbon dioxide (CO_2) produced during material extraction, component fabrication, and component recycling. This is because the benefit of an electric vehicle is that it does not release CO_2 while in use. To simplify the analysis, we had to make some assumptions:

(1) No CO_2 is produced in use and during distribution of components, as the components will be manufactured in-house.
(2) Data will be collected from Casting CO_2, due to lack of information about CO_2 produced in additive manufacturing

The LCA can hence be summarized in Figure 13, with additional LCA charts and graphs in Appendix A.

Table 1
Life Cycle Assessment of Aluminium, Cobalt Chrome, Inconel, Stainless Steel and Titanium

Material	Stage of LCA	CO2 per kg (kg/kg)	Total CO2 (kg/kg)
Aluminium AlSi (10Mg)	Extraction	42.2	61.06
	Manufacturing	1.16	
	Recycling	17.7	
Cobalt Chrome	Extraction	12.5	16.79
	Manufacturing	0.909	
	Recycling	3.38	
Inconel 718	Extraction	18.3	23.18
	Manufacturing	0.996	
	Recycling	3.88	
Stainless Steel 17-4 PH	Extraction	9.58	12.49
	Manufacturing	0.894	
	Recycling	2.02	
Titanium 6Al-4V	Extraction	42.2	50.53
	Manufacturing	1.16	
	Recycling	7.17	

From this, we can conclude that Stainless Steel 17-4 PH has the least environmental impact in regards to CO2 produced. However, the different materials used in form generation will use different volumes of material. Hence, we need to factor in the volume of material used in order to determine the actual total CO2 produced.

We also researched material cost for our evaluation to optimize the design from a business perspective. The cost of the Aluminium A1SI (10Mg), Cobalt Chrome, Inconel 718, Stainless Steel 17-4 PH, Titanium 6A1-4V, and the original Aluminum 7075-T6 are (in SGD per m^3) is 8.08e3-9.46e3, 3.88e5-5.26e5, 1.47e5-1.69e5, 2.81e4-3.22e4, 1.2e5-1.43e5, and 1.66e4 - 2e4 respectively (Ansys Granta, 2019, 2). The product of the prices per unit volume and the volume of material used will then be used in our evaluation.

Additive Manufacturing vs Die Casting

While additive manufacturing is of the future, we took into consideration die casting as well as it was one of the manufacturing methods offered in Fusion360. Using the default material, aluminum, we generated two models using these two fabrication methods, as seen in Appendix B. The results show that the volume of material used in die casting is much greater than in additive manufacturing, due to the precision that it offers as compared to die casting. This means that additive manufacturing will produce less CO2 than die casting as well.

Control

To aid in our evaluation, we set the control to be the original design fabricated using Aluminum 7075-T6, using milling. A simulation was conducted and the results are in Table 2.

Table 2
Original rocker design specifications

Min Safety Factor	3.459	**Mass of component (kg)**	1323
Max Stress (MPa)	59.85	**CO2 produced (kg)**	23.63
Max Displacement (mm)	0.03264		
Strain	4.843e-04		
Volume of Material (mm^3)	1.686e5		

Results

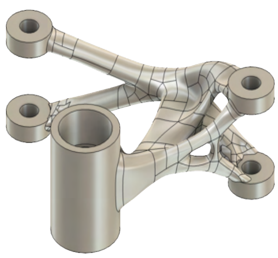
Generated Designs

Thus, we generated 10 models with 5 different materials and 2 different presetted safety factor . To aid our evaluation, we extracted simulation data regarding the (A) Safety Factor; (B) Stress; (C) Displacement; (D) Strain. Additionally, fabrication costs such as (E) Volume of material, and component specifics such as (F) Mass, were extracted. Figure 5 to 9 shows the outcomes of the model generation, while Appendix C presents the heat maps of the additional data.

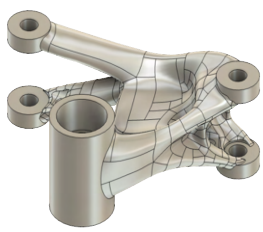
Aluminium AlSi (10Mg)

Figure 3 and 4
Generated Structural Component EVAM Rocker using Aluminium AlSi (10Mg)

*generative design preset safety factor set to 2.5



*generative design preset safety factor set to 4



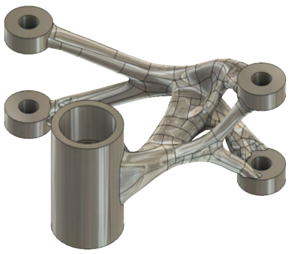
A. Minimum Safety Factor: 1.305
B. Max Stress: 184 MPa
C. Displacement: 0.13 mm
D. Strain: 0.003632
E. Volume of Material: 73.597 cm^3
F. Mass of component: 196.504 g

A. Minimum Safety Factor: 3.86
B. Max Stress: 62.18 Mpa
C. Displacement: 0.05767 mm
D. Strain: 0.001543
E. Volume of Material: 116.959 cm^3
F. Mass of component: 312.218 g

Cobalt Chrome

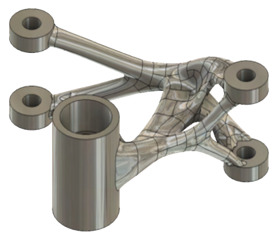
Figure 5 and 6
Generated Structural Component EVAM Rocker using Cobalt Chrome

*generative design preset safety factor set to 2.5



A. Safety Factor: 4.267
B. Stress: 137.3 MPa
C. Displacement: 0.05363 mm
D. Strain: 9.804e-04
E. Volume of Material: 68.669 cm^3
F. Mass of component: 569.269 g

*generative design preset safety factor set to 2

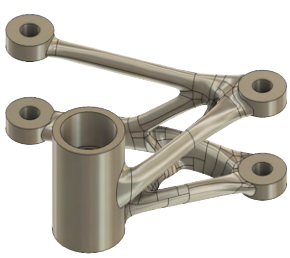


A. Safety Factor: 4.633
B. Stress: 126.5 MPa
C. Displacement: 0.05359 mm
D. Strain: 0.00101
E. Volume of Material: 68.648 cm^3
F. Mass of component: 569.093

Inconel 718

Figure 7 and 8
Generated Structural Component EVAM Rocker using Inconel 718

*generative design preset safety factor set to 2.5



A. Safety Factor: 6.204
B. Max Stress: 124.4 Mpa

*generative design preset safety factor set to 2

A. Safety Factor: 4.906
B. Max Stress: 157.4 MPa

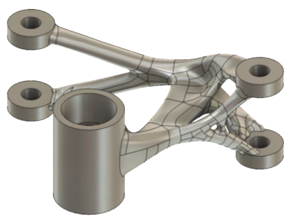
C.	Displacement: 0.06011 mm	C.	Displacement: 0.06146 mm
D.	Strain: 9.97e-04	D.	Strain: 0.001386
E.	Volume of Material: 68.518 cm^3	E.	Volume of Material: 68.807 cm^3
F.	Mass of component: 554.035 g	F.	Mass of component: 556.374 g

Stainless Steel 17-4 PH

Figure 9 and 10

Generated Structural Component EVAM Rocker using Stainless Steel 17-4 PH

*generative design preset safety factor set to 2.5



*generative design preset safety factor set to 2

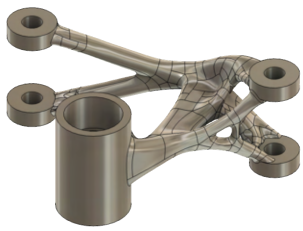
A.	Safety Factor: 4.904	A.	Safety Factor: 3.674
B.	Max Stress: 122.4 MPa	B.	Max Stress: 163.3 MPa
C.	Displacement: 0.05241 mm	C.	Displacement: 0.05239 mm
D.	Strain: 9.315e-04	D.	Strain: 0.001249
E.	Volume of Material: 68.636 cm^3	E.	Volume of Material: 68.636 cm^3
F.	Mass of component: 535.36 g	F.	Mass of component: 535.36 g

Titanium 6Al-4V

Figure 11 and 12

Generated Structural Component EVAM Rocker using Titanium 6Al-4V

*generative design preset safety factor set to 2.5



*generative design preset safety factor set to 2

A.	Minimum Safety Factor: 7.667	A.	Minimum Safety Factor: 4.358
B.	Max Stress: 115.1 MPa	B.	Max Stress: 202.5 MPa
C.	Displacement: 0.09401 mm	C.	Displacement: 0.1566 mm

D. Strain: 0.001387
E. Volume of Material: 68.645 cm^3
F. Mass of component: 304.097 g

D. Strain: 0.002449
E. Volume of Material: 68.573 cm^3
F. Mass of component: 303.773 g

Life Cycle Assessment

With the mass of component generated, the total mass of CO2 can be calculated using equation (1):

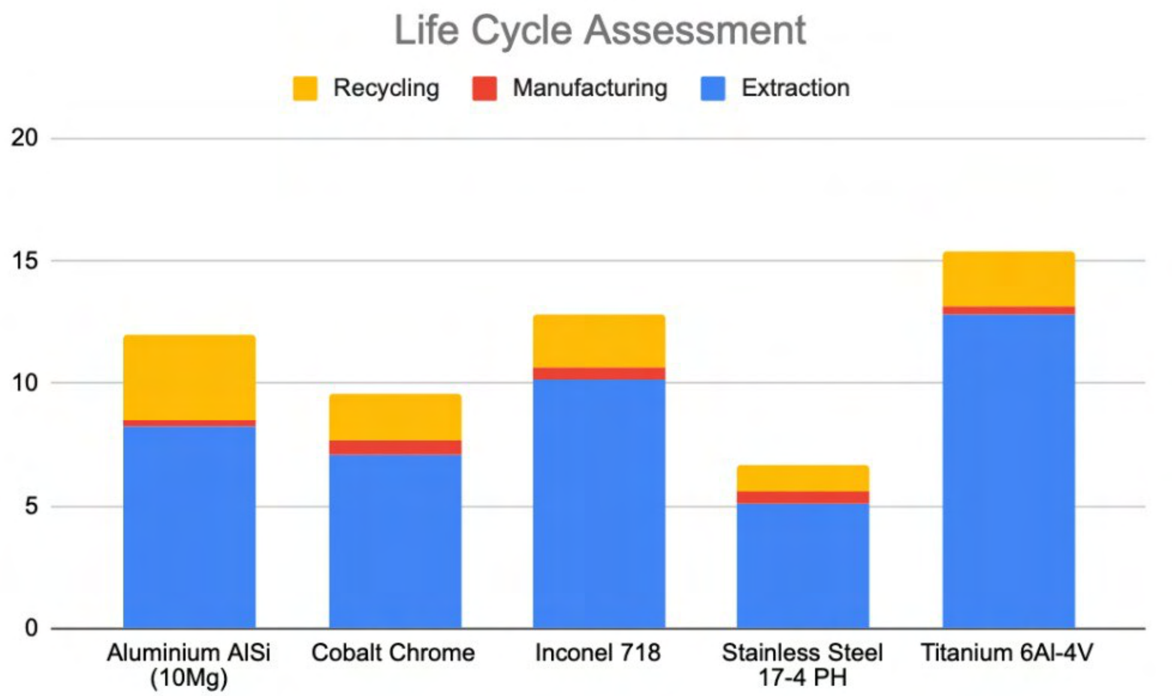
$$total\ CO_2\ produced\ = mass\ of\ component\ \times CO_2\ per\ kg \quad (1)$$

The calculated data is computed in Table 2 and represented in Figure 8.

Table 3
Total mass of CO2 produced based on mass of rocker component

Material	Stage of LCA	CO2 produced (kg)	Total CO2 (kg)
Aluminium AlSi (10Mg)	Extraction	13.17	19.05
	Manufacturing	0.36	
	Recycling	5.52	
Cobalt Chrome	Extraction	7.11	9.55
	Manufacturing	0.52	
	Recycling	1.92	
Inconel 718	Extraction	10.17	12.89
	Manufacturing	0.55	
	Recycling	2.16	
Stainless Steel 17-4 PH	Extraction	5.13	6.69
	Manufacturing	0.48	
	Recycling	1.08	
Titanium 6Al-4V	Extraction	12.79	15.31
	Manufacturing	0.35	
	Recycling	2.17	

Figure 13
Impact Assessment



Evaluation

The generated results can be summarized in Table 4 below:

Table 4
Summarized data from generated models with preset safety factor to 2.5 of different materials

						
Material	Aluminium AlSi (10Mg)	Cobalt Chrome	Inconel 718	Stainless Steel 17-4 PH	Titanium 6Al-4V	Aluminum 7075-T6 (Original design)
Preset safety factor	2.5	2.5	2.5	2.5	2.5	NA
Min Safety Factor	1.305	4.267	6.204	4.904	7.667	3.459
Max Stress (MPa)	184	137.3	124.4	122.4	115.1	49.85
Max Displacement (mm)	0.13	0.05363	0.06011	0.05241	0.09401	0.03264

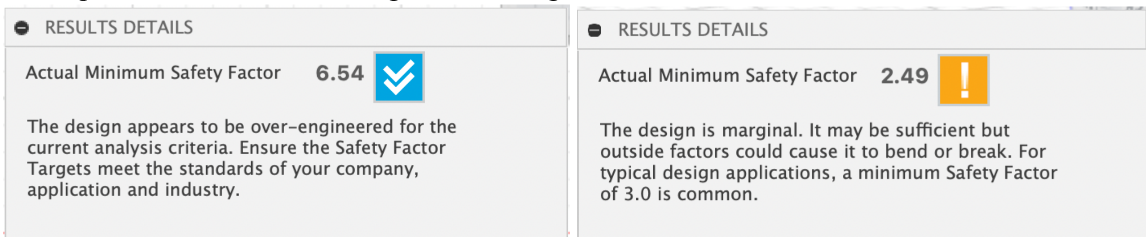
Strain	0.003632	9.804e-04	9.97e-04	9.315e-04	0.001387	4.843e-04
Yield Strength (MPa)	240	586	772	600	882.528	145
Volume of Material (cm^3)	73.597	68.669	68.518	68.636	68.645	1.686e5
Material Cost (SGD)	594,663.76	26,643,572	10,072,146	1,928,671.6	8,237,400	2,798,760,000
Mass (g)	196.504	569.296	554.035	535.36	304.097	1323
CO2 Produced (kg)	11.97	9.55	12.84	6.68	15.36	23.63

* *Improvement in green and worsened in red, from the original design control*

According to the results from fusion 360's simulation, Aluminium's design is marginal and outside factors could cause it to bend or break. Inconel and Titanium's design is over engineered which also means it is too strong for the conditions the design is under, which signals wasting materials and cost.

Figure 14 and 15

Example of Fusion360's warning after running static stress simulations



Further Evaluation

We want to explore how the generated design would change if we vary the preset safety factor according to the previous results (table 3). We predicted that if we preset the safety factor to a higher value, the generated design would turn out to be over engineered and therefore having additional unnecessary mass and materials, and if we preset the safety factor to a lower value, the generated design would turn out to be fragile and would break under external forces.

Therefore to further evaluate our designs, we tried to find the optimal preset safety factor value for each material, and generated a new design under changed preset safety factor as shown in table 4.

The generated results can be summarized in Table 5 below:

Table 5

Summarized data from generated models with revised preset safety factor of different materials

Material	Aluminium AlSi (10Mg)	Cobalt Chrome	Inconel 718	Stainless Steel 17-4 PH	Titanium 6Al-4V	Aluminum 7075-T6 (Original design)
Preset safety factor	4	2	2	2	1	NA
Min Safety Factor	3.86	4.633	4.906	3.674	4.358	3.459
Max Stress (MPa)	62.18	126.5	157.4	163.3	202.5	49.85
Max Displacement (mm)	0.05767	0.05359	0.06146	0.05239	0.1566	0.03264
Strain	0.001543	0.00101	0.001386	0.001249	0.002449	4.843e-04
Yield Strength (MPa)	240	586	772	600	882.528	145
Volume of Material (cm^3)	116.959	68.648	68.807	68.636	68.573	1.686e5
Material Cost (SGD)	680,012.8	26,635,424	10,114,629	1,928,671.6	8,249,880	2,798,760,000
Mass (g)	312.218	569.093	556.374	535.36	303.773	1323
CO2 Produced (kg)	19.05	9.55	12.89	6.69	15.31	23.63

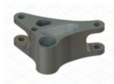
** Improvement in green and worsened in red, from the original design control*

From the second run of generation and simulation, only Aluminium's simulation appears a warning from fusion 360 that the design is marginal; it will break or bend under external conditions. Cobalt's minimum safety factor has increased (worsen) from the first run of simulation with preset safety factor of 2.5. Inconel, Stainless Steel , and titanium's simulation result is better than their first designs (no warning shown from fusion 360). Although each of their masses did increase or remain the same, it is not a huge change (the biggest change of mass from table 1 and table 2 is 2.34 g).

Therefore we will be using Inconel 718, Stainless Steel 17-4PH, Aluminium AlSi (10Mg) and Titanium 6AI-4V from table 4 and Cobalt Chrome from table 3 in the final comparison.

Table 6

Finalized table of the optimal preset safety factor of each material for final comparison.

						
Material	Aluminium AlSi (10Mg)	Cobalt Chrome	Inconel 718	Stainless Steel 17-4 PH	Titanium 6Al-4V	Aluminum 7075-T6 (Original design)
Preset safety factor	4	2.5	2	2	1	NA
Min Safety Factor	3.86	4.267	4.906	3.674	4.358	3.459
Max Stress (MPa)	62.18	137.3	157.4	163.3	202.5	49.85
Max Displacement (mm)	0.05767	0.05363	0.06146	0.05239	0.1566	0.03264
Strain	0.001543	9.804e-04	0.001386	0.001249	0.002449	4.843e-04
Yield Strength (MPa)	240	586	772	600	882.528	145
Volume of Material (cm^3)	116.959	68.669	68.807	68.636	68.573	1.686e5
Material Cost (SGD)	680,012.8	26,643,572	10,114,629	1,928,671.6	8,249,880	2,798,760,000
Mass (g)	312.218	569.296	556.374	535.36	303.773	1323
CO2 Produced (kg)	19.05	9.55	12.89	6.69	15.31	23.63

* *Improvement in green and worsened in red, from the original design control*

Perspectives

Because there are many variables and factors to take into account for our analysis, we divided our analysis into three perspectives (not ordered by importance): Engineering, Business and Environment.

Engineering Perspective

Engineering is concerned with designing the strongest structure, which we will be taking in consideration the material's yield strength as well as each material's generated design's maximum stress data from the static stress simulation done on Fusion360. Material's yield strength tells us how much load the material can take before permanent plastic deformation. And maximum stress from Fusion360's simulation workspace tells us what is the maximum stress experienced by the design at a certain area of the design. Therefore if the value is higher, it would mean that a high amount of stress is focused on one point as all designs face the same loads and constraints while performing the static stress simulation. Which also means that the design is not good at distributing the stress experienced by it.

To judge which material design is the strongest, we would want that design's material to have the highest yield strength, and the lowest max stress value from Fusion360 as this will give us the design that is the strongest yet having a good stress distribution. Therefore we have came up with an equation $Yield\ Strength\ -\ Max\ Stress$ in order to judge which design is the best from an engineering perspective.

Table 7

Table of the results of $Yield\ Strength\ -\ Max\ Stress$ of each material.

Material	Aluminium AlSi (10Mg)	Cobalt Chrome	Inconel 718	Stainless Steel 17-4 PH	Titanium 6Al-4V	Aluminum 7075-T6 (Original design)
Yield Strength - Max Stress (MPa)	143.71	448.7	614.6	436.7	680.03	95.15

From the results in Table 7, Titanium 6A1-4V is the best choice of material from an engineering lens, as it has the highest high yield strength of 882.528 MPa. Though the lowest maximum stress is 49.85 MPa from Aluminum 7075-T6, it also has the lowest yield strength of 145 MPa, hence why it will not be the best option of material.

Business Perspective

From a business point of view, we want to reduce the overall cost of the material. This will be derived by taking the minimum cost per volume (SGD / m^3), multiplied by the volume that was generated in Fusion360. From the data in Table 6, Aluminum A1SI (10Mg) has the lowest overall minimum cost at SGD 680,012.80. The next lowest minimum material cost would be Stainless Steel 17-4 PH which is at SGD 1,928,671.60, a large difference of SGD $1,248,658.20. With that, in terms of minimizing cost, Aluminum A1SI (10Mg) is the best option of material.

Environment Perspective

We want to reduce the overall CO2 produced by the materials, since increased production of CO2 contributes more harm to the environment and people's health. In Table 6, Stainless Steel 17-4

PH produces the least amount of CO2 at 6.69 kg/kg, therefore it will be the material chosen in consideration of the environment.

Rankings

To simplify our analysis, we used a ranking system to determine the best material in consideration of all 3 perspectives, as seen in Table 8. We assigned points to our 6 different materials, with 0 being the lowest and 5 being the highest.

Table 8
Ranking of materials from engineering, business and environmental perspectives

Material	Aluminium AlSi (10Mg)	Cobalt Chrome	Inconel 718	Stainless Steel 17-4 PH	Titanium 6Al-4V	Aluminum 7075-T6 (Original design)
Engineering	1	3	4	2	5	0
Business	5	1	2	4	3	0
Environment	1	4	3	5	2	0
Total Points	7	8	9	11	10	0

Recommendations

With the rankings presented in Table 8, the best overall option of material will be Stainless Steel 17-4 PH, which ranked up the most points. The second best option will be Titanium 6A1-4V which ranked 10 points. Next in line will be Inconel 718 which ranked 9 points, then Cobalt Chrome with 8 points, and Aluminum A1SI (10Mg) which is at 7 points. Lastly, there is Aluminum 7075-T6 which performed the worst in all perspectives given that it has accumulated 0 points total.

Though Stainless Steel 17-4 PH was not ranked the highest from an engineering point of view, in terms of sustainable development, it is the best. It produces the least mass of CO2 emissions which is incredibly important in the modern world where there are serious implications of pursuing harmful practices that contribute to climate change. In developing for the long term where future generations are taken into consideration, it is the best decision to pursue a practice that benefits both the environment and business. In this case, because Stainless Steel 17-4 PH is the second cheapest in terms of cost, it will be great for the business as they can keep manufacturing with the material whilst being considerate to the environment and health of people.

If we were to proceed with the best performing material in terms of strength, then Titanium 6A1-4V would be the option to go for. However, this will not be a sustainable choice as it is ranked the third lowest in terms of the environment's perspective. It produces the third highest mass of CO2 at 15.31kg, which is a difference of 8.72kg of CO2 from Stainless Steel 17-4 PH. And though it will be tough to break and effective product wise, this will only be beneficial short term, and its unsustainable practices cannot be carried forward for the long term and future generations.

Summary of Lessons Learnt

1. The use of generative design can help identify new design possibilities that may not have been considered before.

2. In generating designs, we must use preserve and obstacle geometries in order to output desired outcome.

3. Failure to properly define project requirements and constraints could result in designs that do not meet the necessary specifications. Constraints are needed to achieve the motion or behavior needed.

4. Careful consideration should be given to the selection of materials based on their performance, cost, and sustainability.

5. In analyzing the sustainability factor of materials, a life cycle assessment is an appropriate method in identifying how much CO2 is being produced.

6. Testing and evaluation of the generative design outcomes is crucial to ensure that the design meets all project requirements and constraints.

7. An evaluation of the original design must be conducted in order to have a benchmark that the generated designs can compare to.

8. Continuous improvement and iteration are necessary for refining the design and improving its performance over time.

9. Observing safety factors and stress levels is crucial to determine the design's real-life performance. A design with a low safety factor or high stress may not be reliable, requiring modifications. High values of safety factors can lead to over-engineering.

10. There are always multiple perspectives in evaluating the right material for manufacturing, and we should never rule out the other perspectives in favor of one. And just because a material is the best performing, doesn’t always mean that it’s the material that should be picked, because sustainability has become an important topic for consideration and we should start learning how to build with the future in mind.

References

Ansys Granta. (2019). *Nickel-chromium alloy, INCONEL*. CES 2019 Edupack.

https://www.ansys.com/products/materials

Powell, D. (2023, January 10). *Electric car statistics - EV Data [Update: Jan 23]*. heycar. Retrieved

February 22, 2023, from https://heycar.co.uk/blog/electric-cars-statistics-and-projections

Universal Technical Institute. (2021, October 5). *How Do Car Suspension Systems Work? | UTI*. Universal Technical Institute. Retrieved February 22, 2023, from https://www.uti.edu/blog/automotive/car-suspension