

University of Wales Trinity Saint David

School of Engineering



Manufacturing Design & Technology

ACMA5002

Shea Whitehead

2212438

11/05/2025

Contents

1	List of figures	iii
2	Abstract	1
3	Robot Gripper Redesign (Task 1)	2
3.1	Introduction	2
3.2	Concept Design Appraisal	3
3.2.1	Customer and End User Needs	3
3.2.2	Quality Function Deployment (QFD)	3
3.2.3	Design Specification	5
3.2.4	Material selection	6
3.2.5	Operational requirements.	6
3.3	Manufacturing Process Proposal.....	7
3.3.1	Lean manufacturing	7
3.3.2	Business and Company Needs	8
3.3.3	Cost Drivers	8
3.3.4	Selected Manufacturing Processes	8
3.3.5	Process Selection Justification	9
3.4	Design and Development Work Undertaken	10
3.4.1	DFMEA (Design Failure Mode and Effects Analysis)	15
3.4.2	Scamper.....	15
3.4.3	Environmental and lifecycle	16
3.5	Conclusion	17
4	Task 2- Design for Additive Manufacturing	18
4.1	Introduction.....	18
4.2	Existing component analysis.....	19
4.2.1	Current Design.....	19
4.2.2	Project scope	20

4.3	DfAM Principles and Redesign Approach	21
4.3.1	Topology optimisation	21
4.3.2	Generative Design.	21
4.3.3	Internal lattice structure	23
4.4	Quality Function Deployment (QFD)	24
4.5	AM Process and Material Selection.....	25
4.5.1	Process selection	25
4.5.2	Material selection	25
4.6	Finite Element Analysis (FEA)	26
4.7	Cost and Environmental Implications.....	27
4.7.1	Cost Implications	27
4.7.2	Environmental Implications	28
4.8	Conclusion	29
5	References	30

1 List of figures

Table 1-Customer needs table (Purnell-Whitehead, 2025).....	3
Table 2- Design specification for re-design (Purnell-Whitehead, 2025).....	5
Table 3-Cost Driver Table (Purnell-Whitehead, 2025).....	8
Table 4-DFMEA - Robot gripper arm (Purnell-Whitehead, 2025).....	15
Table 5-QFD for Control Arm (Purnell-Whitehead, 2025)	24
Figure 1-QFD for Re-design of Robot Gripper (Purnell-Whitehead, 2025).....	4
Figure 2-Original design of robot gripper (University, 2024).....	10
Figure 3-Redesign of gripper arm (Purnell-Whitehead, 2025)	10
Figure 4-Clamp cover re-design (Purnell-Whitehead, 2025)	11
Figure 5-Re-designed motor housing (Purnell-Whitehead, 2025).....	11
Figure 6-Original gripper bracket connection (University, 2024)	12
Figure 7-Re-designed gripper bracket connection (Purnell-Whitehead, 2025).....	12
Figure 8-Re-designed bracket (Purnell-Whitehead, 2025)	13
Figure 9-Original mounting bracket (University, 2024)	13
Figure 10-Original Fixing design (University, 2024)	14
Figure 11-All redesigned components. (Purnell-Whitehead, 2025)	14
Figure 12-Range Rover Evoque rear suspension layout (suspensions, 2025)	19
Figure 13-Image of Aston Martin DBX rear control arm (Purnell-Whitehead, 2025).....	20
Figure 14-DBX Suspension specification (Aston Martin, 2025)	20
Figure 15-Fusion 360 Control Arm Design (Purnell-Whitehead, 2025)	21
Figure 16-Applied forces and boundary conditions of the design (Purnell-Whitehead, 2025).....	22
Figure 17-Volumetric lattice structure (Purnell-Whitehead, 2025).....	23
Figure 18-Stress study of design (Purnell-Whitehead, 2025)	26
Figure 19-Ferrari F80 AM design control arm. (AM, 2025).....	27
Figure 20-Bugatti Am brake calliper design (Sher, 2021)	28

2 Abstract

This report presents the redesign and manufacturing optimisation of two engineering components: a robotic gripper (Task 1) and an automotive suspension control arm (Task 2), applying advanced design methodologies to support scalability, performance, and sustainability. Task 1 focuses on transitioning a mechanical gripper from small-scale to high-volume production, incorporating Design for X (DfX), Quality Function Deployment (QFD), DFMEA, and lean principles. The redesign reduces part count, standardises components, and improves serviceability, enabling cost-effective manufacturing through processes like injection moulding and die casting. Task 2 explores Design for Additive Manufacturing (DfAM) in redesigning the rear suspension control arm of the Aston Martin DBX. Leveraging topology optimisation, generative design, and internal lattice structures, the new design achieves significant weight reduction while maintaining structural integrity. Selective Laser Melting (SLM) with Ti-6Al-4V was selected to realise the complex geometry and mechanical demands. Both tasks underscore the transformative role of digital tools and advanced manufacturing strategies in delivering lightweight, cost-efficient, and high-performance components suitable for modern production demands.

3 Robot Gripper Redesign (Task 1)

3.1 Introduction

The transition from small-scale production to mass manufacturing presents unique challenges and opportunities for any product. This review focuses on a mechanical gripper currently produced in limited quantities. Market research suggests a requirement of over 1,000 plus units per week.

This report will evaluate the existing design of the gripper, identifying potential modifications to optimise its components and assembly processes for high-volume production. By addressing factors such as material selection, manufacturing techniques, assembly efficiency, and cost reduction, the redesign aims to maintain or improve performance while ensuring scalability and economic feasibility. The goal is to enable the company to meet market demand effectively, enhance production efficiency. To accomplish this, the report employs methodologies such as Design for X (DFX) throughout the redesign process. These approaches guide design decisions by aligning product optimization with specific performance goals—in this instance, manufacturability. By prioritising manufacturability during the design phase, DFX techniques help minimize the need for expensive modifications after production, ensuring a smoother transition to mass manufacturing (Boothroyd, et al., 2010)

3.2 Concept Design Appraisal

3.2.1 Customer and End User Needs

Modern robotic grippers have significantly improved in strength, speed, and precision due to technological advancements. They can now handle a wide range of materials, including soft fabrics and delicate components, using innovative materials like piezoelectric, shape memory alloys, and smart fluids (Tai, et al., 2016).

Using the initial design, the following key design requirements.

Table 1-Customer needs table (Purnell-Whitehead, 2025).

Customer Needs	Importance	Engineering Requirements
High reliability	5	Durable material, fail-safe joints
Fast production	4	Simple geometry, minimal assembly parts
Low production cost	5	Low material waste, compatible with injection moulding
Ease of assembly	4	Snap-fits, integrated components
Aesthetically simple design	2	Smooth surfaces, compact structure

3.2.2 Quality Function Deployment (QFD)

Often referred to as the house of quality, QFD listens to the voice of the customer. A tool used by designers and engineers to design products that customers desire. Shigeru Mizuno and Yoji Akao created QFD in Japan in the 1960s. It was first presented to an American audience in 1983 when Quality Progress published the article "Quality Function Deployment and CWQC in Japan" by Masao Kogure and Akao. (Kogure, et al., 1983)

Carrying out a QFD for the initial gripper design which is currently being manufactured will be effective in the development of the new design of the gripper intended for large scale production.

Quality Function Deployment (QFD), often referred to as "listening to the voice of the customer," is a systematic approach to converting customer needs into detailed technical requirements at each stage of product development and production. By focusing on the consumer need described in Table 1. The QFD aims to ensure designs meet customer expectations while defining key quality assurance parameters for production.

Unlike traditional quality systems that primarily aim to minimize negative quality aspects (e.g., identifying defects or addressing poor service), QFD emphasises creating positive quality features that enhance customer value and satisfaction. For example, it considers factors such as whether a product is enjoyable and easy to use.

QFD has broad applications across various industries, including aerospace, manufacturing, software development, healthcare, and more. It supports activities like product development, business planning, site evaluation, test planning, and problem-solving by aligning customer-driven priorities with technical and operational goals. (Akao, 2004)

The brief states that the tooling manufacture requires a review of the gripper that is already established. The key design requirement is scaling the product. This will be reflected in the QFD with associated requirements to meet the customer requests.

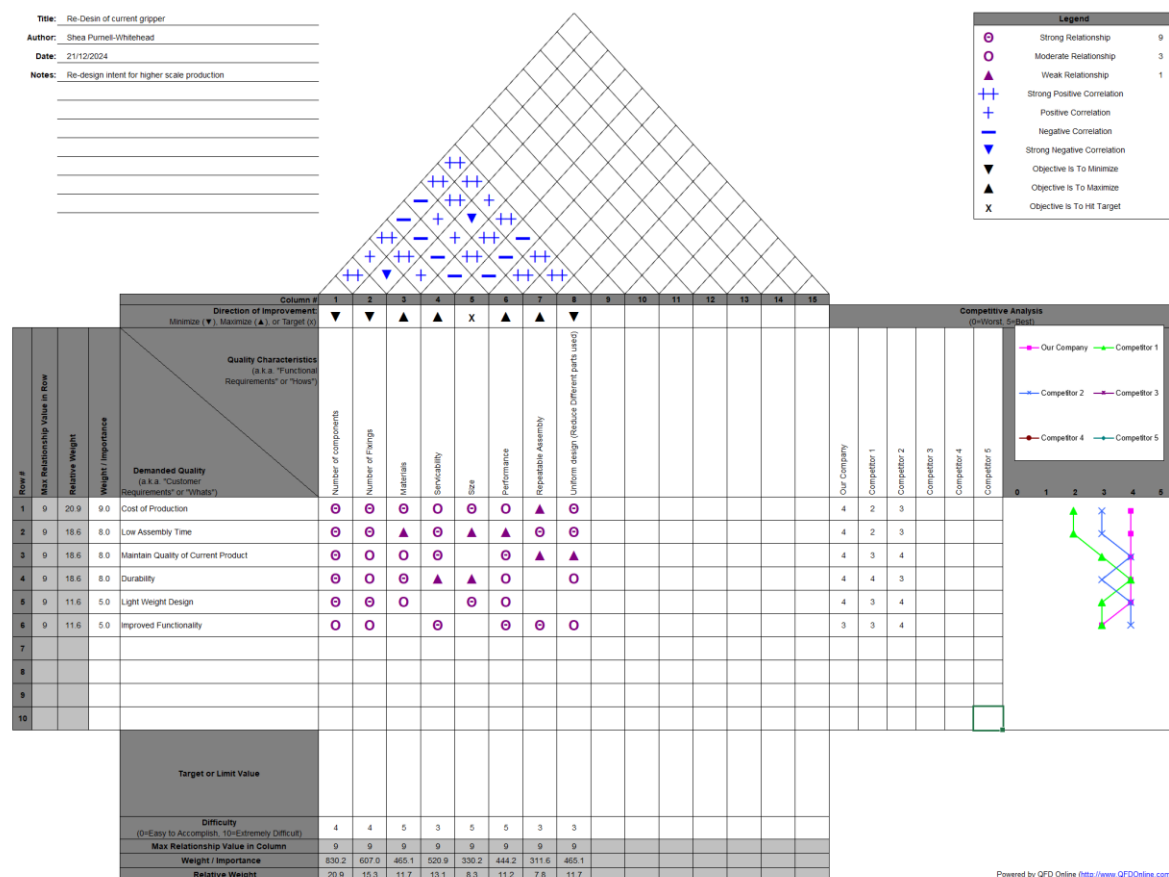


Figure 1-QFD for Re-design of Robot Gripper (Purnell-Whitehead, 2025)

After completing the QFD Figure 1, among the factors outlined, not all are equally significant when scaling production. To identify the key influences on mass production, it is essential to focus on the functional requirements that directly affect manufacturability. This study highlights factors like the number of fixings, the complexity of the assembly process, and assembly components as having a significantly higher weight/importance on the choice of manufacturing methods and the feasibility of scaling a design for mass production.

In contrast, functional requirements, while critical to product performance, do not play a dominant role in determining how easily the product can be manufactured at scale. Prioritizing these

production-critical factors ensures that design decisions support efficient and cost-effective mass production. Although the higher weighted categories have shown the importance when scaling is the objective, The lower weighted should not be disregarded as it is equally important to maintain the quality and reliability of the product that is being created.

3.2.3 Design Specification

A comprehensive design process typically begins with conceptual design, involving the identification of customer needs and problem definition. This stage is followed by information gathering to better understand constraints, requirements, and opportunities. Designers then move on to conceptualisation, where multiple potential solutions are generated. The process continues with concept selection, where the most viable ideas are chosen and refined based on specific criteria. Finally, the design undergoes refinement and review, ensuring that it aligns with functional requirements, customer expectations, and feasibility for production. By iterating through these stages, engineers can develop robust, customer-focused solutions while addressing both technical and practical challenges. (Thramboulidis, 2010).

Table 2- Design specification for re-design (Purnell-Whitehead, 2025).

Category	Specification
Product Description	A mechanical robotic gripper assembly designed for high-volume automation systems
Intended Use	Gripping and releasing small to medium-sized components
Production Volume	≥ 1000 units per week (targeted for scalable, low-cost production)
Functional Requirements	Specification
Gripping Force	Minimum of 50 N to handle typical production parts
Gripping Range	20 mm – 80 mm object diameter
Actuation Method	Pneumatic or servo-motor compatible interface
Operating Orientation	Multi-orientation (horizontal/vertical mounting)
Serviceability	Ease/efficient servicing damaged/worn parts
Cycle Time	≤ 2 seconds per open-close cycle
Component	Material
Gripper Fingers	Aluminium (or PA66-GF30 for polymer option)
Gripper Body	Glass-filled nylon or die-cast aluminium
Fasteners/Pins	Stainless steel
Requirement	Specification
Target Manufacturing Methods	Injection moulding (polymer parts),
Part Count Reduction	Target: ≤ 6 parts (from original 10+)
Assembly Method	Snap-fits, self-aligning geometry, minimal fasteners
Surface Finish	Uniform matte finish

The design shows several key important requirements for scaling, however as described in QFD Figure 1, serviceability scored highly and should be considered in the re-design with the end user in mind.

3.2.4 Material selection

Choosing materials that balances strength, weight and cost is of importance. Also, the manufacturability of the material use should be considered. The current design can be broken down into three sections without including the gripper motor as this will remain the same. The body, the gripper arms and assembly fixings.

The body- Advantages of sheet metal such as stainless steel due to its high resistance to wear, corrosion and deformation. Disadvantages are the material is heavier than other which could limit the use in lightweight robotic systems. Alternatively Aluminium alloys can be used. Advantages include lightweight but robust, corrosion resistance and suitable for CNC machine which can ensure precision in complex designs. Disadvantages are longer production times

Gripper arms- Thermo plastics such as ABS and Nylon, as they are durable with a high resistance to wear, impact and fatigue. Ease of manufacture which can be shaped with precision using injection moulding. Lightweight, which will reduce the overall weight of the gripper which is critical for robotics for reducing inertia and improving speed.

Fixings- To reduce the cost of scaling. Reducing the amount and having standardised fixings outsourced and purchased from external suppliers will significantly outweigh the benefits and cost of producing inhouse.

3.2.5 Operational requirements.

Operational requirements such as gripping force and payload capacity are key design specification. The gripping force should be adequate for its intended operation. Enough to secure but not excessive as to cause damage. As the current design is established it can be assumed that the function is adequate. Production is being increased so the re design or replacement of the motor will not be considered in the re-design.

3.3 Manufacturing Process Proposal

During the manufacturing process proposal, it is important to understand the business/company needs and cost drivers. It is understood the customers primary objective is to scale the business to produce 1000 units per week. Using the QFD we can apply the results into the proposal. It is evident that overall cost and assembly efficiency are the heavily weighted and should be considered in the design. The reduction of unit cost and production efficiency will be key in the design.

3.3.1 Lean manufacturing

Lean is a systematic approach of eliminating waste so that each step of the process is value added. (Womack & Jones, 2010) Describes five principles of lean:

1. **Defining Value:**

Value is determined from the customer's perspective based on their willingness to pay for a product or service. Businesses should focus on eliminating waste and unnecessary costs to meet customer expectations while maximizing profits.

2. **Mapping the Value Stream:**

Analise all resources and processes involved in creating a product or delivering a service. Identify and eliminate activities that do not add value, ensuring each stage of the production cycle is efficient.

3. **Creating Flow:**

Ensure processes are seamless and free from delays or interruptions. Eliminating staggered production and inefficiencies will reduce waste and minimize costs, enabling a steady production stream.

4. **Using a Pull System:**

Avoid overproduction and excess inventory by adopting a just-in-time (JIT) approach. A pull system ensures products or services are developed based on actual customer demand, minimizing work in progress (WIP) and inventory waste.

5. **Pursuing Perfection:**

Embed continuous improvement and lean thinking into the organization's culture. Encourage employees to strive for excellence and foster a mindset of daily incremental progress toward perfection.

Lean methods can be incorporated into the design intent. For example, by having standardised fixings throughout the design, the assembly process will be more efficient as there will be no requirement to search for each individual fixing. Secondly, should the fixings be sourced from an

external supplier, The need for multiple suppliers due to the limited different components can be reduced.

3.3.2 Business and Company Needs

Given the shift from small batch to high-volume production (1000+ units per week), (Cabral, 2024) mentions the company's primary needs can include:

- Reduced unit cost through economies of scale
- Repeatable quality for every unit
- Faster production time and shorter lead times
- Reduced assembly complexity to lower labour costs
- Lower defect rates for long-term reliability and lower returns

These goals necessitate mass manufacturing methods with low per-part cost, high automation potential, and fast cycle times.

3.3.3 Cost Drivers

From a business perspective, several cost drivers influence the design and process selection. The most significant of these include tooling and setup costs, material costs, labour costs, and cycle times. While high initial tooling costs (particularly for injection moulding and die casting) are expected, these are economically justified when production volumes are scaled to mass production. Reducing assembly time and component count directly supports lean manufacturing objectives and further lowers production costs (Babad & Balachandran, 1993).

Cost drivers in this project include:

Table 3-Cost Driver Table (Purnell-Whitehead, 2025)

Cost Driver	Impact on Design
Tooling Costs	High initial cost for moulds/dies — justified only by large volumes
Material Costs	Must balance cost, strength, and machinability or mouldability
Labor Costs	Minimised via automated or semi-automated processes and design for assembly
Machine Time	Faster cycle time methods like injection moulding are favored for polymers
Assembly Time	Design must minimize fasteners and allow quick, tool-less assembly

3.3.4 Selected Manufacturing Processes

Injection Moulding (for plastic parts) (Singh & Verma, 2017)

- Use case: Gripper housing, finger bodies, covers
- Material: Glass-filled nylon

- Low per-unit cost at scale
- High precision and repeatability
- Fast cycle times (~30–60 seconds per part)
- Supports complex geometries and integrated features (snap fits, bosses)

Die Casting (for metal parts) (Wang, et al., 1995)

- Use case: Finger linkages, structural brackets (if metal required)
- Material: Aluminium alloy
- Ideal for medium-complexity metal components in large volumes
- High dimensional accuracy and excellent surface finish
- Can replace multiple machined parts with one die-cast component

Standard Purchase Parts

- Springs, fasteners, pneumatic fittings
- Cost-effective
- No manufacturing needed
- Ensures compliance with standard sizes and safety factors (Responsibility with suppliers)

3.3.5 Process Selection Justification

The mix of injection moulding and die casting is ideal for the gripper's new design, offering:

- Low cost per unit after initial expenditure on tooling
- Compatibility with automation for consistent throughput
- Reduced assembly labour, thanks to design for manufacturability and assembly (DfMA). For example, replacing three assembled metal parts with one moulded housing reduces cost, labour, and quality control steps — supporting lean manufacturing goals.

The proposed manufacturing approach ensures that the redesigned gripper can be produced reliably, efficiently, and economically at scale. It reflects a careful balance between technical requirements, production efficiency, and commercial viability to meet growing market demands with confidence.

3.4 Design and Development Work Undertaken

During the redesign, geometric simplifications were made to eliminate complex profile, facilitating easier moulding and die casting. Component thicknesses were optimised for material flow and cooling consistency, and features such as ribs and bosses were integrated to maintain strength without adding unnecessary weight or cost.

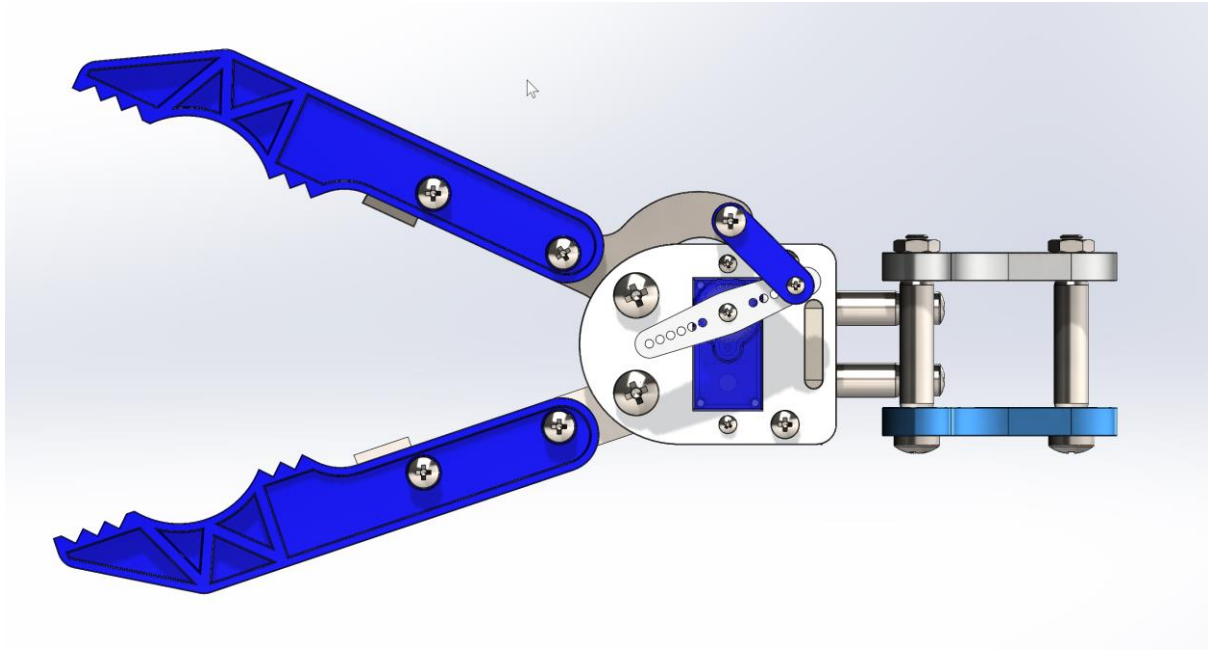
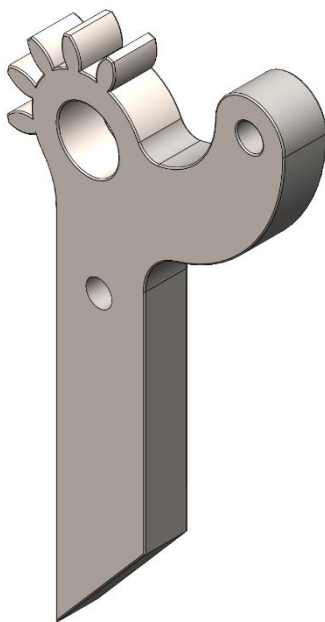
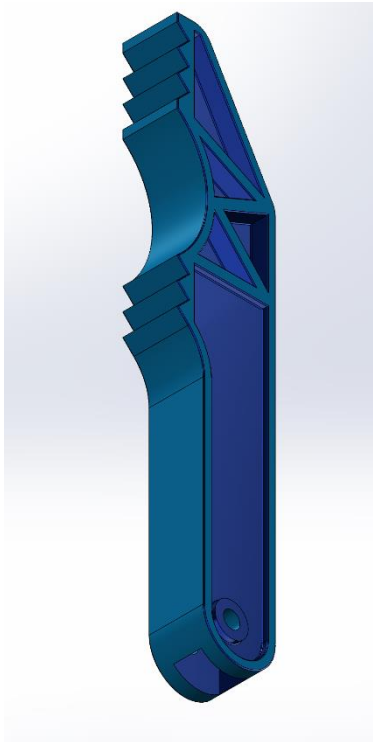


Figure 2-Original design of robot gripper (University, 2024)



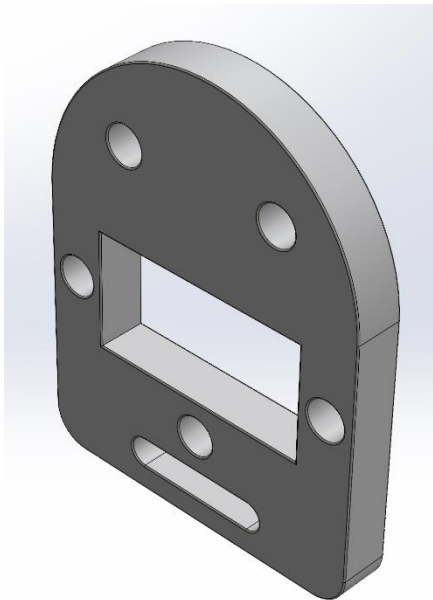
The Original design included two separate driven arms. The new design removes one arm and uses the same arm for both sides of the gripper to reduce the number of different parts used. The fixture holes have also been made uniform throughout the design to enable one type of fixture is used.

Figure 3-Redesign of gripper arm (Purnell-Whitehead, 2025)



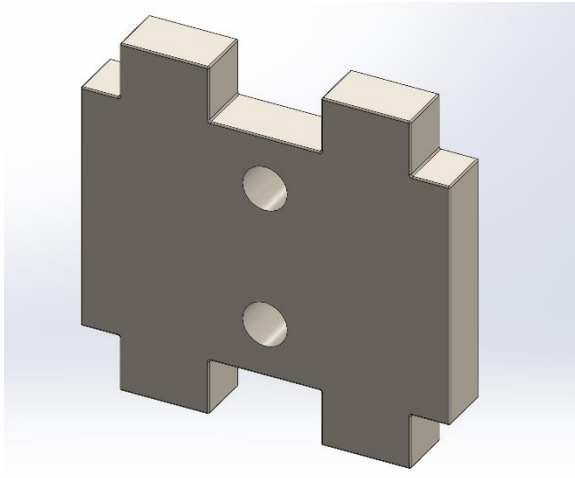
The gripper arm clamp cover has been redesigned closing the body of the cover. The component will now slide over the clamp arm and is held with only one fixing. This provides easy assembly and serviceability should the clamp cover wear. With this universal design, the clamp cover is easily interchangeable and allows for further re-design depend in on the end customers' requirements.

*Figure 4-Clamp cover re-design
(Purnell-Whitehead, 2025)*



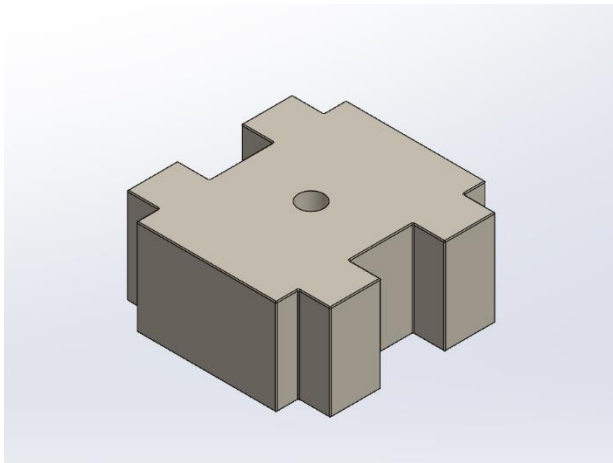
The motor housing now contains one less fixing and also original holes have been resized to same specifications.

*Figure 5-Re-designed motor housing
(Purnell-Whitehead, 2025)*



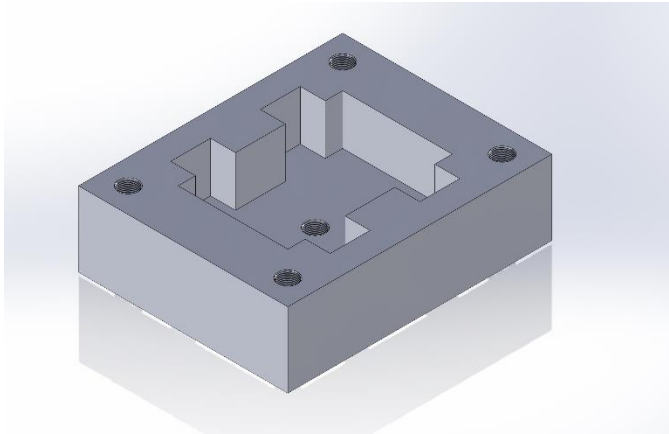
The original gripper bracket containing two fixing holes and smaller in thickness.

Figure 6-Original gripper bracket connection (University, 2024)



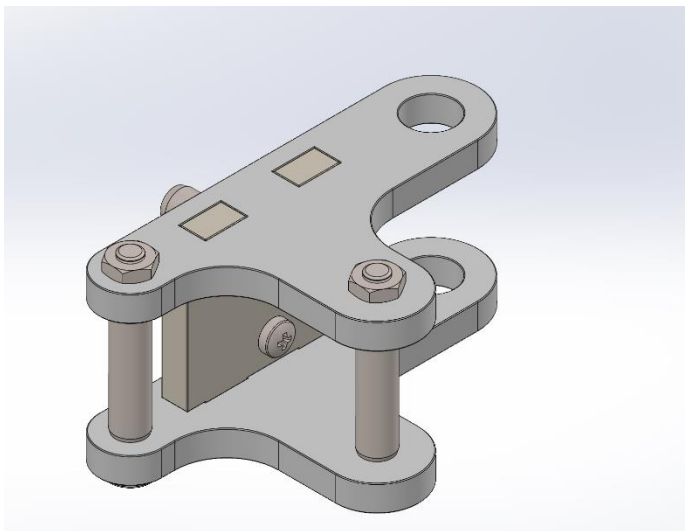
The redesign has one fixing hole. The thickness has been increasing to fit into the re-designed bracket in Figure 8.

Figure 7-Re-designed gripper bracket connection (Purnell-Whitehead, 2025)



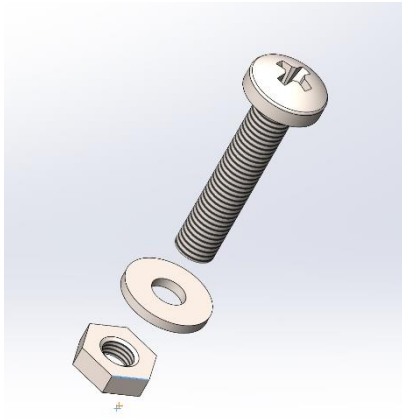
The bracket is now one piece removing the need for sub assembly. With one fixing to the gripper through the centre. A keyway recess has been designed to locate the bracket connector and to support torsional stress.

Figure 8-Re-designed bracket (Purnell-Whitehead, 2025)



Original design of mounting bracket containing several components.

Figure 9-Original mounting bracket (University, 2024)



The original Bolt, Nut and Washer have been used throughout. All fixings excluding the motor assembly now use the same.

Figure 10-Original Fixing design (University, 2024)

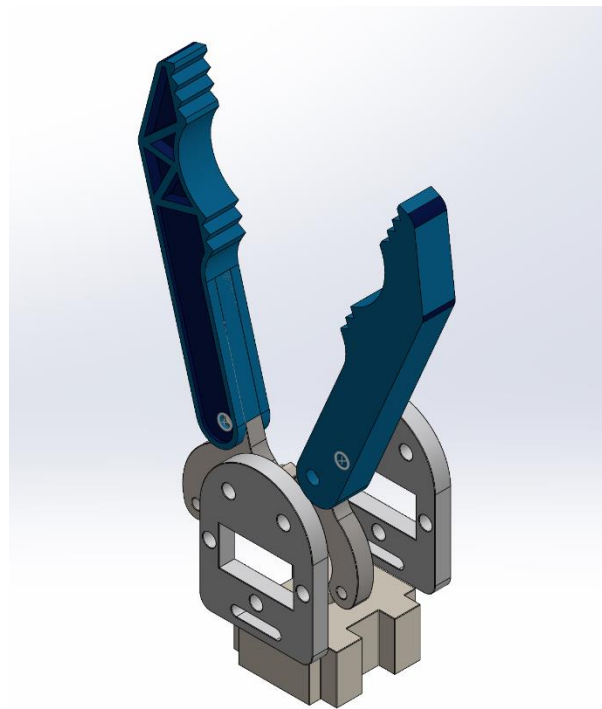


Figure 11-All redesigned components. (Purnell-Whitehead, 2025)

The final redesign shown in figure 11 includes all components with the common fixing holes. A significant removal of components has also been achieved which is seen a success when looking at the QFD and design specification shown in 3.3. Furthermore, scoring highly was the requirement for simple serviceability. This has been achieved with only one fixing required to interchange gripper clamp covers which would be most susceptible to wear as this is a direct contact area. For ease of manufacture the clamping cover shown on the right has had the complex profiling removed and has a flat finish.

3.4.1 DFMEA (Design Failure Mode and Effects Analysis)

Design engineers use DFMEA to identify and highlight any potential failure that could occur before they should occur. This tool is used as a preventative measure in the design process. A severity, Occurrence and detection score is added to calculate the RPN (Risk Priority Number) to help prioritise potential risks (6Sigma, 2024).

Once the failures have been identified, appropriate corrective actions are proposed, and a revised RPN score is assigned. A lower RPN demonstrates how improved controls, and enhanced detectability can significantly optimise a product during the design stage, before production begins. The DFMEA has highlighted the following reductions in RPN due to actions taken.

- Gripper cover breakage from 112 to 42
- Fixings unfastened from 90 to 30
- Gripper slippage from 48 to 16

Although a good tool in the design process, there are some disadvantages. The scoring given is subjective and is likely to differ between individuals setting the scores (Paul, et al., 2011)

Table 4-DFMEA - Robot gripper arm (Purnell-Whitehead, 2025)

FAILURE MODE AND EFFECTS ANALYSIS															
Item: <u>Robot gripper arm</u>			Responsibility: <u>Shea Purnell-Whitehead</u>			FMEA number: <u>1A</u>									
Model: _____			Prepared by: <u>Shea Purnell-Whitehead</u>			Page : <u>1</u>									
Core Team: <u>UWTSD</u>						FMEA Date (Orig): <u>02/02/2025</u> Rev: _____									
Process Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l a s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r	Current Process Controls	D e t e c	R P N	Recommended Action(s)	Responsibility and Target Completion Date	Action Results			
												Actions Taken	S e v	O c c	R P N
Pick up product	Gripper cover breakage	Gripper fails	7		Material Fatigue	4	Regular maintenance checks	4	112	Regular maintenance checks		High strength material used	7	2	42
	Fixing unfastened	Insecure mechanism	6		Incorrectly fastened	3	Follow torque procedure	5	90	Repair on failure		Reduced amount of fixings	6	1	30
	Gripper slippage	Dropped product	8		Inadequate clamping force	2	None	3	48	Add maintenance checks		Service Motor	8	2	16

The potential failure modes described in Table for have been address in the re-design by:

- Ensure adequate strength material is used and a reduction in components with the potential to fail.
- Limiting the amount of fixings used and outsourcing fixing supply.
- Interchangeable gripper cover design with efficient serviceability time.

3.4.2 Scamper

Every problem presents an opportunity for a solution, and there are many established techniques for problem-solving. One such method is the SCAMPER technique, which employs a series of targeted, thought-provoking questions to inspire modifications or enhancements to existing products or ideas. Widely recognized as an effective learning tool, SCAMPER encourages creativity by promoting awareness, motivation, adaptability, fluency, and originality. Its power lies in prompting individuals to consider questions they wouldn't typically ask (Serrat, 2017). The SCAMPER acronym represents the following types of changes in the re-design:

- **S – Substitute** (components, materials)
- **C – Combine** (Combined several components of the fixing bracket into one piece)
- **A – Adapt** (Altered the gripper cover to one fixing and standardised fixings)
- **M – Modify/Magnify** (Modified gripper arm)
- **P – Put to other uses**
- **E – Eliminate** (Excessive components and fixings)
- **R – Rearrange/Reverse**

3.4.3 Environmental and lifecycle

Environmental considerations have also been a key component in creating the design. The process Injection moulding and die casting has been chosen which because it allows the use of widely recyclable materials. Added the reduction of overall components and fixings lowers the amount of material required.

As previously mentioned, the lifecycle of the product has been further improved with use of serviceable components in high wear areas of the gripper.

3.5 Conclusion

This report has presented the redesign of a mechanical gripper to meet the demands of mass production, targeting over 1,000 units per week. Using Design for X methodologies such as QFD, DFMEA, and SCAMPER, the design was optimised for manufacturability, cost-efficiency, and ease of assembly.

Key improvements include reduced part count, standardised fixings, and modular components to enhance serviceability.

Total part count removed as follows:

- 5x bracket components removed, now in two pieces
- 4x fixings
- 4x Washers
- 4x Sleeve
- 4x Nuts

Manufacturing processes like injection moulding and die casting were selected to support scalability while maintaining product quality. Environmental and lifecycle considerations were also addressed through material choices and the design of serviceable high-wear parts.

The final design aligns with both technical requirements and business goals, offering a scalable, efficient solution ready for high-volume production.

4 Task 2- Design for Additive Manufacturing

4.1 Introduction

The manufacturing landscape has evolved significantly with the adoption of Additive Manufacturing (AM) technologies. Traditional design practices, tailored to the limitations of subtractive or formative manufacturing, often result in overengineered and heavy components. Design for Additive Manufacturing (DfAM) leverages AM's design freedom to create optimised, lighter, and more functional parts.

This report focuses on redesigning an automotive suspension control arm currently used as part of the rear suspension of Aston Martins SUV, the DBX. A critical structural component. The control arm connects the vehicle chassis to the wheel hub which endures dynamic forces during braking, cornering, and driving over uneven terrain. Traditional control arms are often made through forging or casting, leading to excess material and weight to account for worst-case loading.

Through topology optimisation, internal lattice structures, and AM-specific design strategies, a redesigned control arm was developed, targeting significant weight savings while maintaining mechanical integrity. Selective Laser Melting (SLM) and titanium alloy were chosen for manufacturing due to their superior mechanical properties and suitability for complex geometries.

4.2 Existing component analysis.

Aston Martins current design is market leading and has been optimised for its intended function. With the vehicle being capable of producing 707PS and 900NM of torque with a kerb weight of 2245KG. The importance in the design of the suspension components is crucial to able to withstand the forces generated.

Below in Figure 12 shows a Range Rover Evoque rear suspension setup with the lower control arms being a two-wishbone setup with a solid body made from steel.

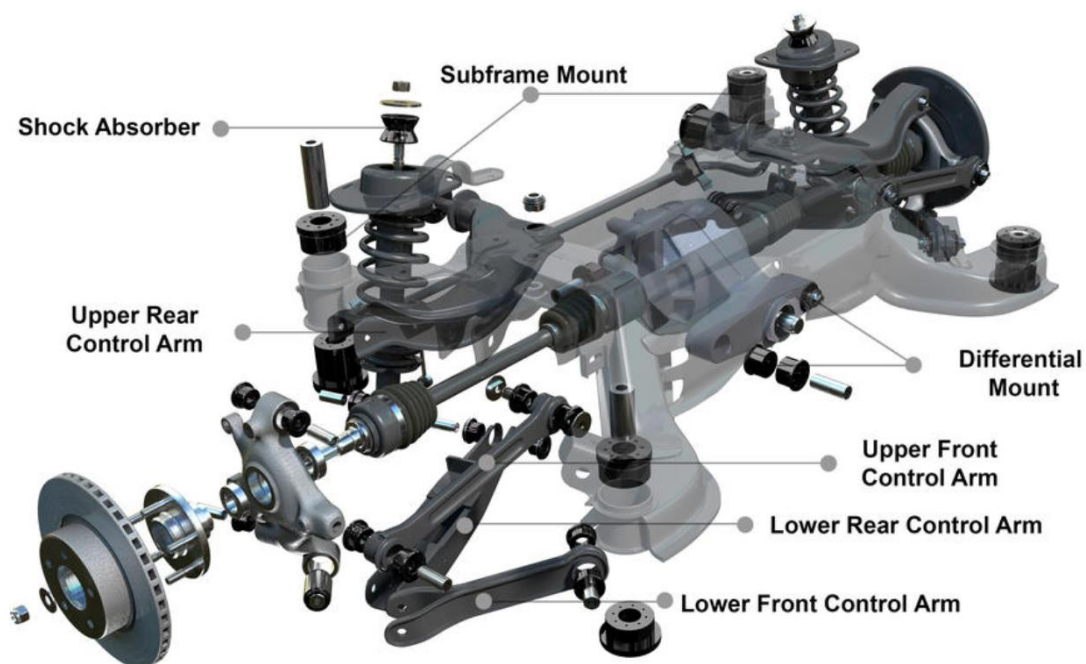


Figure 12-Range Rover Evoque rear suspension layout (suspensions, 2025)

4.2.1 Current Design

The current design (figure 13) comprises of a double wishbone system with hollow or webbed sections to reduce mass designed for safety and dynamic loading. Extruded and hollow from cast aluminium (figure 14) (Aston Martin, 2025).

In comparison to other manufacturers control arm, Aston Martin have redesigned theirs to incorporate a considerable amount of weigh saving with the hollowed/webbed features and using cast aluminium all while maintaining market leading functionality.

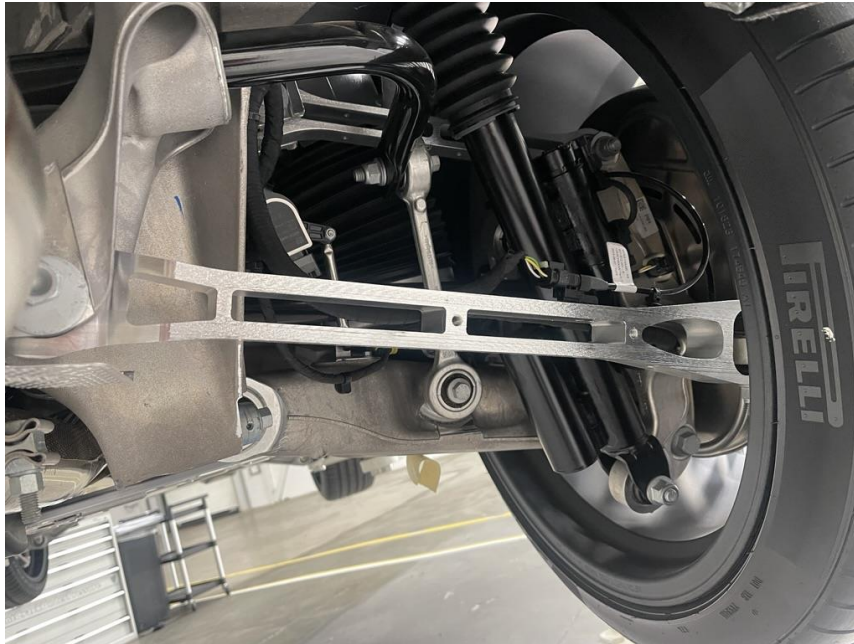


Figure 13-Image of Aston Martin DBX rear control arm (Purnell-Whitehead, 2025)

SUSPENSION
Cast aluminium suspension and subframe technology
Front: Independent forged / hollow cast double wishbone split link with hydrobushing and integrated hub bearings
Rear: Extruded and hollow form cast multi-link
Subframes: Hollow cast aluminium subframes (two-piece front, single-piece rear) with integrated driveline cooling aero ducting
Adaptive triple chamber air suspension with quad spring rates
Variable ride height (raised by up to 45mm or lowered by 50mm) with auto speed lowering and access mode
Variable rate 'Damptronic® Sky' adaptive damping with independent adjustment capability for compression and rebound
1,400Nm 48v electronic active anti-roll control system (48-volt eARC) with active 48v regenerative charging and drive mode controlled off-road "zero load" cross linking.

Figure 14-DBX Suspension specification (Aston Martin, 2025)

4.2.2 Project scope

Using the current design, the project aims to use DfAM to see if what improvements if any can be made to the suspension control arm. Testing possible alternative methods and materials and the limits in which they can achieve.

4.3 DfAM Principles and Redesign Approach

4.3.1 Topology optimisation

Topology optimisation was the starting point of the redesign process. Using Fusion 360's generative design module, the initial geometry of the conventional control arm was subjected to realistic loading conditions based on typical operating forces experienced during braking, cornering, and road vibration. The optimisation was configured to minimise mass while ensuring a minimum factor of safety of boundary conditions (red in figure 15) included fixed constraints at the chassis mounting points and an applied downward and lateral loads at the ball joint (Arrow figure 15) representing forces.

The resulting geometry demonstrated a significantly organic shape, with material retained only along the principal stress paths.

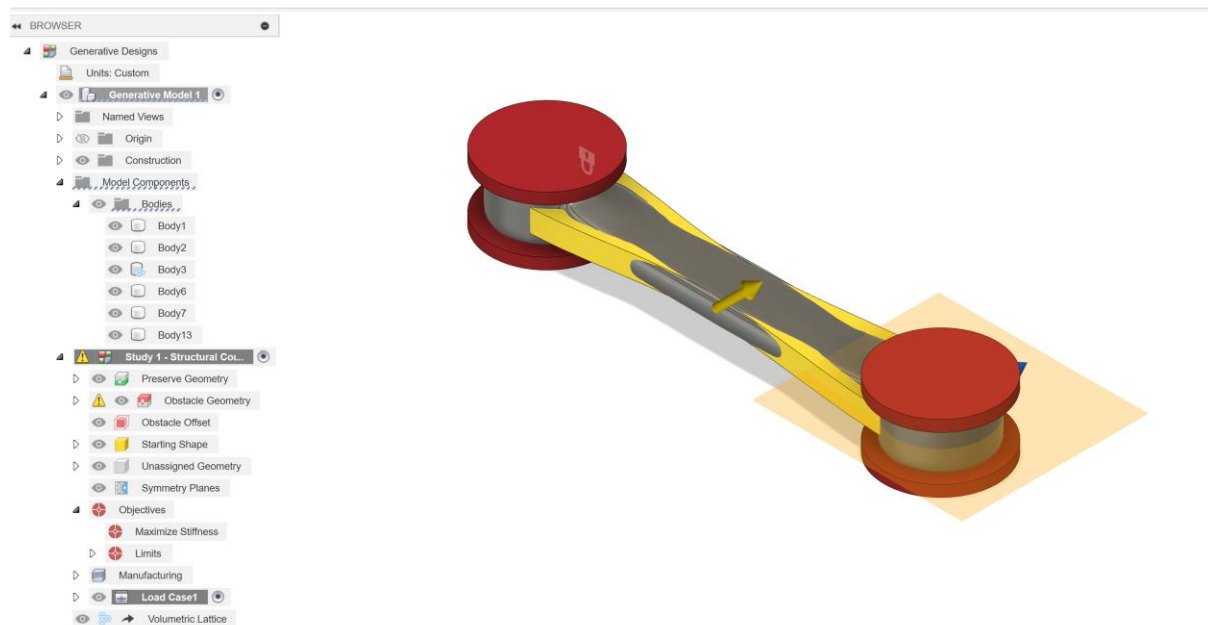


Figure 15-Fusion 360 Control Arm Design (Purnell-Whitehead, 2025)

4.3.2 Generative Design.

3.1 Generative Design

A core feature of the redesign process was the use of generative design tools in Autodesk Fusion 360. Unlike traditional CAD-driven modelling, generative design uses AI algorithms to produce multiple viable geometry options based on defined constraints and performance objectives. It iteratively evaluates thousands of design permutations, helping engineers find innovative solutions that would be difficult or time-consuming to conceptualise manually.

For the control arm, key parameters were defined, including (figure 16):

- Preserved regions: mounting holes and contact surfaces that must remain untouched.
- Obstacle regions (Red): areas where material should not exist (e.g. clearance for wheel or brake components).
- Loading conditions: Gravity (Yellow arrow) and forces of approximately 30000N applied at the ball joint to simulate aggressive cornering and braking, with mounting points constrained (Blue arrow).
- Objectives: minimum factor of safety (FOS) of 2.0 and minimised mass.
- Manufacturing method: set to Additive - Metal, enabling the algorithm to suggest Optimised geometries.

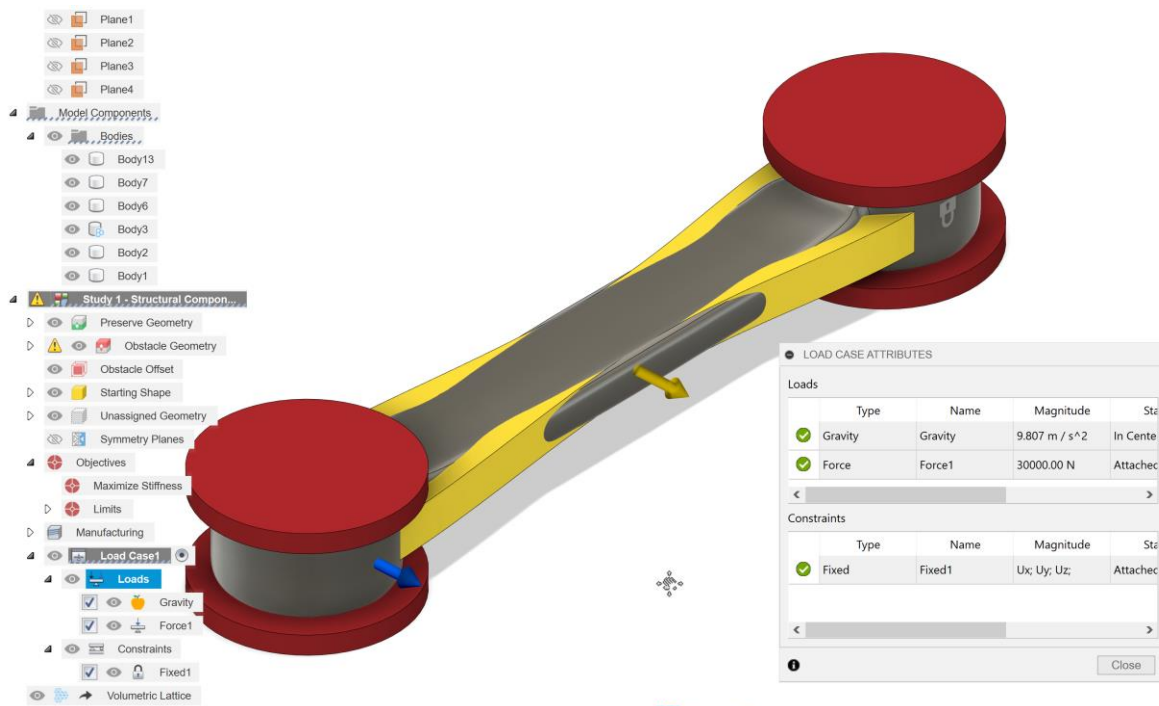


Figure 16-Applied forces and boundary conditions of the design (Purnell-Whitehead, 2025).

The generative design module returned several solutions with high-performance organic geometries. The chosen candidate featured skeletal structures with smooth load paths and internal cavities, indicating efficient material usage. This model was then refined and adapted manually to improve printability, integrate internal lattice structures, and align with manufacturability constraints of the selected AM process.

Generative design proved essential in delivering a part that was lighter, stiffer, and better aligned with AM capabilities than would be feasible through traditional CAD modelling or even basic topology optimisation alone (Tkachenko & Wang, 2024)

4.3.3 Internal lattice structure

To further reduce the component's mass without compromising stiffness, internal lattice structures were introduced into the lower stress regions of the control arm, particularly in the main body away from mounting zones. A gyroid lattice was selected due to its favourable mechanical properties and isotropic nature, which provides uniform stiffness in multiple directions (Figure 16).

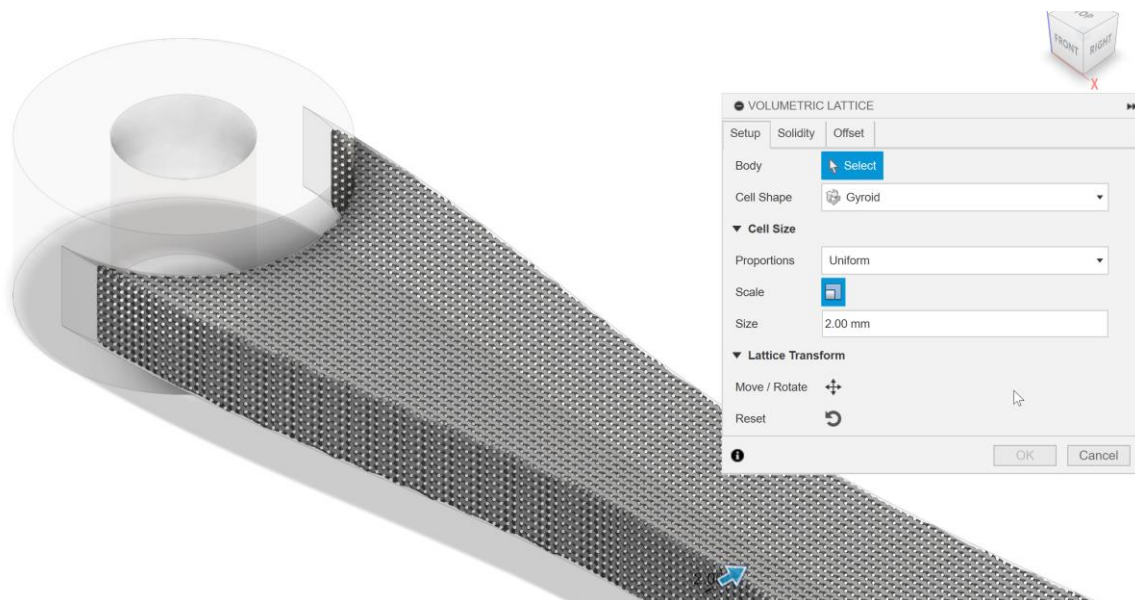


Figure 17-Volumetric lattice structure (Purnell-Whitehead, 2025)

While increased lattice use reduces support structure needs, it also raises design complexity and processing demands. Finite Element analysis under varied loading conditions shows that TO 4.3.1 based lattice strategies offer 40–50% higher specific stiffness compared to non TO designs. Among all, the Graded strategy emerged as the most effective, balancing mechanical performance with manufacturability (Panesar, et al., 2018).

4.4 Quality Function Deployment (QFD)

Table 5-QFD for Control Arm (Purnell-Whitehead, 2025)

				Column #	1	2	3	4	5	6	7
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▼	▲	▲	X	▲	▲
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Type of material	amount of material	Performance	Servicability	Size	Repeatable Assembly	
1	9	20.9	9.0	Cost of Production	⊖	⊖	⊖	⊖	⊖	▲	
2	9	18.6	8.0	Production time	⊖	⊖	⊖	▲	⊖	▲	
3	9	18.6	8.0	Maintain Quality of Current Product	⊖	⊖	⊖	▲		▲	
4	9	18.6	8.0	Durability	⊖	⊖	⊖	⊖	▲		
5	9	11.6	5.0	Light Weight Design	⊖	⊖	⊖		⊖		
6	9	11.6	5.0	Strength	⊖	⊖	⊖	▲	⊖	▲	
7											
8											
9											
10											
Target or Limit Value											
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)					4	4	5	3	5	5	3
Max Relationship Value in Column					9	9	9	3	9	1	
Weight / Importance					900.0	607.0	788.4	167.4	583.7	69.8	
Relative Weight					28.9	19.5	25.3	5.4	18.7	2.2	

The QFD in Table 5 has been used for the re-design. The component needs to be of a lightweight design and be able to withstand extreme condition while being cost effective. The QFD score reinforces this statement as the highest scoring two characteristics are type of material and performance.

The use of the QFD methodology helped prioritise technical decisions during the redesign phase. For example, the reduction of mass was strongly linked to customer performance expectations (e.g. handling). This drove the use of internal lattice structures and material minimisation strategies.

QFD ensured that customer-focused goals were maintained throughout the design process and informed key engineering decisions, resulting in a component that not only performs well but also aligns with Aston Martin's premium brand values.

4.5 AM Process and Material Selection

4.5.1 Process selection

Additive manufacturing (AM) technologies are increasingly being utilised in the automotive sector for both component production and process optimisation. These techniques enable innovative material use and design flexibility, supporting everything from prototyping to full-scale production. Aluminium alloys and polymers are shaped using Selective Laser Sintering (SLS), Selective Laser Melting (SLM), and inkjet printing to produce parts like suspension (Sarvankar & Yewale, 2019).

Manufacturing Processes:

Hot-work steels and polymers are used with SLS, SLM, and Fused Deposition Modelling (FDM) to create prototypes, casting aids, and customised tools.

Process Selection: Selective Laser Melting (SLM)

- High precision and excellent surface finish.
- Capability to build complex internal geometries (lattices, hollows).
- High mechanical strength.

4.5.2 Material selection

Titanium and its alloys are increasingly used in motorcycles and automobiles to reduce component weight. Applications include exhaust systems, engine valves, connecting rods, and fuel tanks, especially in high-performance or large motorcycles. Alloys like Ti-6Al-4V and Ti-Al-Fe are common, while commercially pure titanium is favoured for parts requiring high formability (Takahashi, et al., 2020).

Although Ti-6Al-4V components produced via Selective Laser Melting (SLM) have the potential to match the fatigue properties of wrought material, this was not achieved in (Edwards & Ramulu, 2014) study due to issues like high residual stresses, surface roughness, microstructure, and porosity. Improving these properties through process optimization, post-processing (e.g. machining, stress relief), and techniques like Hot Isostatic pressing or peening could enhance fatigue performance. However, such steps may increase costs, emissions, and production time, potentially reducing the competitiveness of additive manufacturing compared to conventional methods.

4.6 Finite Element Analysis (FEA)

Using the dimensions of the current design, with boundary conditions applied to simulate the current webbed design. Figure 18 shows an example of generated stresses applied. Even with the high strength Inconel alloy (metals, 2025) the high stress areas at the midpoint of the control arm are at the highest stress range and would exceed the yield point with the potentially dangerous outcomes in automotive use. and would not be suitable for the redesign.

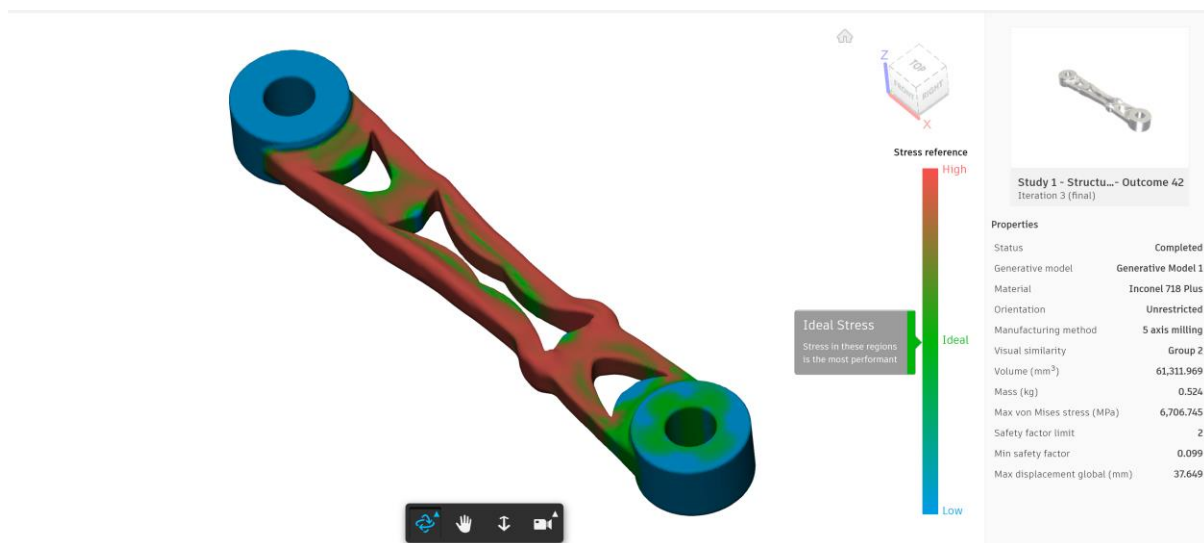


Figure 18-Stress study of design (Purnell-Whitehead, 2025)

Using FEA is a useful tool in DfAM. With the FEA able to produce 3D prototypes. The model is easily adapted from forces applied to materials used allowing extensive testing and optimisation before any prototype is needed to be produced. This has cost reduction benefits due to time saved in testing, scrap cost and production costs.

4.7 Cost and Environmental Implications

4.7.1 Cost Implications

Additive Manufacturing (AM), particularly Selective Laser Melting (SLM), has higher upfront costs than traditional manufacturing methods. Metal powders such as Ti6Al4V are significantly more expensive, and the process itself involves slower build times and intensive post-processing (e.g. support removal, heat treatment, machining).

However, for Aston Martin, a low-volume, high-performance car manufacturer, these costs are justifiable. The ability to consolidate multiple parts, eliminate tooling, and produce lightweight, optimised geometries aligns well with the company's bespoke production model. AM also allows rapid iteration and customisation without incurring the delays and expenses associated with traditional retooling.

Other low volume performance automotive manufacturers Such as Ferrari, Bentley and McLaren are beginning to use AM in their vehicles.



Figure 19-Ferrari F80 AM design control arm. (AM, 2025)

Bugatti have also used AM to produce a brake calliper (Figure20) made from Ti6Al4V alloy that weighs 2.9KG in comparison to the current aluminium calliper which weighs 4.9KG. A significant reduction in weight saving which all manufacturers strive for (Sher, 2021).



Figure 20-Bugatti Am brake calliper design (Sher, 2021)

Although unit cost is higher, the long-term benefits including reduced assembly time, weight savings, and design flexibility can result in overall cost efficiencies for limited production runs or high-performance models.

4.7.2 Environmental Implications

Additive Manufacturing (AM) creates complex components layer by layer with high precision and significantly less material waste compared to conventional methods. It offers clear environmental advantages, such as reduced raw material use, lower energy consumption, and fewer emissions. As sustainability becomes a growing priority for industries, AM is increasingly viewed as a tool for achieving environmental goals. Industry leaders are promoting waste reduction, improved manufacturing environments, and the use of innovative materials (Mohd, et al., 2021).

4.8 Conclusion

The redesign of the Aston Martin DBX suspension control arm using Design for Additive Manufacturing (DfAM) principles demonstrates the transformative potential of additive manufacturing in the automotive sector. Through the integration of topology optimisation, generative design, and internal lattice structures, a lightweight yet structurally sound component was developed. Selective Laser Melting (SLM) and Ti-6Al-4V alloy were selected to support the creation of complex geometries with high mechanical performance. While challenges such as cost, residual stresses, and post-processing remain, the benefits in weight reduction, design flexibility, and environmental impact make AM an increasingly viable alternative, especially for low-volume, high-performance applications. As the industry continues to evolve, technologies like AM will play a vital role in pushing the boundaries of innovation, efficiency, and sustainability in automotive design and manufacturing.

5 References

6Sigma, 2024. *6sigma*. [Online]

Available at: <https://www.6sigma.us/six-sigma-articles/risk-priority-number-rpn/>

[Accessed 12 03 2025].

Akao, Y., 2004. *Quality Function Deployment-Intergrating Customer Requirements into Product Design*. New York: Productivity Press.

AM, M., 2025. *Ferrari's new F80 supercar features structural Additive Manufacturing for first time*. s.l.:Metal AM.

Aston Martin, 2025. *Aston Martin*. [Online]

Available at: <https://www.astonmartin.com/en-gb/models/dbx707>

[Accessed 05 05 2025].

Babad, Y. M. & Balachandran, B. V., 1993. Cost Driver Optimization in Activity-Based Costing. *The accounting review*, 68(3), pp. 563-575.

Boothroyd, G., Dewhurst, P. & Knight, W. A., 2010. *Product Design for Manufacture and Assembly*. W.A: CRC Press.

Cabral, H., 2024. Scale-Up and Automation: Transforming Industry Through Efficiency and Innovation. *Perspective - Pharmaceutical Bioprocessing*, 12(6), pp. 242-243.

Edwards, P. & Ramulu, M., 2014. Fatigue performance evaluation of selective laser melted Ti–6Al–4V. *Materials Science & Engineering A*, Volume 598, pp. 327-337.

Kogure, M., Akao & Yoji, 1983. Quality Function Deployment and CWQC in Japan. *Quality Progress*, October, pp. 25-29.

metals, S., 2025. *Special Metals*. [Online]

Available at: <https://www.specialmetals.com/documents/technical-bulletins/inconel/inconel-alloy-718.pdf>

[Accessed 06 05 2025].

Mohd, J. et al., 2021. Role of additive manufacturing applications towards environmental. *Advanced Industrial and Engineering Polymer Research*, 4(4), pp. 312-322.

Panesar, A., Abdi, M., Hickman, D. & Ashcroft, I., 2018. Strategies for functionally graded lattice structures derived using topology optimisation for Additive Manufacturing. *Additive Manufacturing*, Volume 19, pp. 81-94.

Paul, G. M., Cheung, W. M., Tang, X. & Dai, W., 2011. Decision-making in product quality based on failure knowledge. *International Journal of Product Lifecycle Management*, 5(2), pp. 143-163.

Purnell-Whitehead, 2025. *FMEA*. Barry: s.n.

Purnell-Whitehead, 2025. *Solidworks design*. Barry: s.n.

Purnell-Whitehead, S., 2025. *Cost Driver Table*. Barry: s.n.

Purnell-Whitehead, S., 2025. *Customer needs table*. Barry: s.n.

Purnell-Whitehead, S., 2025. *Fusion 360 Control Arm Design*. Barry: s.n.

Purnell-Whitehead, S., 2025. *image of Aston Martin DBX rear control arm*. Barry: s.n.

Purnell-Whitehead, S., 2025. *Re-design QFD*. Barry: s.n.

Sarvankar, S. G. & Yewale, S. N., 2019. Additive Manufacturing in Automobile Industry. *International Journal of Research in Aeronautical and Mechanical Engineering*, 7(4), pp. 1-10.

Serrat, O., 2017. The Scamper technique. In: *Knowledge solutions*. Singapore: Springer, pp. 311-314.

Sher, D., 2021. *VoxelMatters - The heart of additive manufacturing*. [Online]
Available at: <https://www.voxelmatters.com/watch-a-3d-printed-brake-caliper-being-put-to-the-test/>
[Accessed 06 05 2025].

Singh, G. & Verma, A., 2017. A Brief Review on injection moulding manufacturing process. *5th International Conference of Materials Processing and Characterization (ICMPC 2016)*, 4(2), pp. 1423-1433.

suspensions, s. p., 2025. *super pro suspensions*. [Online]
Available at: <https://superpro-suspension.com/eu/search/product/universal-parts/sway-bar-links/sway-bar-links-for-land-rover-range-rover-evoque>
[Accessed 22 04 2025].

Tai, K. et al., 2016. State of the Art Robotic Grippers. *Robotics*, 5(2).

Takahashi, K. a., Mori, K. a. & Takebe, H., 2020. *Application of Titanium and its Alloys for Automobile Parts*. Chiba, MATEC.

Thramboulidis, W., 2010. *From requirements to design specification. A formal approach*. *International design conference*. Dubrovnik, s.n.

Tkachenko, A. & Wang, C. J., 2024. *Analysis of engineering structures and components created using the generative design*. Brighton, IOP Publishing.

University, o., 2024. *Gripper design in brief*. Swansea: Uiniversity of Wales Trinity St David.

Wang, L., Makhlof, M. & Apelian, D., 1995. Aluminium die casting alloys: alloy composition, microstructure, and properties-performance relationships. *International materials review*, 40(6), pp. 221-238.

Womack, J. P. & Jones, D. T., 2010. *Banish Waste And Create Wealth In Your Corporation*. Second Edition ed. New York: Free Press, Simon and Shcauster.