

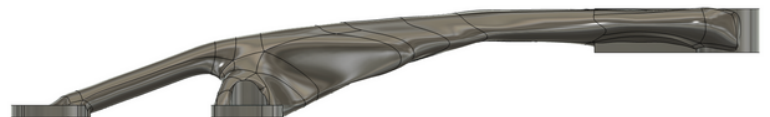
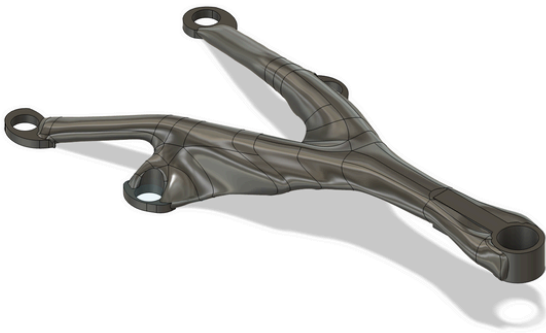
# Right Crank Arm

## Pro Aluminium (Gravel Bike)



### Rated At 100g

- Stress SF: 1.84
- Max displacement: 0.061mm
- Yield SF: 1.85
- Buckling sf: 13.2



159g



£110



68kgCO<sub>2</sub> e

### Made With

- 5-axis milled Aluminium 6061 for lightweight strength and durability
- 75% recycled Aluminium stock to reduce environmental impact
- Matte silver anodised finish for enhanced corrosion resistance and aesthetic appeal

### For testing:

- 3D printed on the Ultimaker S5, utilising advanced dual-extrusion FDM technology
- High-strength, lightweight HDPE material for exceptional durability and performance

# Technical cost analysis and Prediction

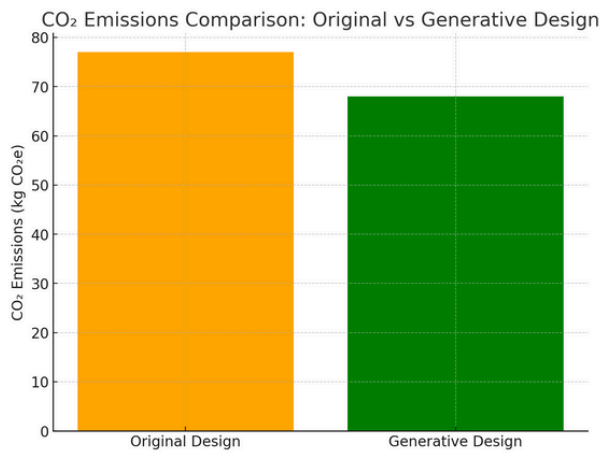
## CNC Manufacturing

Year	Number of Units	Target Cost Per Unit	Cost Reduction (%)	Lead Time
2025	1	1521	0	6
2026	100	124	92	12
2027	1000	97	94	21
2028	10000	28	98	30
2029	100000	11	99	45

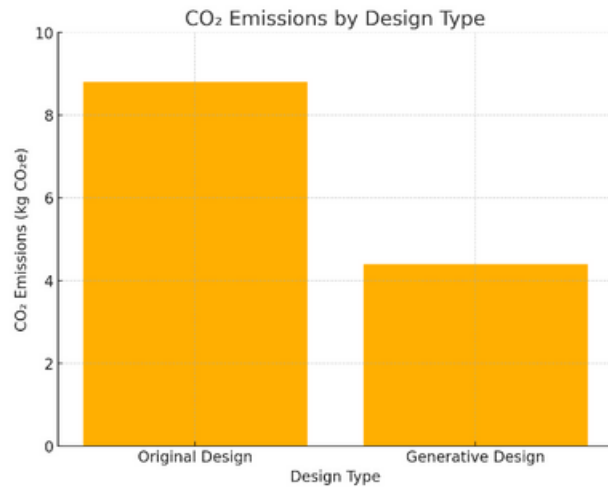
## FDM Manufacturing

Year	Number of Units	Target Cost Per Unit	Lead Time
2025	1	58	2
2026	100	46	4
2027	1000	39	5
2028	10000	34	7
2029	100000	30	10

## CNC Embodied Carbon

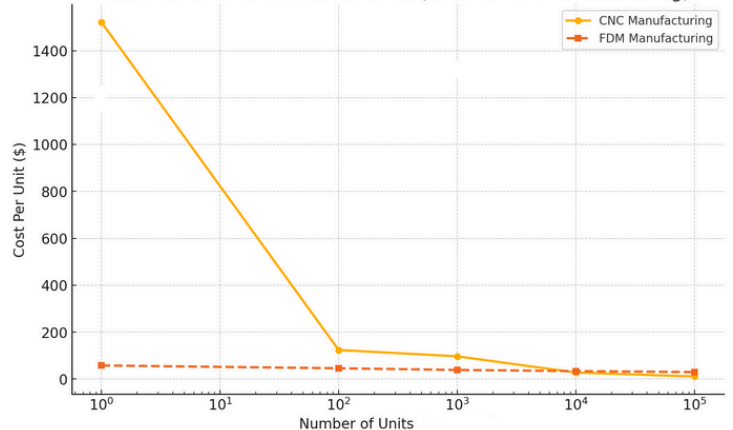


## FDM Embodied Carbon



- Increased production volume reduces cost per unit due to:
  - Efficient use of materials.
  - Additional operational savings.
- New product designs are increasingly cost-efficient, featuring:
  - Reduced material usage.
  - Lower CO<sub>2</sub> emissions during production.

## Cost Per Unit vs Number of Units (CNC vs FDM Manufacturing)



### Trade-Offs:

- CNC machining offers better precision for complex parts but at the cost of high waste and emissions.
- Additive manufacturing excels in sustainability and cost for small-scale, generative designs but may face limitations for large-scale or heavy-duty parts.

# In depth analysis of the manufacturing cost (CNC)

## Machine Haas UMC-750, a 5-axis CNC vertical machining centre.

- Stock volume is 94% a waste material, which is £77, material can be reused to manufacture more products.
- Machining hourly rates (£147/hour)
- Net cost (Machining Cost + Aluminium cost - Waste cost)
- Environmental impact: 8.24 kg CO<sub>2</sub>e per kg of Aluminium used. (Exponential Impact)

Units	Waste Cost (£)	CO <sub>2</sub> Saved (kg CO <sub>2</sub> e)	Net Cost (£)
1	77	21	110
100	7721	2121	10965
1000	77209	21207	109646
10000	772093	212068	1096460
100000	7720928	2120682	10964605

# In depth analysis of the manufacturing cost (FDM)

## Ultimaker S5

- Material Cost:
  - £7 per kg for filament.
  - For 1 part (~0.159 kg), the material cost is £1.11 per unit.
- Manufacturing Time Cost:
  - 4 hours, 7 minutes, 47 seconds (~4.13 hours) per part.
  - At £15/hour, the time cost is £61.95 per unit.
- Total expected Cost per Unit:
  - Material Cost + Time Cost = £63.06 per unit.

## Technical Specification Full mass

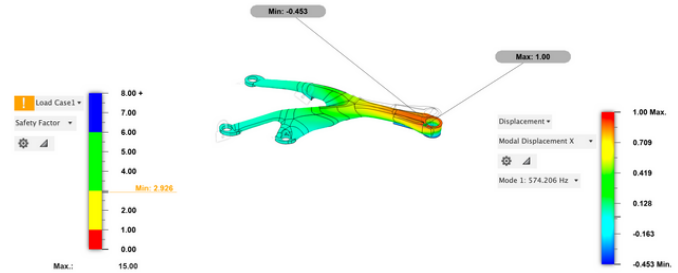
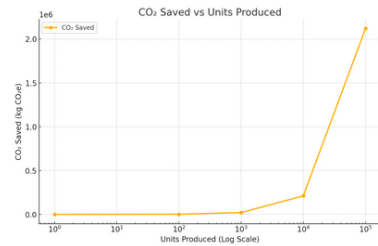
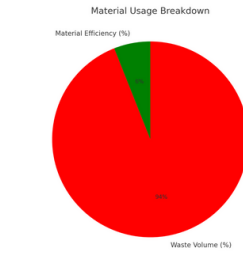
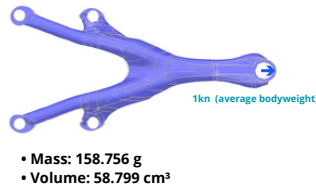
**Buckling Safety Factor:** 20.98

**Stress SF:** 2.87

**Max displacement:** 0.09516mm

**Yield SF:** 2.88

**Modal Analysis, Mode 1:** 574Hz



## Production Insights

### Design Features:

- Lightweight Generative Geometry:
  - Designed using generative algorithms to minimise material usage while maintaining structural strength.
  - Organic, flowing geometry optimises stress distribution.
- Achieves medium tolerances (DN-ISO 2768) for precision fits, since ultra precision is not needed for the product.
- Customisable Attachment Points:
  - Configured for seamless integration with standard bike frames and pedals.

### Sustainability Features:

- Material Efficiency:
  - Generative design reduces material waste by up to 50% compared to traditional designs
  - Additive manufacturing further minimises waste to near-zero
- CO<sub>2</sub> Emissions:
  - Subtractive Manufacturing: Reduced to 68 kg CO<sub>2</sub>e (Generative Design) from 77 kg CO<sub>2</sub>e (Original Design)
  - Additive Manufacturing: Significantly lower at 4.4 kg CO<sub>2</sub>e
- Recyclable Materials:
  - Use of Aluminium 6061, which is highly recyclable and has a low environmental impact when reused

### Manufacturing Features:

- Subtractive Manufacturing (CNC):
  - Machine: Haas UMC-750 (5-axis CNC machining center).
  - Cycle Time: 45 minutes per part)
  - Material: Aluminium 6061 for durability and weight optimisation.
- Additive Manufacturing (FDM):
  - Printer: Ultimaker S5 (dual extrusion FDM 3D printer)
  - Cycle Time: ~4 hours 7 minutes per part
  - Material: High-strength polymer filaments for prototypes or lightweight components.
- UK-Based Manufacturing

### Designer Intent Notes:

- Prioritised for Lightweight Performance:
- Designed for competitive cycling applications where weight reduction and durability are critical.
- Generative design enhances visual appeal while optimising structural performance.
- Targets premium cycling markets with an emphasis on customisability and performance gains.



## Bike Crank

An aluminium bike crank for a racing bike

### Company details:

The Generative Design Bike Crank, designed by Naghim Ibragimov, is priced at £110 per unit and weighs 159 g. It is engineered to support a maximum load of 100 kg with specific yield and buckling safety factors. Constructed from Aluminium 6061, the design uses advanced generative algorithms to optimise material usage, ensuring lightweight performance while maintaining durability.

Manufactured through CNC machining and additive manufacturing (FDM), the crank reduces CO<sub>2</sub> emissions by up to 12%, with emissions as low as 68 kg CO<sub>2</sub>e (CNC) or 4.4 kg CO<sub>2</sub>e (FDM).

### Raw Materials

#### Materials/ingredients origin (sourcing information)

Generated Product places a strong emphasis on sourcing materials responsibly, prioritising the use of recycled aluminium to demonstrate their unwavering commitment to resource efficiency. By leveraging new technologies such as topology optimisation and lattice structures in their additive manufacturing processes, the company achieves significant material reduction while preserving, and often enhancing, functionality and quality. This innovative approach ensures that each design is optimised for performance while minimising waste. Furthermore, this efficiency-driven ethos permeates every stage of their production lifecycle, from material acquisition to product end-of-life, reinforcing their role as a leader in sustainable manufacturing.

### Manufacturing

#### Details on manufacturing process

The manufacturing process is centred around advanced additive manufacturing techniques, designed to enhance mechanical properties through the strategic use of composite materials and reinforced structures. By combining precision engineering with innovative material science, these methods ensure that printed parts consistently meet or exceed stringent reliability and performance standards for demanding world wide applications. Simultaneously, the production remains steadfast in its commitment to sustainability, integrating eco-friendly practices at every stage of production, from material selection to energy-efficient manufacturing processes. This holistic approach underscores their dedication to creating durable, high-performance products with minimal environmental impact.

### Manufacturing

#### Applicable fair labor certifications

Within the project it's our priority to be committed to upholding fair labour standards, demonstrated through partnerships with certified organisations that prioritise ethical practices in manufacturing. By adhering to internationally recognised certifications the company ensures responsible sourcing and promotes transparency and accountability throughout its supply chain. This commitment extends to safeguarding workers' rights at all levels of production, fostering safe and equitable working conditions, fair wages, and opportunities for professional growth. Through these efforts, production team is not only advances ethical manufacturing practices but also supports the well-being of communities involved in their operations.

### Manufacturing

#### Environmental impact statement

To minimise carbon emissions, the production places a strong emphasis on incorporating recycled aluminium into their designs, significantly reducing waste during production. This practice is part of their broader goal to establish a closed-loop recycling system, further limiting their environmental impact by reusing materials at the end of a product's lifecycle. Additionally, the company leverages advanced production techniques such as additive manufacturing and process optimisation to enhance efficiency and reduce energy consumption. By meticulously tracking carbon footprint data and implementing targeted strategies for emission reduction, we set a benchmark for accountability and sustainability in manufacturing. These efforts demonstrate their dedication to creating eco-conscious products while actively addressing the challenges of climate change.

## **Manufacturing**

### **Carbon footprint disclosure and verification**

Providing proper care instructions for garments is essential to ensuring product longevity and maintaining quality over time. We emphasise eco-friendly care recommendations, such as washing in cold water to conserve energy and line drying to reduce reliance on energy-intensive dryers. Additionally, the use of gentle, biodegradable detergents is encouraged to minimise chemical footprints and reduce water pollution. By promoting these best practices, the company not only helps consumers extend the lifespan of their clothing items but also fosters greater awareness of sustainable living. These guidelines align with their commitment to reducing environmental impact across every stage of a product's lifecycle.

## **Care Instructions**

### **Garment/product care instructions**

Proper care instructions are essential to maximising the longevity and performance of garments and products while reducing their environmental impact. The production team provides detailed eco-friendly care recommendations that empower customers to maintain product quality responsibly. These include washing in cold water to save energy, line drying to minimise reliance on energy-intensive dryers, and using gentle, biodegradable detergents to reduce chemical footprints and water pollution. Additionally, specific guidance on handling, cleaning, and storing products is tailored to ensure durability under various conditions. By educating consumers on sustainable care practices, the company not only extends the lifespan of its products but also promotes environmentally conscious habits. These efforts reflect our holistic approach to sustainability, ensuring that both production and post-purchase use align with their eco-friendly mission.

## **Durability**

### **Expected product durability**

Expected durability is a cornerstone of professional right bike crank product design. By utilising high-strength aluminium alloys such as 6061, the company creates components that offer exceptional longevity due to their superior corrosion resistance, lightweight properties, and mechanical strength. These materials are meticulously chosen to ensure the products can withstand wear and tear over time, even in demanding conditions. This durability not only enhances reliability but also provides long-term value to consumers by reducing the need for frequent replacements. Additionally, the resilience of these components makes them ideal for applications where exposure to environmental factors, such as moisture, heat, or stress, demands robust performance. Through this focus on longevity, we reinforce its commitment to creating high-quality, sustainable solutions.

## **Recycling**

### **Recyclability of product**

The recyclability of products is a key pillar in sustainability initiatives. By integrating recyclable materials such as high-grade aluminium alloys, the company ensures that products can be efficiently recovered and reused at the end of their lifecycle. This intentional design approach streamlines material reclamation processes, reducing waste and conserving resources. Furthermore, prioritising recyclability aligns with circular economy principles, where materials are continually repurposed to minimise environmental impact. Through these efforts, we not only support sustainable manufacturing practices but also demonstrate a firm commitment to environmental responsibility, paving the way for a future where product lifecycles contribute to a more resource-efficient world.

## **Packaging**

### **Recyclability of packaging**

Packaging recyclability is a vital aspect of sustainable consumption, and our product is dedicated to advancing this through innovative solutions such as returnable packaging systems. These systems actively encourage customers to participate in sustainability efforts by returning used packaging materials instead of discarding them. This strategic approach significantly reduces single-use waste while promoting a culture of environmental responsibility. By providing easy-to-access recycling channels and incentives for participation, the company fosters stronger customer engagement and builds a sense of shared commitment to sustainability. Such initiatives not only align with broader environmental goals but also enhance brand trust and loyalty by demonstrating tangible actions toward reducing waste.

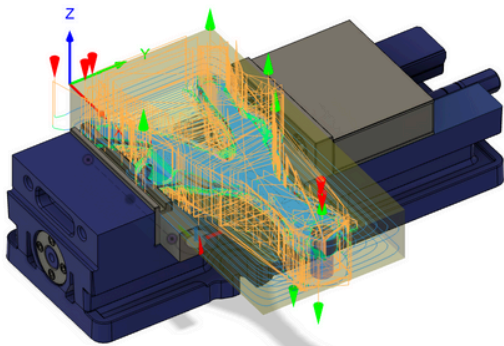
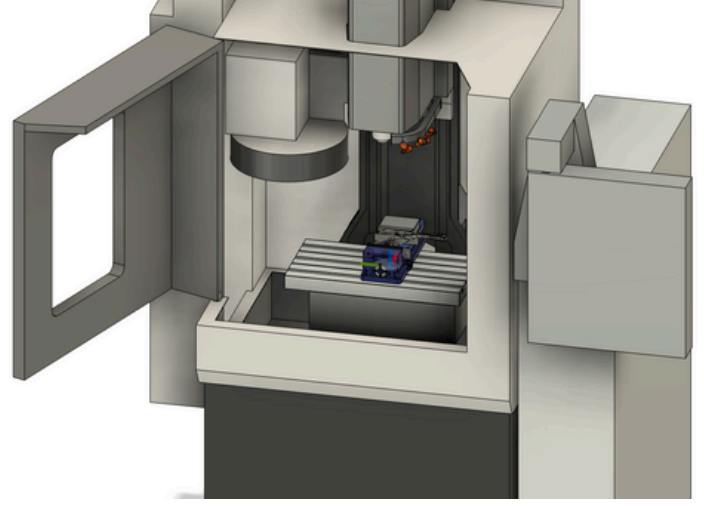
## Process Plan (CNC)

**OP10** – Machining top side from 230 x 110 x 40 mm<sup>3</sup>  
Aluminium 6061 stock

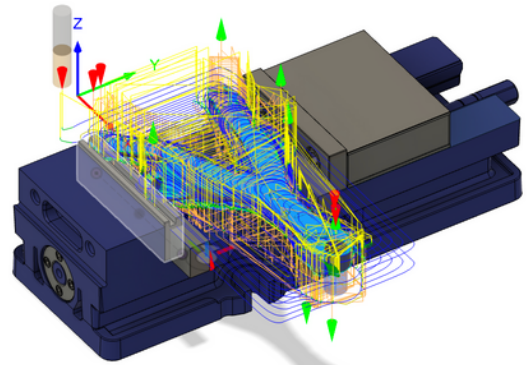
- **Machine:** Haas UMC-750 (5-axis CNC)
- **Machine time:** 00:44:57

**OP20** – Finishing bottom side, held in softjaws

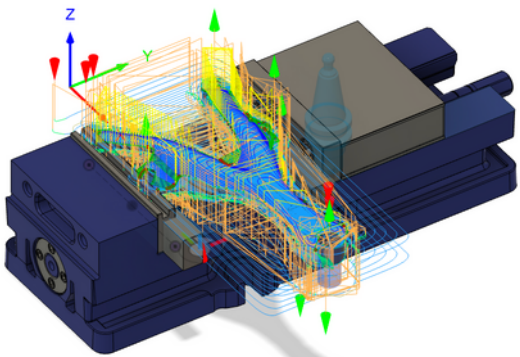
- **Machine:** Haas UMC-750
- **Machine time:** 00:07:47



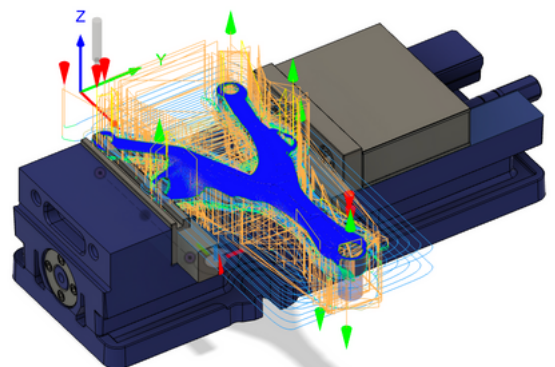
Working Coordinate System



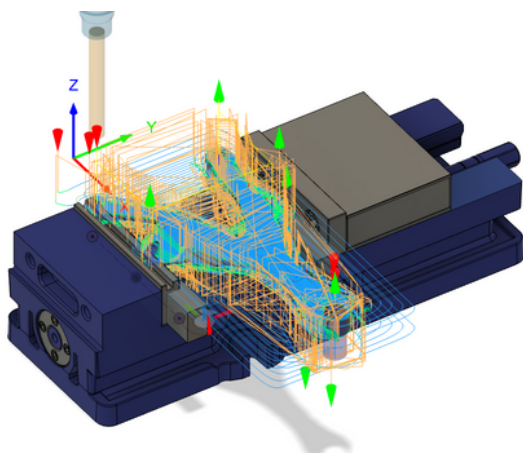
1. Adaptive Roughing



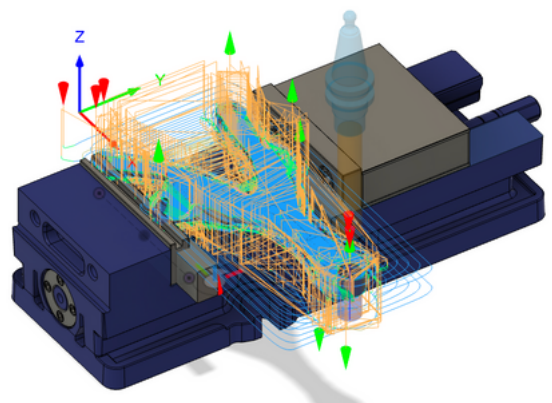
2. Contouring (Semi finishing operation))



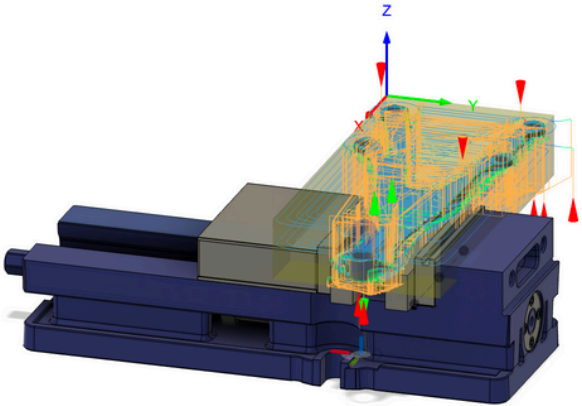
3. Parallel Finishing



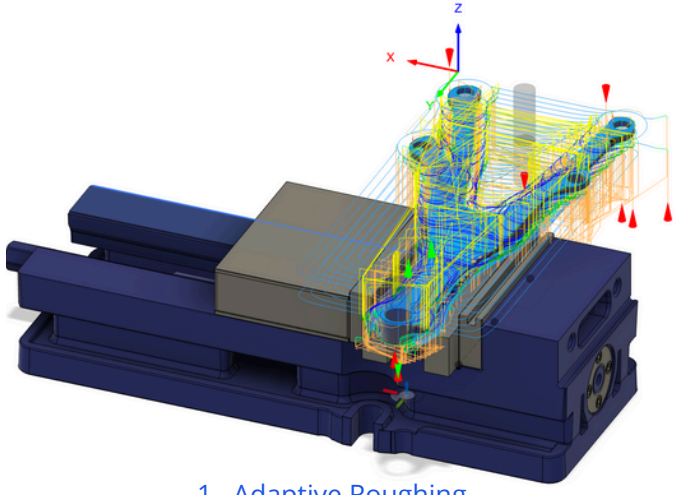
4. Holemaking x4



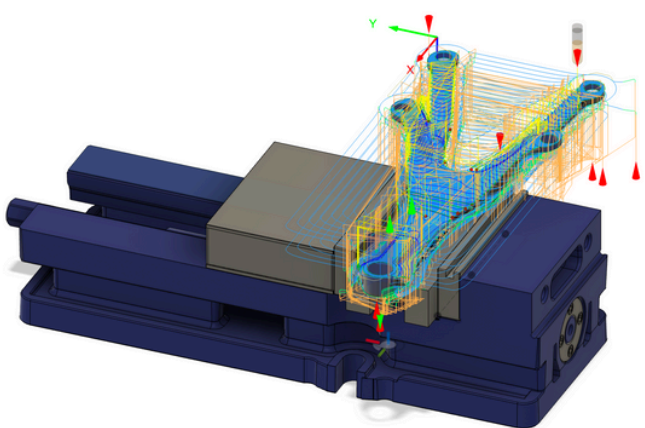
5. Holemaking x1



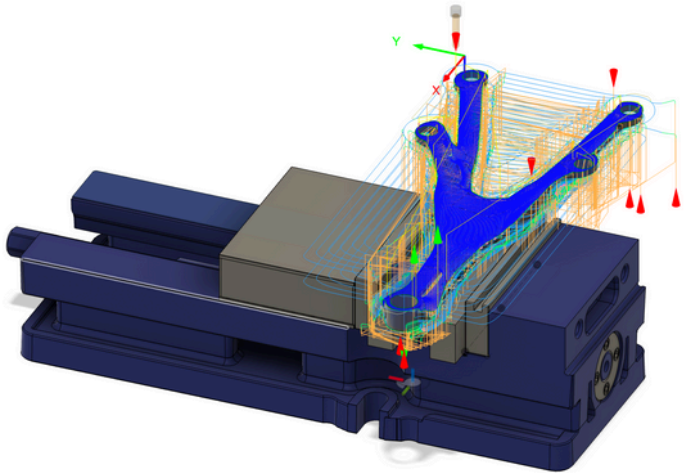
Working Reversed Coordinate System



1. Adaptive Roughing

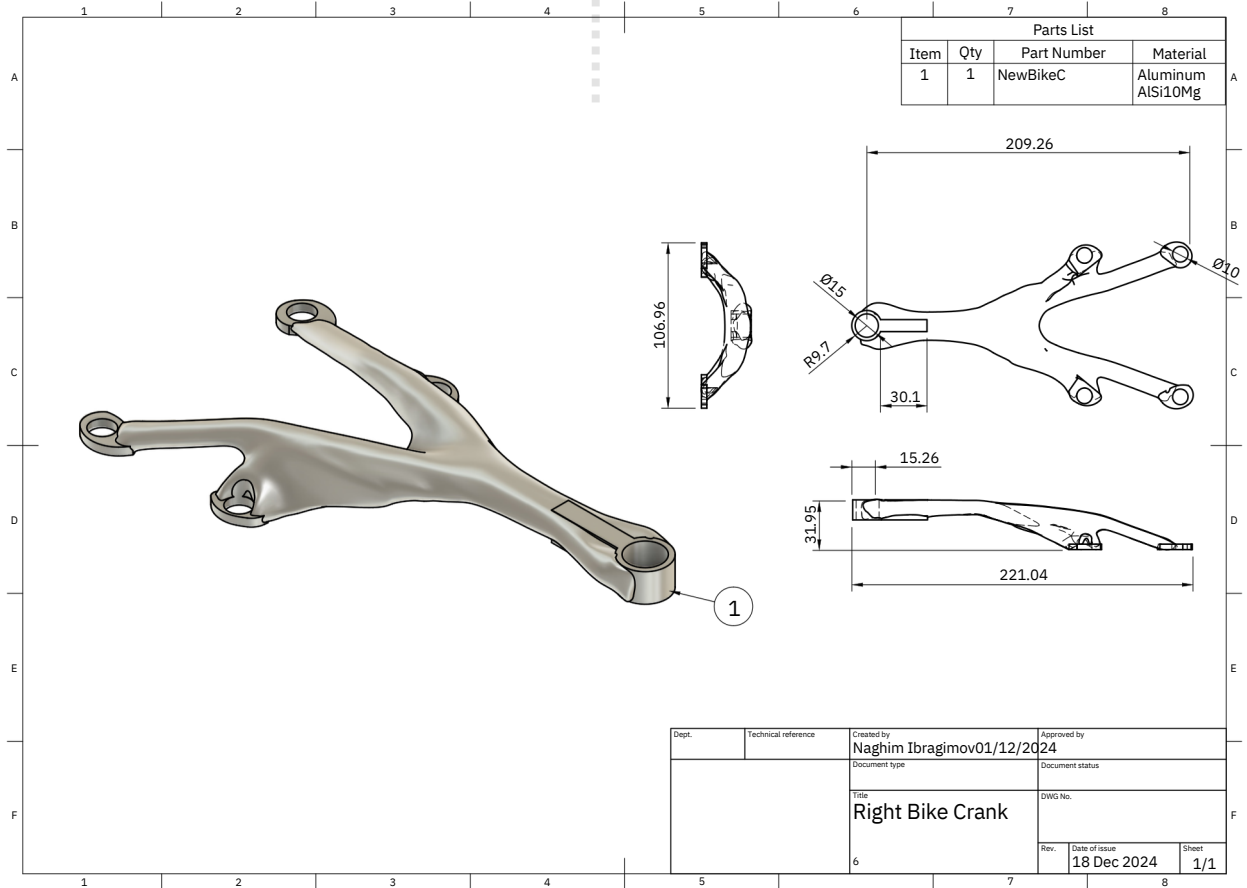


2. Contouring (Semi finishing operation))



3. Parallel Finishing

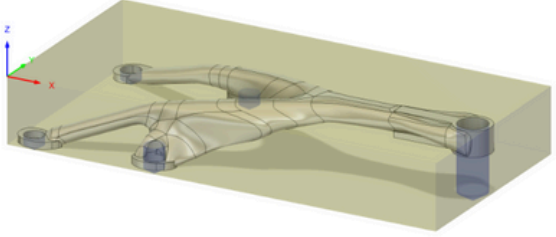
**2D Drawing of the Part**








# Setup Sheet for Program 1001

JOB DESCRIPTION: Setup2

DOCUMENT PATH: NewBikeC v7

Setup	
<p><b>WCS: #0</b></p> <p><b>Stock:</b> DX: 223.04mm DY: 108.96mm DZ: 33.43mm</p> <p><b>PART:</b> DX: 221.04mm DY: 106.96mm DZ: 32.43mm</p> <p><b>STOCK LOWER IN WCS #0:</b> X: 0mm Y: 0mm Z: -33.43mm</p> <p><b>STOCK UPPER IN WCS #0:</b> X: 223.04mm Y: 108.96mm Z: 0mm</p>	

Total
<p>NUMBER OF OPERATIONS: 8</p> <p>NUMBER OF TOOLS: 6</p> <p>TOOLS: <b>T6 T7 T2362 T6841 T7405 T16887</b></p> <p>MAXIMUM FEEDRATE: 6100mm/min</p> <p>MAXIMUM SPINDLE SPEED: 40000rpm</p> <p>CUTTING DISTANCE: 100246.52mm</p> <p>RAPID DISTANCE: 36975.14mm</p> <p>ESTIMATED CYCLE TIME: 51m:42s</p>

Tools			
<p><b>T6 D6 L6</b> Type: drill DIAMETER: 10mm TIP ANGLE: 118° LENGTH: 85mm FLUTES: 2 DESCRIPTION: Drill bit</p>	<p>MAXIMUM FEED: 1045mm/min MAXIMUM SPINDLE SPEED: 4500rpm CUTTING DISTANCE: 85.02mm RAPID DISTANCE: 596.36mm ESTIMATED CYCLE TIME: 12s (0.4%)</p>	<p>HOLDER: ISO20 ERM16Mx053 v2</p>	
<p><b>T7 D7 L7</b> Type: ball end mill DIAMETER: 8mm CORNER RADIUS: 4mm LENGTH: 28.21mm FLUTES: 4 DESCRIPTION: SwissTech Ball Nose End Mill, 8mm, 4 fl, Carbide, TiCN VENDOR: SwissTech</p>	<p>MAXIMUM FEED: 3500mm/min MAXIMUM SPINDLE SPEED: 16000rpm CUTTING DISTANCE: 7290.01mm RAPID DISTANCE: 5277.98mm ESTIMATED CYCLE TIME: 7m:15s (14%)</p>	<p>HOLDER: ISO20 ERM16Mx053 v2</p>	
<p><b>T2362 D2777 L2777</b> Type: ball end mill DIAMETER: 4mm CORNER RADIUS: 2mm LENGTH: 25mm FLUTES: 4 DESCRIPTION: 4MM BALL END MILL VENDOR: DATRON PRODUCT: 0078544B</p>	<p>MAXIMUM FEED: 2400mm/min MAXIMUM SPINDLE SPEED: 40000rpm CUTTING DISTANCE: 25624.99mm RAPID DISTANCE: 1164.28mm ESTIMATED CYCLE TIME: 10m:58s (21.2%)</p>		
<p><b>T6841 D13551 L13551</b> Type: flat end mill DIAMETER: 12mm LENGTH: 58mm FLUTES: 4 DESCRIPTION: 12MM FLAT END MILL VENDOR: DATRON PRODUCT: 0078652</p>	<p>MAXIMUM FEED: 6100mm/min MAXIMUM SPINDLE SPEED: 40000rpm CUTTING DISTANCE: 34515.98mm RAPID DISTANCE: 24877.87mm ESTIMATED CYCLE TIME: 11m:8s (21.5%)</p>		
<p><b>T7405 D2684 L2684</b> Type: ball end mill DIAMETER: 6mm CORNER RADIUS: 3mm LENGTH: 25mm FLUTES: 1 DESCRIPTION: 6MM BALL END MILL VENDOR: DATRON PRODUCT: 0068196E</p>	<p>MAXIMUM FEED: 4000mm/min MAXIMUM SPINDLE SPEED: 40000rpm CUTTING DISTANCE: 3405.06mm RAPID DISTANCE: 4220.06mm ESTIMATED CYCLE TIME: 1m:50s (3.5%)</p>		

**T16887 D8473 L8473**


Type: ball end mill  
 DIAMETER: 3mm  
 CORNER RADIUS: 1.5mm  
 LENGTH: 50mm  
 FLUTES: 2  
 DESCRIPTION: 3MM BALL END MILL  
 VENDOR: DATRON  
 PRODUCT: 0078503

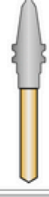
MAXIMUM FEED: 1600mm/min  
 MAXIMUM SPINDLE SPEED: 40000rpm  
 CUTTING DISTANCE: 29325.46mm  
 RAPID DISTANCE: 838.59mm  
 ESTIMATED CYCLE TIME: 18m:34s (35.9%)

**Operations**

Operation 1/8		<b>T6841 D13551 L13551</b>	
DESCRIPTION: Adaptive4	MAXIMUM SPINDLE SPEED: 40000rpm	Type: flat end mill	
STRATEGY: Adaptive	MAXIMUM FEEDRATE: 6100mm/min	DIAMETER: 12mm	
WCS: #0	CUTTING DISTANCE: 25408.79mm	LENGTH: 58mm	
TOLERANCE: 0.1mm	RAPID DISTANCE: 13355mm	FLUTES: 4	
STOCK TO LEAVE: 0.5mm	ESTIMATED CYCLE TIME: 7m:6s (13.7%)	DESCRIPTION: 12MM FLAT END MILL	
MAXIMUM STEPDOWN: 19.5mm	COOLANT: Mist	VENDOR: DATRON	
OPTIMAL LOAD: 4.8mm		PRODUCT: 0078652	
LOAD DEVIATION: 0.48mm			

Operation 2/8		<b>T7 D7 L7</b>	
DESCRIPTION: Contour5	MAXIMUM SPINDLE SPEED: 16000rpm	Type: ball end mill	
STRATEGY: Contour	MAXIMUM FEEDRATE: 3500mm/min	DIAMETER: 8mm	
WCS: #0	CUTTING DISTANCE: 7290.01mm	CORNER RADIUS: 4mm	
TOLERANCE: 0.01mm	RAPID DISTANCE: 5277.98mm	LENGTH: 28.21mm	
STOCK TO LEAVE: 0mm	ESTIMATED CYCLE TIME: 7m:15s (14%)	FLUTES: 4	
MAXIMUM STEPDOWN: 0.8mm	COOLANT: Flood	DESCRIPTION: SwissTech Ball Nose End Mill, 8mm, 4 fl, Carbide, TiCN	
		VENDOR: SwissTech	

Operation 3/8		<b>T6 D6 L6</b>	
DESCRIPTION: Drill5	MAXIMUM SPINDLE SPEED: 4500rpm	Type: drill	
STRATEGY: Drilling	MAXIMUM FEEDRATE: 1045mm/min	DIAMETER: 10mm	
WCS: #0	CUTTING DISTANCE: 42.12mm	TIP ANGLE: 118°	
TOLERANCE: 0.01mm	RAPID DISTANCE: 530.69mm	LENGTH: 85mm	
	ESTIMATED CYCLE TIME: 9s (0.3%)	FLUTES: 2	
	COOLANT: Flood	DESCRIPTION: Drill bit	

Operation 4/8		<b>T6 D6 L6</b>	
DESCRIPTION: Drill6	MAXIMUM SPINDLE SPEED: 4500rpm	Type: drill	
STRATEGY: Drilling	MAXIMUM FEEDRATE: 1045mm/min	DIAMETER: 15mm	
WCS: #0	CUTTING DISTANCE: 42.9mm	TIP ANGLE: 118°	
TOLERANCE: 0.01mm	RAPID DISTANCE: 65.67mm	LENGTH: 85mm	
	ESTIMATED CYCLE TIME: 3s (0.1%)	FLUTES: 2	
	COOLANT: Flood	DESCRIPTION: Drill bit	

Operation 5/8		<b>T16887 D8473 L8473</b>	
DESCRIPTION: Parallel2	MAXIMUM SPINDLE SPEED: 40000rpm	Type: ball end mill	
STRATEGY: Parallel	MAXIMUM FEEDRATE: 1600mm/min	DIAMETER: 3mm	
WCS: #0	CUTTING DISTANCE: 29325.46mm	CORNER RADIUS: 1.5mm	
TOLERANCE: 0.01mm	RAPID DISTANCE: 838.59mm	LENGTH: 50mm	
STOCK TO LEAVE: 0mm	ESTIMATED CYCLE TIME: 18m:34s (35.9%)	FLUTES: 2	
MAXIMUM STEPOVER: 0.25mm	COOLANT: Mist	DESCRIPTION: 3MM BALL END MILL	
		VENDOR: DATRON	
		PRODUCT: 0078503	

Operation 6/8		<b>T6841 D13551 L13551</b>	
DESCRIPTION: Adaptive14	MAXIMUM SPINDLE SPEED: 40000rpm	Type: flat end mill	
STRATEGY: Adaptive	MAXIMUM FEEDRATE: 6100mm/min	DIAMETER: 12mm	
WCS: #0	CUTTING DISTANCE: 9107.19mm	LENGTH: 58mm	
TOLERANCE: 0.1mm	RAPID DISTANCE: 11522.87mm	FLUTES: 4	
STOCK TO LEAVE: 0.5mm	ESTIMATED CYCLE TIME: 4m:2s (7.8%)	DESCRIPTION: 12MM FLAT END MILL	
MAXIMUM STEPDOWN: 19.5mm	COOLANT: Mist	VENDOR: DATRON	
OPTIMAL LOAD: 4.8mm		PRODUCT: 0078652	
LOAD DEVIATION: 0.48mm			

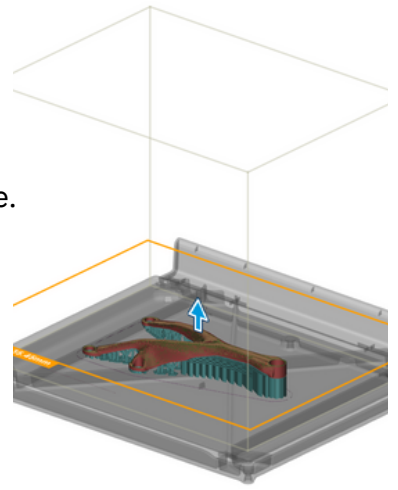
Operation 7/8		<b>T7405 D2684 L2684</b>	
DESCRIPTION: Contour8	MAXIMUM SPINDLE SPEED: 40000rpm	Type: ball end mill	
STRATEGY: Contour	MAXIMUM FEEDRATE: 4000mm/min	DIAMETER: 6mm	
WCS: #0	CUTTING DISTANCE: 3405.06mm	CORNER RADIUS: 3mm	
TOLERANCE: 0.01mm	RAPID DISTANCE: 4220.06mm	LENGTH: 25mm	
STOCK TO LEAVE: 0mm	ESTIMATED CYCLE TIME: 1m:50s (3.5%)	FLUTES: 1	
MAXIMUM STEPDOWN: 1mm	COOLANT: Mist	DESCRIPTION: 6MM BALL END MILL	
		VENDOR: DATRON	
		PRODUCT: 0068196E	

Operation 8/8		<b>T2362 D27777 L27777</b>	
DESCRIPTION: Parallel4	MAXIMUM SPINDLE SPEED: 40000rpm	Type: ball end mill	
STRATEGY: Parallel	MAXIMUM FEEDRATE: 2400mm/min	DIAMETER: 4mm	
WCS: #0	CUTTING DISTANCE: 25624.99mm	CORNER RADIUS: 2mm	
TOLERANCE: 0.01mm	RAPID DISTANCE: 1164.28mm	LENGTH: 25mm	
STOCK TO LEAVE: 0mm	ESTIMATED CYCLE TIME: 10m:58s (21.2%)	FLUTES: 4	
MAXIMUM STEPOVER: 0.28mm	COOLANT: Mist	DESCRIPTION: 4MM BALL END MILL	
		VENDOR: DATRON	
		PRODUCT: 0078544B	

## Process Plan (FDM Additive Manufacturing)

### OP10 – 3D Printing the Bike Crank using the Ultimaker S5

- **Machine:** Ultimaker S5 (Dual Extrusion FDM Printer)
- **Material:** High-strength polymer filament equivalent to Aluminium 6061 properties.
- **Print Orientation:** Optimised for structural strength and minimal support material usage.
- **Layer Height:** Typically 0.2 mm. This is essential for balancing resolution and speed
- **Cycle Time:** 4 hours, 7 minutes, 47 seconds.



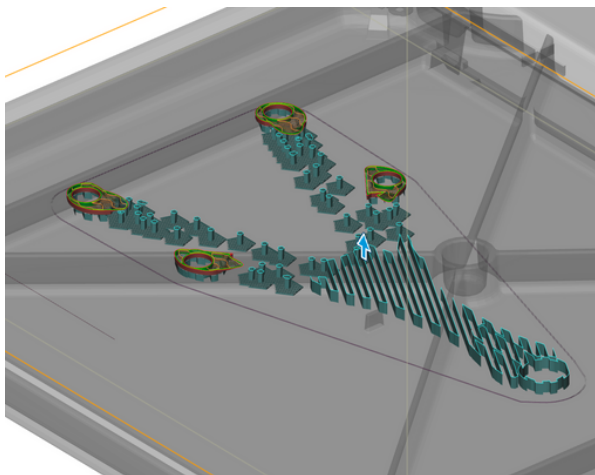
### OP20 – Post-Processing

- **Support Removal:** Detaching any support structures manually or with tools.
- **Surface Smoothing:** **Important:** Sanding or Chemical smoothing for enhanced finish.
- **Quality Inspection:** Ensuring structural integrity and smoothness.

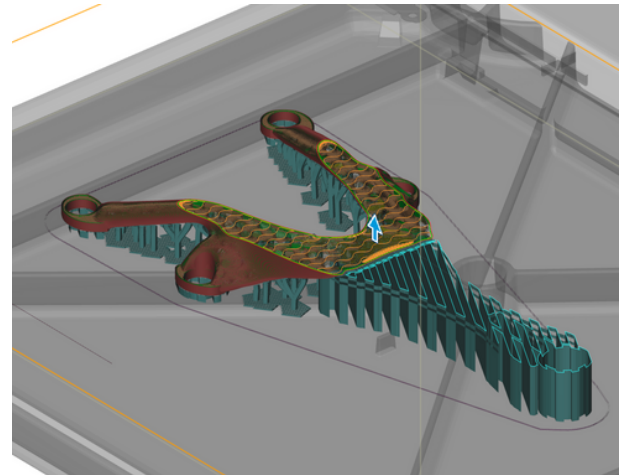
### Manufacturing Process Example

#### ▼ Statistics

Layer Count	236
Current Height	35.450mm
Current Time	4:07:47



Layer 32



Layer 124

### Post Processing Notes (Visual Studio Code [gcode])

- **Post-processing of G-code includes:**
  - Optimising travel paths to reduce non-extrusion movements.
  - Adjusting print speeds and feed rates (F) for better surface quality.
  - Tuning layer height and extrusion values (E) to ensure proper part dimensions.

#### Example Commands:

- **G90:** Sets absolute positioning for coordinates.
  - **M107:** Turns off the fan.
  - **G92 E0:** Resets the extruder position.
- Full Line command Example:**
- G1 X271.448 Y103.782 F960 E5.001:
  - **G1:** Linear movement with extrusion.
  - Moves to X=271.448, Y=103.782 at a feed rate of 960 mm/min, extruding 5.001 mm<sup>3</sup> of material.

```
;Part 1
;LAYER_COUNT:236
;LAYER:1
M107
;rapid-leaky
G90
M82
G0 X42 Y20.5 Z0.2 F7200
G1 E37 F720
G92 E0
G0 F7200
;bead-prime
G1 X142 F720 E3.135
G1 F2100 E2.635
;rapid-dry
G0 X128.19 Y63.602 F7200
G1 F2100 E3.135
;bead-skirt/brim
G1 X271.448 Y103.782 F960 E5.001
G1 X276.478 Y108.93 E5.091
G1 X278.146 Y110.791 E5.123
G1 X279.645 Y113.289 E5.159
G1 X280.614 Y115.947 E5.195
G1 X280.968 Y117.779 E5.218
```

# Support settings

Preset Name	Strong
Preset Description	The following settings have been changed: Number of Perimeters: Normal = 2, Strong = 5 Number of Top Layers: Normal = 4, Strong = 5 Number of Bottom Layers: Normal = 3, Strong = 6 Infill Density (%): Normal = 25, Strong = 50

## ▼ Bar

Number of Support Perimeters	<input type="text" value="1"/>
Number of Support Top Layers	<input type="text" value="3"/>
Number of Support Bottom Layers	<input type="text" value="3"/>
Support Infill Density (%)	<input type="text" value="0"/>
Support Infill Angle (deg)	<input type="text" value="0"/>
Support Top and Bottom Layer Infill Density (%)	<input type="text" value="100"/>
Support Top and Bottom Layer Infill Angle (deg)	<input type="text" value="0"/>
Alternate Support Top and Bottom Layer Infill Angles	<input checked="" type="checkbox"/>
Support-to-Body Horizontal Gap (mm)	<input type="text" value="0.25"/>

## ▼ Setter

Number of Support Perimeters	<input type="text" value="1"/>
Number of Support Top Layers	<input type="text" value="1"/>
Number of Support Bottom Layers	<input type="text" value="1"/>
Support Infill Density (%)	<input type="text" value="100"/>
Support Infill Angle (deg)	<input type="text" value="30"/>
Support Top and Bottom Layer Infill Density (%)	<input type="text" value="100"/>
Support Top and Bottom Layer Infill Angle (deg)	<input type="text" value="120"/>
Alternate Support Top and Bottom Layer Infill Angles	<input checked="" type="checkbox"/>
Support-to-Body Horizontal Gap (mm)	<input type="text" value="0.25"/>

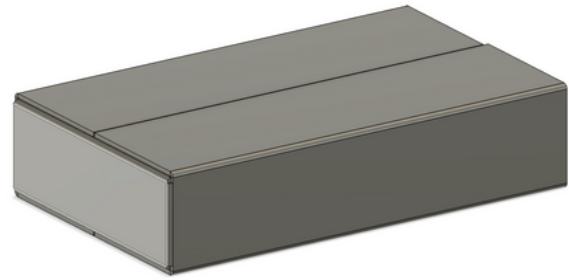
## ▼ Volume

Number of Support Perimeters	<input type="text" value="1"/>
Number of Support Top Layers	<input type="text" value="1"/>
Number of Support Bottom Layers	<input type="text" value="3"/>
Support Infill Density (%)	<input type="text" value="15"/>
Support Infill Angle (deg)	<input type="text" value="30"/>
Support Top and Bottom Layer Infill Density (%)	<input type="text" value="60"/>
Support Top and Bottom Layer Infill Angle (deg)	<input type="text" value="120"/>
Alternate Support Top and Bottom Layer Infill Angles	<input type="checkbox"/>
Support-to-Body Horizontal Gap (mm)	<input type="text" value="0.25"/>

## Packaging

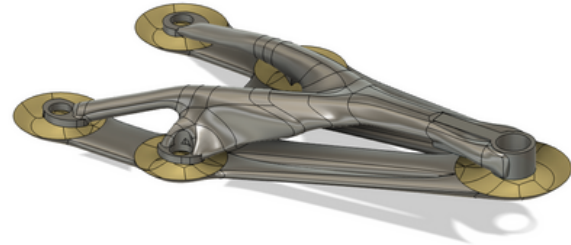
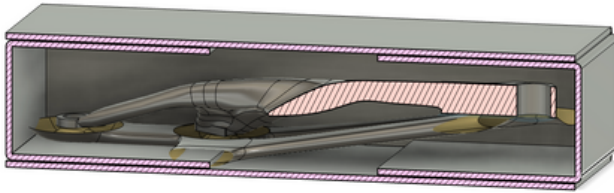
### Box (Cardboard):

- Material: Cardboard
- Density: 689 kg/m<sup>3</sup>
- Thickness: 1 mm
- Mass: 0.260 kg per box
- Volume: 377,300 mm<sup>3</sup>

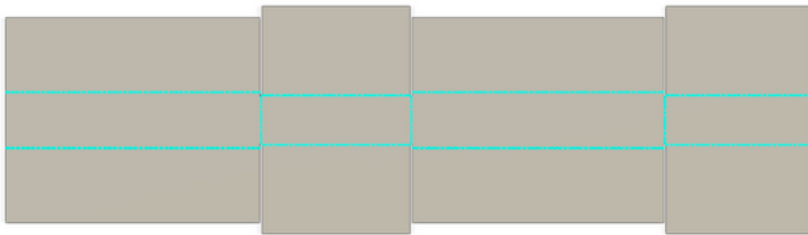


### Tray (HDPE):

- Material: High-Density Polyethylene (HDPE)
- Density: 1 g/cm<sup>3</sup> (0.001 g/mm<sup>3</sup>)
- Thickness: 1 mm
- Mass: 0.029 kg per tray
- Area: 28,964 mm<sup>2</sup>



### Flat Pattern



### Cardboard Parameters

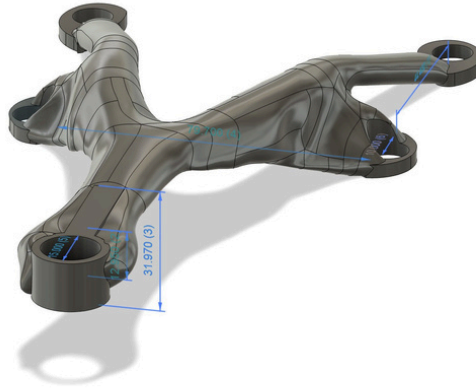
Cardboard(1) (Default)	
Thickness	1.50 mm
K Factor	1
Miter/rip/seam gap	1.50 mm
Bend Conditions	
Bend radius	0.20 mm
Relief shape	Straight
Relief width	1.50 mm
Relief depth	0.75 mm
Relief remnant	3.00 mm
Corner Conditions	
2 Bend Intersection	
Relief shape	Trim to Bend
Relief size	6.00 mm
Relief placement	Intersection
3 Bend Intersection	
Relief shape	Round with Radius
Relief radius	1.50 mm

### Cost Analysis of Box and Tray

Units	Cost of Box (£)	Cost of Tray (£)	Total Cost (£)
1	0	0	0
100	3	6	9
1,000	30	58	88
10,000	300	580	880
100,000	3,000	5,800	8,800

Cost of 1 Unit for tray and a box is less than a £1, hence was not considered in the table, since no company in the world will buy cardboard for one unit only. The total cost for 1 unit would be expected to be around £0.092

# Inspection Report



Document	NewBikeC.v22
Measurement Unit	Millimeters

## Geometric Dimensions

■ Out of Tolerance      ■ In Tolerance

### Inspection Results1

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Top-Bottom	Surface to Surface	12.900	12.950	-0.300	0.300	0.050	-	In Tolerance =

### Inspection Results2

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Top-Bottom	Hole	31.950	31.970	-0.500	0.500	0.020	-	In Tolerance =

### Inspection Results3

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Width (hole)	Center to center	79.667	79.700	-0.1000	0.100	0.033	-	In Tolerance =

### Inspection Results4

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Radius	Hole	15.000	15.000	-0.100	0.100	0.000	-	In Tolerance =

### Inspection Results5

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Radius 2	Hole	10.500	10.000	-0.100	0.100	-0.500	-0.400	Out of Tolerance ▼

### Inspection Results6

Features								
Name	Type	Nominal	Measured	Tolerance		Deviation	Error	Result
				Lower	Upper			
Distance in y-axis (hole)	Center to center	44.463	44.400	-0.100	0.100	-0.063	-	In Tolerance =

# Comparative Critique: Sustainability Considerations Across Economies of Scale and Performance

## Small Scale:

- Small Scale Production:

Additive manufacturing (FDM) is more sustainable at low production volumes due to minimal waste, lower setup costs, and energy efficiency.

- produced good prototypes
- Material efficiency is high for FDM as only the required amount is used, but production speed is slower, limiting scalability.

## Large Scale:

- Subtractive manufacturing (CNC) becomes more cost-effective and scalable for high production volumes, despite higher material waste.
- Generative design helps reduce waste, but the impact is less significant compared to additive methods.

## Sustainability Trade-offs:

### CNC Machining:

- Generates significant material waste (~94% for traditional designs), but with high precision and faster output for mass production.
- Recycling and reusing aluminium can offset waste and reduce environmental impact.

### Additive Manufacturing:

- **Near-zero waste**, making it highly sustainable.
- However, slower speeds and higher per-unit costs at scale can offset its environmental benefits.

### Performance:

- High performance parts for example my bike crank often require high strength materials.
- Sustainability aligns with performance by using generative designs to optimise material usage and reduce weight, directly improving efficiency in use.

## Risk Identification and Mitigation

### Material Choice:

- Risk: Using non recyclable or low durability materials increases lifecycle costs and environmental impact.
- Mitigation: Select Aluminium 6061 (highly recyclable) or HDPE (durable and reusable) to balance cost, performance, and sustainability.

### Manufacturing Strategy:

- Risk: Over reliance on subtractive manufacturing for small production runs increases waste and cost. Plus creates a lot of redundant prototypes.
- Mitigation: **Use FDM for prototyping** and low volume production, transitioning to CNC for scalability.

### Supply Chain and Material Sourcing:

- Risk: Non local material sourcing increases costs and carbon footprint.
- Mitigation: Use only UK manufactured materials to minimise transportation emissions and ensure quality.

### Production Volume Uncertainty:

- Risk: Misjudging production volume can result in large costs.
- Mitigation: Implement flexible production strategies, with FDM for lower volumes and CNC with strategic planning scale .