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NSF250R 24/25 Group Project

Group Design Project - ACHA5014

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1 Introduction

This project explores key development areas on the UWTSR Race Team's Honda NSF250R, aiming to enhance performance ahead of the 2025 season. By focusing on engine tuning, aerodynamics, and chassis adjustments, the goal is to maximise performance for a competitive edge on track.

Key areas of investigation include:

- **Engine Tuning:** Implementing a new ECU with an increased RPM limit and additional sensors.
- **Airbox Development:** Evaluating the impact of increased airbox volume on engine performance.
- **Fuel Tank Development:** Assessing changes in fuel tank size and positioning.
- **Fuelling & Airflow:** Investigating alternative fuels, secondary injector installation, bell mouth design, and air intake optimisation.
- **Geometry Changes:** Testing adjustable offset yokes and rear sets for improved handling.
- **Front Fairing Aerodynamics:** Enhancing fairing size to improve airflow around the rider.

2 Project Organisation

Table 1: Project organisation & allocation of tasks.

Name	Project Role	Project Responsibilities
Olly Gillson	Team Lead Engine Management/Intake & Fuelling Systems	• Bellmouth and secondary injector design. • Fuelling maps and engine strategies.
Oska Robertson	Rider Dynamics	• Rear set design and development.
Megan Gwilym	Research/Engine Management	• Alternative fuels research • Fuelling calculation research • Secondary injector timing research
Harry Rogers	Meeting Minutes Motorcycle Dynamics	• Adjustable offset yokes. • Adjustable rear suspension linkage.
Aaron Lilly	Fuel Storage	• Fuel tank development.
Edward Walden	Intake Systems	• Airbox design and improvement.
Jake Davies	Aerodynamics	• Front fairing aerodynamics development.
Harvey Merrett	Intake Systems	• Air intake duct design.

3 Project Contributions

3.1 Olly Gillson

3.1.1 Bell Mouth Design & Development

Bell mouth design can improve engine performance by using the pulse tuning effect. Changes in the intake train length influence how long it takes for an air pulse, reflected from the closed intake valve, to return to the engine. By timing this pulse to arrive just before the intake valve closes, more incoming air is forced into the cylinder, increasing overall performance (Williams, 2024).

Blair & Cahoon tested three bell mouth profiles and found the elliptical profile achieved the highest mass airflow rate. Models of the OEM and elliptical bell mouth were produced (Figure 1). The elliptical profile was modelled using the parameters provided (Figure 2). The exit diameter was modified to fit that of the throttle body of the Honda.



Figure 2: OEM bell mouth profile (left) & elliptical profile (right).

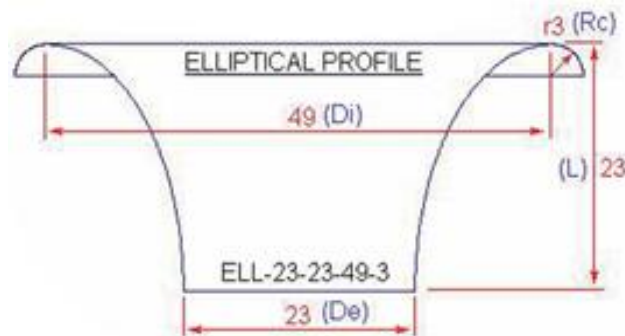


Figure 1: Elliptical profile parameters (Blair, G. & Cahoon, W.)

Baseline mass airflow rates (Table 2) were established through flow bench testing, using the OEM airbox assembly, throttle body with butterfly held at 100% open, and bell mouth. These tests were to provide a benchmark for future flow bench tests with a range of bell mouth designs, however subsequent testing was performed using computational fluid dynamics (CFD) on modelled OEM and elliptical profiles.

Table 2: Flow bench test results.

Test	Water Pressure (Inches)	Water Pressure (Pa)	Flow (%)	Flow (L/m)
Standard Airbox Assy	10	2488	77.1	4049.31

Flow bench pressure data of 2488Pa was used to simulate the intake stroke of the engine whilst the remaining area simulating the airbox was set to atmospheric pressure. Comparing the original and revised bell mouth designs, CFD results showed a 2% increase in mass airflow (Table 3) and improved flow around the leading edge, reducing particle detachment (Figure 3).

Table 3: CFD results of OEM and elliptical bell mouth profiles.

Profile	Mass Airflow (Kg/s)
OEM	1.03
Elliptical	1.06

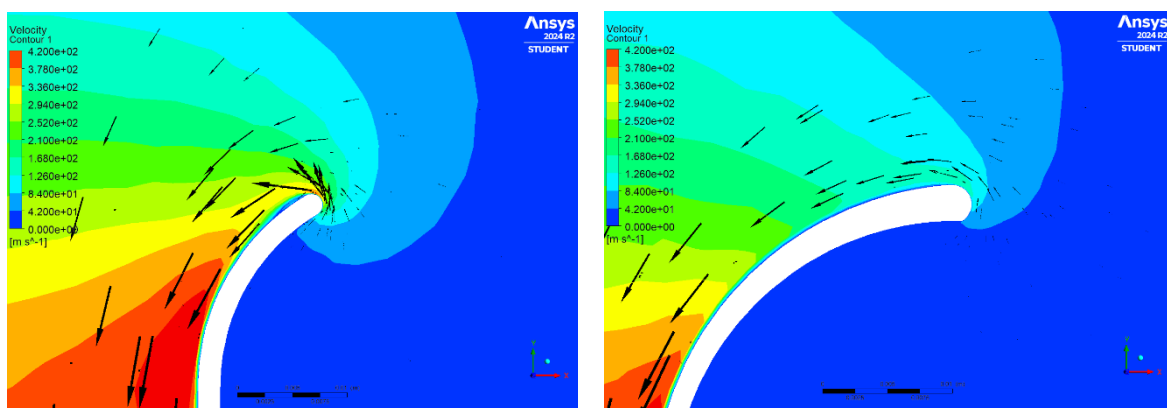


Figure 3: CFD results showing particle deflection on the bell mouth leading edge (OEM left, elliptical right).

3.1.1.1 Test Data Accuracy

While the flow bench provided pressure readings, these do not fully represent real-world operating conditions. The Honda is equipped with two pressure sensors, one in the airbox and one in the throttle body that were previously unavailable for data logging. With the recent engine control unit (ECU) installation, these sensors will provide accurate pressure data across the RPM range, improving future CFD simulations.

3.1.1.2 Future Work

With the new ECU installed, RPM data can now be extracted, allowing for the design of bell mouth lengths optimised for specific track requirements. By tuning the bell mouth to a track's average RPM, pulse tuning effects can be leveraged to improve power output precisely where it is most needed.

Further work on the bell mouth profile can be conducted to establish whether changes to leading edge curve has any effect on mass airflow performance.

3.1.2 Engine Management, Tuning & Data Acquisition

After installing the new ECU and wiring loom, DoPE Engine Management software was installed. Upon connection, a KTM map was discovered. A backup of this map, along with screenshots of its parameters, was taken in case of future reference. Attempts to acquire a suitable Honda map led to discussions with Geotech and Dell'Orto. Initially, the acquired map could not be uploaded due to an ECU firmware mismatch. Further discussions resulted in obtaining a compatible map, which was successfully loaded onto the ECU.

With the map loaded, efforts were made to start the engine which only resulted in backfire. The original Honda ECU uses two crank triggers (Figure 4), it was thought that this might be the cause of issues however swapping between them did not resolve the problem.

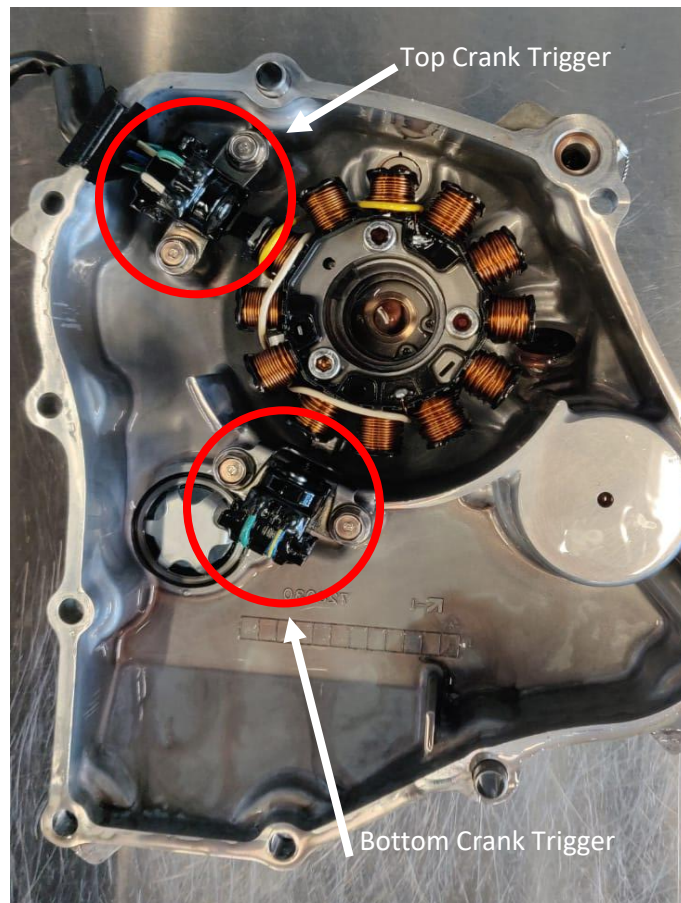


Figure 4: Crank trigger location on internal of engine casing.

3.1.2.1 Ignition Advance Timing

Suspecting a timing issue, a timing gun was used, revealing that original ignition advance timing (table 4) did not align approximately 20° advance of the top dead centre (TDC) mark indicated on the engine casing. To correct this, ignition timing was adjusted in increments to find a correct value to bring the timing in line with TDC. These values were further adjusted to account for ignition advance. A value of 120° plus the original values (table 5) brought the timing to the desired location.

Table 4: Original ignition advance timing.

	Throttle [%]									
	0.7	1	2	5	10	15	20	25	30	35
RPM	1000	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
	1500	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
	2000	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
	2500	17.3	17.3	18.6	19.8	19.8	19.8	19.8	19.8	19.8
	3000	13.5	14.9	18.0	19.8	19.8	19.8	19.8	19.8	19.8
	3250	10.0	18.1	18.9	19.8	19.8	19.8	19.8	19.8	19.8
	3500	10.0	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4
	3750	10.0	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
	4000	10.0	28.3	28.3	28.3	28.3	28.1	28.3	28.3	28.3

Only a limited number of values (up to 40% throttle and 4000 RPM) were modified as a safeguard as if the engine exceeded these values, it would revert to the incorrect timing and cut.

Table 5: Revised ignition timing (120 + original values).

	Throttle [%]									
	0.7	1	2	5	10	15	20	25	30	35
RPM	1000	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8
	1500	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8
	2000	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8	139.8
	2500	137.3	137.3	138.6	139.8	139.8	139.8	139.8	139.8	139.8
	3000	133.5	134.9	138.0	139.8	139.8	139.8	139.8	139.8	139.8
	3250	130.0	138.1	138.9	139.8	139.8	139.8	139.8	139.8	139.8
	3500	130.0	141.4	141.4	141.4	141.4	141.4	141.4	141.4	141.4
	3750	130.0	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7
	4000	130.0	148.3	148.3	148.3	148.3	148.1	148.3	148.3	148.3

Despite continued refinements to ignition value and injection values, the engine failed to start, still producing backfire and at times combustion gases were seen to exit the airbox. This confirmed that spark and fuel were reaching the cylinder, but timing remained incorrect. The collected data was shared with contacts at Geotech in hopes of finding a resolution.

3.1.3 Scoping Crank, Ignition, and Injection

After the efforts detailed in section 3.1.2 and a lack of support from external bodies it was decided more investigation should be performed. Using an oscilloscope, waveforms for the crank trigger, injection, and ignition were analysed. Figures 5, 6, and 7 display the captured data.

- The blue trace represents the crank trigger. A significant gap in the waveform indicates a missing tooth on the crank, which corresponds to TDC.
- The green trace represents the injector voltage. A voltage drop signifies injector discharge.
- The red trace represents the ignition voltage. Like the injector, a drop in voltage indicates an ignition coil discharge.

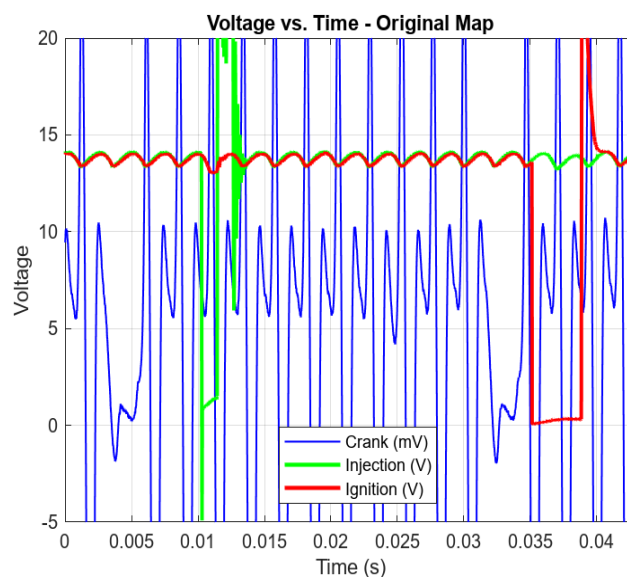


Figure 5: Original map crank, injector and ignition trace.

Figure 5 shows the traces recorded with the original map loaded. When comparing the ignition trace to the ignition advance values in Table 4, the values do not align as expected, with the ignition trace appearing after top dead centre (ATDC). However, further comparison between Figures 5 and 6 shows that the updated values from Table 5 have shifted the ignition trace to before top dead centre (BTDC), aligning with the expected 20° advance. At this point in testing, it was discussed whether the issue may be with injection and ignition values acting out of phase.

To confirm this injection timing was adjusted by adding 120° to the original phase values of 315° . However, since this exceeded 360° the engine attempted to inject fuel every four strokes instead of the intended two. To correct this, the injection timing was recalculated to align to the same number of degrees before ignition timing observed in the original map.

Despite the changes made and confirmation of timing through scoping tools, the engine would not start.

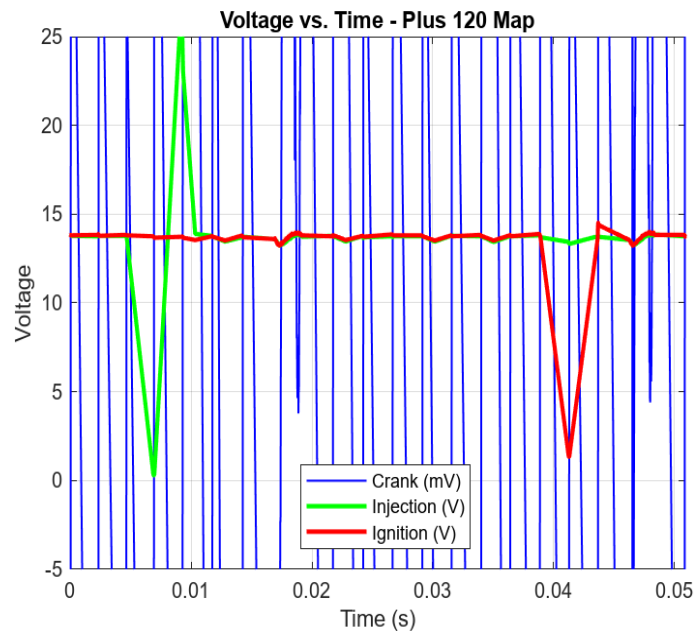


Figure 7: Plus 120° to ignition advance trace.

Continued investigation of the ECU settings revealed that the missing crank teeth count was incorrect (figure 7). The settings were adjusted to match the correct number of missing teeth on the flywheel.

PICKUP_TOTAL_TEETH_NBR	PICKUP_MISSING_TEETH_NBR
12	☐ cam ☐ 1 ☒ 2 ☐ 3

Figure 6: Missing teeth set to 2 (Honda OEM crank has 1 missing tooth).

Figure 8 details scope traces after this setting was corrected and shows an injection and ignition pulse every 360°. This trace suggests a wasted spark system combined with a staged fuel injection strategy where a portion of the total fuel is injected onto the back of the closed intake port during one rotation, with the remainder injected as the valve opens. It is likely that this is the case as the ECU uses a crank position sensor reading missing teeth on the fly wheel rather than a cam position sensor and so has no way to confirm which TDC is ignition or exhaust.

Timing light tests confirmed that this change affected spark timing. However, subsequent adjustments to the ignition timing values had no impact on spark timing. It was later determined that modifying the missing crank teeth value caused an internal error, preventing any further changes from taking effect confirmed with the use of timing light tests showing no change after adjusting ignition advance values.



Figure 8: Corrected crank trigger trace.

3.1.3.1 Engine Start

Before sending the ECU to Dell'Orto for reconfiguration, a final attempt was made to start the engine. A flywheel with two missing teeth was acquired and installed. Initial start attempts were made with the base map installed, but the engine did not start.

Further tests confirmed that both fuel injection and spark were functioning. A final test was conducted using a small amount of start assist, which successfully started the engine. Subsequent startups were achieved without start assist. The engine idled smoothly, and the throttle responded well.

3.1.4 Further Work

With the engine successfully running dynamometer tests can be performed to provide baseline data. Power and torque curves will be used to validate changes made to ignition and injection timings in hopes to improve power and performance.

The new ECU allows for data acquisition, sensors (Table 6) can now be installed and calibrated. Front and rear wheel radius was measured and circumference calculated, speed sensor pickup ring teeth values have been updated (Figure 9).

Table 6: Sensor list

Sensor	Name	ECU Pin	Type	Voltage	Description
Rear Suspension	AN5V15	43	ADC		Generic Analog Input
Front Suspension	AN5V13	8	ADC		Generic Analog Input
Wheel Speed Front	ICTTL1	20	IC		Input Capture
Wheel Speed Rear	ICTTL2	19	IC		Input Capture
Throttle Position	AN5V1	6	ADC		Analog Input
Brake Pressure					
Airbox Pressure	AN5V2	5	ADC		Analog Input
Airbox Temperature					
Water Temperature	AN5V11	15	ADC		Analog Input
Oil Temp	AN5V8	11	ADC		Analog Input
Oil Pressure	AN5V4	33	ADC		Analog Input
Lambda	LMD_UN(RE)	22	LAMBDA		UEGO Probe
	LMD_IP(APE)	26			UEGO Probe
	LMD_VM(IPN)	27			UEGO Probe
	LMD_IA(RT)	29			UEGO Probe
	LMD_H-	41			UEGO Probe Heater
Quick Shift	GPIO2	49	GPIO		Digital Input

Session / Wheels

GEN_SESSION_TYPE
0

FR_WHEEL_CIRC [M]
1.838

RR_WHEEL_CIRC [M]
1.900

FR_WHEEL_TEETH
48

RR_WHEEL_TEETH
48

Figure 9: Wheel circumference & pickup teeth count settings.

The suspension travel potentiometer ranges have been updated to match the configuration and have been zeroed. The digit values, located in the left-hand columns of the lookup tables in Figure 10, represent the potentiometer position. To determine the scaling factor, the total potentiometer length of 150mm was divided by the final digit value of 62,016, resulting in 0.002419. This scaling factor was then used to convert digit values into potentiometer positions in millimetres.

ElaborationComparison

Choose the elaboration you want:

☐ From file elaboration
Table KTM_STD_2015_2014ECU

☒ Previously saved elaboration

Elaboration info

Name
SUSF_MO44

Description
Almeria LUT SUSF

Data

	128	0
	4672	10.58
	8832	19.9
	13184	30.06
	17216	39.75
	21632	50.16
	25984	60.28
	30528	70.56
	34816	80.4
	38784	90.1
	43136	100.23
	47872	110.77
	52288	120.69
	56768	130.72
	62016	142.28

Elaboration info

Name
SUSF_MO44

Description
Almeria LUT SUSF

Data

	128	0
	4672	11.3
	8832	21.36
	13184	31.89
	17216	41.64
	21632	52.32
	25984	62.85
	30528	73.84
	34816	84.21
	38784	93.81
	43136	104.33
	47872	115.79
	52288	126.47
	56768	137.31
	62016	150

Ok

Figure 10: Old (left) & updated (right) Suspension potentiometer lookup tables.

3.1.5 Sensor mounts

The Dellorto ECU allows for data capture. To accommodate this various sensor are retrofitted.

3.1.5.1 Wheel Speed Sensor Mounts

3.1.5.1.1 Front

The front wheels speed sensor mount has been designed to use the front mud guard securing points and is placed in such a way that the front mud guard protects it from debris. PLA prototypes have been printed to test for fitment (Figure 11).

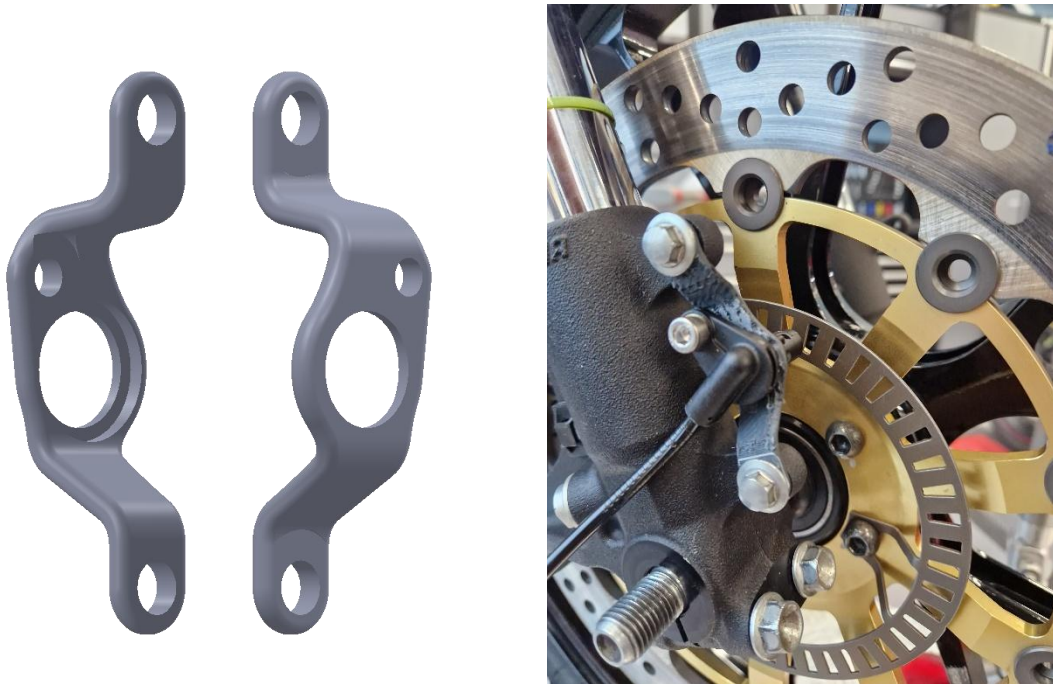


Figure 11: Model of front wheel speed sensor mount (left), sensor mount and pickup ring fitted (right).

3.1.5.2 Rear

Revisions were made to previous models of the bespoke rear caliper bracket to accommodate a new rear wheel speed sensor. However, fitment issues arose, as there was no clear way to mount the sensor in alignment with the desired pickup ring (Figure 13) without causing interference when adjusting the rear wheel swingarm position.

After further discussion, it was decided to machine two mounting holes into the original caliper hanger to better support a sensor mount (Figure 12). While this new location resolved some issues, it introduced its own challenges, as the inner pickup ring originally designed for the bespoke caliper bracket could no longer be used. Additional details on this adjustment are discussed in section 3.1.7.

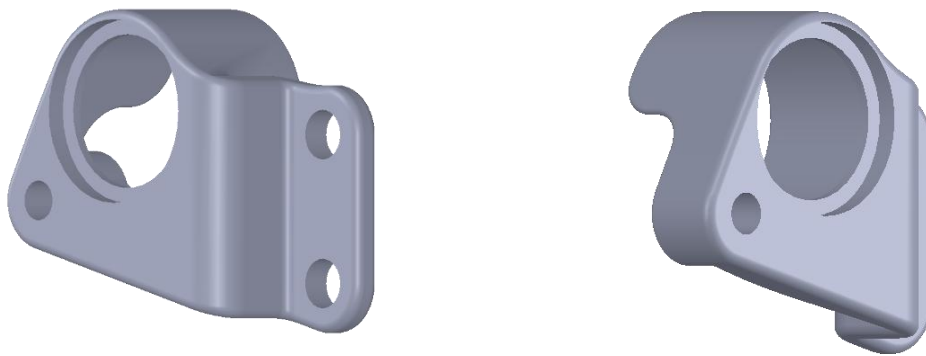


Figure 12: Rear wheel speed sensor mount.

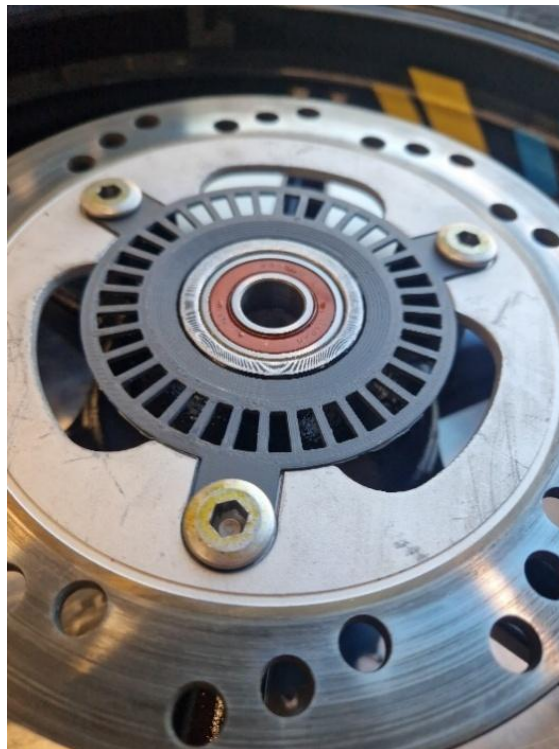


Figure 13: Original pickup ring design.

3.1.6 Front Pickup Ring

A custom front pickup ring was designed to work with the front wheel speed sensor. Initial prototypes were developed in a pre-formed state to determine the correct arm angle and fitment (Figure 14). Once validated, a bespoke forming tool (Figure 15) was created, allowing a flat rotor model to be cut from plate steel and shaped accordingly.

Early designs encountered issues with disc warping, which were traced to uneven stresses caused by the material distribution on the angled arm. To address this, revisions were made to include a cutout in the angled arm alongside an increase in the size of the missing gaps, improving sensor registration (Figure 16).

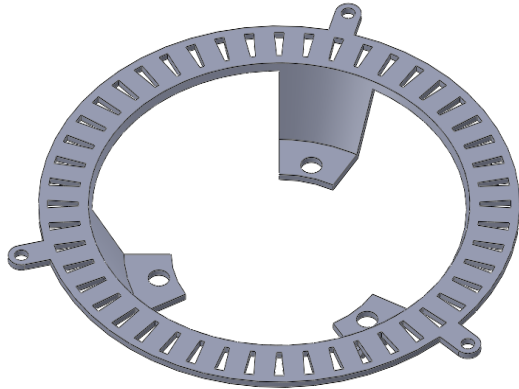


Figure 14: Formed rotor model (left), prototype (right).



Figure 15: Forming tool base (left), top (right).

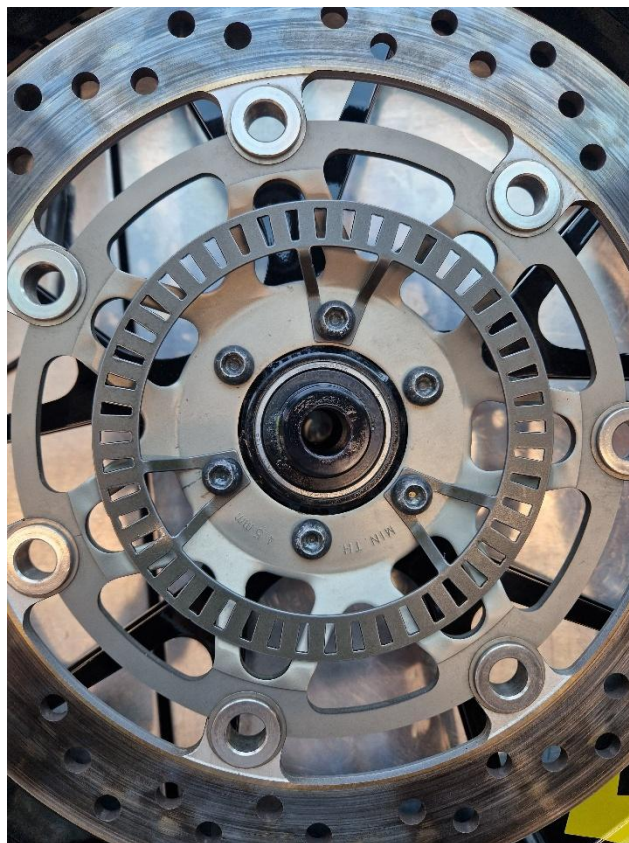


Figure 16: Final pickup rotor design.

3.1.7 Rear Disc

To allow the use of a rear wheel speed sensor while maintaining full rear wheel movement within the swingarm, the decision was made to integrate the speed sensor pickup into the rear brake disc. Initially, a test piece was 3D-printed using PLA to check fitment. Once confirmed, a mild steel prototype was created to ensure the sensor would work properly. Basic tests were conducted by mounting the sensor and disc onto the Honda, connecting the sensor to an Aprilia RS660, and spinning the Honda wheel. The tests successfully verified that the speed was displayed on the Aprilia's dashboard.

Online research of rear discs for sports bikes showed construction using AISI 420 Stainless Steel (Tarazon, 2024). Material research shows that its high iron content makes this material ferrous, combined with high chromium content providing a high level of corrosion resistance (Figure 18). It was decided this material would be best suited for the custom rear disc.



Figure 17: Rear disc mild steel prototype.

Composition overview

Compositional summary

Fe83-88 / Cr12-14 / C0.26-0.35 (impurities: Mn<1, Ni<1, Si<1, P<0.04, S<0.03)

Material family	Metal (ferrous)
Base material	Fe (Iron)

Composition detail (metals, ceramics and glasses)

C (carbon)	0.26	-	0.35	%
Cr (chromium)	12	-	14	%
Fe (iron)	* 82.6	-	87.7	%
Mn (manganese)	0	-	1	%
Ni (nickel)	0	-	1	%
P (phosphorus)	0	-	0.04	%
S (sulfur)	0	-	0.03	%
Si (silicon)	0	-	1	%

Figure 18: AISI 420 stainless steel material properties (Ansys Granta).

3.2 Test Day Results

During the university test day at Pembrey Circuit, a thorough assessment of engine performance was conducted with particular attention given to lambda values to ensure combustion remained within safe parameters. Initial monitoring revealed concerning spikes in lambda at higher RPM ranges, with peak values reaching 1.8 indicating an excessively lean burn condition that required immediate investigation.

The first corrective measure involved removing the safety mesh from the bell mouth opening, as initial observations suggested that fuel from the high injector was accumulating rather than fully entering the combustion chamber. While this adjustment led to some improvement in lambda readings, the values remained higher than expected. Further analysis indicated that the high injector might have been firing unnecessarily at part throttle, potentially causing fuel delivery restrictions due to the throttle butterfly's position. To address this, the injector splitting table was modified to ensure the high injector only fired at wider throttle openings. This modification resulted in additional improvements to lambda stability.

Table 7: Standard injector splitting table.

		Throttle %															
		10	20	30	40	50	60	70	80	90	100	100	100	100	100	100	100
RPM	1500	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	2000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	2500	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	3000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	3500	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	4000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	5000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	6000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	7000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	8000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	9000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	10000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	11000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	12000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	13000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40
	14000	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40	40

Table 8: Modified injector splitting table.

		Throttle %															
		10	20	30	40	50	60	70	80	90	100	100	100	100	100	100	100
RPM	1500	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	2000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	2500	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	3000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	3500	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	4000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	5000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	6000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	7000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	8000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	9000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	10000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	11000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	12000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	13000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40
	14000	100	100	100	100	100	100	100	80	60	40	40	40	40	40	40	40

In parallel, adjustments were made to the injector compensation table, which controls fuel delivery by modifying base injection opening times. Compensation values were increased by 10% across the entire table, enriching the mixture by extending injector open times. This change proved successful, bringing the average lambda down to 0.89, a much more desirable range for optimal combustion.

Beyond fuel mixture tuning, engine braking strategies were another key focus of the test day. Initial runs saw bypass opening values increased by 20% over standard settings, delivering a noticeable boost in engine braking force. A subsequent stint was run with these values reduced by the same margin for comparison. Rider feedback strongly favoured the increased engine braking response, prompting further incremental adjustments of 25% and 30%. However, these finer changes were not as perceptible to the rider, suggesting that data analysis should determine whether the additional increases provided measurable benefits.

Overall, the Pembrey test day returned highly promising results, with the engine performing reliably and both rider and crew chief happy with results. Despite the progress, occasional lambda spikes persisted even after injector adjustments, indicating that additional refinement is necessary. The next phase of development will include dynamometer testing to verify consistent engine operation and long-term reliability. Further data analysis will also be crucial in fine-tuning engine strategies to eliminate remaining inconsistencies and ensure peak performance in future sessions.

3.3 Oska Robertson

3.3.1 Work Content

This project focused on the design and development of adjustable motorcycle rear sets with the objectives of improving adjustability, reducing weight, and enhancing ergonomics. The process involved research, design, development, and analysis of the rear set structure using CAD modelling and finite element analysis (FEA).

3.3.1.1 *Research Carried Out*

- Conducted a comparative study of existing adjustable rear sets.
- Measured dimensions of stock rear sets to ensure compatibility with the motorcycle frame.
- Investigated materials and manufacturing processes for weight reduction and durability.
- Analysed ergonomic factors affecting rider comfort and control.

3.3.1.2 *Designs Carried Out*

- Created a parametric CAD model using Fusion due to difficulty obtaining SolidWorks License.
- Developed an adjustable mechanism for footpeg and lever positioning.
- Designed a modular structure, allowing individual parts to be replaced after a crash.
- Ensured symmetrical left and right components to simplify manufacturing.

3.3.1.3 *Development Carried Out*

- Optimized design for CNC machining using Aluminium
- Evaluated a hollow core footpeg design to reduce weight while maintaining strength.
- Explored carbon fibre integration for further weight savings.

3.3.1.4 *Testing Carried Out*

- Conducted FEA simulations to assess structural integrity under applied loads.
- Simulated maximum force of 1500N at 45° to represent real-world cornering and braking conditions.
- Applied 2× safety factor (3000N) to ensure durability.
- Identified a simulation setup error that showed no force on the connecting beam, requiring further refinement.

3.3.1.5 *Build Carried Out*

- Due to time constraints, a physical prototype was not produced.
- The design is fully prepared for 3D Printing prototype once production is initiated.

3.3.1.6 *Analysis Carried Out*

- Stress Analysis: Maximum stress recorded was 200MPa, well below the material yield strength of 690MPa, confirming a safe design.
- Weight Analysis: Material selection and design optimizations led to a significant reduction in overall weight.
- Manufacturing Feasibility: CNC machining is the most efficient production method, and identical left/right components simplify the process.

3.4 Harry Rogers

3.4.1 Offset Adjustment

The design will have to incorporate built in offset adjustments. Offset adjustment will allow more freedom with geometry changes allowing for finer tuning of stability and handling

3.4.2 Reduced Mass

The design will aim to reduce the overall mass of the assembly without compromising on the strength or stiffness characteristics

3.4.3 Relocation of Steering Damper

The design will isolate the steering damper mount away from the bottom yoke to a standalone mount on the forks. This will allow the steering damper to be moved, giving room for the new intake ducts.

3.4.4 Research

3.4.4.1 *Research Yoke Design*

Firstly, yokes from MotoGP, World Superbikes, British Superbikes, and Moto3 have been researched. It has been found that many top-tier racing teams adjust offset in the frame rather than in the yokes, or they simply use different yokes with various built-in offsets—an approach deemed too expensive for this project. Aftermarket yokes with built-in offset adjustment have also been examined, an example of which is shown in Figure 19 (Robby Moto Engineering, 2021). These yokes often have built in offset adjustment with various designs but were often intended for larger capacity bikes that have greater strength and stiffness requirements. The shape and size of race bike yokes has been observed, revealing that top yokes are generally smaller than bottom yokes, indicating that the bottom clamp carries a greater load, this is like the current yokes fitted to the NSF250R. In Moto3, it has been noted that the top yoke typically uses one pinch bolt, while the bottom uses two. Finally, photos of other yokes from various bikes have been gathered for future inspiration.



Figure 19: Adjustable offset yokes (Robby Moto Engineering, 2021).

3.4.4.2 Research Methods of Offset Adjustment

Offset adjustment methods in other yokes have been researched. It has been found that eccentric oval or circular inserts are commonly used, and these inserts can be changed or flipped to alter the offset. Aftermarket yokes have often been observed to include ± 3 mm of adjustability, so the same approach will be adopted for this design.

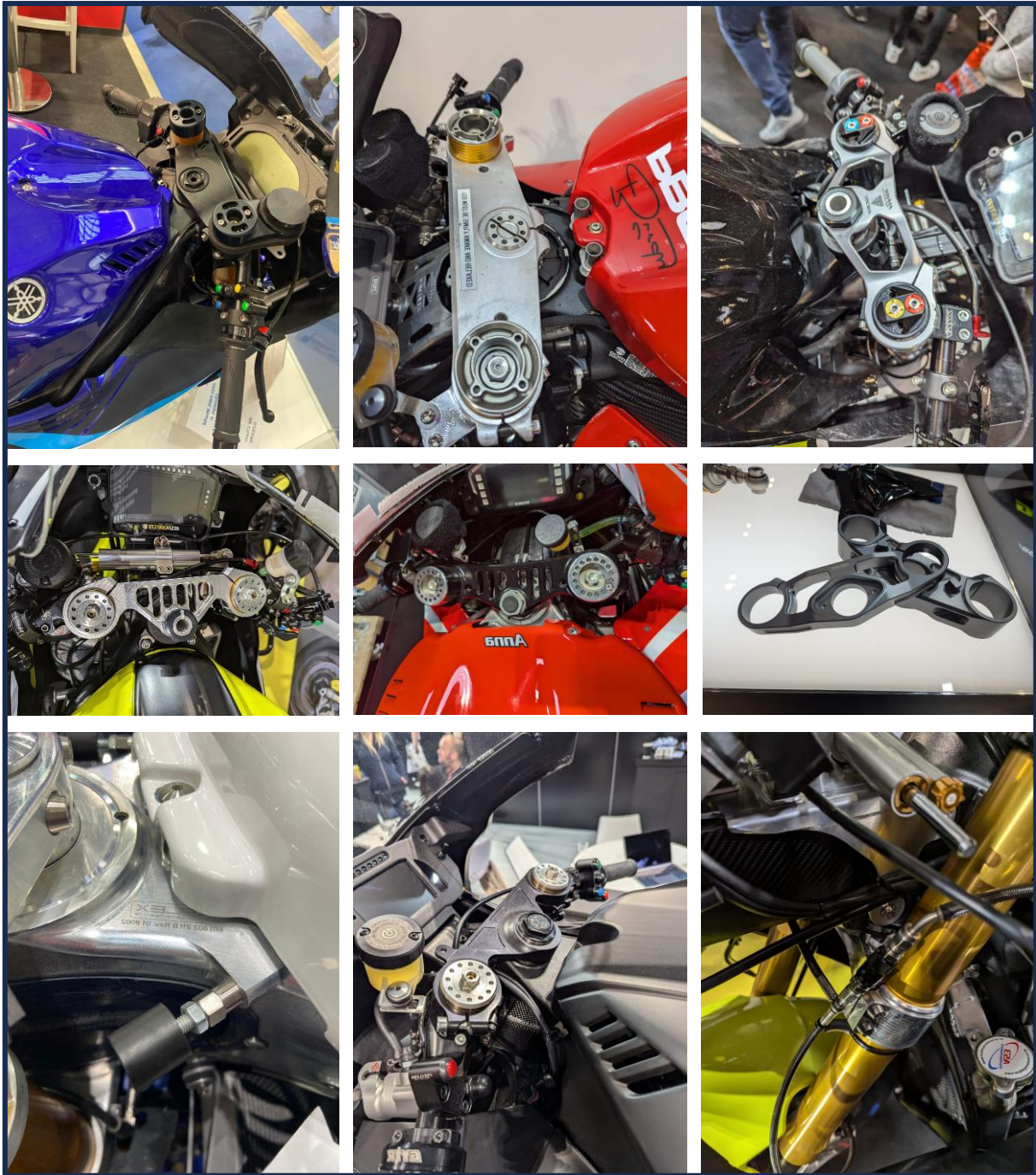


Figure 20: Research photos taken at 2024 NEC bike show.

3.4.4.3 Material Research

The material chosen for this project is 6082 aluminium alloy. This was chosen as it is in stock in the university workshop and has been pre allocated for the project. This material is not natively in SolidWorks, so it has been added in manually. Material properties were gathered from (thyssenkrupp Materials UK, 2023).

3.4.5 Measurements & Force Calculations

3.4.5.1 Yoke Dimensions

- Fork diameter for upper and lower clamps
- Bearing ID for steering stem
- Base offset
- Fork leg width
- Minimum wall thicknesses and depth of yokes
- Weight of all components
- Pinch bolt diameters and thread specifications
- Wheelbase
- Bike mass and rider mass (with full kit)

Table 9: Measured bike geometry and parameters.

Bike parameters		
Fork length below bottom bearing	460	mm
Fork length above bottom bearing	155	mm
wheel radius	289.35	mm
Lever length	749.35	mm
Fork lever length below (l)	0.74935	m
Fork lever length above (l)	0.155	m
Mass of bike	92	kg
Mass of rider	86.9	kg
Total mass (M)	178.9	kg
Horizontal Cog from front (Pb)	551	mm
Horizontal Cog from front (Pb)	0.551	m
Horizontal Cog from rear (b)	638.1	mm
Horizontal Cog from rear (b)	0.6381	m
Vertical Cog (h)	615.2	mm
Vertical Cog (h)	0.65	m
Mass total	178.9	kg
Velocity	21.16	m/2
Radius C	24.64	m/2^2
Gravity	9.81	m/2^2
Lean angle	55	°

Next, the motorcycle's centre of gravity was measured with the rider positioned on the bike. This was determined by placing two scales beneath each wheel and recording the combined weight of the motorcycle and rider with full gear. After this initial measurement, the rear wheel was elevated by 0.63m onto the bench, with the scales still positioned beneath each wheel, and the resulting weight distribution was documented. Using these measurements, along with the known wheelbase, the centre of gravity in the X and Y axes was calculated. This process was conducted for both empty and full fuel tank conditions. The resulting data was subsequently utilised in the force calculations. The results from this can be seen in Table 10.

Table 10: Centre of gravity with & without fuel load.

nsf 250 no fuel				nsf 250 full fuel			
	Weight (kg)		Geometry (m)		Weight (Kg)		Gemoterty (m)
Front	47.6	Wheel Base L	1.217	Front	52.00	Wheel Base L	1.217
Rear	39.00	Front wheel radius	0.289	Rear	42.00	Front wheel radius	0.289
Front Wf (rider)	80.5	Back wheel radius	0.300	Front Wf (rider)	84.30	Back wheel radius	0.300
Rear Wr (rider)	93	Average radius Rav	0.295	Rear Wr (rider)	97.50	Average radius Rav	0.295
Lifted front	35.50	Lift height	0.475	Lifted front	37.00	Lift height	0.475
Lifted Wrlifted (rider)	72.5	Lifted Angle Θ (Degrees)	22.97	Lifted Wrlifted (rider)	74.00	Lifted Angle Θ (Degrees)	22.97

Centre of Gravity (m)		Weight Split (%)		Centre of Gravity (m)		Weight Split (%)	
X	0.548	Front	54.97	X	0.544	Front	55.32
Y	0.411	Rear	45.03	Y	0.447	Back	44.68
Xrider	0.652	Rider Front	46.40	Xrider	0.653	Rider Front	46.37
Yrider	0.634	Rider Rear	53.60	Yrider	0.666	Rider Back	53.63

Rider Weight (Kg)	81.05	Block Height (m)	0.475	Rider Weight (Kg)	81.05	Block Height (m)	0.475
bike weight	86.60			bike weight	94.00		

3.4.6 Calculate Forces from Gathered Dimensions

The next step was to calculate the forces acting on the bike while riding. This would include maximum possible forces while braking, cornering and force generated while going over bumps.

3.4.6.1 Maximum Geometry Limited Braking Forces

The geometry of the bike was mapped out in SolidWorks so the total length from the bottom bearing to the contact patch, including the rake angle, could be established. All forces were calculated at the bottom bearing of the headstock, and this approach was used consistently. the front-end geometry

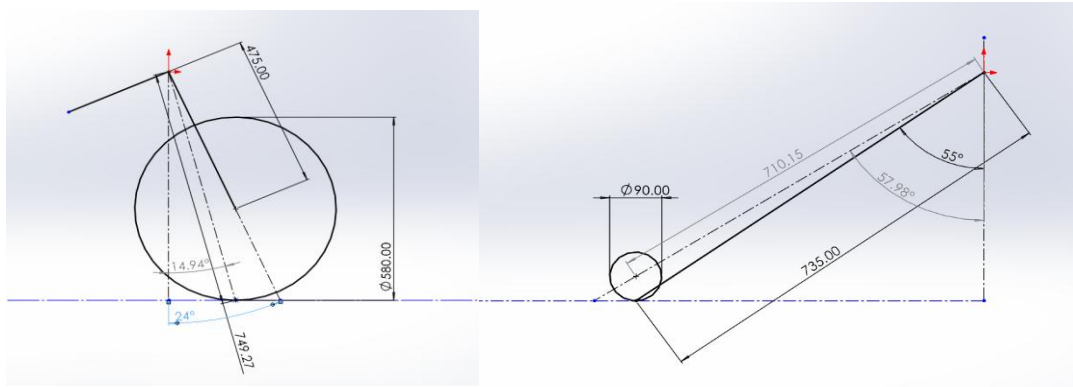


Figure 21: SolidWorks sketches of front-end geometry and tyre corrected lean angle.

was also mapped out in SolidWorks at 55° lean angle, along with the tyre profile to find corrected lean angle. Both these sketches can be seen in Figure 21.

The equation in Figure 22 from MotoSpec, (2019) was then applied to determine the maximum geometry-limited deceleration in G, which was converted to m/s^2 and combined with the mass of the bike and rider to calculate the maximum horizontal force at the contact patch. Finally, that deceleration value was used to find the maximum vertical force (NF) acting on the contact patch under braking. This same geometric data later served as the basis for FEA simulations.

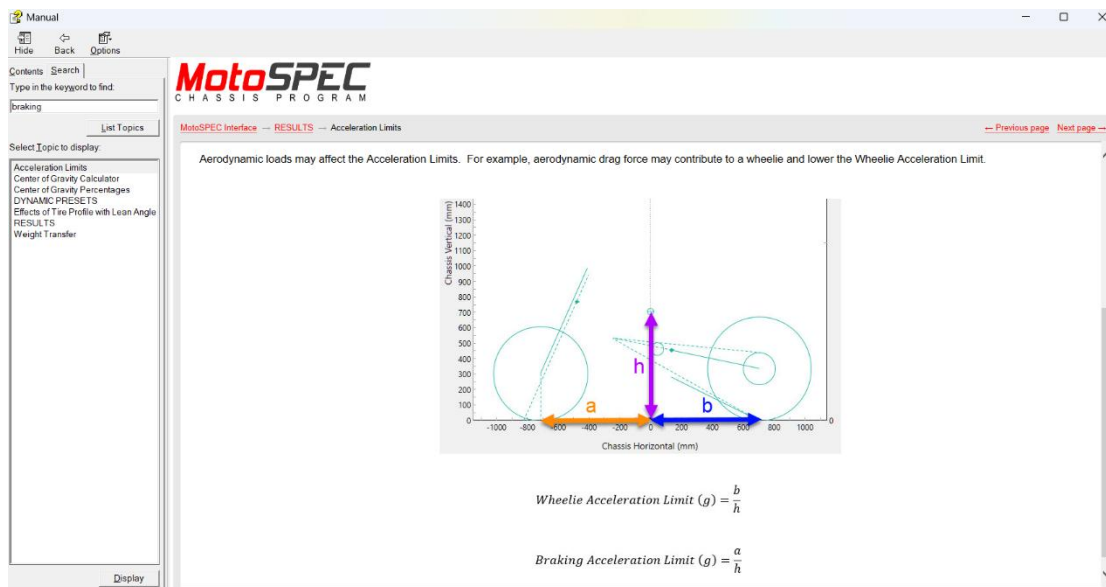


Figure 22: Geometry limited breaking equations in (MotoSpec, 2019).

3.4.6.2 Maximum Lateral & Vertical Forces at Lean Angle

Lap data from a Moto3 bike around a lap of Jerez was utilised to determine the velocity and turn radius in the final corner, which, combined with the gravity constant, was used to compute the bike's lean angle. The bike's mass, along with its velocity and corner radius, was then applied to calculate the centripetal forces, while Mg was also obtained for later use in FEA simulations (Cossalter, 2006).

3.4.6.3 Bump Forces

Bump force was next derived from data recorded during the same Jerez lap by examining suspension position traces in the last corner, where a curb was encountered. The curb height and duration were measured from the suspension position trace, and suspension velocities were noted. By using the starting and ending velocities over the bump duration, a force was calculated. This force was then added to the braking and cornering forces to simulate a worst-case scenario for the bike.

3.4.7 Calculated Force Results

Table 11: calculated forces acting on the front end.

Horizontal Forces on Bottom Yoke at Max Possible Braking			Horizontal Forces on Bottom Yoke at Max Measured Braking		
Max Deceleration	0.848	g	Max Deceleration	0.650	g
Max Deceleration	8.313	m/s ²	Max Deceleration	6.374	m/s ²
Reaction Force	1487.192	N	Reaction Force	1140.360	N
Torque at Bottom Yoke	1114.427	N/m	Torque at Bottom Yoke	854.529	N/m
Horizontal Forces on Top Yoke at Max Possible Braking			Horizontal Forces on Top Yoke at Max Measured Braking		
Max Deceleration	0.848	g	Max Deceleration	0.650	g
Max Deceleration	8.313	m/s ²	Max Deceleration	6.374	m/s ²
Reaction Force	1487.192	N	Reaction Force	1140.360	N
Torque at Top Yoke	230.515	N/m	Torque at Top Yoke	176.756	N/m
Vertical Front Wheel Force at Max Possible Braking			Vertical Rear Wheel Force at Max Possible Braking		
Gravity Constant	9.810	m/s ²	Gravity Constant	9.810	m/s ²
Max Deceleration	0.895	G	Max Acceleration	0.940	G
Max Deceleration	8.313	m/s ²	Max Acceleration	9.218	m/s ²
Force Front	2022.628	N	Force Rear	266.551	N
Max Lateral Force @ 55°			Bump Parameters		
Centripetal Force	3250.880	N	Height	0.021	m
mg	1755.009	N	Duration	0.037	s
			Final Velocity	0.038	m/s
			Starting Velocity	0.180	m/s
			Acceleration	3.838	m/s ²
			Force	686.589	N
			Rake Angle	24.000	°

3.4.8 Offset Mechanism

Eccentric oval inserts had been chosen as the offset method and had been designed in SolidWorks to align the yokes with the bike's critical dimensions. The final mechanism, shown in Figure 23, had been established to include a fixed steering stem (retained in the bike during offset adjustment), eccentric ovals fitted into matching cutouts in the yokes, and identical preload and bottom yoke lockrings to streamline offset changes.

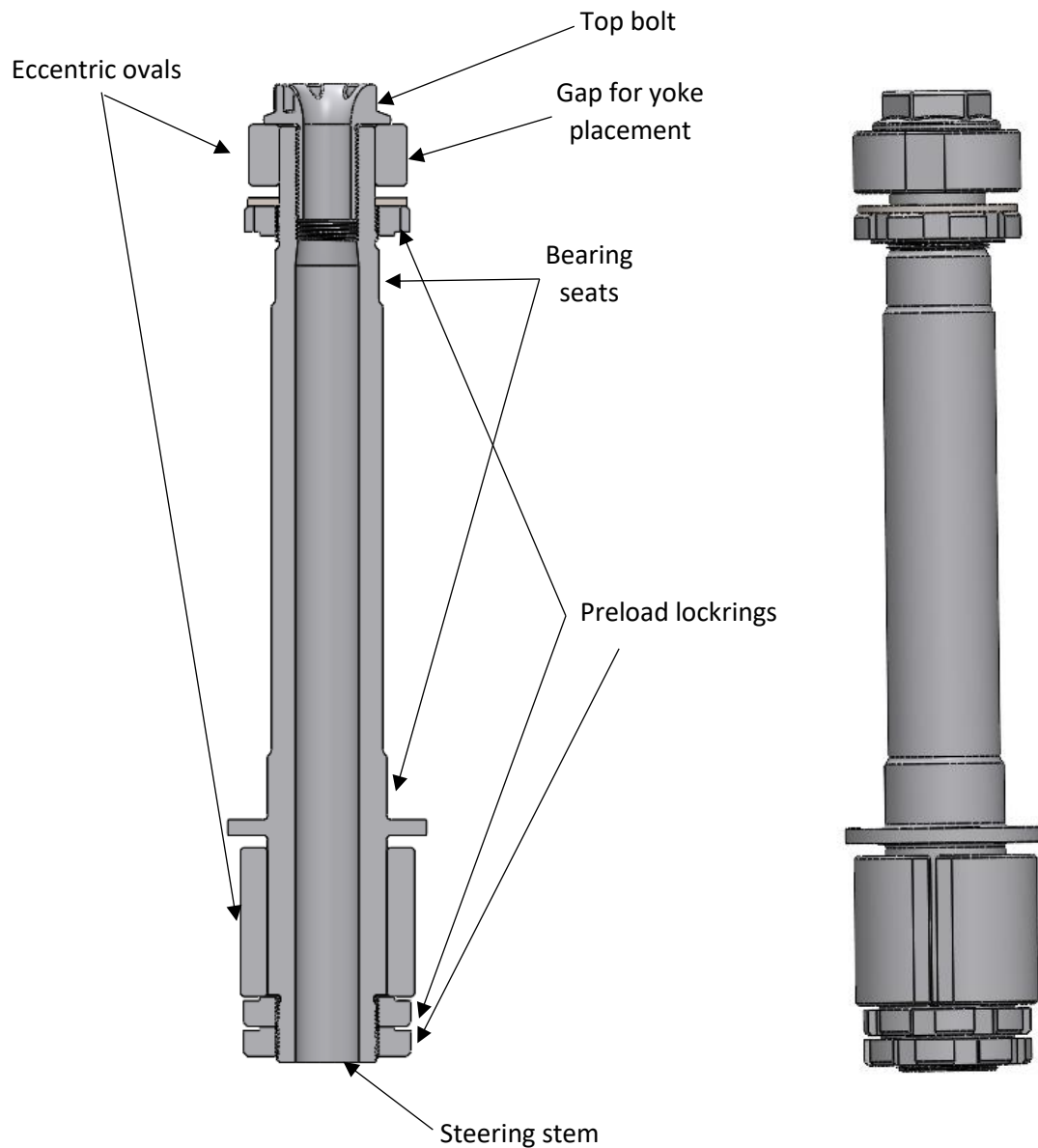


Figure 23: Steering stem and offset mechanism diagram.

3.4.9 Topology Study

3.4.10 Yoke Blanks for Topology Study

A baseline shape from which the yokes would be modelled was created using a SolidWorks topology study. To begin, a fully solid top and bottom yoke were formed, making sure that all major dimensions were incorporated, including fork diameter, factory offset, fork spacing, and measurements for the offset insert. In addition, the thickness of the yokes were intended for two M8 pinch bolts on the bottom yoke and a single M8 pinch bolt on the top yoke.

Next, a stress analysis simulation was carried out. In this simulation, the yokes were constrained at the stem's oval, and the loads were transferred through the fork leg clamps both horizontally and vertically. Once this stress analysis was concluded, its results were employed in the topology study. The objective of that study was to minimise mass while preserving structural integrity and adhering to certain design guidelines. Consequently, a minimum wall thickness of 5mm was enforced, and a safety factor of 1.5 was specified to account for unexpected loading conditions. Once completed, the shapes that emerged were taken as a baseline for developing the final design. The generated shape as well as the original yokes can be seen in Figure 24.

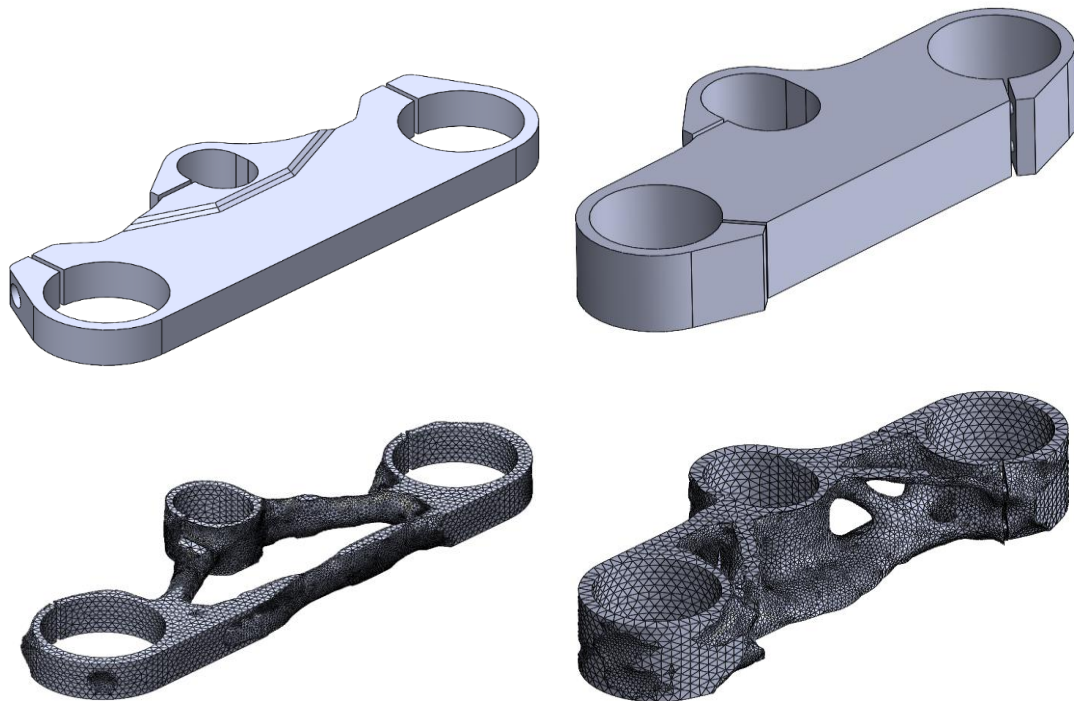


Figure 24: Topology subjects before and after the study finished.

3.4.11 Modelling & simulation Design Optimisation

3.4.11.1 First Draft

Building upon the shape that had been established in the topology study, a first-draft yoke design had been created. This preliminary design had been modelled on the rough form of the topology samples and would serve as a foundation for further development once the FEA tests had been conducted. The top and bottom yoke, which can be seen in Figure 25, have been assembled with a test stem serving as the base feature.

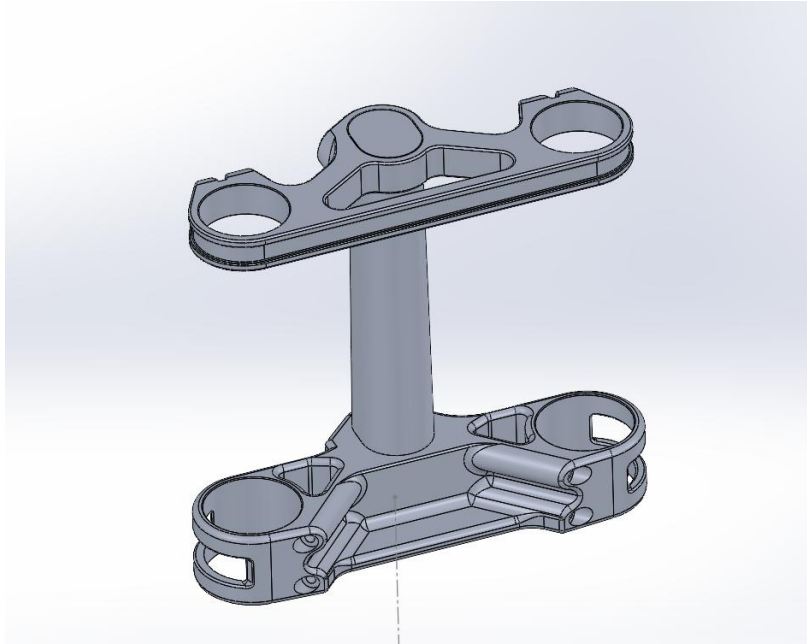


Figure 25: first draft yoke design post topology study.

3.4.11.2 FEA Set Up & Execution

The next step was to use the previously calculated forces in Table 11 to create a series of simulations for this design, as well as for all subsequent designs. These simulations would remain consistent and unchanged throughout to preserve continuity in the analysis.

3.4.11.3 Longitudinal, Braking FEA Simulation

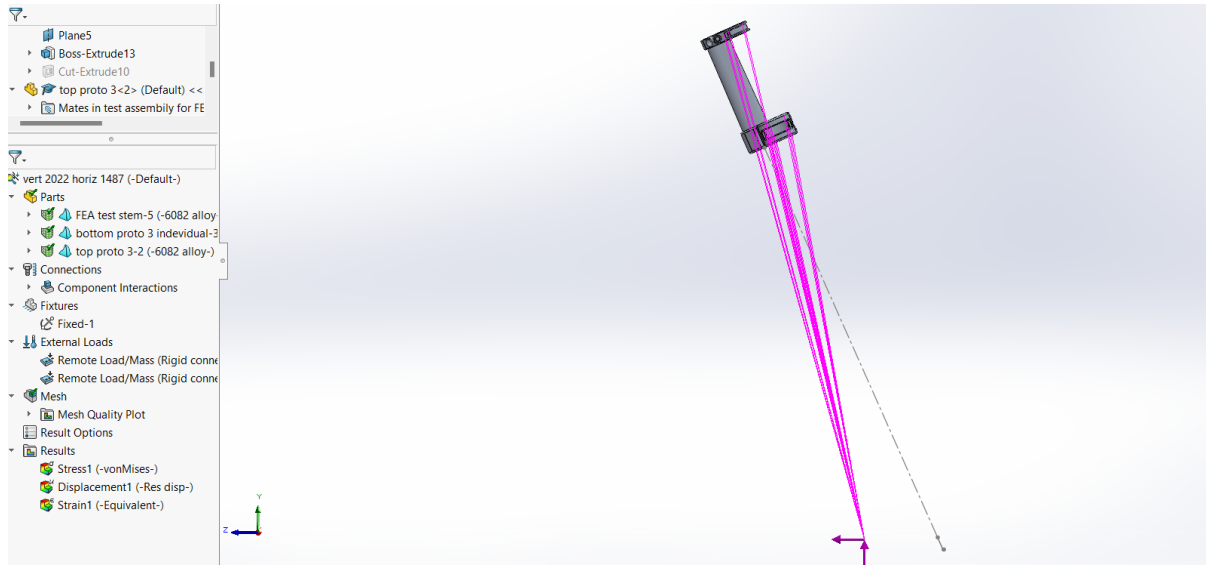


Figure 26: Longitudinal/braking FEA simulation on first draft.

The first simulation has been created to assess the longitudinal, braking load conditions. The assembly has been oriented in SolidWorks at 24° , thereby representing the yokes at the bike's rake angle. The yokes have then been constrained at the stem so that all forces are directed onto them. Next, a sketch has been produced in the stem's part files, and a reference point has been placed at the contact patch previously identified in Figure 21. Next, two remote point load forces have been introduced into the simulation at the contact patch point, both directed toward the fork leg clamps. One has had the longitudinal braking force applied rearward, and the other has had NF applied upward. The material has been set to 6082 alloy, with a blended curvature-based mesh size ranging from 22mm down to 1.13mm, and large deformation has been deactivated. During the project's research phase, this constraint method was employed by Alexandre et al., (2021) in a paper looking at yoke design optimisation. Consequently, a similar approach has been adopted for this project.

3.4.11.4 Lateral, Mid Corner FEA Simulation

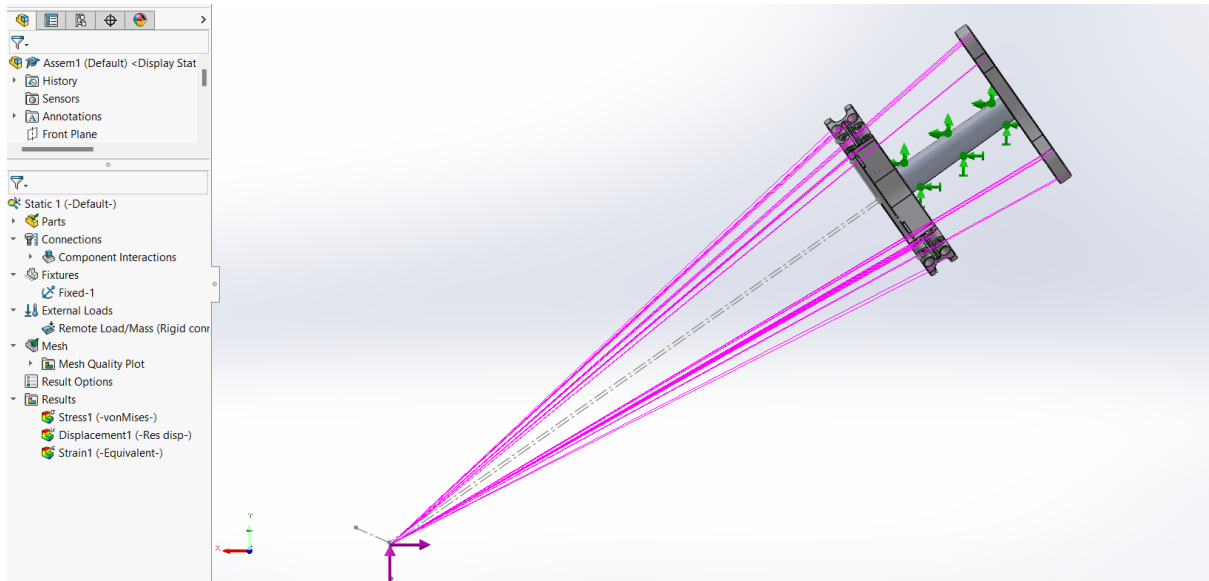


Figure 27: lateral/cornering FEA simulation on first draft.

The second FEA simulation has been created to represent cornering forces. It has been established in a manner similar to the braking simulation. The yokes have been imported into SolidWorks at 55° of lean angle, and the forces have been applied in the same way as before. The centripetal forces have been directed horizontally toward the yokes, while the Mg force has been applied vertically upward. once again, the material has been set to 6082 alloy, with a blended curvature-based mesh size ranging from 22mm down to 1.13mm, and large deformation has been deactivated. Research from Cossalter, (2006) has demonstrated how these forces act on the chassis, and this knowledge has guided the simulation setup.

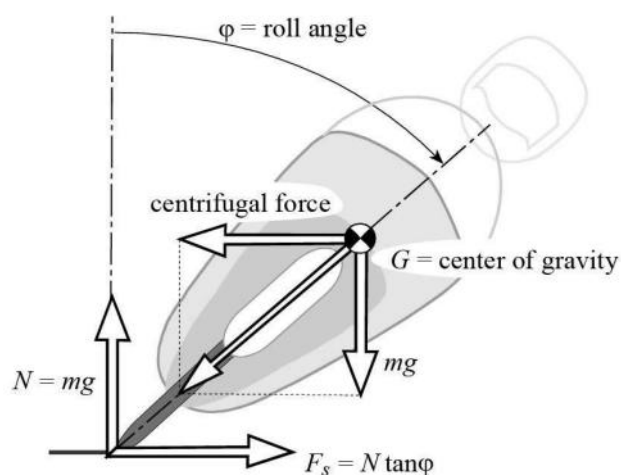


Figure 28: diagram explaining lateral forces acting on a motorbike mid corner (Cossalter, 2006).

3.4.12 FEA Analysis

Looking at the braking simulation, the FEA results have confirmed that the required strength margin for braking loads has been comfortably met by the current yoke design, with yield stress maintained well below critical levels. It has been revealed by the stress distribution that certain regions remain relatively lightly loaded, indicating the feasibility of introducing weight-saving refinements without compromising structural integrity. By thinning or contouring these low-stress areas, overall mass can be reduced. At the same time, low displacement values have indicated that sufficient rigidity has been preserved.

Results from the cornering simulation show stresses comfortably below the yield threshold. these cornering results have confirmed that ample structural margin has been achieved by the first yoke design. It has been shown by the stress contours that certain areas carry comparatively low loads, meaning material can be removed without threatening structural integrity. Displacement under lateral loads has remained minimal. Localised stress regions around clamp bores and fillet transitions have been identified well within safe limits, and minor shape or thickness modifications can be introduced for further refinement. Results from both simulations can be seen in Figure 29. The braking test is shown above, and the cornering test .

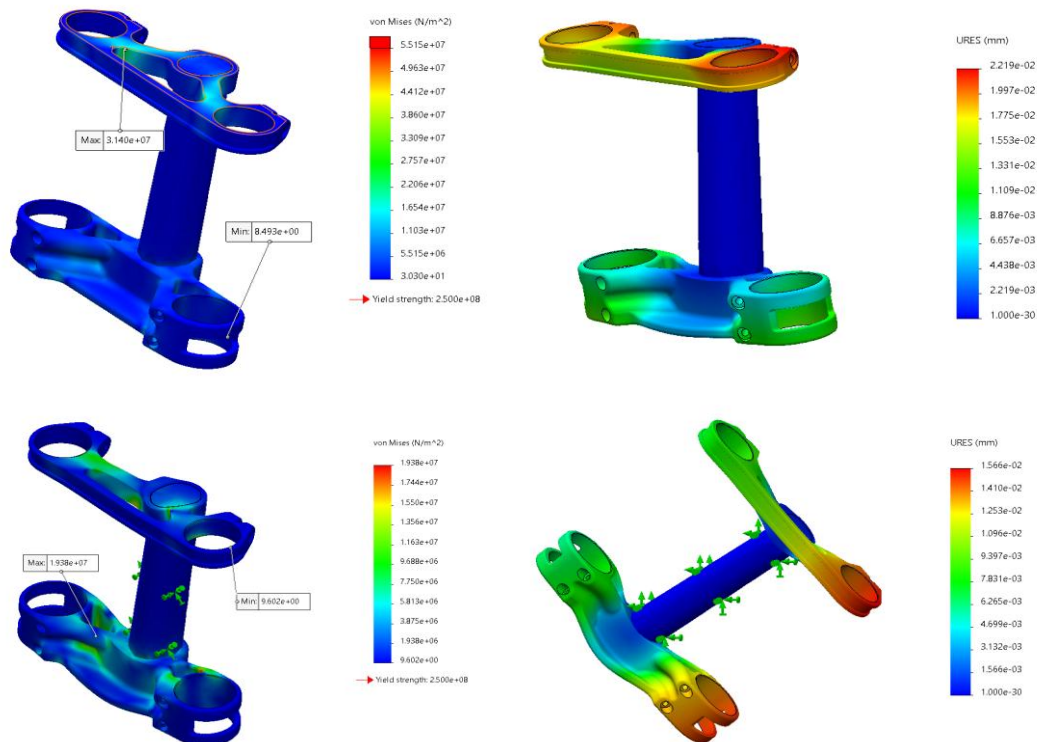


Figure 29: Braking and Cornering FEA simulation results.

3.4.13 Simulation Driven Development

From the FEA results gathered above, it was then possible to begin refining the top and bottom yoke models. Every iteration was assembled in the same way as the draft so the solutions could be carried out. Photographs of the developed yokes can be found in Figure 30 and Figure 31. lock stops were also integrated into the bottom yoke. These were replaceable to allow for different sizes to be used with different offset positions.

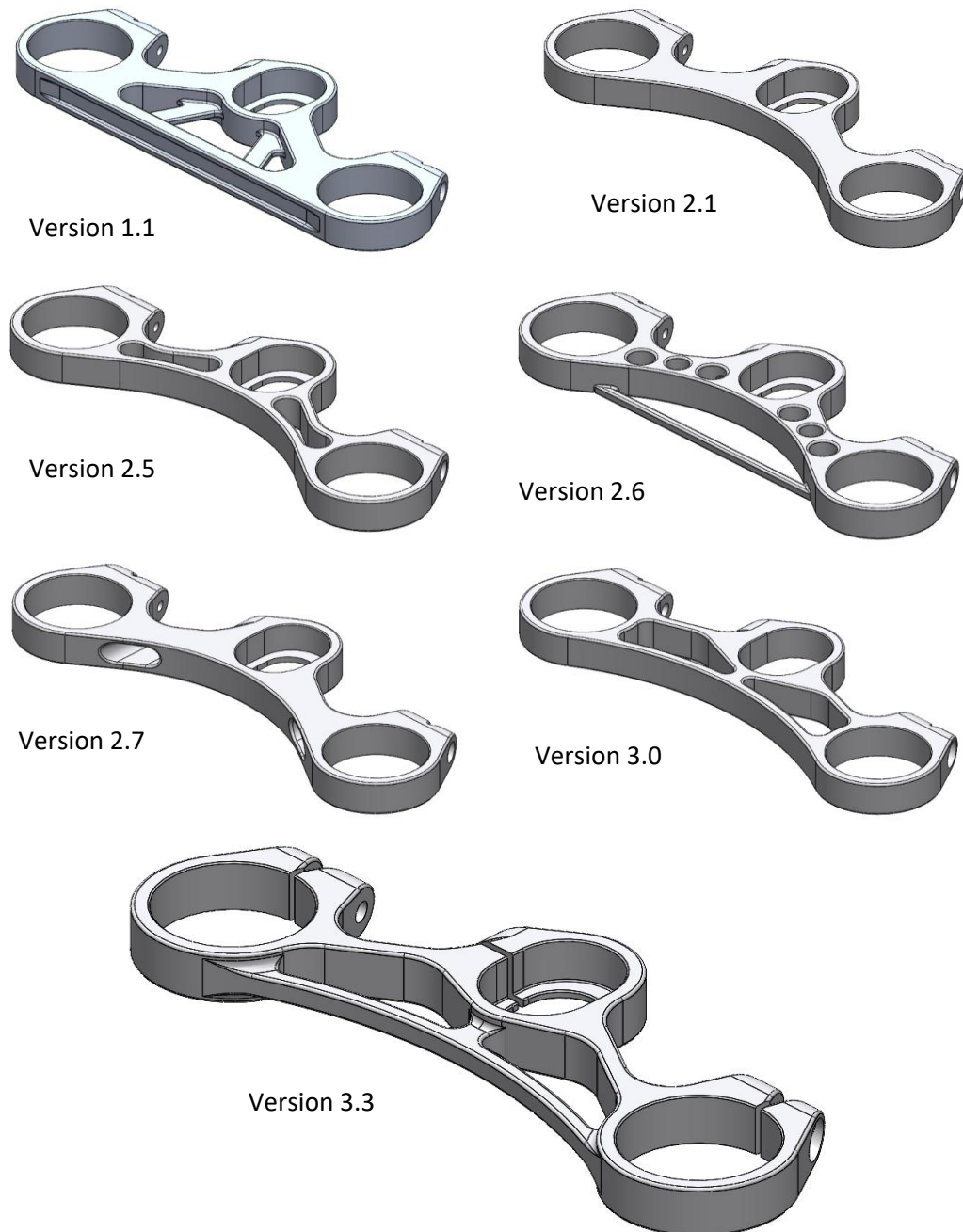


Figure 30: Top yoke development versions.

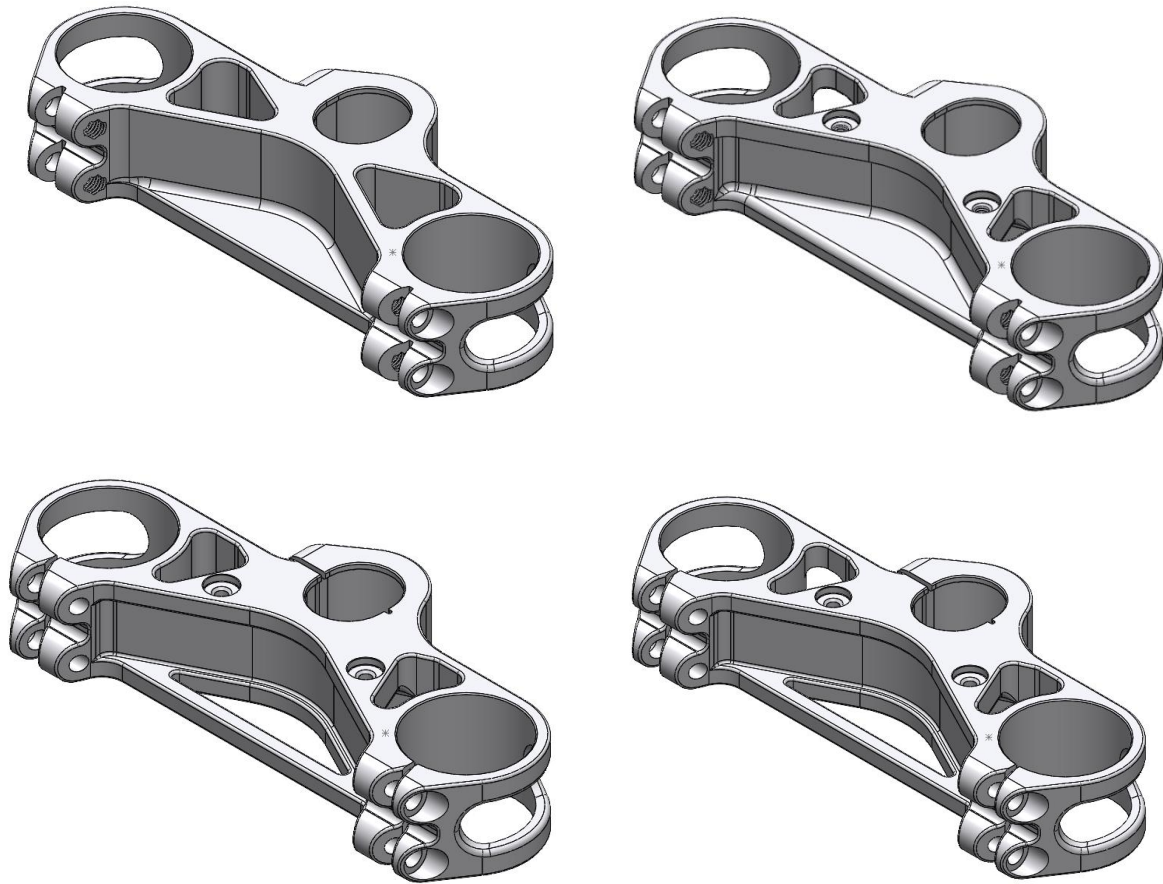


Figure 31: Bottom yoke development versions.

3.4.14 FEA Validation

3.4.14.1 Validate SolidWorks FEA Process with Analytical Solutions

To validate SolidWorks FEA to ensure it is calculating stress, displacement and Strain correctly, it was compared to manually calculated solutions.

3.4.14.2 Cantilever Beam Bending Test

First validation was a cantilever beam test. This was done by calculating the Von Mises stress, resultant displacement and equivalent strain on a 6082-aluminium beam. Table 12 displays the material properties and dimensions for the test.

Table 12: 6082 aluminium beam properties & bending parameters.

Parameter	Symbol	Value	Units
Beam Length	L	0.100	m
Beam Height	H	0.010	m
Beam Width	B	0.020	m
Beam Cross-Section	B*H	0.200	m
Applied Force	F	500	N
Young's Modulus	E	7.00E+10	Pa
Yield Strength	σ_y	2.50E+08	Pa
Poisson's Ratio	ν	0.33	–
Density	ρ	2700	kg/m ³
Outer Fibre Distance	c	0.005	m
Second Moment of Area	I	1.67E-09	m ⁴

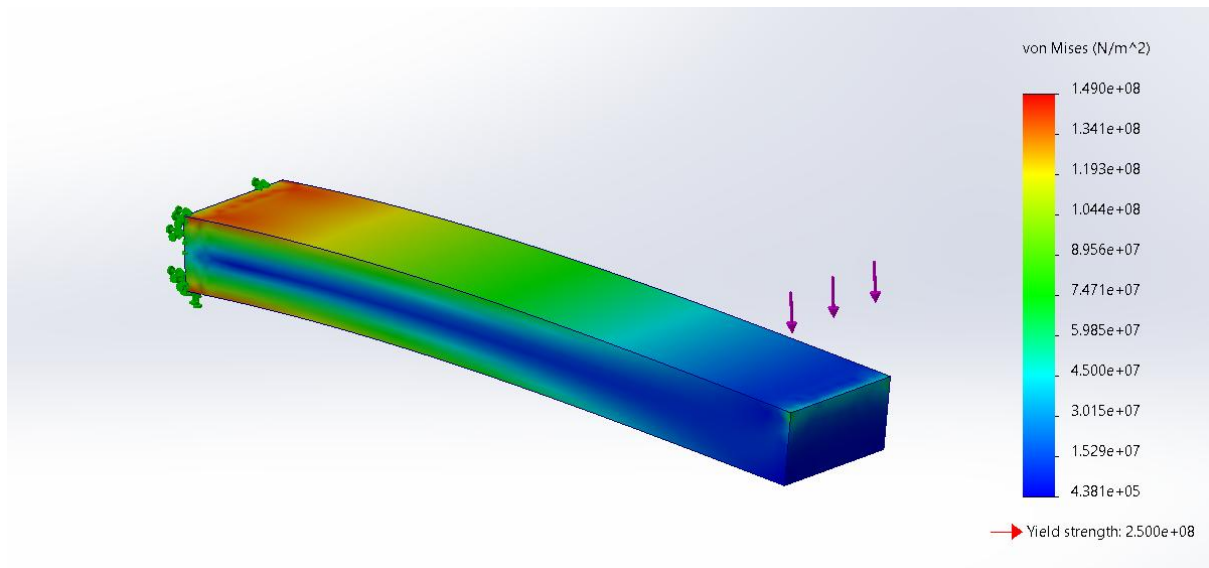


Figure 32: SolidWorks 2023 Bending simulation model.

3.4.14.2.1 Von Mises Stress

Maximum Bending Moment

$$M = F \times L$$

$$M = 500 \times 0.100 = 50 \text{ N}\cdot\text{m}$$

Second Moment of Area (Rectangular Cross Section)

$$I = (b \times h^3) / 12$$

$$I = (20 \times 10^3) / 12 = 1.67 \times 10^{-9} \text{ m}^4$$

Outer Fiber Distance

$$c = h / 2 = 10 / 2 = 0.005 \text{ m}$$

Bending Stress at Outer Fiber

$$\sigma_{\text{max}} = (M \times c) / I$$

$$\sigma_{\text{max}} = 1.5 \times 10^8 \text{ N/m}^2 (150 \text{ MPa}).$$

Von Mises Stress in Pure Bending

$$\sigma_{\text{VM}} = 150 \text{ MPa}.$$

3.4.14.2.2 Equivalent Strain

Strain via Hooke's Law

$$\epsilon_{\text{max}} = \sigma_{\text{max}} / E$$

$$\epsilon_{\text{max}} = (1.50 \times 10^8) / (7.0 \times 10^{10}) = 2.14 \times 10^{-3}$$

3.4.14.2.3 Resultant Displacement

Maximum Deflection Formula

$$\delta = (F \times L^3) / (3 \times E \times I)$$

$$\delta = (500 \times (0.100)^3) / (3 \times (7.0 \times 10^{10}) \times (1.67 \times 10^{-9}))$$

Numerical Calculation

$$L^3 = (0.100)^3 = 0.001 \text{ m}^3$$

$$\text{Numerator} = 500 \times 0.001 = 0.5$$

$$\text{Denominator} = 3 \times (7.0 \times 10^{10}) \times (1.67 \times 10^{-9}) = 350.7$$

$$\delta = 0.5 / 350.7 = 0.00143 \text{ m} = 1.43 \text{ mm}$$

3.4.14.3 Tensile Test

Next, a tensile test was completed. This was done by calculating the Von Mises stress, resultant displacement and equivalent strain on a 6082-aluminium beam. Table 13 displays the material properties and dimensions for the test.

Table 13: 6082 aluminium beam properties and Tensile/Axial parameters.

Parameter	Symbol	Value	Units
Beam Length	L	0.100	m
Beam Height	H	0.010	m
Beam Width	B	0.020	m
Cross-Sectional Area	A	0.200	m ²
Applied Force	F	3000	N
Young's Modulus	E	7.00E+10	Pa
Yield Strength	σ_y	2.50E+08	Pa
Poisson's Ratio	ν	0.33	–
Density	ρ	2700	kg/m ³
Calculated Axial Stress	σ	1.50E+07	Pa
Calculated Strain	ϵ	2.14E-04	–

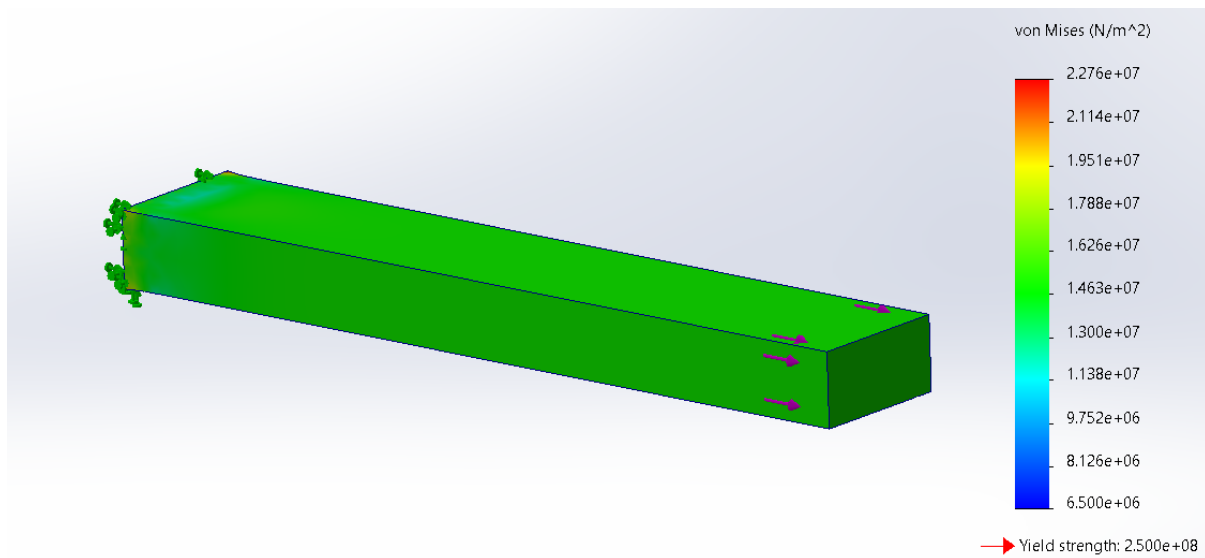


Figure 33: SolidWorks 2023 Tensile/Axial simulation model.

3.4.14.3.1 Von Mises Stress

Cross-Sectional Area

$$A = b \times h$$

$$A = 20 \text{ mm} \times 10 \text{ mm} = 200 \text{ mm}^2.$$

$$200 \text{ mm}^2 = 200 \times 10^{-6} \text{ m}^2 = 2.0 \times 10^{-4} \text{ m}^2.$$

Normal (Axial) Stress

$$\sigma = F / A$$

$$\sigma_{\text{Max}} = 3000 \text{ N} \div (2.0 \times 10^{-4} \text{ m}^2) = 1.5 \times 10^7 \text{ N/m}^2 = 15 \text{ MPa}.$$

$$\sigma_{\text{VM}} = \sigma = 15 \text{ MPa}.$$

3.4.14.3.2 Equivalent Strain

$$\varepsilon = \sigma / E$$

$$\varepsilon_{\text{VM}} = (1.5 \times 10^7) / (7.0 \times 10^{10}) = 2.14 \times 10^{-4}$$

3.4.14.3.3 Resultant Displacement

Cross-Sectional Area

$$A = b \times h$$

$$A = 2.0 \times 10^{-4} \text{ m}^2$$

Axial Elongation Formula

$$\Delta = (F \times L) / (E \times A)$$

Substitute Known Values

$$\text{Numerator: } F \times L = 3000 \text{ N} \times 0.100 \text{ m} = 300 \text{ N}\cdot\text{m}$$

$$\text{Denominator: } E \times A = (7.0 \times 10^{10} \text{ Pa}) \times (2.0 \times 10^{-4} \text{ m}^2) = 1.4 \times 10^7$$

Calculate Elongation

$$\Delta = 300 / (1.4 \times 10^7) = 2.14 \times 10^{-5} \text{ m} = 0.0214 \text{ mm}$$

3.4.14.4 FEA validation Results

Table 14: Results for cantilever beam bending test.

Cantilever beam bending test					
Analytical Solution			SolidWorks 2023		
Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)	Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)
1.50E+08	1.43E+00	2.14E-03	1.49E+08	1.42E+00	2.11E-03

SolidWorks 2023 and Analytical solution Percentage error		
Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)
100.67%	100.56%	101.42%

Table 15: Results table for Tensile/Axial test.

Tensile test					
analytical solution			SolidWorks 2023		
Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)	Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)
1.50E+07	2.14E-02	2.14E-04	1.50E+07	2.13E-02	2.21E-04

SolidWorks 2023 and Analytical solution Percentage error		
Von-Mises (N/m ²)	Displacement URES (mm)	Strain (ESTRN)
100.00%	100.38%	96.70%

Looking at Table 14 and Table 15, it can be seen that SolidWorks results generally agree with the analytical method, with a maximum error of 4% in the equivalent strain during the tensile test. In *A First Course in the Finite Element Method*, (Logan, 2007), it has been explained that discrepancies of approximately 5–10% between FEA and closed-form solutions are typically considered normal, arising from discretisation errors and slight variations in boundary conditions or material modelling. Therefore, a 4% deviation is well within the accepted range, thereby validating the accuracy of the SolidWorks simulation, and ensuring that the development of the yokes can continue.

3.4.15 Final Yoke Design & Prototype

3.4.15.1 Physical Design

In Figure 34, the final design of the yokes has been presented. The top yoke's shape has been revised from the topology, with thicker spires connecting the fork clamps to the stem and thinner bracing across the front. The bottom yoke has been retained closer to the topology, with hollowed areas around main load paths to reduce weight. The lock stop locations have been placed onto main support splines to further minimise mass. The pinch bolt locations on the top and bottom yoke have been oriented for easy socket access while the yokes are installed, and the bike's fairing is in place. Finally, M3 bolt holes have been introduced on the underside of the bottom yoke to serve as mounting points for a carbon-fibre base plate. Images can be found in Figures 35 & 36.

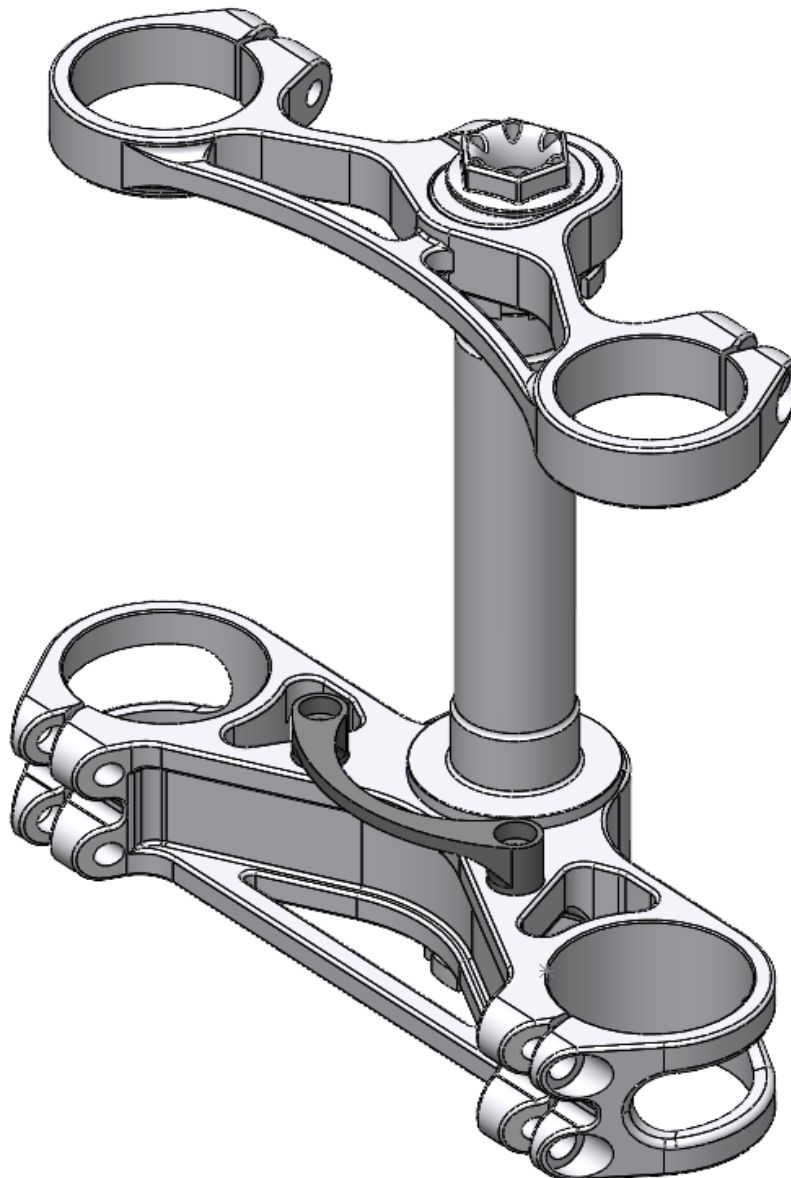


Figure 34: Final yoke design assembly.

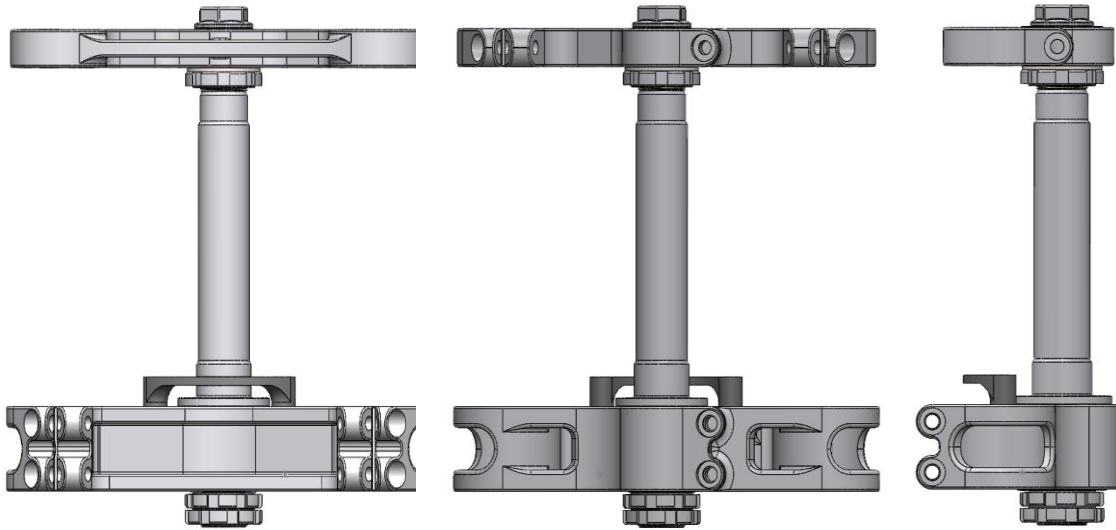


Figure 35: Yoke assembly front, back and side perspective.

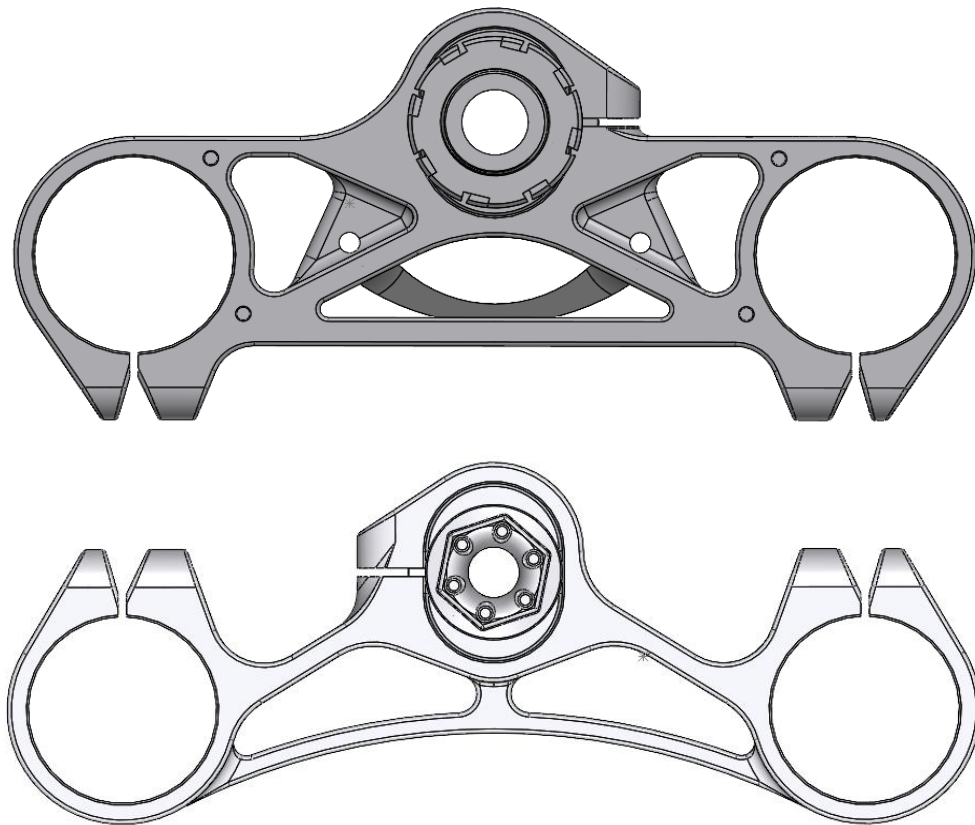


Figure 36: Final yoke design from above and below perspective.

3.4.16 FEA Results

The following figures show the FEA results for the final top and bottom yoke designs, with the 686N bump force added. This shows a realistic worst-case scenario that the yokes are likely to see. The expected forces are much lower.

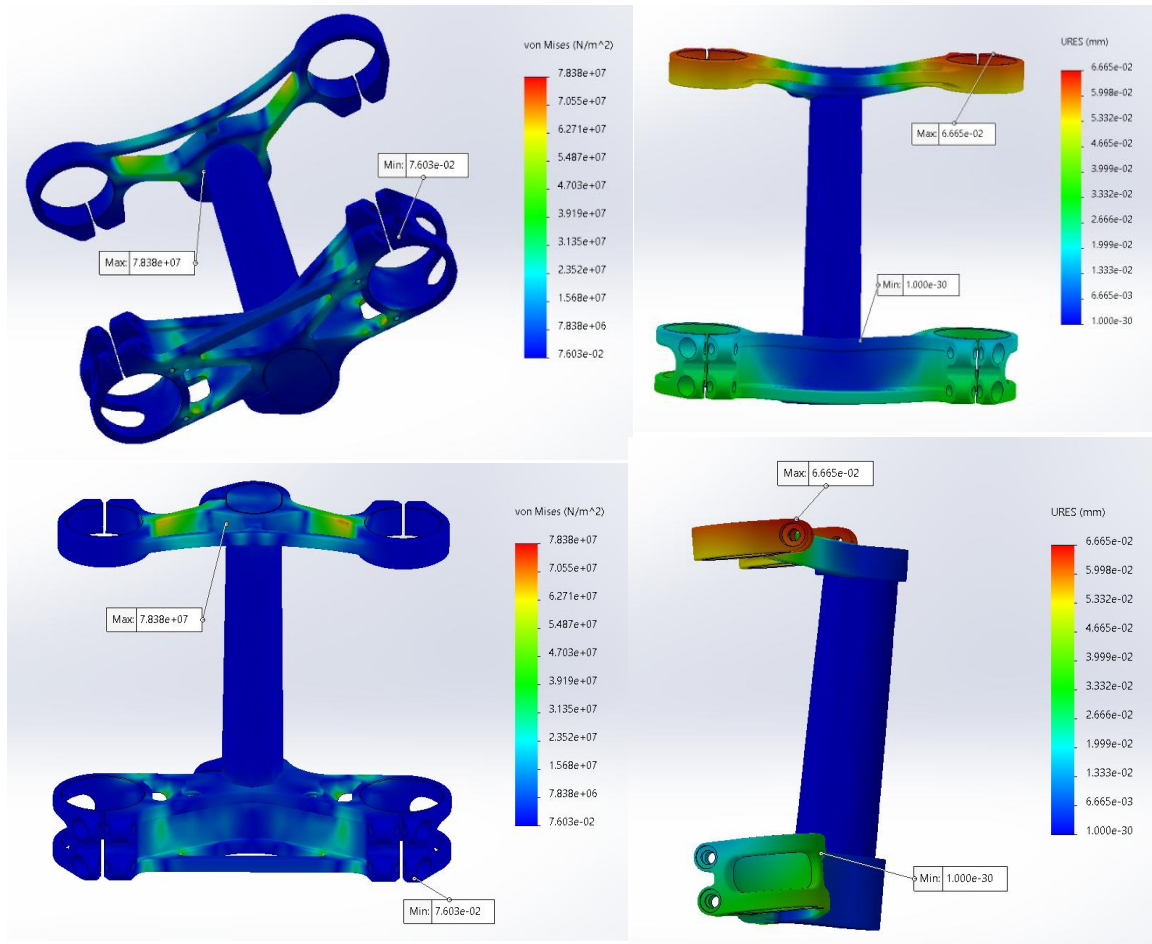


Figure 37: Breaking FEA simulation results.

In Figure 37, the braking simulation combined with the bump force was examined. The top yoke was found to experience the highest stress and deformation, with values of 7.838E+07Pa and 6.665E-02mm, respectively. All components were manufactured from 6082 aluminium, whose yield strength is 2.5E+08Pa. Under these worst-case loads, the resulting maximum stress remains well below the material's yield strength, providing a safety margin of roughly 3.2. Consequently, the yoke assembly can withstand forces more than triple those encountered in this combined loading scenario before reaching its yield limit.

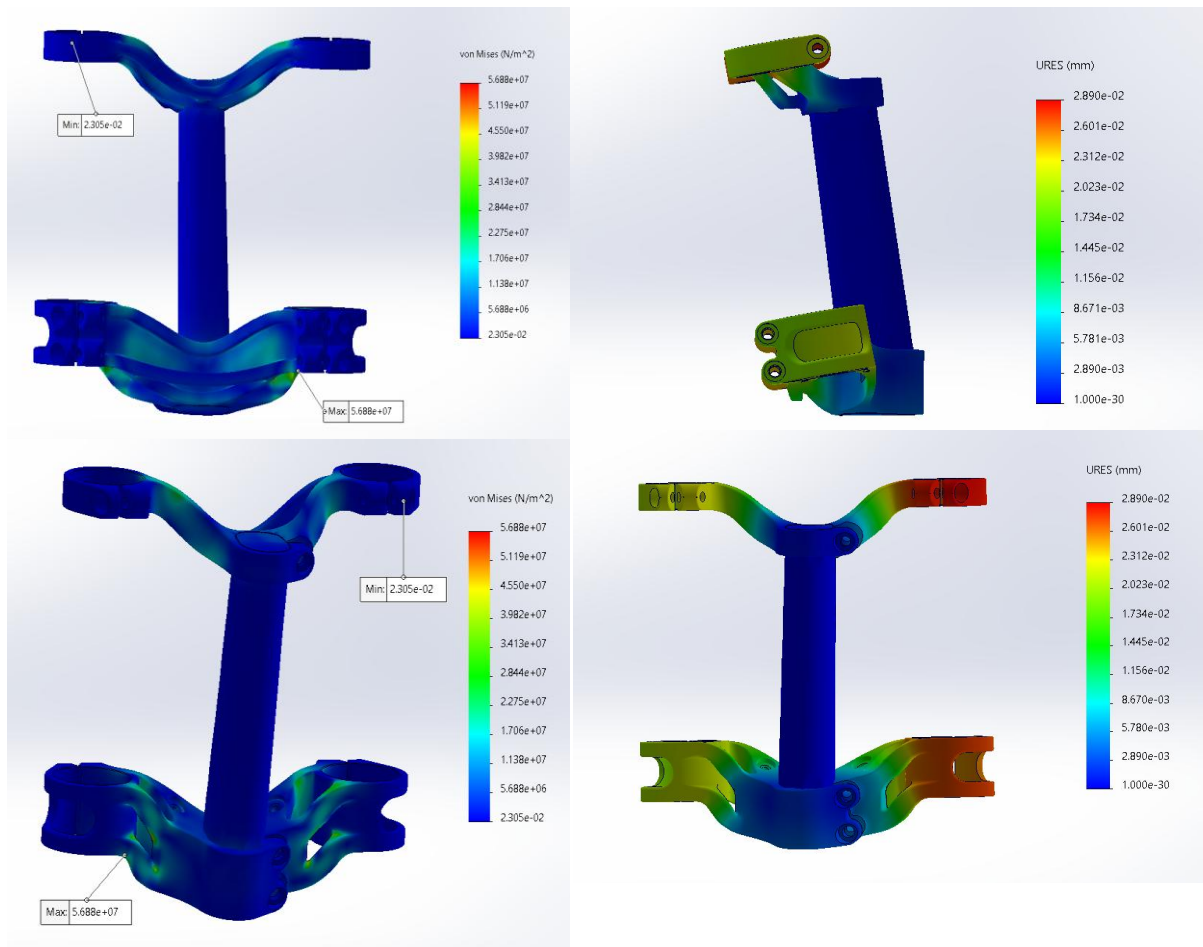


Figure 38: Mid corner FEA simulation results.

Mid-corner load scenario combined with a bump force can be seen in Figure 38. The top yoke exhibits a peak stress of approximately $5.688 \times 10^7 \text{ Pa}$, while the maximum displacement reaches around $2.89 \times 10^{-2} \text{ mm}$. Both values remain comfortably below the previously established yield threshold, resulting in a safety margin of about 4.4. This indicates that the yoke is operating well within safe limits under these combined mid-corner and bump conditions.

It has been demonstrated in both simulations that the yokes remain well within the loads encountered, allowing scope for additional refinement. Numerous areas have been identified where further material removal could reduce weight. To refine the yokes even more, real-world data from both the new and old assemblies must be collected, which would provide vital insights into their respective stress and flex characteristics.

3.4.17 3D Printed Prototype

Once the design was finalised and FEA yielded positive results, a Physical prototype could be produced. All parts were 3D printed out of PLA to test fit together to ensure all dimensions are correct. This can be seen in Figure 39.

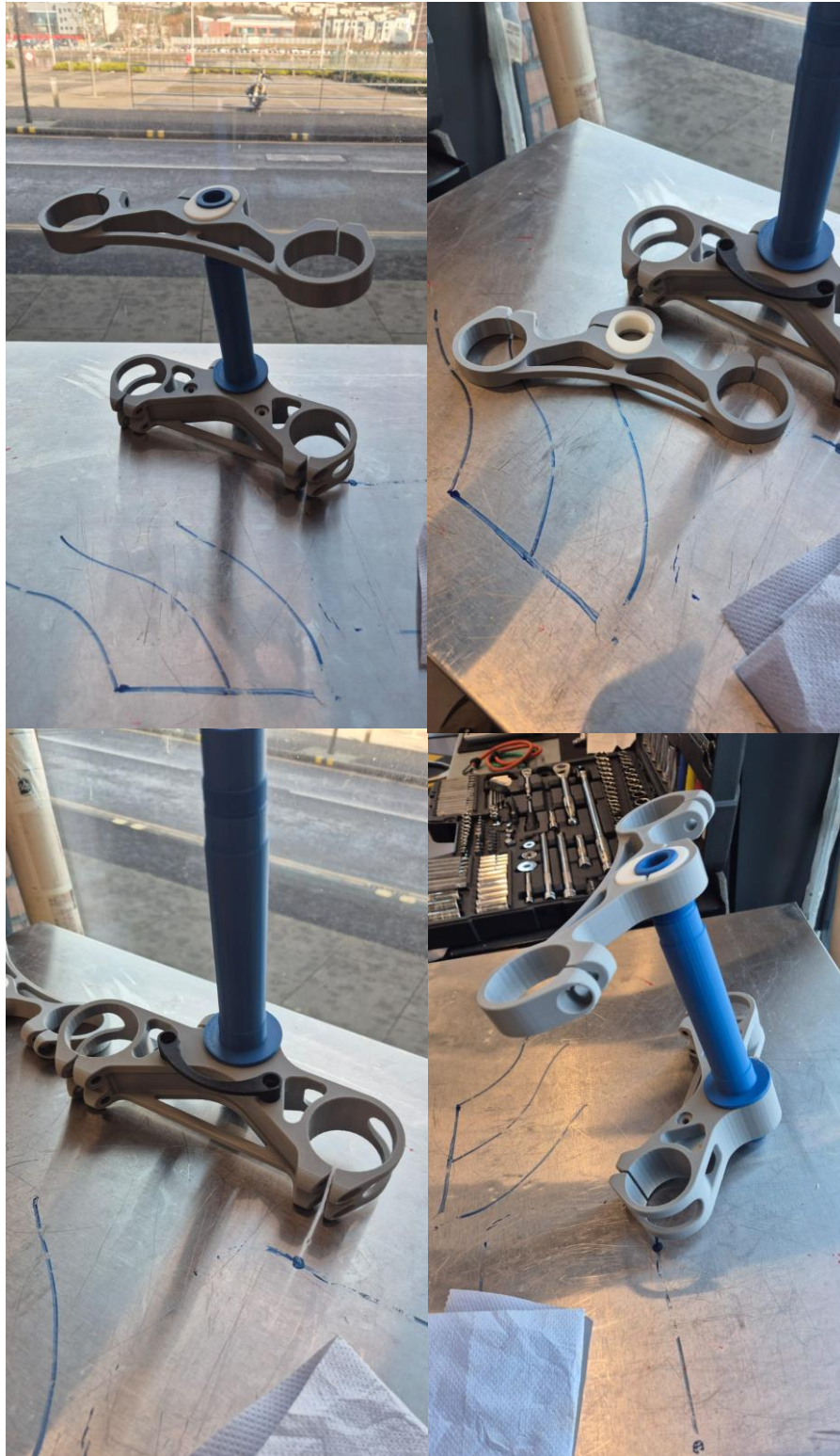


Figure 39: 3D printed prototype assembly.

3.5 Aaron Lilly

3.5.1 Work Content

My role in our group project was to design and create a new fuel tank and cover. The main goal was to maximize space at the front of the bike to fit a larger airbox, improving airflow and power output, which could give us a competitive advantage in races.

I used SolidWorks for surface modelling to turn my ideas into a digital model. My design drew inspiration from the original bike and features from other motorcycles I researched. After creating the initial model, I worked closely with a teammate designing the airbox to ensure perfect fitment between the fuel tank cover and the airbox. Coordination was key to avoid issues during later stages.

In addition to the fuel tank and cover, I also designed 'tank extenders' that could be bolted onto the cover to adjust its shape and feel for different riders and tracks.

Testing is crucial to evaluate the fuel tank, airbox, and cover. We'll run the bike on a dyno to measure power output improvements. Comfort and ergonomics are also important, as the rider's comfort is essential for maintaining control during races. Additionally, we'll test the fuel tank and cover for usability, ensuring they're easy to assemble, remove, and maintain, especially after a crash or during general maintenance. Addressing these factors will ensure the final product performs well and is user-friendly.

3.5.2 Research Carried Out

The initial phase of research involved examining motorcycles that are closely related to the one we are using. A key focus was on the Honda NSF250RW (Honda, 2025), which is a high-performance motorcycle specifically adapted for world championship-level racing. This bike shares many similarities with ours but includes significant modifications to optimize its performance for competitive racing at the highest levels. These modifications provide valuable insights into how manufacturers enhance the aerodynamics, fuel efficiency, and overall design for elite racing.

Further research was conducted on the KTM 250GPR (KTM, 2025), a world championship-level motorcycle used in the Moto3 category. This bike represents KTM's approach to creating a competitive and efficient racing machine. Both the Honda NSF250RW and the KTM 250GPR incorporate larger airboxes located at the front of the motorcycle. These airboxes are supported by air ducts strategically designed to maximize airflow to the engine. This improved airflow contributes to better engine performance and overall efficiency during races.

In order to accommodate these larger airboxes, manufacturers have developed innovative solutions to manage space constraints. One notable adaptation is the redesign of the fuel tank. The fuel tanks in these bikes are often relocated and reshaped to utilize the available space under the seat unit. This design choice ensures that the motorcycles maintain the required fuel capacity to complete a full 100 km race while optimizing other critical performance elements (Opong, R. 2022).

For our specific application, the requirements differ significantly from those of world championship-level racing. The races we compete in are shorter in duration, and our fuel consumption is approximately 0.4 Liters per lap. Given that the maximum number of laps we perform in the NGRRC championship is eight, our total fuel requirement is significantly lower. To meet these demands, we require a fuel tank with a capacity of 3.5 Liters, which is sufficient to complete the race while keeping the motorcycle lightweight and efficient.

This research highlights the importance of tailoring design and modifications to the specific needs of the race format, balancing performance, efficiency, and practicality.



Figure 40: KTM 250GP (KTM, 2025).



Figure 41: Honda NSF250RW (GPmotorbikes, 2025).

3.5.3 Designs Carried Out

After finishing my initial research, I moved on to the design phase for the fuel tank and its cover. To start, I took a 3D scan of the original fuel tank. This scan was really useful because it gave me a solid reference point to work from when shaping my new design. Having this digital model of the original tank made it easier to figure out the best way to adapt the design while making sure it still fit properly on the bike.

At the same time, I was working in the same assembly as Ted, who was designing the airbox. His piece needed to connect directly to the fuel tank cover I was working on, so we had to coordinate closely. Working in the same assembly made this much easier because I could check how our designs fit together as we went along. This way, we avoided problems that might have come up later if we hadn't communicated during the design process.

Designing the fuel tank cover took some time. I went through multiple attempts and several different variations before settling on the final shape. It wasn't easy to balance the functional requirements with the overall design, but after experimenting with a few options, I found a shape that worked well and looked good too. Once I was happy with the fuel tank cover, I was ready to move on to designing the fuel tank itself.

My first design for the fuel tank had it attaching to the back of the airbox. At first, this seemed like a logical solution, but when we had our first VIVA's (design review sessions), I realized there were some issues with this approach. Based on the feedback I got during the review, I redesigned the fuel tank so it would suspend from the tank cover instead. This change made the design more practical and improved how the parts worked together. I was much happier with this updated version.

After finalizing the designs for both the fuel tank and the cover, the next step was creating a mold. The mold was a key part of the process because it would be used in the AutoClave to produce the fuel

tank. I designed the mold carefully, keeping in mind the shape of the tank and the materials I'd be using. The goal was to make sure the mold was accurate so that I could lay up the carbon fibre sheets properly and get a high-quality final product.

This process took a lot of effort, but it was worth it to make sure the final design met all the requirements and was ready for manufacturing.

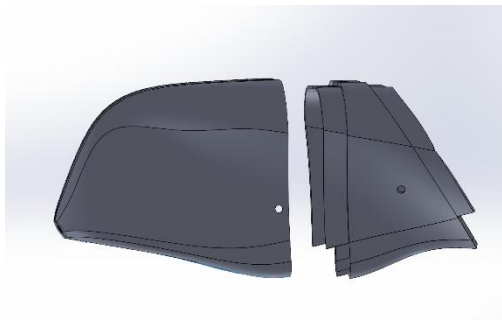


Figure 42: Development of Tank Cover.

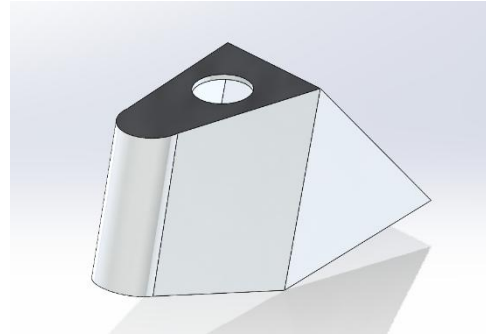


Figure 43: Fuel tank development.

3.5.4 Testing Carried Out

Before moving on to the build phase, it is essential to carry out a thorough testing phase to ensure that all components are accurately scaled, fit together as intended, and are ready for manufacturing. This phase will allow us to identify and resolve any potential design or fitment issues early, saving time and resources during the production process.

One of the primary methods we will use during this phase is 3D printing. By 3D printing prototypes of the fuel tank, fuel tank cover, and any connecting components, we can physically test their dimensions and fitment on the bike. This will allow us to confirm that the parts align correctly with the existing frame and other elements, such as the top of the engine, without committing to costly materials or time-intensive processes. These prototypes will also help us identify any areas that might need adjustments, such as mounting points or clearances.

Another aspect of this testing phase will involve checking how the 3D-printed models interact with other parts designed by team members, such as the airbox. By assembling these components in a mock setup, we can ensure proper alignment and fitment before moving on to the final materials. This collaborative testing process will help avoid compatibility issues that could arise during the build phase.

Additionally, this phase will involve assessing the ergonomics of the fuel tank and cover. Using the 3D-printed models, we can have the rider test the comfort and positioning of the tank cover on the bike. This includes evaluating how the rider's body interacts with the tank during typical riding positions

and movements. Any feedback regarding comfort or usability will be used to refine the design before production.

To further ensure the designs are scaled and functional, we will also test the integration of the fuel pump into the 3D-printed fuel tank model. This step includes confirming that the mounting holes, seal dimensions, and overall fitment align perfectly with the pump's specifications. Testing the fuel pump's placement and connections during this phase will help us avoid issues later in the build phase

3.5.5 Build Carried Out

Once the testing phase is complete and the designs are finalized, we will move on to the build phase.

The fuel tank cover will be constructed using pre-preg carbon fibre. This material is chosen for its strength, lightweight properties, and ability to maintain precise shapes. The process begins with laying up the carbon fibre sheets onto the mold that was designed and created during the earlier stages.

After the carbon fibre sheets are laid up, the mold will be placed into the AutoClave. The AutoClave process applies heat and pressure, curing the carbon fibre into a strong and durable part that matches the desired shape (www.easycomposites.co.uk, 2022)

This method ensures a high-quality finish and excellent performance characteristics for the fuel tank cover, making it both lightweight and robust enough to handle the stresses of racing. Once the part is removed from the AutoClave, any excess material will be trimmed, and the surface will be finished to ensure a clean and professional look.

The fuel tank will be manufactured from aluminium. The process starts with cutting the aluminium sheets to the correct dimensions using a waterjet. These sheets will then be manually folded to create the necessary shapes and angles, as specified in the final design. Accuracy is critical at this stage to ensure the folds are consistent and match the intended design.

One important feature of the fuel tank is the integration of the fuel pump mounting point. The design includes a boss, which will be welded onto the tank. This boss will have tapped bolt holes to secure the fuel pump in place. Special attention will be paid to the positioning of the boss to ensure the pump fits correctly and functions without any issues. The tapped holes will be carefully machined to match the specifications of the bolts, providing a secure and reliable connection.

In addition to the boss and bolt holes, the fuel tank design also incorporates a seal to prevent fuel leaks. The seal will be positioned between the fuel pump and the tank, with the dimensions and thickness carefully calculated during the design phase. This seal is critical to maintaining the integrity of the system, ensuring that no fuel escapes during operation. During the build phase, the seal's fit and effectiveness will be tested to confirm it meets the required standards.

Once all the pieces of the fuel tank are folded and the boss is in place, the parts will be welded together to form a sealed and functional unit. The welding process is crucial to ensuring the tank is leak-proof and durable. After welding, the tank will undergo thorough inspections and pressure testing to confirm its structural integrity. If necessary, any imperfections will be addressed, and the welds will be ground and polished to create a clean and professional finish.

By incorporating these features and following these manufacturing processes, we will produce both the fuel tank cover and fuel tank to the required specifications. This ensures they meet the performance, durability, and usability standards needed for competitive racing. The finished components will then be ready for further testing and integration into the bike.

3.5.6 Analysis Carried Out / Further Testing

We plan to test this project during the Pembrey weekend of the NGRRC championship, which is scheduled to take place from the 30th of May to the 1st of June. This testing period will give us a valuable opportunity to evaluate how well the new components work under race conditions and identify any potential improvements we can make before future events.

One of the key aspects I want to focus on during testing is the usability of the fuel tank. This includes assessing how easy it is to fit the tank onto the bike, remove it when necessary, and perform essential tasks like refuelling and draining the tank. These processes need to be as straightforward and efficient as possible. Any issues with these steps could cause delays or complications during race weekends, which is something we want to avoid. By testing this in a real-world setting, we can identify any problems and address them before they become a larger issue.

In addition to usability testing, I also plan to experiment with different “tank extenders.” These extenders will be bolted onto the new fuel tank cover and are designed to widen or adjust the shape of the tank. The idea behind this is to give the rider the chance to try out different tank shapes and see how they affect their comfort and riding performance. We can also pair these variations with different tank grips to see if certain combinations work better for the rider’s needs. Comfort and control are incredibly important, as they directly impact the rider's ability to maintain focus and perform consistently during a race.

By testing these variations during the Pembrey weekend, we can get direct feedback from the rider about which tank shape and grip configuration works best for them. This is especially useful since the event is timed, allowing us to compare lap times before and after each change. This data will help us determine if the modifications we make have a noticeable impact on performance. If the rider identifies any areas where the design could be further improved, we can incorporate their feedback into future iterations of the tank design.

3.6 Megan Gwilym

In this report I have been tasked with creating alternative fuels and designing a holder for the secondary injector for the NSF250. I was given four types of SUSTAIN fuels and tasked to mix these to find a methanol and ethanol base blend. By testing blends, I wish to discover what is the most efficient, as regards, power generation, fuel burn and overall improvements to the NSF250.

3.6.1 Research

The first step in this project was to gather as much research as possible on blending fuels. At the start, I had access to four different SUSTAIN fuels to create alternative fuel blends for the NSF250 next season. These fuels included:

- SUSTAIN classic racing 50
- SUSTAIN classic super 80
- SUSTAIN racing moto 40
- SUSTAIN 100 98RON E10

To begin my research, I utilized the resources available to me, starting with attending third-year lectures that covered Chemistry & Combustion, as well as Fuel Blending & CO₂, taught by Owen Williams. These lectures provided a strong refresher on the fundamental principles of physics and chemistry, helping me better understand fuel composition and behaviour.

Discussions with lectures had encouraged me to focus on ethanol and methanol blends would be the key to optimizing engine performance. 'Ethanol, with its higher-octane rating than regular gasoline, allows the motorcycle to run smoother and faster (Tru-tension, 2024).

Methanol on the other hand, burns cleaner than gasoline, is less flammable, and has the potential to generate more power. While methanol is less energy-dense than gasoline, it allows for a higher fuel burn rate with the same amount of air, ultimately increasing overall power output. (Williams.O, UWTSD 2024).

Within the lectures I studied the combustion of fuels, the importance of the level of isooctane in automotive fuels, and the progression of chemistry bonding.

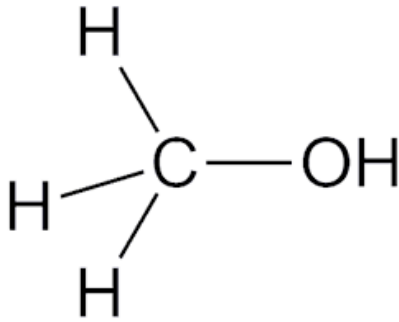


Figure 44: Methanol.

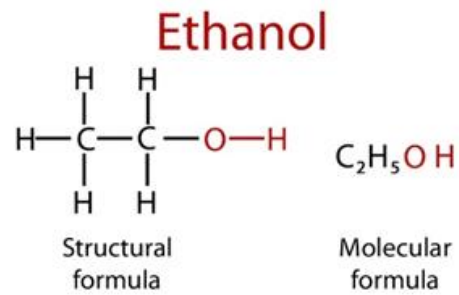


Figure 45: Ethanol.

3.6.2 Development

Below in the tables are the 4 fuels that I examined and tested. I was provided with certificate of analysis sheets which supplied me with the following information below.

From the 'Fuel Blending' lectures I received the relevant formulas to calculate the air to fuel ratio (AFR) for two of the four fuels, namely, Sustain Racing Super 80 and the Sustain Racing Moto 40.

The above information is necessary to analyse and evaluate the various fuels and their composition before I embarked on the process of mixing them. This information therefore is important in deciding on the various ratios in the ethanol/methanol and balanced blends.

Below are the tables with the 4 fuels:

Table 16: SUSTAIN Fuels.

<u>SUSTAIN Classic Racing 50</u>	<u>SUSTAIN Classic Super 80</u>
- Ethanol: 0.7%	- Ethanol: 10%
- Methanol: 0.1%	- Methanol: 0.1%
- Oxygen: 3.37%	- Oxygen: 3.26%
- Net Energy: 40.86 MJ/kg	- Net Energy: 41.38 MJ/kg
- Density: 768.3 kg/m ³	- Density: 752.3 kg/m ³
✓ Final AFR: 13.87	
✓ Final Energy Content: 40.86 MJ/kg	
✓ Final Density: 768.3 kg/m ³	

<u>SUSTAIN Racing Moto 40</u> - Ethanol: 0.1% - Methanol: 0.1% - Oxygen: 3.55% - Net Energy: 41.18 MJ/kg - Density: 749.0 kg/m ³	<u>SUSTAIN 100 98RON E10</u> - Ethanol: 9.7% - Methanol: 0.1% - Oxygen: 3.59% - Net Energy: 41.55 MJ/kg - Density: 742.9 kg/m ³ ✓ Final AFR: 14.18 ✓ Final Energy Content: 41.55 MJ/kg ✓ Final Density: 742.9 kg/m ³
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$$V_{gasoline} = V_{total} - V_{ethanol}$$

$$AFR \text{ by mass} = \frac{\text{Air mass}}{\text{Fuel mass}}$$

- AFR for SUSTAIN Racing Moto 40:

$$\begin{aligned}
 AFR &= 14.7 \times \left(1 - \frac{3.55}{100} \times 2.7\right) \\
 &= 14.7 \times (1 - 0.9585) \\
 &= 14.7 \times 0.90415 \\
 &= \mathbf{13.29}
 \end{aligned}$$

- AFR for SUSTAIN Classic Super 80:

$$\begin{aligned}
 AFR &= 14.7 \times \left(1 - \frac{3.26}{100} \times 2.7\right) \\
 &= 14.7 \times (1 - 0.08802) \\
 &= 14.7 \times 0.91198 \\
 &= \mathbf{13.40}
 \end{aligned}$$

3.6.3 Ethanol-Rich Blends

Ethanol-Rich blends have a higher ethanol percentage, improving octane and combustion cooling while maintaining good energy content.

Table 17: Ethanol-rich blends.

Blend	Ethanol (%)	Methanol (%)	Oxygen (%)	Energy (MJ/kg)	AFR
E30	12.8	0.07	3.45	41.43	14.24
E40	13.9	0.08	3.48	41.37	14.19
E50	14.9	0.08	3.5	41.3	14.14

Ethanol is widely used in motorsports for its high-octane rating (Gotlieb, 2023) and cooling properties. In the NSF250, its 108-octane prevented knock, supported higher compression, and enhanced power. The motorcycle also absorbs heat, reducing engine temperatures and improving efficiency. Ethanol's oxygen content boosts combustion improves throttle response and lap times.

Key factors when testing ethanol blends (E30, E40, E50) include power output, throttle response, engine temperatures, fuel consumption, and tuning. While ethanol enhances mid-range power and stability at high RPMs, it requires a richer air-fuel ratio, which results in an increase in fuel use. It is also corrosive to some fuel system components and can cause cold-start issues.

To maximize ethanol's benefits in the NSF250, proper tuning and ethanol-compatible components are essential. Ethanol has a lower energy density than gasoline; for example, E85 (a blend of 85% ethanol and 15% gasoline) contains approximately 73%–83% of the energy found in pure gasoline, necessitating increased fuel injection to maintain power output (U.S. Department of Energy, 2019).

Additionally, ethanol's stoichiometric air-fuel ratio (AFR) differs from that of gasoline; pure ethanol has a stoichiometric AFR of about 9:1, whereas gasoline's is approximately 14.7:1, requiring adjustments to fuel mapping for optimal combustion (HPTuners, 2024). Furthermore, ethanol is hygroscopic, meaning it absorbs moisture from the air, which can lead to corrosion in fuel system components. Therefore, using materials compatible with ethanol, such as stainless steel or specific polymers, in fuel lines, injectors, and seals is crucial to ensure durability and performance.

3.6.4 Methanol-Rich Blends

Methanol-Rich blends introduce methanol, which has high octane and a strong cooling effect but lower energy content.

Table 18: Methanol-rich blends.

Blend	Ethanol (%)	Methanol (%)	Oxygen (%)	Energy (MJ/kg)	AFR
M10	0.09	10.0	8.19	38.8	12.88
M20	0.08	20.0	12.75	35.8	11.06
M30	0.07	30.0	17.31	32.8	9.81

Methanol is another high-performance fuel used in motorsports due to its extreme cooling effects and high knock resistance. It has an octane rating of around 110 and burns cooler than ethanol, reducing engine temperatures even further. Methanol also contains oxygen, which can improve combustion efficiency and allow for more aggressive ignition timing. (Staff, 2015).

When testing methanol blends (M10, M20, M30), key considerations include, power output, fuel consumption, engine cooling and tuning. Methanol requires a significantly richer air-fuel ratio than ethanol, leading to increased fuel use. It is highly corrosive to certain materials and absorbs water, which can create fuel system complications. Despite these challenges, methanol blends provide excellent power gains and cooling benefits, making them ideal for short, high-intensity races.

To optimize methanol's performance in the NSF250, adjustments to fuel injection, AFR, and ignition timing are necessary. Using methanol-compatible fuel system components is crucial to prevent damage. When blended correctly, methanol can deliver outstanding power, throttle response, and thermal efficiency, making it a valuable choice for racing applications. (Staff, 2015).

3.6.5 Balanced Ethanol-Methanol Blends

Balanced Ethanol-Methanol blends mixes balance ethanol and methanol to combine the benefits of both while maintaining stable energy output.

Table 19: Balanced ethanol-methanol blends.

Blend	Ethanol (%)	Methanol (%)	Oxygen (%)	Energy (MJ/kg)	AFR
E20/M10	8.8	10.0	7.42	39.68	13.24
E30/M10	11.1	10.0	7.5	39.48	13.11
E20/M20	8.6	20.0	11.92	36.68	11.58

A blend of ethanol and methanol balances their strengths: ethanol improves combustion stability, while methanol enhances cooling and knock resistance. The right ratio of the two enhances throttle response, power, and fuel efficiency. However, mixed blends require precise tuning, as methanol's high fuel consumption and ethanol's richer air-fuel ratio can lead to increased fuel usage. Additionally, both fuels can be corrosive, necessitating compatible fuel system components. Despite these challenges, a well-balanced mix can provide strong performance benefits for NSF250 racing.

3.6.6 Recommended Blends for NSF250

This table summarizes the best blends based on different performance needs.

Table 20: Recommended blends.

Purpose	Recommended Blend	Key Benefits
Maximum Power with Safe AFR	E30, E40	High octane, easy tuning, minimal energy loss
Drag Racing / Max Cooling	M20, M30	Methanol cooling, highest octane, requires major tuning

E30 & E40 Blends

E30 and E40 blends provide a balance between power and efficiency, making them ideal for endurance racing. Their high-octane rating (108) allows for increased compression without knocking, improving mid-range power and stability at high RPMs. These blends also maintain a safer air-fuel ratio, making tuning easier and ensuring minimal energy loss, which enhances throttle response and overall efficiency.

However, ethanol blends consume more fuel than pure petrol (Eia US Energy Information Administration, 2025), which can impact fuel strategy over longer races. Additionally, while they offer some cooling benefits, they are not as effective as methanol in managing engine temperatures, requiring careful heat management.

M20 & M30 Blends

M20 and M30 blends prioritize cooling and knock resistance, making them well-suited for high-intensity, short-distance races like drag racing. The high-octane rating (110) allows for aggressive ignition timing, maximizing power output while keeping engine temperatures lower due to methanol's cooling effect. This is particularly beneficial in preventing heat-related performance losses during demanding race conditions.

Despite these benefits, methanol-based blends require significantly more fuel due to their lower energy content, meaning higher fuel consumption. Methanol is also more corrosive than ethanol, necessitating modifications to the fuel system to prevent damage. Additionally, major tuning adjustments are required to optimize engine performance, making these blends less convenient for general racing use.

Ethanol-Methanol Mixed Blends

A combination of ethanol and methanol blends aims to balance the strengths of both fuels. These blends offer stable combustion from ethanol while utilizing methanol's superior cooling properties. The result is improved throttle response, increased power, and better efficiency across different racing conditions. The flexibility provided by these blends allows racers to optimize fuel choice based on track demands and temperature conditions.

However, mixed ethanol-methanol fuels require precise tuning to avoid engine stress and excessive wear. They also tend to have higher fuel consumption than standard petrol-based alternatives. Additionally, their corrosive nature means fuel system durability is a crucial consideration when using these blends.

Each blend has its own advantages and drawbacks, and choosing the right fuel depends on the balance between power output, cooling requirements, and fuel efficiency based on racing conditions.

$$\text{Amount of component} = \left(\frac{\text{Percentage}}{100} \right) \times 1000$$

- E30 Blend (30% Ethanol, 70% Petrol):

$$\begin{aligned} \text{Ethanol} &= \frac{30}{100} \times 1000 = 300\text{mL} \\ \text{Petrol} &= \frac{70}{100} \times 1000 = 700\text{mL} \end{aligned}$$

- E40 Blend (40% Ethanol, 60% Petrol)

$$\begin{aligned} \text{Ethanol} &= \frac{40}{100} \times 1000 = 400\text{mL} \\ \text{Petrol} &= \frac{60}{100} \times 1000 = 600\text{mL} \end{aligned}$$

- M20 Blend (20% Methanol, 80% Petrol)

$$\begin{aligned} \text{Methanol} &= \frac{20}{100} \times 1000 = 200\text{mL} \\ \text{Petrol} &= \frac{80}{100} \times 1000 = 800\text{mL} \end{aligned}$$

- M30 Blend (30% Methanol, 70% Petrol)

$$\begin{aligned} \text{Methanol} &= \frac{30}{100} \times 1000 = 300\text{mL} \\ \text{Petrol} &= \frac{70}{100} \times 1000 = 700\text{mL} \end{aligned}$$

3.6.7 Final Steps

During this project, I focused on formulating and calculating various ethanol and methanol fuel blends for the NSF250. While I was unable to fully complete the practical testing due to time constraints, I successfully developed the necessary mathematical models and blend compositions. These calculations provide a strong foundation for future testing and refinement, ensuring that the fuels can be evaluated effectively in real-world racing conditions.

Moving forward, the next step would be to conduct physical testing of these blends on the NSF250. This would involve running the engine on each blend to measure its impact on power delivery, fuel consumption, and overall performance. Additionally, analysing exhaust emissions and monitoring engine temperatures would provide valuable insights into the suitability of each blend for competitive racing.

3.6.8 Secondary Injector

3.6.9 Design Concept & Initial Considerations

When designing the secondary injector holder, I needed to ensure it was positioned just above the bell-mouth while allowing for precise fuel delivery timing. My goal was to create a stable yet adjustable structure that would optimize fuel introduction into the system.

Initially, I considered two design concepts:

1. A top section that could be adjusted vertically.
2. A split-bar structure connected with screws to allow height adjustment.

However, due to space constraints, I determined that a fully adjustable design was not practical. Instead, I opted for a fixed-position holder with a pre-set distance from the bell-mouth. This approach provided stability while ensuring accurate injector placement.

3.6.10 Material Selection & Structural Integrity

The holder needed to be both strong and lightweight to prevent unnecessary weight from affecting the motorcycle's performance. Additionally, it had to withstand constant vibrations and high temperatures without failing.

I chose aluminium as the primary material because of its excellent strength-to-weight ratio. It provided the necessary durability while also being resistant to heat and mechanical stress. This ensured that the part would not shatter under impact or prolonged use.

3.6.11 Safety Considerations & Vibration Resistance

One of my main concerns was ensuring the injector remained stable under the extreme vibrations experienced in racing conditions. If the injector were to break or become dislodged, it could cause severe engine damage and pose a serious safety risk to the rider.

To prevent this, I incorporated safety bars in the corners of the holder (shown in Image 3). These bars reinforced the structure, reducing excessive movement and distributing vibration forces throughout the frame. This additional support significantly minimized the chances of failure, ensuring both reliability and rider safety.

3.6.12 CAD Development & Design Process

I began the design process by taking precise measurements of the injector to ensure a secure and accurate fit. Using these measurements, I developed a CAD model to refine the structure of the holder.

- First CAD Design (Figure 1): I defined the side profile of the bracket, including critical dimensions for stability. I incorporated smooth curves and radii to enhance durability while minimizing weight. The image shows the key dimensions of the holder, ensuring proper fitment in the available space.
- Second CAD Design (Figure 2): I focused on the injector mounting section, ensuring it aligned correctly with the injector's shape and locking features. The design was created specifically around the injector's top connector to provide a secure and stable hold.
- Final CAD Assembly (Figure 3): This image shows the completed structure, including the safety bars and the way the injector is positioned within the holder. The bottom ring was designed to rest on the bell-mouth, further improving stability.

After creating the first design, I found that the holder was slightly too tall to fit within the available space. To resolve this, I shortened the design to ensure a proper fit while maintaining its structural integrity and function.

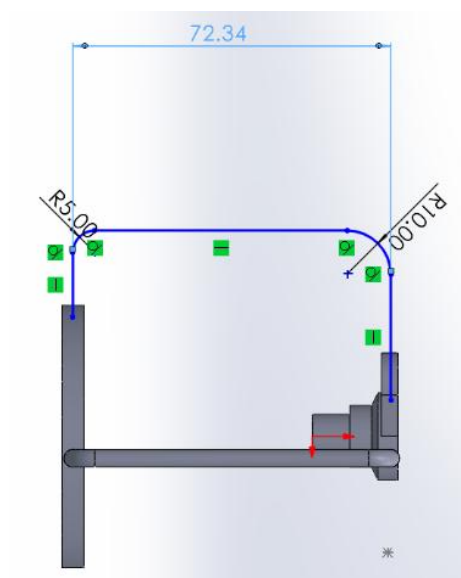


Figure 46: Side Profile

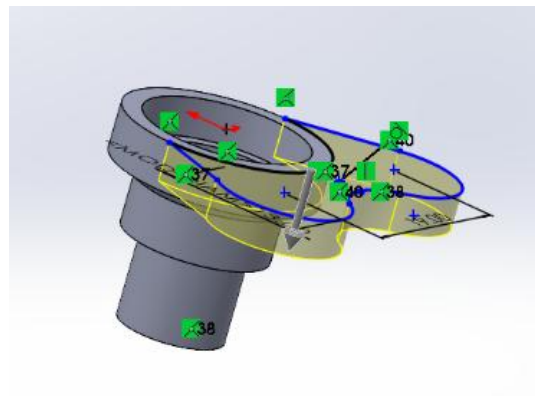


Figure 47: Injector mount.



Figure 48: Completed structure.

3.6.13 Final Steps & Prototype Development

After finalizing the design, the injector holder was tested using a full CAD model of the NSF250 to evaluate its fitment, stability, and functionality. This virtual testing allowed me to analyse clearance, alignment, and potential interference with other components before physical production.

Based on the results, I refined the design where necessary to enhance stability, durability, and overall performance, ensuring it was race-ready before moving toward prototype manufacturing.

3.7 Jake Davies

3.7.1 Work Content

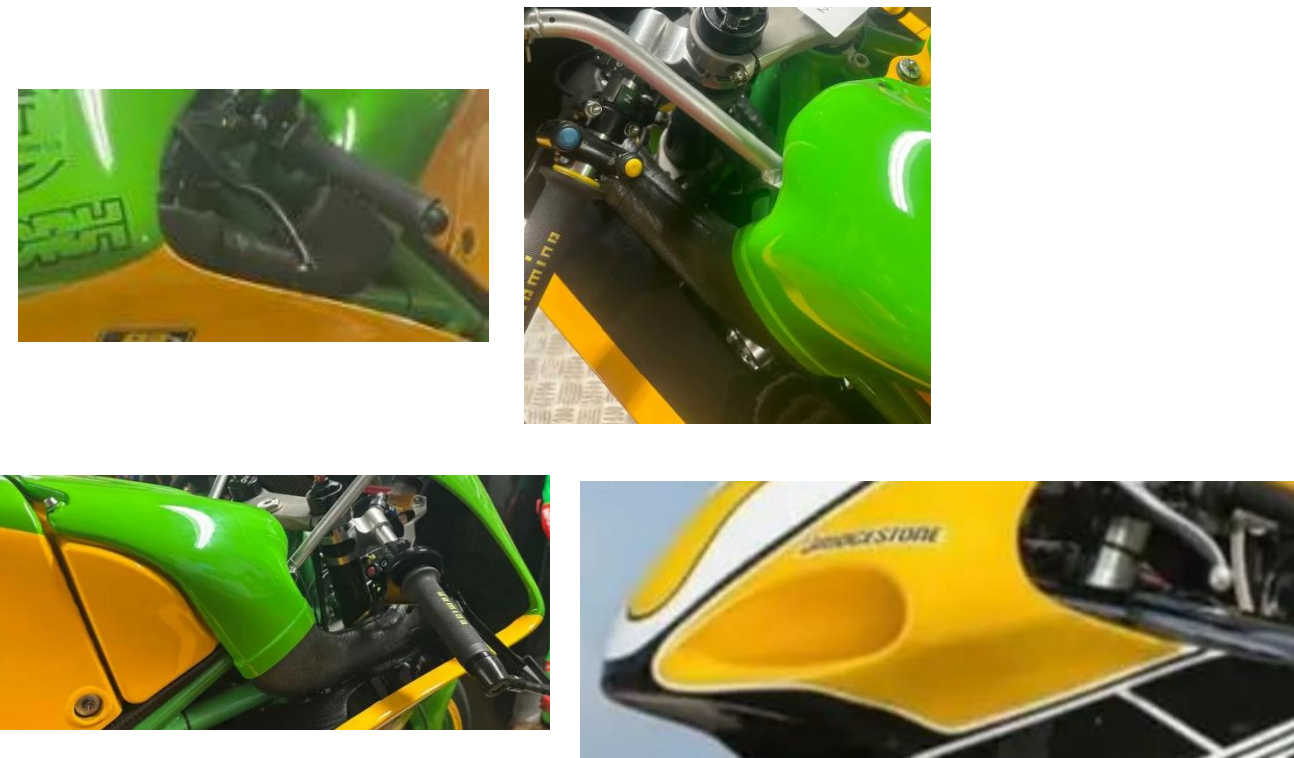
For my role in this group project, I decided to redesign the original intake. The main goal for this part is to increase airflow leading to more horsepower especially when another member of the group has added a secondary fuel injector. These results would help give us an advantage in the upcoming races.

I used a 3D scan of the bikes fairing, which was uploaded into SolidWorks, this was because it was a lot more accurate for sizing and placement of the duct, then using this scan I designed the intake within SolidWorks and a lot of the inspiration came from other products I have seen which I liked the style and placement of. I worked closely with a couple of teammates to bounce ideas of what direction to go when I wanted to redesign.

The front mount intakes haven't been made yet, but I will be ensuring work towards completing this will be done with the help of a member who has been doing work to the fairing, so we will use each other's knowledge to ensure success in this area.

The production of the middle mount sleeves was a late addition as I intended to make the duct all as one piece, but we evaluated this and decided 3 sections would be better as individual parts are easier to test more specifically to the section of interest.

3.7.2 Research Carried Out



These are some photos I was using for reference for my design as they were very similar to the style of intake that I wanted to make. These images inspired my design a lot and were very useful to keeping track of the end point I wanted to reach with my design.

	A	B	C
Displacement		0.00025 m	
RPM		7250	
Rho		1.287 kg/m ³	
Air Speed		343 m/s	
Flow Rate		0.0302 m ³ /s	
Flow Rate		0.0389 kg/s	
Area		8.81E-05 m ³	
Area		88070.94 mm ³	
Diameter		1.06E-02 m	
Diameter		10.59 mm	

I did some calculation to work out the minimum diameter of the intake required to feed the engine enough air. The grey columns were base factors to consider so the top is the cc of the engine then we have rpm which is half of the max rpm as it fills with air every other stroke, there is the expected air density at 1-degree Celsius Sea level. And the maximum velocity before it would choke the system which is the speed of sound.

To work out the flow rate I did the displacement* the rpm divided by 60. Then to convert it into kg/s I divided that by the Rho value.

The area was calculated by the flow rate in kg/s divided by the Rho* the air speed

To get the diameter I did $2 \times \sqrt{\text{area} / \pi}$ and then just converted the units to mm by x1000.

These calculations resulted in me knowing the minimum diameter the duct needed to be to ensure that the engine can be fed with enough oxygen which also acted as a guide for me to know how big I can make the intake as if it was too large it can result on lowering the overall performance of the engine and having a negative impact. I will need to get some track tested data to know how to refine the sizing of the duct any further whether it needs to be made bigger or smaller.

3.7.3 Position of intake

The position of the intake would be ideally through the centre of the fairing as that is the highest-pressure zone of the bike, this wasn't possible as the ecu is mounted underneath the dash leaving not a lot of room for anything else to go there, therefore we had to switch to side mounted intake. Mounting the intake on the side allowed to have a bigger size as there was much less space constraints this also benefited us because it should result in much less turbulent air as the duct is much more direct with less bends or pinch points throughout the pipe.

Having the intake mounted on the side also reduces the risk of heat soak as it will be getting much more air flow around it rather than it being tucked away under the fairing, this will result in colder air going into the airbox which is better as it has higher density of oxygen.

When using a side mounted intake, it can cause some instabilities when cornering and at high speeds due to the imbalance of downwards pressure on that side of the bike, this will need to be evaluated when the intake is on the bike and has been tested on track. It will also have less consistency in air delivery than a central mounted intake, but this is the best position for it to go due to the space constraints from the ecu.

3.7.4 Things to consider when designing an intake

Ensure that there are few numbers of pinch points or bends withing the intake as this can result in turbulence and pressure invariants.

The intake length was determined abit by space and it was the distance it needed to be to ensure a smooth path for the air to channel through.

Material selection is important when making anything but with the intake it needs to be super light but also durable so for that I will be using carbon fibre

Consider what will be used to prevent water dust and debris from entering the airbox via the intake whether that is foam or abit of wiring to stop large stones.

Intake opening styles, there are multiple styles that I want to test with this intake. These are a standard whole in the fairing leading to the duct, a raised lip on the external part of the fairing to smoothen flow from the sharp edge and a NACA duct which is like a sweep in from the fairing moulding into the start of the intake.



NACA ducts look like this, and they tend to improve the aerodynamic efficiency in comparison to having a whole in the fairing. it's kind of swept away first, this also helps reduce turbulent air as the air will stick to the bottom of the duct as it flows into the intake. This style of duct is usually found on aeroplanes but have been seen used in a couple of MotoGP bikes such as the Honda.



The raised lip would look like this as it follows similar principles to a bell mouth which helps coheres the air into the intake whilst reducing the turbulent air as it creates a smooth transfer from outside atmosphere to inside the duct.

3.7.5 The goal for the intake

The goal for this intake is to make it a ram air intake which is just when u create an area that is higher pressure than the airbox to force the air to move faster at higher pressures. I'm aware that it is near impossible to raise the airbox pressure above ambient pressure until you are moving at around 200mph, but it is possible to lower the vacuum which means it is easier for the piston to draw max pressure into the cylinder. Depending on the speed you are travelling depends on how big the intake diameter needs to be this is why I want to have multiple different sizes to test which works best for our bike, this also allows freedom of having different size intakes for different tracks where the average speed may be higher or lower.

3.7.6 Design and further development



This was the first re-design after the feedback from the first viva, the method for this design changed a lot as before I tried making multiple pieces whereas here, I made multiple different sketches and used the lofted tool to connect all the different sketches. This design still wasn't right though as it had too many pinch points especially when it was switching from a circle to an oval closer to the airbox.



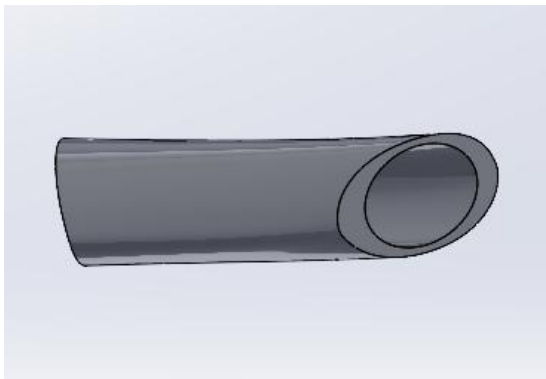
I then tried this intake which was using the same theory but was a bit longer so it could reduce the rate of change in angle which worked as it helped smooth out some of the pinch points, so I carried on with this style as this was an improvement to the previous design.



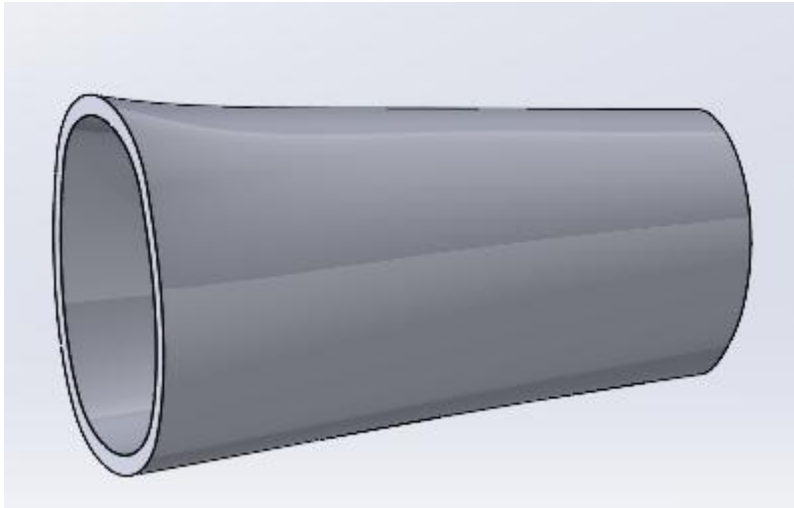
After speaking with Ian and using other models from my research I decided to get rid of the sweep on the top as it was worse for airflow because it was a fast change of direction. With this model I was able to make the intake much smoother with very little pinch points and having a guide for where the intake opening will sit on the fairing as I used a 3d scan of the bike to position it. I wasn't completely happy with this design as on the rear section there was a sharp angle, so I wanted to change this.



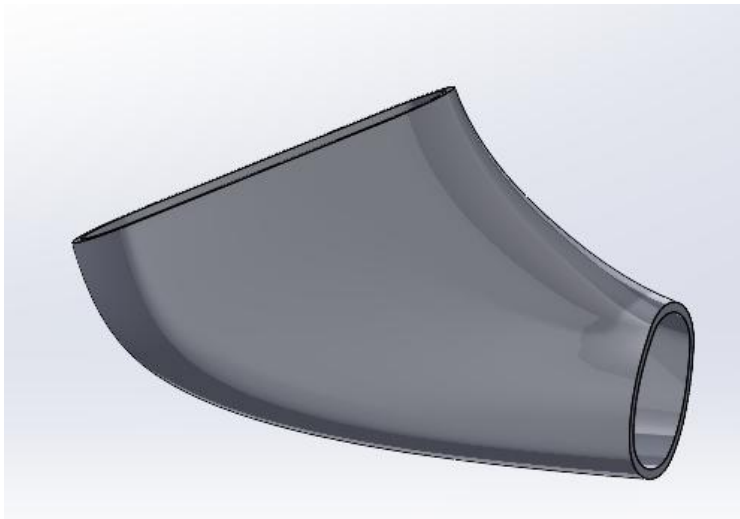
This was the result of the changes I made, and I was much happier with this as it sat a lot flusher with the angle of the chassis and was the smoothest of all my designs. I also readjusted the position of the opening so it was more accurate to how it would be when the part is on the bike.



I then split the sections up by inserting planes into the desired places and extrude cutting away the rest of the intake so I can try multiple versions of each section of the intake without having to change the whole thing. This is the front section that will be mounting to the fairing.



This was the middle section of the intake. This part will have both sleeves attached to it as the front part will be attached to the fairing and the rear section will mount to the airbox.



This is the rear section of the intake that will be mounting to the airbox. These three sections will be produced separately so I needed to make a sleeve to hold them together.



These are both sleeves for the either side of the middle section and they will be bonded to it to hold them in place and having these parts separate will allow us to swap individual parts of the intake for testing to find out what is the best solution. This will also be good for on the track as if the intake breaks the whole thing doesn't have to be made only the section that is carrying the damage. The sleeves have a flared entry to allow a bit of ease when piecing it together as if it was the exact size, it would make it much harder align the sections together correctly

3.8 Harvey Merrett

3.8.1 Introduction

To introduce this report I will be underlying the roles and responsibilities of myself and describing my roles and responsibilities involved in the group project. During the time so far I have been testing different designs for the reconstruction and modification of the front fairing on the NSF-250. The roles and responsibilities considered are pinnacle to the project running smoothly and making sure we have a functioning vehicle in a safe condition for the testing in may.

Not only has the group project been done to try and progress the overall performance of the motorcycle but it has also been done to allow myself and my colleagues free roam to get 'hands on' and to try and enhance the performance through our own ideas with guidance from the project leader and lectures.

3.8.2 Project Organisation

Allocations, roles and tasks were down to the student's discretion ad what type of roles they were interested in. for example, I wanted to be able to do something that I had felt would be challenging and I would gain a lot of experience and skills from.

Olly Gillson was appointed our group project leader furthermore; he would help us with getting started and organizing weekly meeting for us to attend and track progress within the group project.

6 Fairing Aerodynamics - Harvey					
6.1	Research	In Progress	30/09/2024	11/10/2024	12
6.2	CAD/3D Scan Fairing	On Hold	11/10/2024	31/10/2024	21
6.3	Prototyping & Testing	Not Started	31/10/2024	30/11/2024	31
6.4	Production & Fitment	Not Started	30/11/2024	10/01/2025	42
6.5	Realworld Testing	Not Started	31/12/2024	28/02/2025	60
6.6	Monitoring & Adjustments	Not Started	28/02/2025	02/04/2025	34

Figure 1

Here in this figure, you can see my individual tasks describing the tasks that needed to be done in the front fairing reconstruction and the timings that I have tried to stick through throughout the report. This has been done not only so we can keep progress of our group project but also so new can set short term goals and milestones. Not only does this keep us motivated to get work done but it also allows us to track the group project as a whole to see if we are on schedule for testing in may.

3.8.3 Work Completed

During my time so far on this group project there have been many designs carried out which I will explain further on in this report.



Figure 2

Figure 2 is the design which I have surface modelled on SolidWorks 2023. My aim for the design was to be able to have a mesh of the fairing itself but to create a more streamlined version. One of the biggest aims was to be able to tuck the rider, Ian Henshaw's, elbows and knees as far under the fairing extension as much as possible as the standard fairing was not wide enough and was causing too much drag. It has cleared his wrists by 20mm meaning there will not be any more impact causing a smaller frontal area and theoretically making it more streamlined.

In figure 3 we can see a CFD scan in SolidWorks also known as flow simulation. Unfortunately, this is as far as I have gotten in terms of CFD but I am looking at testing in the wind tunnel as soon as my smaller 3d scale of the fairing is available.

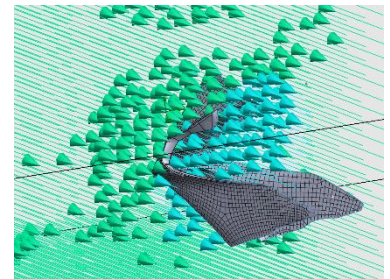


Figure 3



Figure 4 shows the fairing extension sat temporarily on the fairing. I have scaled it like this, so it is removeable for the presentation.

Figure 4

3.8.4 Research Carried Out

In developing the aerodynamic fairing for the Honda NSF250R, extensive research was conducted to optimize performance by reducing drag and enhancing stability. Aerodynamics plays a crucial role in motorcycle racing, influencing top speed, handling, and fuel efficiency. Our design approach was guided by studies of existing Moto3 fairings and research into aerodynamic principles employed by leading teams.

Our primary focus was minimizing aerodynamic drag, as air resistance significantly impacts straight-line speed and acceleration. Research indicates that streamlined fairings help smooth airflow around the motorcycle, reducing turbulence and wake effects. By incorporating smooth, continuous surfaces and eliminating abrupt transitions, our design aims to maintain laminar flow and decrease pressure drag.

The influence of airflow on high-speed stability was also a key consideration. Studies show that aerodynamic lift can affect handling, particularly at high speeds where airflow distribution around the fairing plays a critical role in keeping the front wheel stable. Our design incorporates subtle deflectors and carefully shaped fairing contours to ensure airflow remains controlled and predictable, enhancing overall rider confidence.

Moto3 teams have explored various aerodynamic solutions to maximize performance. For instance, KTM introduced enclosed rear wheel designs to optimize airflow and reduce drag. Many considerations and forums were read in terms of design, however instead of copying a design I wanted to design and fabricate my own.

Emmett, D. (2021). *Moto3 Aerodynamics: How The Law Of Unexpected Consequences Produced Closed Rear Wheels*. Retrieved from

https://motomatters.com/analysis/2021/11/04/moto3_aerodynamics_how_the_law_of.html

Foale, T. (n.d.). *Tony Foale Designs, article on motorcycle aerodynamics*. Retrieved from

<https://motochassis.com/Articles/Aerodynamics/AERO.htm>

Not only was there research on the design, I had to do extensive research on SolidWorks techniques that I have not used before. Some of these include surface modelling, knitting surfaces and extruding them together. Lots of my research on techniques came from tutorial videos and help forums online.

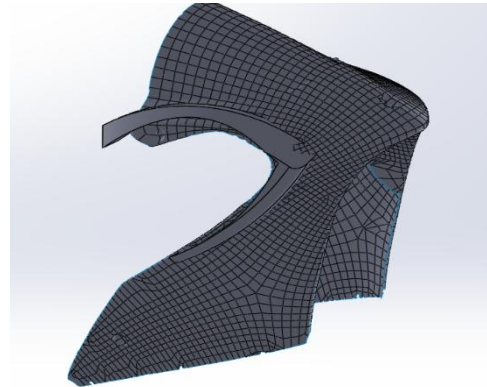
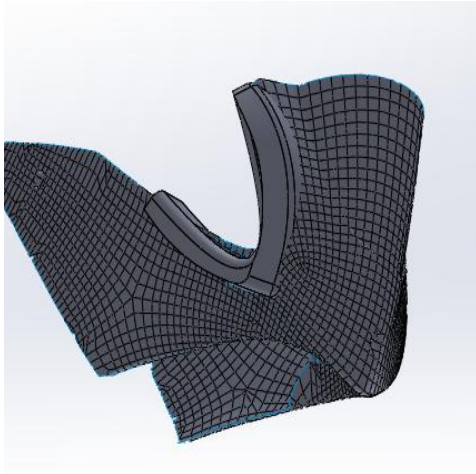
3.8.5 Experiments Carried Out

Many experiments were carried out in the process of the group project. In the duration of the group project, I have been doing many different tasks to try and better my ability at the front fairing reconstruction.

For example, at the start of the group project I had attempted to measure the fairing by hand to get the most accurate design but after many attempts I realized how difficult using trigonometry the geometry would be and possibly how inaccurate it would be. Therefore, instead of wasting time I decided to stick to the original plan and continue to model the fairing extension through SolidWorks.

I had searched up many techniques for SolidWorks such as, surface modelling, 3d sketching on surfaces. Creating planes in a 3d mesh was also a challenge for myself but after some guidance from peers I was able to make the design work.

3.8.6 Designs Carried Out



In these four images you can see the slow but drastic improvement in designs. The first three designs were the pinnacle of establishing a foundation of the standards I needed to set myself to be able to produce and make a realistic fairing that can benefit on the NSF-250. They differ in many ways such as designs, aerodynamic quantities and even as far as being aesthetically pleasing.

The final design allows a sleek look which is aerodynamic and serves the purpose to the rider of allowing air flow to go around the elbow and knees of a rider. As stated by Ian Henshaw the sole purpose was to be able to allow the air to wrap around him as he feels even though he is fully tucked he is still in the way of the air line and is technically creating a bigger frontal area. Therefore the fourth and final design should stop this.

Therefore the fourth design was the final design I was happy with and was the design that I took forward for the group project.

3.8.7 Development Carried Out

Many developments have happened so far for the reconstruction of the front fairing. For example, as previously explained I have found it difficult with the design of the fairing extension. The design required many hours brainstorming techniques to allow myself to have the best shot at creating a relevant design.

I had struggled with the design mainly as the 3D scan of the fairing was not a solid body in SolidWorks. Due to this the origin and planes were all out of place meaning I had to find out how to manually move the and be able to start the design from scratch.

Another big development was trying to allow myself to find the relevant technique. As seen in the designs I have tried to first use a 2d sketch and extrude my way into the fairing but was giving me an inadequate design. Next, I tried to shell my way around the fairing to create a solid edge but due to the contour of the fairing it would not render the feature.

Finally, I tried to 3d sketch of the fairing and extrude the surface meaning I had to manually design the mounting points and measure how big the actual fairing should be. Whilst doing this I also had to learn techniques such as knitting and thickening the sketch to be able to 3D print the design.

Many other developments occurred during the progression of the fairing. These especially happened with conversations from lecturers such as Ian Henshaw and Andrew Harrison. These mainly included the design and CFD work as I felt working in person would be more beneficial for the wants that I needed for the design and the needs of the fairing to make sure it is suitable for use and will fulfil all of its need.

3.8.8 Testing Carried Out

so far I have not had the opportunity to do any forms of testing on the fairing due to being delayed in my fairing design. These delays have been down to design errors and rebuilding the fairing myself. I would rather be slightly delayed meaning I have a design that I feel is more suitable and will work better then jumping straight making a prototype that I know would fail and is not good enough.

Second to this I have struggled to get CFD completed so far as due to the fairing not being a solid body and the fact that I have made a sketch on it means the flow simulation on SolidWorks and ANSYS flow straight through the body. However, I am looking at either creating a smaller model of the fairing so I can actively put it in the wind tunnel so I can test it in person at University. Or I am going to split the fairing design from the actual fairing and convert it to a solid body to be able to put it in a CFD software.

3.8.9 Build Carried Out



Figure 9

Here we can see the photo of the fairing extension on the fairing itself for the first time. It was a task to find the best way to mount the fairing but with it only being on a test fairing I have only duct tape it to the fairing itself. In the presentation I would like it be removable to that is the step I have gone in.

The dimensions fit and the extension hugs the fairing nicely, not only this it also covers the handlebars meaning the rider's hands are no longer part of the frontal area. Due to this, theoretically the bike should be more aerodynamic and should have better airflow surrounding the rider giving it that more of a 'slice through air feeling'.

Currently this part is just a prototype for testing, and I will commence with final building if this product performs well in testing.

3.8.10 Next Steps

Some of my next steps throughout the rest of the year are to have a better designed final product after taking in considerations from testing and analysis. That is the main reason why I haven't added an analysis as I feel like I have touched upon not having the analysis done currently.

I also would like to crack down on the CFD as soon as possible so I can see how the new fairing performs. Failure to this I would like to have a smaller scaled fairing design made so I am able to put it in the wind tunnel to simulate some real world testing. This will also be very beneficial as I feel like I would be ahead of the may testing as having similar real world data so I can make modifications early.

3.9 Edward Walden

The research carried out for this project was primarily looking at other race bikes and seeing what designs they had applied to improve their airbox, for example shape, size, volume of the airbox, where the intake connects to the airbox and the interior design of the airbox.

3.9.1 Airbox Design

One design factor that I ensured to include in the design the new airbox, stemming from the conducted research, is taking up space from the fuel tank, and using that space to incorporate a larger airbox, as shown in the photos below. As more volume in the airbox allows it to store more low velocity, high pressure air, which would ideally increase performance.



3.9.2 Airbox interior Design

When it came to designing the interior of the airbox, it was important to have it designed in such a way that would slow down the air coming in through the air intake before having that air go through the air filter and build up pressure around the bellmouth. So, for this a system was devised to split the space inside the airbox into two parts. The top half would connect to the air intake, and on the opposing side would be the air filter, meaning the air coming into the airbox would have to travel the length of the airbox before going through the air filter. This design would theoretically cause the air coming in to lose its velocity, meaning that the air surrounding the bellmouth would have low velocity and high pressure.

3.9.3 Material

Aswell as these design factors, another point of research was to find out what kind of material the airbox should be made of. Looking at aftermarket airboxes for the Honda NSF gave me the idea to have the new airbox made from carbon fibre, due the airbox now being fully exposed, meaning it is liable to sustain damage in the event of a crash. This means the airbox needs to be made from either; a strong, durable material to prevent as much damage as possible if there is a crash, or a cheap yet somewhat durable material so spare airboxes can be made, allowing for a quick and efficient change between sessions if the airbox does end up being damaged during a session.

3.9.3.1 *High Density Polyethylene*

The idea to use High Density Polyethylene was debated because it is a material that is “Cost effective” meaning multiple airboxes could be created using HDPE within a tight budget, meaning we would be able to swap a damaged airbox out for a fresh one fairly easily if one were to break. However, HDPE not only has “poor weathering resistance” which means it would not be able to handle the natural environment of the racetrack, but it also “sensitive to stress cracking”, and due to the high stress environment not only outside but also inside the airbox, this material simply is not suitable to make the airbox from. These drawbacks could be improved with the addition of some kind of metal like aluminium combined with it, however a better-quality thermoplastic would still be preferable. (James, T. (2019))

3.9.3.2 *Acrylonitrile Butadiene Styrene:*

I also considered Acrylonitrile Butadiene Styrene (ABS) for the possible build material for the new airbox due to its “Reasonable production costs”, and it is easy to work with in terms of getting it into the shape of the airbox. Additionally, ABS is “lightweight” which is ideal for the application of the NSF 250, as weight reduction is will help improve the on track performance of the bike. Aswell as this, ABS has a “low heat and electricity conductivity”, which could prove useful in this application, since there are certain sensors and wiring that will be running alongside the new airbox when it is all in place, so a material which will stop any of those electrical components affecting it would be ideal. (Adreco Plastics, (2022))

However, there are disadvantages of using this form of thermoplastic for the build, for example, it has poor “weathering” resistance, which could cause problems in the racing environment we are intending to use it in. Additionally, ABS does not stand up too well against “UV exposure”, this could mean that it would not be an ideal material to use for racing purposes, as most commonly during the summer, the material will be exposed to sunlight on the track, and as a result it will be exposed to UV light. (Adreco Plastics, (2022))

These drawbacks of the ABS thermoplastic could be solved however by using compounds in the construction of the airbox. For example, using layers of different materials (for example fibreglass, or non-woven carbon fibre [in order to keep costs down]) would perhaps be able to enhance the strength and integrity of the ABS, which could make it a viable material to use for the airbox.

3.9.4 Carbon Fibre

Carbon fibre is the most expensive of the materials covered, however its advantages do justify its cost of manufacturing. Carbon fibre not only has a “high tensile strength” which allows it to “withstand significant pulling or stretching forces” making it ideal for a racing environment, and would give the airbox a higher chance of survival in the event of a crash, but it is also a very light material due to the lightweight fibres used to create it, “which contributes heavily to its strength-to-weight advantage”. (Composite Construction UK, (2023))

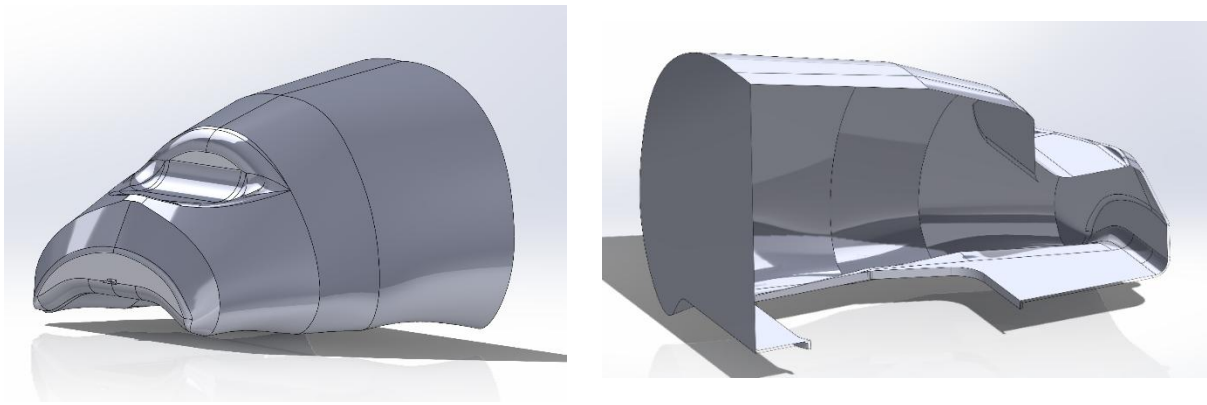
Although the advantages of using carbon fibre seem to make it the perfect material, it does have drawbacks which call into question its suitability for its role as an airbox in a racing environment. Firstly, as mentioned previously, carbon fibre is a very expensive material to obtain and use, meaning it would cost a lot more than other options to make spare airboxes to use in the event one of them were to break. Secondly, and more importantly, carbon fibre shows no forms of deformation before reaching its maximum stress. “Once the ultimate strength of the material is exceeded, carbon fibre will fail suddenly and catastrophically.” This could pose a serious safety risk if the carbon fibre airbox fails during a session on the track. Additionally, if the airbox were to fail “catastrophically”, small parts of carbon fibre could end up going into the throttle body and therefore the engine. (Composite Construction UK, (2023))

There are possible solutions to this however, for example having layers of fibreglass to externally cover the airbox, and either the same or different material (like epoxy resin) on the inside of the airbox, to stop the carbon fibre from becoming a hazard to the rider and the engine if the carbon fibre were to fail. As well as this, to help cut down on costs of using carbon fibre, non-weave carbon fibre could be used in the airbox, although not as expensive, non-weave carbon fibre also has a lower maximum stress value, so an airbox using this or even regular carbon fibre will have to undergo rigorous testing to ensure the conditions we intend to place it in will not cause it to fail.

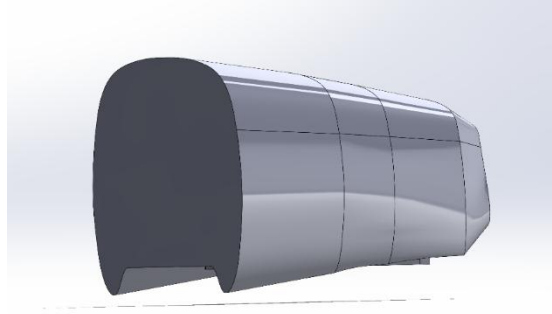
3.9.5 Designs

The first full design I made for the airbox included all the features i wanted based on the research I conducted, it had a larger volume, both in width and height, it was able to connect onto the lower half of the airbox housing via the mating part that had been previously created, and the design of it included space for the riders chin guard, so the rider would be able to fully tuck in on the straights without the new airbox getting in the way.

The limitations of this airbox design however were revealed when we placed it onto the computer model of the NSF. We discovered that it was not only too big to fit onto the Honda NSF as it was too long, but also, the shape of the airbox needed to better coincide with the fuel tank cover redesign, and additionally it needed to better follow the curvature of the NSF to further reduce the riders tucking ability, as the one I had made did not angle downwards as much as I expected it would

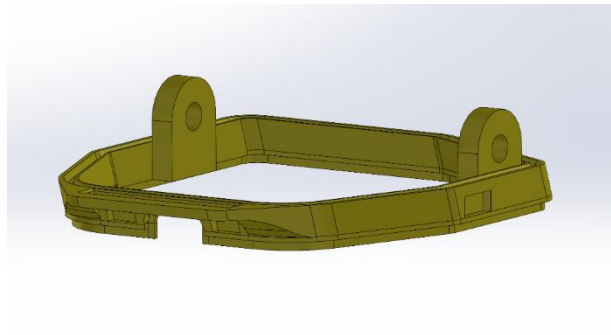


Taking these limitations into account I then created a second model of the new airbox, reducing the overall length of the airbox, allowing it to fit onto the NSF better, but also changing its shape to allow it to fit onto the new design of the fuel tank cover with more ease than before. Additionally, I also changed the lower half of the airbox to allow the model to have a smoother lower half, as the one I had previously made was not only inconsistent, but did not look anywhere near as appealing as it would if the bottom half was smoothed out more, allowing the new airbox to be more aerodynamic due to its smoothness, but also looked more appealing when placed onto the NSF. Although this model is not yet fully completed, the primary changes that I have attempted to make to my first design have been a success. Once the model has been fully completed then it will ideally be ready to be manufactured and tested against the original NSF airbox.



There are more changes that still need doing to my airbox design, for example as mentioned previously, I need to make sure the top of the airbox tapers downwards as it reaches the front, to ensure the shape of the airbox flows with the rest of the NSF and also to make sure the shape of it does not hinder the rider's ability to tuck when on straight parts of whatever circuit it is being ridden around.

Additionally, there is a mating part, of which the purpose is to connect the existing lower half of the NSF airbox, to the new redesigned top half that I am making. The design I have been given does have the correct shape to fit onto the lower half of the airbox, however the way in which it connects to the top half of the airbox doesn't work due to it coming into contact with the engine's top cover. I need to work on a more efficient redesign of the mating part, specifically, redesigning how the mating part attaches to the new airbox.



I previously attempted a redesign for this mating part, relocating the connecting mounts to the inside walls of the mating parts as seen below, which would be possible to make, however upon evaluation, this design unfortunately would not work. This is due to it not being possible to attach the mating part to the new airbox from the inside. So, a redesign of the connecting parts is required in order for the new airbox to be put onto the NSF.

4 Progress Report

Achievement and progress have been measured relative to initial project plan and individual Gantt charts.

4.1 Olly Gillson

4.1.1 Install & Test New ECU

The removal of OEM ECU and loom along with the installation of the NEW ECU and loom was completed successfully. Software was installed and confirmed working after which ECU parameters were backed up, the provided Honda base map was successful transferred to the ECU. Overall, the milestone was completed ahead of schedule.

1	Milestone 1 – Install & Test New ECU						
1.1	☒	Remove OEM ECU & Loom	Med	Complete	30/08/2024	07/10/2024	8
1.2	☒	Install New ECU & Loom	Med	Complete	07/10/2024	14/10/2024	8
1.3	☒	Install Dellorto DOPE Software	Med	Complete	14/10/2024	18/10/2024	5
1.4	☒	Backup Current ECU map	High	Complete	21/10/2024	25/10/2024	5
1.5	☒	Install Honda ECU map	High	Complete	25/10/2024	31/10/2024	7
100%							

Figure 49: Milestone 1 plan.

4.1.2 Engine Testing

Delays in engine testing meant this milestone was not completed within the allocated time. The engine has been successfully started and taken through the rev range. Work is still underway to further test engine management and strategies with the upgraded ECU.

2	Milestone 2 – Engine Testing						
2.1	☐	Test Engine with Honda Map	High	In Progress	31/10/2024	30/11/2024	31
2.2	☐	Tweak Map Parameters	Med	In Progress	30/11/2024	31/01/2025	63
2.3	☐	Test Engine with New Parameters	High	In Progress	30/11/2024	28/02/2025	91
2.4	☐	Real-World Testing	Med	On Hold	15/03/2025	31/01/2025	-42
0%							

Figure 50: Milestone 2 plan.

4.1.3 Bell Mouth Design

Bell mouth research design and testing has been successfully completed ahead of schedule, a prototype has been produced, and confirmation of fitment has been proven. Further production is on hold until the engine is confirmed running where real-world testing can take place.

3	Milestone 3 – Bell Mouth						
3.1	☒	Research	Med	Complete	30/09/2024	14/10/2024	15
3.2	☒	Design & Prototyping	Med	Complete	14/10/2024	30/11/2024	48
3.3	☒	Testing	High	Complete	15/11/2024	31/12/2024	47
3.4	☐	Production	Med	On Hold	01/01/2025	08/01/2025	8
3.5	☐	Real-World testing	Med	On Hold	15/03/2025	02/04/2025	19
60%							

Figure 51: Milestone 3 plan.

4.1.4 Other

Progress has been made in setting up the bike for data acquisition. During periods when work on the main objective was not possible, necessary side tasks were undertaken to make productive use of time. These tasks contributed to the overall goal of ECU setup while supporting data acquisition.

4.2 Oska Robertson

The design research phase was successfully completed on schedule, including the modelling of the original concept in CAD. The CAD development process exceeded expectations, yielding highly promising results. However, this phase took longer than initially anticipated.

Following the completion of CAD modelling, the project has now reached the prototyping stage. While preparations have been finalized, the actual construction of the prototype has not yet commenced.

Unfortunately, production, fitting, and subsequent monitoring and adjustment phases have faced setbacks due to illness. These tasks remain incomplete, causing delays in the overall timeline. Without the setbacks mentioned above, these tasks would have been completed sooner.

4.3 Harry Rogers

4.3.1 Research Phase

The research phase generally proceeded as planned. All measurements were accurately gathered, facilitating smooth progression to subsequent stages. Investigations into offset adjustments and yoke design provided valuable insights that directly influenced the final design. Specifically, the inspiration for offset adjustment was drawn from existing aftermarket solutions. Additionally, all necessary forces were accurately calculated, enabling effective use of FEA later in the project. However, the original yokes were ultimately not drawn due to uncertainty regarding the exact material, making it impossible to confidently validate the accuracy of subsequent FEA studies. This part of the project took much longer than expected, with it being completed just after Christmas.

## Research Phase							
##	##	Measure existing fork yokes	Med	Complete	07/10/2024	14/10/2024	8
##	##	CAD existing fork yokes	Med	Complete	07/10/2024	14/10/2024	8
##	##	Gather deceleration data for calculations	High	Complete	15/10/2024	18/10/2024	4
##	##	Calculate forces on the headstock bearings	High	Complete	19/10/2024	21/10/2024	3
##	##	Research yoke design from MotoGP and world SBK	High	Complete	20/10/2024	23/10/2024	4
##	##	Decide on yoke design method of offset adjustment t	High	Complete	23/10/2024	26/10/2024	4
### 0%							

Figure 52: Research phase Gantt chart.

4.3.2 Design Phase

The design phase also progressed smoothly. The model was successfully created based on the initial topology and further refined through FEA analysis, as originally planned. The positive results obtained from the FEA allowed the project to advance confidently into the prototyping phase. A 3D printed assembly was produced to verify dimensions and ensure proper fitment to the bike. Due to time constraints and limited availability of the printer, the decision was made to forgo creating an SLS prototype. This phase also took longer than expected, with it being finished in the middle of March.

## Design Phase							
##	##	CAD preliminary design for replacement yoke	Med	Complete	26/10/2024	29/10/2024	4
##	##	Refine model with various levels of hollowing	Med	In Progress	29/10/2024	01/11/2024	4
##	##	Perform FEA analysis on yokes.	High	In Progress	01/11/2024	15/11/2024	15
##	##	Finalize first prototype design	Med	Not Started	16/11/2024	20/11/2024	5
##	##	PLA print first prototype to investigate part fitment	High	Not Started	21/11/2024	28/11/2024	8
##	##	Test fit PLA printed part	High	Not Started	29/11/2024	01/12/2024	3
##	##	SLS print final amended prototype	High	Not Started	02/12/2024	10/12/2024	9
##	##	Fit SLS yokes to bike for a floor rest	High	Not Started	11/12/2024	15/12/2024	5
##	##	Finalize yoke design and tolerances for machining	Med	Not Started	06/01/2025	15/01/2025	10
0%							

Figure 53: Design phase Gantt chart.

4.3.3 Testing Phase

This phase of the project has not yet commenced due to delays experienced in the previous phase. The next steps involve preparing detailed engineering drawings and submitting them for machining. Once the component is manufactured, it will be fitted to the bike and evaluated during the upcoming race weekend.

## Testing phase							
##	##	Machine finalized yokes and steering tube	High	Not Started	16/01/2025	25/01/2025	10
##	##	Test fitment on bike	High	Not Started	26/01/2025	27/01/2025	2
##	##	Ground test bike with yokes installed	High	Not Started	26/01/2025	27/01/2025	2
##	##	First track test on bike	High	Not Started	04/02/2025	07/02/2025	4
##	##	First race with new components	High	Not Started	24/03/2025	27/03/2025	4

Figure 54: Testing phase Gantt chart.

4.4 Aaron Lilly

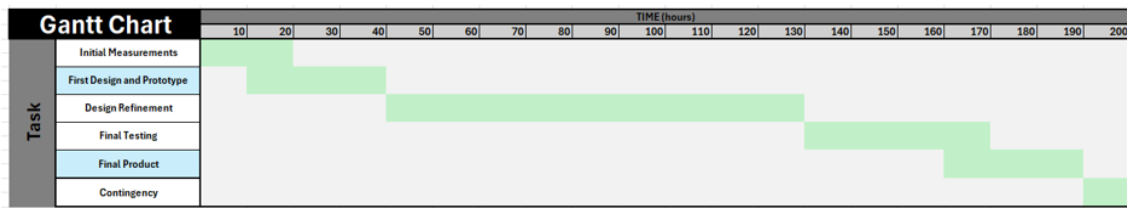


Figure 55: Personal GANTT Chart.

Above is a screenshot of a personal Gantt chart I made to stay on track with my project. Despite this I did run into a few issues.

Firstly, I ran into some design issues, being newer to CAD and surface modelling this took me a little bit longer than I was hoping. Aswell as this, despite having things in place to streamline the process for making all parts compatible and fit well, there was an issue with the airbox model being too big, which delayed my progress and pushed the milestone for the testing and build phases back. This is still an ongoing issue as of now.

A new plan is in place to hopefully finish the project, with a new physical testing milestone of the Pembrey race weekend with NGRRC.

4.5 Megan Gwilym

Throughout this project, I successfully completed the selection and calculation of alternative fuel blends, while some practical testing stages remained unfinished due to time constraints.

4.5.1 Milestone 1

Choosing Alternative Fuels, I successfully researched and identified suitable fuels for the NSF250, focusing on high-octane content, performance potential, and compatibility. This included evaluating SUSTAIN Racing 50 and Classic Super 80 for their renewable content and combustion properties. I also calculated the necessary parameters to predict their impact on engine performance.

4.5.2 Milestone 2

Blending Alternative Fuels, I completed all mathematical calculations for blending ethanol and methanol-based fuels. This included determining volume ratios, mass conversions, and air-fuel ratio adjustments for E30, E40, M20, M30, and mixed blends. While I was unable to proceed with small-batch production or physical testing, these blends are fully prepared for future practical evaluation, ensuring a strong foundation for continued development.

Moving forward, the next steps would involve producing and testing the fuel blends on a dyno and track to verify their real-world performance. These final stages will be crucial in optimizing the NSF250's fuel system for racing applications.

4.6 Jake Davies

Task	Start Date	Duration	End Date
Initial Measurements	30/09/2024	15	15/10/2024
Design ideas	30/09/2024	15	15/10/2024
First Design	15/10/2024	31	15/11/2024
First Prototype	15/10/2024	31	15/11/2024
Design Refinement	15/10/2024	61	15/01/2025
Final Testing	15/10/2024	92	14/02/2025
Production	14/02/2025	30	14/03/2025

These were the milestones I set for myself but I didn't hit them as after the first viva I wanted to start fresh because I believed I would just do better work from scratch again, so me and Ian worked together to get a fairing scan with the internal components behind the fairing included to give me the exact parameters I needed to create my design. My design phase took longer than expected as I kept wanting to change it because I wasn't happy with the work I had produced. I then decided to rework the fairing scan as I didn't like having the entire thing when I was only working on one side of the bike. This made it much easier to visualise where everything was going.

I tried to get some CFD for the intake but during the calculations my solid works crashed and corrupted the file for the intake, so it set me back abit as I had to spend some time re making what I already had.

My first prototype is ready, and I need to run some tests, but I haven't been able to get the CFD done on the new model as I need to further extend my understanding of using the flow simulation but I plan to have it tested on the bike if possible so I can have some real time data.

After I have some testing complete and I evaluate all the data, make any modifications to the intake design, I will be ready to make an actual product made of the desired material.

4.7 Harvey Merrett

To review my work I feel that I have made significant progress compared to the first VIVA presentation. I have a stable design which I can use for a foundation and a full scale model made. Although I am behind schedule according to the Gantt chart I feel that in being delayed it has allowed me to make major changes and modifications that would have possibly hindered the performance of the design.

Due to this I know also know what I need to do for the rest of the project to have success.

4.8 Edward Walden

Several key milestones have been completed in the redesign of the Airbox for the Honda NSF, marking substantial progress in the project. These milestones reflect both the research and development phases, as well as the engineering and design adjustments made along the way.

4.8.1 Completed Milestones:

Initial Research and Conceptual Design: Research was carried out on other race bikes to understand their airbox designs. Insights gathered from this research were incorporated into the first design phase, such as increasing the airbox volume by utilizing space from the fuel tank area. This larger airbox volume allows for the storage of low-velocity, high-pressure air, which is expected to improve performance. Additionally, the interior of the airbox was designed to reduce air velocity and increase pressure at the bellmouth, enhancing airflow.

Prototype Design: The first full airbox prototype was created, incorporating the desired features such as increased volume, improved aerodynamics, and enhanced rider comfort. The airbox was designed to allow for better integration with the rider's chin guard, ensuring the rider could tuck fully on the straights without obstruction. This design was tested in a computer model of the NSF to identify potential fitting issues.

Refinement of the Airbox Shape and Size: After identifying limitations in the first prototype, such as its length and incompatibility with the fuel tank cover, a second design was created. This version was more compact, ensuring it could fit the NSF chassis while aligning better with the redesigned fuel tank cover. The smoother lower half of the airbox also improved its aerodynamic properties and visual appearance.

4.8.2 Future Milestones:

Tapering and Integration with the NSF Chassis: One key milestone moving forward is ensuring the airbox top tapers downward at the front, ensuring a smoother transition with the rest of the NSF design. This will help improve aerodynamics and prevent interference with the rider's ability to tuck during high-speed sections of the track. Which I intend to incorporate in the newest version of the airbox model.

Redesign of the Mating Part: A critical aspect of the redesign involves the mating part, which connects the new airbox to the lower section of the existing airbox housing. The current design for the mating part interferes with the engine's top cover. A more efficient redesign of the mating part is necessary to facilitate proper attachment and ensure compatibility with the engine compartment.

Material Selection and Testing: Another milestone will be finalizing the material choice for the airbox. Carbon fibre has been considered due to its strength-to-weight ratio, but its high cost and potential safety risks in the event of failure warrant further testing and evaluation. The material choice will be integral to the durability and performance of the final product.

Final Testing and Optimization: The final milestone will be conducting rigorous testing of the airbox design, ensuring it performs under real-world racing conditions. This includes testing for durability, aerodynamics, and compatibility with the bike's other systems. Any necessary adjustments will be made based on performance feedback.

Through the successful completion of these milestones and a clear path toward further optimization, the project is poised to achieve its goal of creating a high-performance, durable, and functional airbox for the Honda NSF.

5 Success & Failures

5.1 Successes

5.1.1 ECU Installation and Initial Setup

- Successfully removed the OEM ECU and wiring loom, replacing them with a new ECU and loom.
- Installed and configured the necessary software, backed up ECU parameters, and loaded a compatible Honda base map.
- Achieved engine start-up after resolving crank trigger issues.

5.1.2 Bell Mouth Design and Testing

- Completed research, design, and CFD testing of an elliptical bell mouth profile, showing a 2% increase in mass airflow compared to the OEM design.
- Produced a prototype and confirmed fitment, laying the groundwork for future real-world testing.

5.1.3 Data Acquisition System

- Successfully integrated additional sensors with the new ECU.
- Calibrated sensors and updated lookup tables, enabling future data-driven tuning and performance analysis.

5.1.4 Yoke Design and FEA Validation

- Developed an adjustable offset yoke design using topology optimisation and FEA simulations.
- Validated the design with analytical solutions, ensuring structural integrity under braking and cornering loads.
- Produced a 3D-printed prototype to verify fitment and functionality.

5.1.5 Alternative Fuel Research

- Researched and calculated ethanol and methanol blends, identifying optimal ratios for performance and efficiency.
- Provided a foundation for future dyno and track testing to validate fuel performance.

5.1.6 Collaborative Design Efforts

- Coordinated between team members to ensure compatibility between components.
- Utilised CAD and 3D scanning to refine designs and address fitment issues early in the process.

5.2 Failures

5.2.1 Engine Testing Delays

- Encountered significant delays in engine testing due to unresolved timing and injection issues.
- Initial attempts to start the engine resulted in backfires, requiring extensive troubleshooting and external support.
- Limited progress in refining ignition and fuelling maps due to unresolved ECU configuration issues.

5.2.2 Prototype Production Delays

- Several components (adjustable rear sets, fuel tank, intake ducts and fairing modifications) were not physically prototyped or tested due to time constraints.
- Machining delays impacted the ability to validate designs in real-world conditions.

5.2.3 CFD and Flow Bench Limitations

- Flow bench testing provided limited data, and CFD simulations did not fully replicate real-world operating conditions.
- Lack of real-time pressure data from the engine restricted the accuracy of airflow optimisations.

5.2.4 Material and Manufacturing Challenges

- Uncertainty about the original yoke material made it difficult to validate FEA results against real-world performance.
- Carbon fibre and aluminium fabrication processes were not completed, delaying final component production.

5.2.5 Team Coordination Issues

- Lack of attendance to weekly team meetings despite continued efforts to arrange suitable times.

5.2.6 Incomplete Testing and Validation

- Many designs were not tested on the bike or dyno, leaving performance gains unverified.
- Lack of track testing for adjustable yokes and other chassis modifications meant handling improvements remained theoretical.

5.3 Lessons Learned

5.3.1 Improved Collaboration

- Closer coordination between sub-teams could prevent late-stage issues.
- Regular progress reviews and shared timelines would help keep the project on track.

5.3.2 Real-World Data is Essential

- Relying solely on simulations (CFD, FEA) without real-world validation can lead to gaps in performance understanding.
- Future projects should prioritise dyno and track testing to confirm theoretical improvements.

5.4 Conclusion

While the project achieved significant milestones in design and theoretical analysis, the inability to fully test and validate many components limited the practical impact of these advancements. Moving forward, prioritising real-world testing and improving team coordination will be key to ensuring future projects deliver both innovative designs and proven performance gains.

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7 Appendix



Figure 56: Pico scope setup for recording engine component electrical traces.

7.1.1 Meeting Minutes

NSF250 24/25 Group Project GRP minuets						
07/10/2024						
attendance		staff present				
Harry Rogers	yes	Ian Henshaw				
Olly Gilson	yes					
Edward Walden	yes					
Aaron Lilly	yes					
Oska Robertson	yes					
Megan Gwilym	yes					
Jake Davies	no					
Harvey Merrett	no					
13:00	meeting comences					
13:03	Discussed if members are still happy with the area they have chosen to develop. Everyone is happy to proceed.					
13:05	Discussed possible fuel types that could be used and tested on the dyno					
13:07	Discussed ways the rear sets can be re designed with more adjustment.					
13:15	Discussed what race regs should be considered.					
13:20	discussed possible air box and fuel tank options for development.					
13:30	Discussed allocating the Gantt chart and costing roles being decided at the next meeting.					

Figure 57: 07/10/2024 minutes.

NSF250 24/25 Group Project GRP minuets						
21/102024						
attendance			staff present			
Harry Rogers	y		ian			
Olly Gilson	y					
Edward Walden	n					
Aaron Lilly	n					
Oska Robertson	n					
Megan Gwilym	y					
Jake Davies	y					
Harvey Merrett	y					
11:13	discuss when the fearing will be scanned. Advised by ian that mesurments can be taken befor the scan is done. Discussing modifying a new fairing for the bike before building a bespoke one.					
11:14	possibility to modify the clock mount to aid packaging. Discuss a comuial cad model of the bike we can all work off.					
11:16	discussing air box positioning, how it will be changed by edward					
11:17	discussing air intake postioning. How will it work around the clocks. Discussing fairing mounts and what will change.					
11:24	discussing megans progress with fuel types. Discussed how much reserch has been done and her usderstanding. Olly spoke about assistance with reserching secendory injector timing					
11:25	discussing a comunial gantt chart we can all use.					
11:26	discussign aarons plans with the fuel tank. What shape it will be chaging to. Also subframe and seat hight changes					
11:28	ian discusses intake options for different speeds. Possiblbly having multiple intake options for different tracks,					
11:31	dfiscussing lists of rolles and responsabilitys in teams (ganttt charts) for other assignments					
11:33	discussing the time line for the intake design starting. Also timeline for getting designes done before christmas					
11:35	discussing testing dates for pembrey.					
11:36	discussing new fairing design. What will it look like, possible comparisons with other race bikes. Time scale for design work to be finnishd by					
11:40	discussed materials used in the intake, abs currently with carbon being the end goal					
11:44	discussing coordinating workshop time so the bike is in a usable condition for everyones project					
11:47	meeting ends					

Figure 58: 21/10/2024 minutes.

NSF250 24/25 Group Project GRP minuets						
28/10/2024						
attendance		staff present				
Harry Rogers	y					
Olly Gilson	y					
Edward Walden	n					
Aaron Lilly	n					
Oska Robertson	y					
Megan Gwilym	n					
Jake Davies	n					
Harvey Merrett	n					
11:15	meeting starts					
11:15	start discussing with oska about progress on the rear sets. currently in design phase and moving in to designing replacement next week					
11:19	discuss progress on the triple clamps. analysis of current yokes has been compleate. moving to designing the new ones					
11:22	meeting ends					

Figure 59: 28/10/2024 minutes.

NSF250 24/25 Group Project GRP minuets					
11/11/2024					
attendance		staff present			
Harry Rogers	y	ian henshaw			
Olly Gilson	y				
Edward Walden	n				
Aaron Lilly	n				
Oska Robertson	n				
Megan Gwilym	n				
Jake Davies	n				
Harvey Merrett	n				
meeting held in workshop going forward					
11:15	meeting starts				
11:16	Harry begin discussing progress on yoke reserch. Also began creating the orignal parts in solidworks for comparrison.				
11:20	ian suggested comnducting FEA studys on the original yokes once modeled. Discussed how this could be done				
11:25	discussed CFD progress with the belmouth design. Looksed through currect photos of bellmouths				
11:28	discussed next steps of bellmouth devolpment on the flow bench. Olly will be flow benching the airbox next.				