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SCHOOL OF ENGINEERING

SPORTS 2000 BODYWORK PACKAGE
GROUP PROJECT
FINAL REPORT

M5X00400

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Introduction (MH)

For the second year Sports 2000 bodywork package group project, eight automotive and motorsports engineering students were tasked with taking an existing aerodynamically improved bodywork package, created by a current third year student, and adapting it to fit the vehicle, maintaining as much aerodynamic advantage as possible.

Initially, the group investigated how well the bodywork fitted the car, by creating an accurate CAD model of the chassis, so the car could be offered up to it and collisions could be identified. Upon doing this, the group assessed the series' rules and regulations to establish where the prototype bodywork package was deemed illegal and researched how best to rectify this. Once all fitment errors were found, the bodywork redesign began, adapting the initial file. Upon realising the severity of the fitment issues, it was decided a complete bodywork redesign should be carried out from scratch to ensure the new bodywork package fitted correctly. Throughout the redesign process, constant aerodynamic analysis was carried out to ensure the aerodynamic gain of the redesign was compromised as little as possible. This was tested through Computational Fluid Dynamics (CFD).

Throughout the project particular emphasis was placed working in accordance with the given budget, and on ensuring the manufacturing processes that would be utilised were correctly and thoroughly researched, allowing the group to make the best use of the University facilities available to them. Use of the correct materials and best purchasing methods were also researched, all with assistance and guidance from composites and manufacturing technicians.

When these initial stages were completed, it was decided by the group what the final outcome would be due to budget and time restraints, and progress began on the manufacturing phase of the project, allowing the group to begin to make the updated bodywork package.

Project Organisation

Allocation of Roles

Max Hart

Administrator, Project Leader

Project leader

Admin - meeting minutes, planning

Materials research

Public relations

CFD analysis - secondary

Ryan James

CAD Operations - Fitment

CAD rolling chassis organisation

MoTeC load analysis

Buck Preparation

Fastening & splitting

Ainsley Martin

Aerodynamicist

CFD analysis - primary

Aerodynamic advisor

Proving project worth

George Jones

CAD Operations - Design

CAD bodywork organisation

Redesign of concept bodywork

Nicholas Thomas

Regulations Analyst

MoTeC load analysis

Materials research

Rules & regulations research

CNC Preparation

Fastening & splitting

Simon Williams

Materials, Manufacturing

Materials research

Manufacturing research

Manufacturing budget advisor

Ewan Carter

Wing End Plate Investigation

Research and analysis of wing
endplate optimisation

Kai Tang

Louvres Investigation

Research and analysis of wheel
louvre optimisation

Table 1 - Overall Group Tasks

Task	Dates (Planned)	Dates (Actual)	Description	People
Plan Project	8/10/18 - 12/10/18	8/10/18 - 12/10/18	Make detailed chronological plan for all group members, discuss overall initial ideas.	All
meetings	continuous	continuous	Attend regular weekly group meetings plus meetings with technicians and supervisor.	All
CAD Chassis	10/10/18 - 9/11/18	10/10/18 - 23/11/18	Make a detailed simulated rolling chassis in CAD to be used for the basis of all future design and CFD.	All
Research	10/10/18 - 3/12/18	continuous	Research the bodywork concept, finances and available budget. Send out letters to series officials and research materials and manufacturing processes.	MH, GJ, SW, NT, EW
Fit Concept	28/10/18 - 9/11/18	28/10/18 - 05/12/18	Turn solid concept chassis into shelled body in order to fit to CAD chassis, aiding collisions checking.	GJ, MH, RJ, AM
Re-Design concept	8/11/18 – 7/1/19	05/01/19 - 26/02/19	Re-design the bodywork package to fit the chassis, re-analyse CFD and ensure regulations are met.	GJ
Manufacturing Training	14/11/18 – 6/2/19	14/11/18 - 13/03/18	Attend workshop sessions run by the composites department.	All
CFD new bodywork	28/01/19 - 21/01/19	8/2/19 - 29/3/19	Fine tune newly developed bodywork once locked down through CFD investigation.	AM, MH
First Viva	3/12/18 – 5/12/18	23/12/18 - 5/12/18	Prepare in advance a presentation summarising group progress, with two-minute speech from each member.	All
Split New Bodywork	14/1/19 – 6/2/1	19/02/19 - 5/03/19	Split the new bodywork into manufacturable sections, research and design how to fasten and attach it to body.	RJ, NT
Make New Bodywork	6/2/19 – 29/3/19	22/03/19 - ongoing	Utilise composites facilities to make bucks and moulds, then final bodywork pieces.	All
Complete report and Viva	22/3/19 – 1/4/19	20/3/19 – 1/4/19	Compile a report on the full project and present results.	All

Please see Appendix 1 - Initial Group Gantt Chart

Maximilian Hart - Team Leader

For this project the author assumed the role of team leader. As well as various research, development and manufacturing tasks, personal tasks consisted of organisation and administrative duties.

This section of the report aims to detail the author's work carried out throughout the project, reflecting on progress made and the success of the work completed overall.

Summary of Work Completed

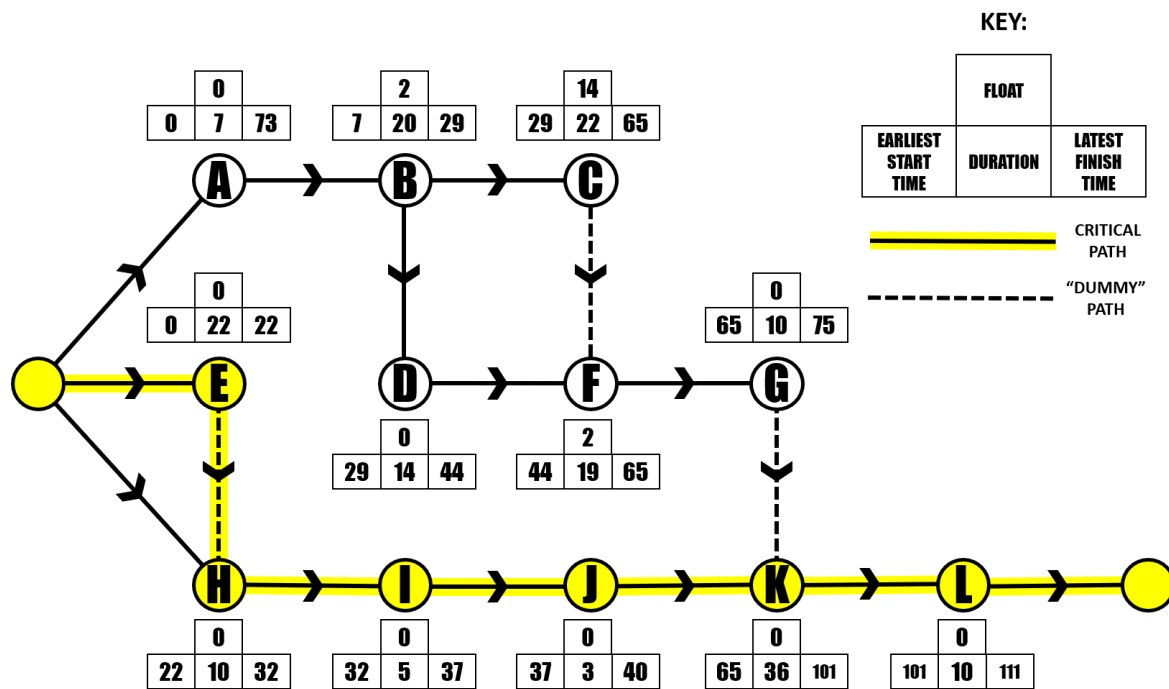
Table 2 - Work Completed (MH)

TASK	COMPLETED WITH	HOURS
Initial planning	All	10
Initial administrative tasks	-	5
Meetings	All	50
General administrative tasks	-	15
CAD chassis parts	All	20
Research Tasks	AM, RJ, NT, GJ, SW	10
Photograph Gunn	AM, RJ, NT, GJ, SW	4
Workshop sessions	All	40
Fit and calibrate push-rods	AM, RJ, NT	4
Thicken bodywork	AM, GJ	5
Viva 1	All	10
Write letter to regulators	NT	5
Writing secondary briefs	-	2
Meeting to lock down bodywork	AM, RJ, NT, GJ, SW	2
Learn CFD	AM	10
Creating CFD instructions	AM	5
Rake attitude study	AM	9
Ride height attitude study	AM	9
Yaw attitude study	AM	9
Final CFD validation	AM	5
Viva 2 and Report	All	20
		TOTAL = 242 HOURS

Team Leader Role

The author oversaw the initial setup and organisation of the project, ensuring each member was briefed properly on what was required of them, as well as ensuring they had an equal workload and everyone was involved with the project to their full potential. Ensuring the project started smoothly and in an efficient, logical manor was crucial, as studies show this is the most common time to face a problem in a project. It was important to promote a sense of enthusiasm amongst team members and ensure the project was set up quickly so work could commence (Abyad, 2018).

Throughout the project, the author enforced the plan and schedule as much as possible, mitigating the chance of overall delay. As the workload evolved, it was clear that the initial schedule would be too tight to incorporate all the tasks necessary to proceed, hence figure 1 includes revised dates and the final outcome aims changed throughout the project. As team leader, it was imperative to keep on top of the need to reschedule so the team had a clear idea of what was expected of them and when task completion was expected, within a realistic timescale. The author created a critical path analysis diagram at the beginning of the project to emphasise which tasks had to be completed to progress within the project. This gave the team members a clear idea of the importance of their tasks, and a set time in which to finish them.



Task	Task Description	Preceding Task	Duration (days)
A	Initial ideas	-	7
B	CAD chassis	A	20
C	Initial aero/CFD analysis	B	22
D	Mount JH body on chassis	B	14
E	Materials research	-	22
F	Identify collisions & redesign JH bodywork	B,D	19
G	Re-do CFD	C,F	10
H	Split body into parts	-	10
I	Finalise materials research	E,H	5
J	FEA chosen materials	I	3
K	Manufacture bucks & moulds	J	36
L	Produce all bodywork	K	10

Figure 1 - Project Critical Path Analysis

The author produced a contingency plan amongst the group to mitigate risk of falling behind schedule if, for any unforeseen circumstances, a team member could not complete the work required of them. It was ensured that each member felt comfortable being the secondary worker for each task and was sufficiently trained to do so.

Table 3 - Contingency Plan

Primary Role	Secondary Role
Maximilian Hart Team leader	George Jones
Ainsley Martin Aerodynamics	Maximilian Hart
Ewan Carter FEA (initially) Wing investigation (latterly)	Ainsley Martin
George Jones CAD operations - bodywork	Ryan James
Nicholas Thomas Rules and regulations researcher	Ewan Carter
	Kai Tang
Ryan James CAD operations - chassis	George Jones
Kai Tang Public relations (initially) Louvre Investigation (latterly)	Maximilian Hart
Simon Williams Materials researcher	Nicholas Thomas

The author decided a system of cross-checking should be implemented throughout the project. When a team member submitted a piece of work, an independent party within the group would cross-reference the information and check any other aspects of it to ensure it conforms to referenced sources and their own understanding. Obviously, this takes time and therefore could only be completed to the best of the individual's ability at the time of checking, but doing so reduced the possibility of error, hence mitigating the chance of delay to the project. This system proved particularly important when producing the CAD rolling chassis as multiple measurement errors became apparent but were quickly rectified.

As team leader, it was important administrative duties were upheld throughout the project, notably organising regular meetings for the group (*please see appendix 7*) and taking minutes for each one. This ensures the team stay up to date on proceedings and know what is expected by the time of the following meeting.

One of the most important roles of a team leader is to overcome obstacles the group may face as efficiently and productively as possible. It became apparent during the project that certain group members were not producing the same amount of work as the rest. This was deemed to be an issue as every group member is required to input an equal amount of work, so the author oversaw the process of suggesting to the individuals that their current roles should be dropped, and each should oversee an independent investigation into optimising elements of the bodywork that had not yet been explored. This enabled the individuals to take control of their own section of the project and not slow down the rest of the group.

The author drafted detailed briefs to fully explain what was expected from these investigations (*please see appendix 2*) and reminded each individual that the full support of the group was still available, they were still part of the team, and the work they would complete was still important to the overall project's completion. This process was confirmed and assisted by the group project supervisor (TT) before any advancements were made.

The author's Belbin Model analysis shows the highest score on the 'completer finisher', 'implementer' and 'co-ordinator' categories. This led the group to believe the author is well suited to the role of team leader as this portrays an organised individual who sees tasks through to the end and leads well. Scoring highly on the 'completer finisher' and 'co-ordinator' sections is an asset to a leader as it shows an ability to oversee these tasks and ensure they are being completed correctly and efficiently. The author's score was also high in the 'implementer' category. This is beneficial to a leader as it shows an ability to bring new ideas to the group (Belbin, 2010; Weimer, 2014).

Design Process

Every team member contributed to the initial CAD model of the rolling chassis upon which the body was placed. The author modelled the wheels, uprights, air box, radiator and drive shafts. Each component takes time to produce as measurements have to be taken accurately on the actual car and recorded clearly to be transferred to CAD. A tolerance was set for each component, generally the team aimed to work to within a maximum of $\pm 5\text{mm}$, with more intricate components requiring a smaller tolerance of maximum $\pm 2\text{mm}$. Once the component was measured, it was referred to another team member to check for error and inaccuracy, and the CAD model was produced. Emphasis was put onto the correct geometry of the component rather than aesthetics, as this is most important for creating correct body fitment.

After six and a half weeks, the rolling chassis CAD model was fully complete and the bodywork was produced by the CAD Design Manager (GJ). This bodywork package was made as a surface on Solidworks which was thickened by four members of the team, one of which was the author. Using Solidworks surface tools, problem areas within the bodywork could be identified and fixed, usually where corners and creases were too tight and resulted in zero thickness geometry. This process allowed the body to be easier to adapt and mount to the chassis as mating and aligning in Solidworks was possible.

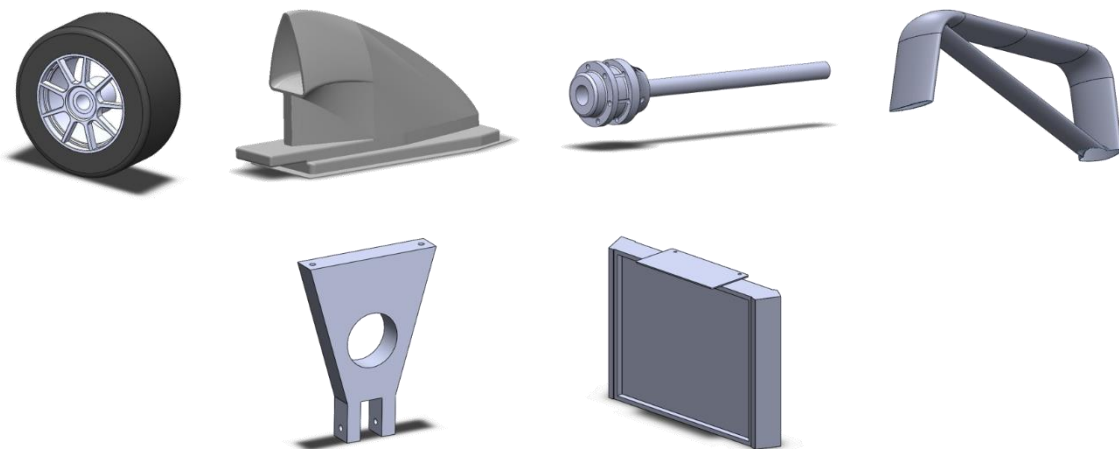


Figure 2 - CAD Components (MH)

Research

The author conducted thorough research into the resin infusion process (*please see appendix 3*). This was decided at the time to be the most appropriate method to manufacture the bodywork, hence thorough research was required to ensure the group could use the workshop facilities available in the most efficient, safest way possible.

Additionally, the author researched which specific materials should be used to ensure the best material was chosen considering what is required from the bodywork. This research was basic initial materials research and was just a starting point for this area; it was completed in more detail by other team members later in the project.

Measurement of aerodynamic load through the car was also researched; it was decided the best method is to fit calibrated push rod sensors to the vehicle, that feed live data to the MoTeC system. Four group members undertook this task, installing the sensors as follows:

- Consult wiring diagram and find pushrod sensor input locations.
- Plug all sensors into correct inputs on car.
- Find MoTeC math channels and output values.
- Apply a load by hand to check signal and check if plugged into the right place.
- Use Longacre coil spring tester to set constant pressure in pounds.
- Convert this to Newtons and input pressure exerted into MoTeC software.
- Repeat this for each 10 Newton increment between 0 and 100 Newtons first of all.
- Check inputted data on MoTeC; a linear graph should be seen
- Repeat for remaining sensors, only 3 readings need to be taken as linearity confirmed.
- View output channels on MoTeC - applied load to all by hand to check live output.
- Mark each with correct position on vehicle.

This process ensured the pushrods were functioning correctly and were correctly calibrated, allowing the group to measure aerodynamic loads on the bodywork; specifically to test the aerodynamic gain of the splitter designed by John Iley. The data acquired will be compared to CFD results, this can be used to validate any simulated data.

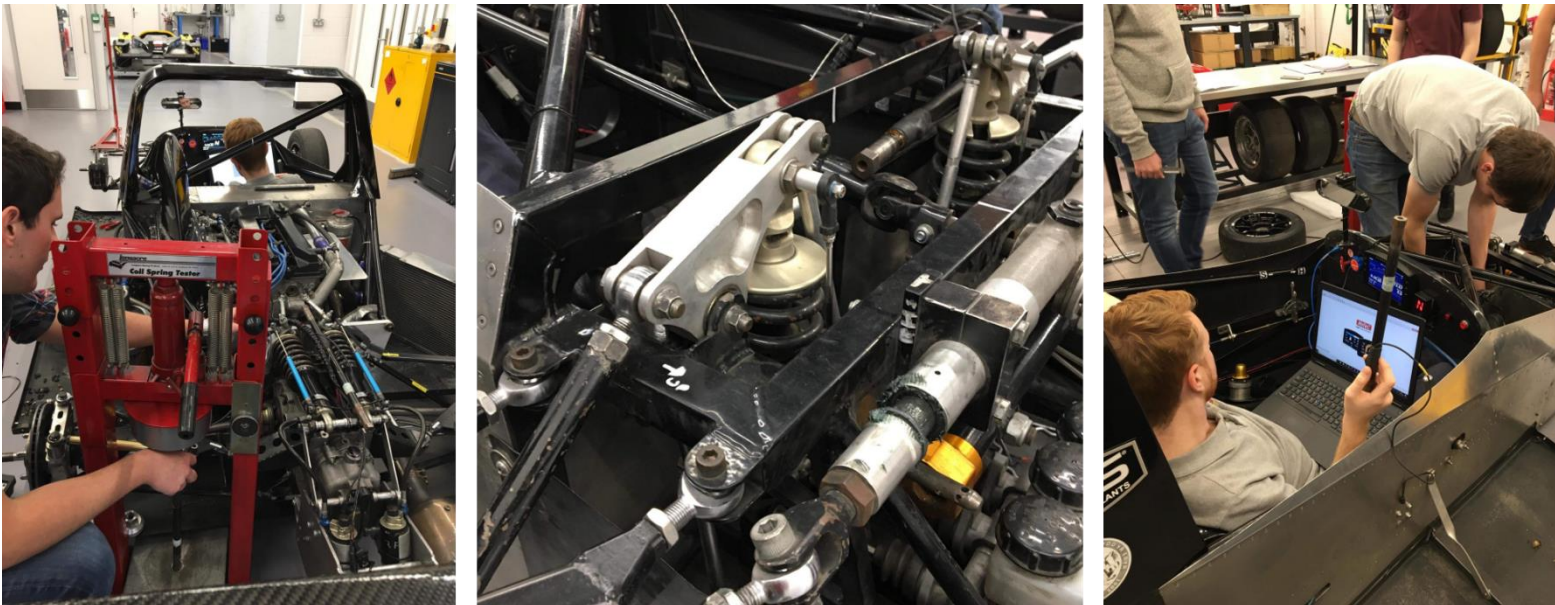


Figure 3 - Push-rod Installation

To enable the bodywork to be produced, the team needed to ensure the bodywork met rules and regulations and was deemed legal by the organisers. A case study into the Loaded Gun TS11 was conducted prior to design starting, to see how it could influence the group's bodywork package. The author wrote a letter to the organisers of Sports 2000 highlighting any design elements with the new bodywork design that the group had deemed questionable with regards to legality. This was an important step as the organisers have to say yes for the group to be able to start the manufacturing phase. If the organisers would have deemed the bodywork design illegal because of elements also seen on the Loaded Gunn, the group would have no choice but to launch a formal complaint as this is clearly unfair practice. This would delay the project considerably.

An important task completed by the author also was writing a letter to the Sports 2000 regulators. This letter outlined the group's concerns regarding the legality of the proposed bodywork design; the idea behind which stemmed from copying the Gunn TS11, which the group's regulations analyst deemed to be breaking the rules in multiple areas. The author wrote the letters in a way that pointed out the illegal elements of the Gunn but phrased as elements of the group's design. This does not land fellow competitors in trouble, whilst encouraging the series regulators to respond positively, as everything mentioned was already in use on a competing vehicle. If the regulators respond negatively, unfortunately the group will have no option but to explicitly point out the Gunn's illegalities. It is unlikely the regulators will stop them from competing, thus meaning they should allow the group's proposed design. The author chose to write the letters in this manner as a persuasive device to ensure the proposed design was deemed legal.

Development

During the design process the group aerodynamicist (AM), was required to run many different geometries to establish which design elements work best. This requires a firm understanding of Computational Fluid Dynamics (CFD). Towards the end of the group project, CFD was used for the final geometry to establish the optimum rake and ride height for the vehicle running that bodywork, as well as how it is affected by yaw. This involves running many repetitive runs to gain results for a variety of these setups. The author received training from Ainsley to achieve a level of competency in CFD that ensured the workload could be spread between two people, speeding up the analysis process. The author was instructed on exactly what each individual setting does and what works best for the widely used Ahmed body initially, and once the results from that were sufficiently close to accepted values, final bodywork geometry.

From this, the author went on to create comprehensive instructions for running both the Ahmed body and bodywork package in CFD (*Please see appendix 4*). This consolidated what was learned and helped to gain a deeper understanding of each setting, as every step was researched and explained (Sirius CFD, 2012). These notes were created with the view of other team members, specifically those with individual projects, being able to integrate CFD aerodynamic study into their work. This was successfully utilised by one member of the group, then externally verified by the group supervisor and a student working towards another group project wishing to learn more about CFD. This external verification proved very useful in insuring the notes made sense to an individual who has never used CFD before .

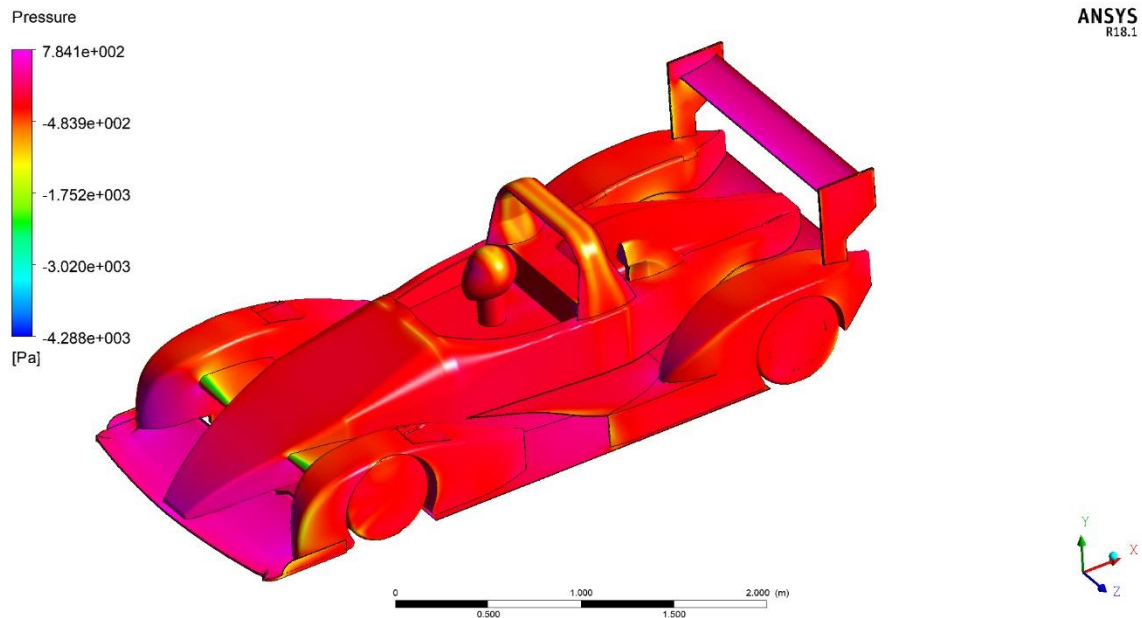


Figure 4 - Results from a CFD run conducted by the Author

Manufacturing

Every Wednesday at 09:00, the group meet with the composites technician (AT) in the composites workshop to practice key skills and methods required to manufacture the bodywork. This allowed the author to understand processes required for the manufacturing phase and enhance practical skills such as sanding, filing and laying-up of composite materials.

Analysis

The author has developed a deeper understanding of what is expected of a group leader through this project. Leadership and team management skills are an important part of an engineer's skillset; the ability to overcome unforeseen obstacles in an efficient and timely manner is key to ensuring a team stays on schedule and stays focused. Poor organisation of any project can lead to confusion and loss of morale; this being especially important in an engineering project such as this, where multiple different tasks happen simultaneously yet rely on each other's completion to ensure the project as a whole can progress (Hayes, 1997). It was important because of this to understand the relationship between working as an individual and working as an individual within a group. The author learnt the importance of overseeing the organisation of different group member's skillsets. Physical jobs were given to those more confident practically, whilst team members who felt most comfortable academically contributed predominantly by doing detailed research. However, it was encouraged that every team member used this project as an opportunity to practise as many skills as possible, hence, each were allocated a variety of CAD and research tasks and partook in the weekly composite workshop sessions. The author saw the importance of ensuring each team member had a constant, manageable workload and was pushed to test their abilities wherever possible.

The author would be confident that if the project was repeated, or a similar project was undertaken, it would be completed with equal success but with improved efficiency, implementing what has been learned from this experience.

Ryan James - CAD Operations - Fitment

Work Content

Throughout the project the author was involved in many different aspects, a general list of tasks is in table 4. To avoid repetition in the report with other team members the rolling chassis related tasks and Buck Creation Related tasks have been described in Detail in this section.

Tasks Completed

Table 4 - Work Completed (RJ)

Task	Completed With	Hours
Draught Project Plan		2
Cad chassis tub with mount points		20
Meetings	Group	50
CAD All Rolling Chassis Components	Group	5
Create Rolling Chassis assembly		5
Recheck Actual Rolling Chassis Full Dimensions	Nick George Ainsley Simon Max	15
Correct any CAD Component Geometries		20
Finish CAD Rolling Chassis Assembly		10
Research Gunn TS11	George Max Ainsley Nick	4
Workshop composites sessions	Group	40
Turned original concept body into surface sections	George Jones	2
Helped check original concept body collisions	George	3
Helped Check new Group Body for Collisions	George	3
Draft straight-line test plan		2
Fit pushrods and calibrate	Nick max Ainsley	4
Viva 1 Plan and Carry Out		10
split body new body design	Nick	4
Designed Attachment	Nick	2
Adjust Parts for CNC	Nick	2
Design JIG/Frame for CNC	Nick	4
Experiment with JIG Joints		4
Acquire Parts for Jig		8
Build CNC Jig		12
Experiment with Foam Adhesion	Nick	6
Mount Foam to JIG for Machining	Nick	3
TOTAL		230

Initial Checks

The first task was to assess the concept design. Upon close inspection it became clear that the concept bodywork had a considerably different design to the current package and with a few measuring checks, it became apparent that the bodywork would not fit over the radiator and the wheel track was slightly smaller on the concept. This led to further checks and yet more points of potential collision, so it was decided the best course of action would be to create a CAD rolling chassis so the concept package could be checked as a CAD assembly on top and the body work could be corrected to fit.

Rolling Chassis in CAD

Creating chassis Tub

The first step was to create the chassis tub that all the suspension and steering parts would then be attached to. It was imperative that all the mounting points and the overall size were accurate so the suspension would articulate on the model in the same axis as the actual vehicle. As the concept body work had the front plane running centrally along its length the chassis was created in the same orientation and with the same origin point see figure (5).

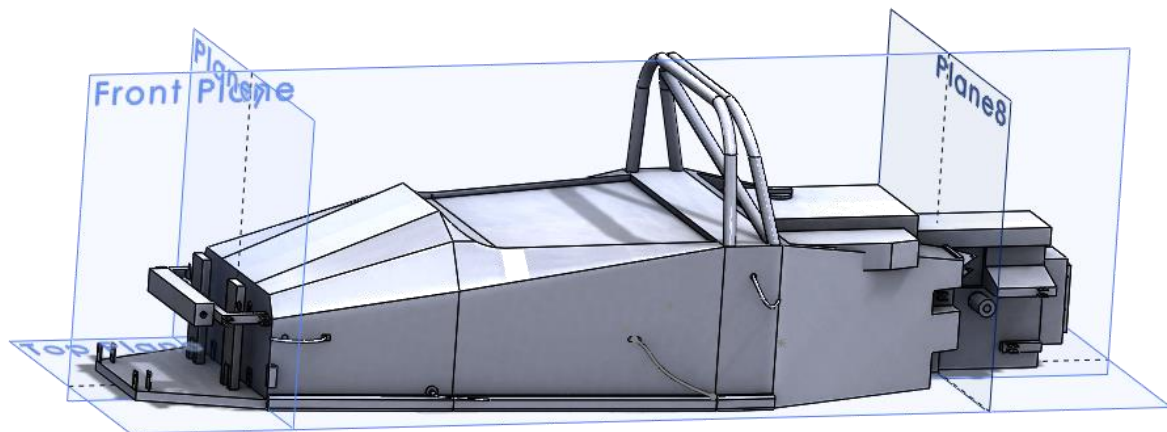


Figure 5 - chassis tub planes

As the suspension measurements were extremely critical so a laser was used to divide the car down the centre (Figure (6)) to measure the mounting points from in the y direction. To keep accuracy in the x direction a plane was taken on the pedal box bulk head for the front suspension and another was taken at the shift plate for the rear suspension. The top plane was taken from the floor of the car for z measurements.

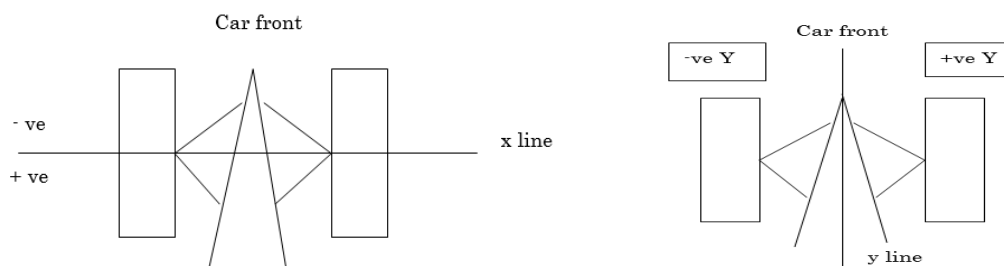
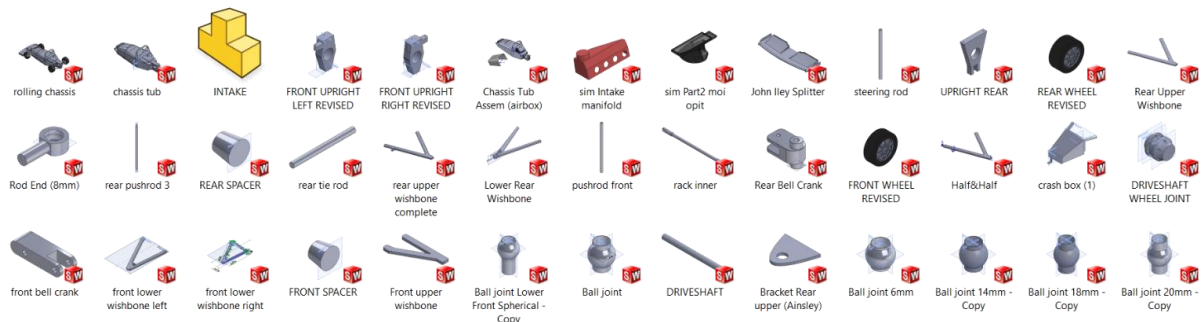


Figure 6 - X and Y Axes

As any inaccuracies would be exaggerated in the suspension the chassis tub mounting points were measured in a variety of different ways to cross check readings i.e. with self-levelling lasers, plumb lines, Vernier's, micrometres and squares.

Creating Assembly Parts

Once the central Tub was complete the entire group worked together to make all the parts needed to finish the rolling chassis. This eased the work load initially but created more problems in the long run, as incorrect CAD took longer to remeasure and correct.



Check Complete Model

The full articulating rolling chassis model was then checked with a variety of group members to ensure it was correct for wheel and suspension positions at a variety of wheel heights and steering angles. The complete model can be seen in figure (7). This was a slow process to ensure the readings were precise as any CAD designs would be made from the model, again the measurements were taken with a variety of different techniques (Sydenham, 1994) with different people to check for the correct result.

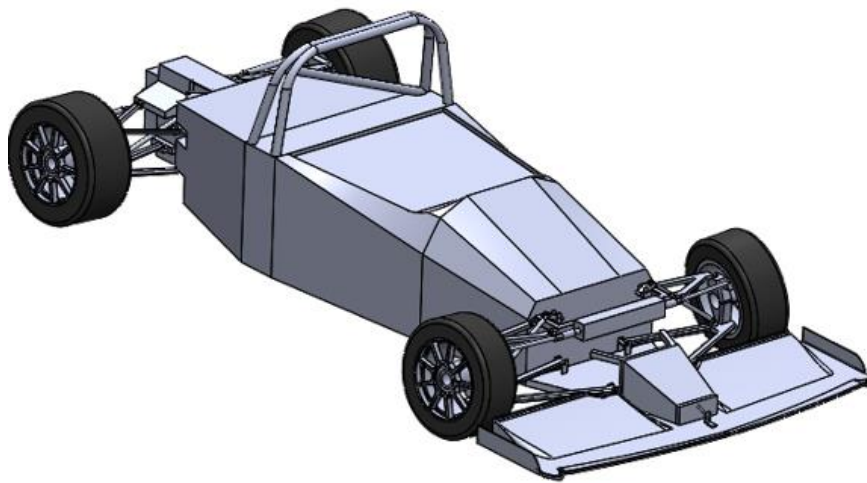


Figure 7 - Complete Chassis Model

Review of Rolling Chassis Creation

With the difficulty encountered using multiple group members CAD, it was decided that for any future CAD tasks, that one group member would create them as an individual and others would then help check over the accuracy of the work. This approach made the process faster as group members then didn't have to wait for each other to complete Tasks to continue with their work.

Creating the rolling chassis assembly model allowed the group to move through the project with confidence about what would and wouldn't fit on the vehicle. It also allowed the attaching methods for the bodywork to be designed.

Master Pattern Creation

Maximum Part size

Once the bodywork has been split into sections for fitment the sections had to be further split into parts for CNC this is due to the limitations of CNC machine sizes (Overby, 2011). The maximum size of a part in the universities 5-axis machine allowing for full tool head movement is 0.7m x 1.5m x 0.45m see figure (8)

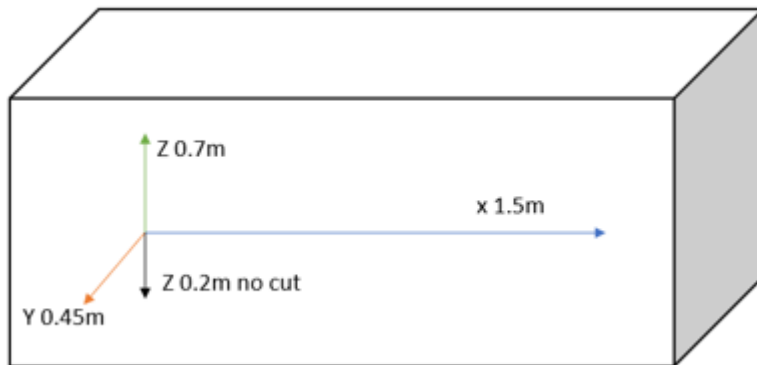


Figure 8 - Internal available CNC dimensions.

Design Jig and Frame

As can be seen in figure (8) the lowest 200mm in the z direction is not used when the head is rotated to horizontal. This means to simplify the machine coding if the part is smaller than 700mm high it would be advantages to create a Jig to mount the foam on. If the part was deep to save foam an internal wooden structure would be created see figure (9).

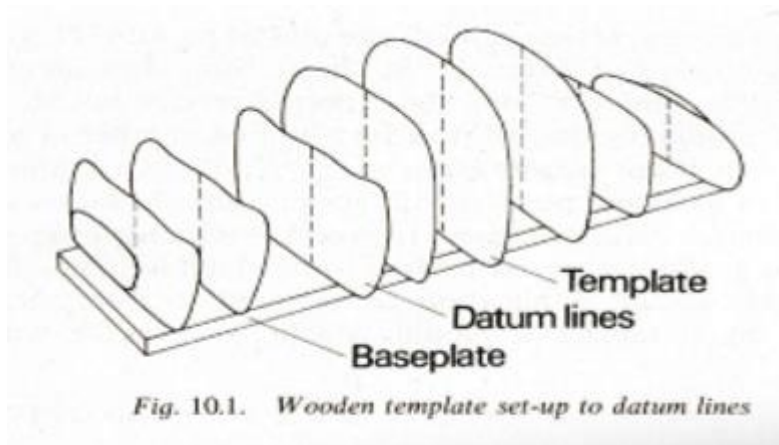


Figure 9 - Wooden Frame

(Wood, 1980)

As the first piece cut would be a wheel pontoon the waste in the centre would be less than $4.8 \times 10^{-3} \text{ m}^3$ so only a Jig was created.

Acquire Parts for Frame and JIG

To reduce the strain on the project budget; wood, fixings and other items were acquired through sponsorship from outside sources. This was a valuable lesson in the need for sponsorship in sport and how important it is to forge ties with outside companies (Mousavi, 2011).

Test Joints and mounting

As sponsorship provided wood for frame work it would also be used to create a jig to raise and support the foam for machining. The jig would have to not vibrate when the tool head is cutting the foam as movement in the foam would result in a rough irregular cut finish. The main concerns were the jigs joints vibrating and the foam moving and vibrating on the jig.

To find the best jig joints wooden joints were researched (Soltis, 1999). 3 types were created out of plywood and tested; pocket screws, end screwed and dovetail. Each type of joint was made at 90° and glued allowing 24hours for it to set. Then they were weighted at a set distance and the torque was calculated to find the strongest to break, the results were recorded. The end screw took 40Nm the pocket screw took 60Nm and the dovetail took 90Nm see figure (10).



Figure 10 - end screws top left then pocket top right then dovetail

The results clearly showed the dovetail joints to be the strongest, as the wood had to brake to brake the dovetail joint whereas the screw holes weakened and split the wood under load for the pocket and end screwed. The dovetail joints are by far the most labour intensive to create.

To attach the foam to the Jig, dowels were used as they would provide some rigid structure up inside the foam. A vice like clamp across the bottom see (figure 11) was created to keep the foam tight to the dowels. expanding foam was used inside the dowel holes drilled into the foam sheets.



Figure 11 - clamp dowels and expanding foam.

The dowels are clamped to the base in a large wooden vice inside the box and pass through tight upper holes this allows for them to be removed with the machined foam and new ones inserted to reuse the Jig. The range of the clamp allows for 1, 2 or 3 sheet widths of foam to be used this makes it usable for most of the pattern manufacturing.

Experiment with Foam Adhesion

When machining multiple sheets of foam, they need to be stuck together. These sheets would need to have their faces machined first to give flat surfaces to stick and so no holes would be in the finished product. Ideally this would be done with polyurethane glue but that would not be ordered in time to start machining, so for the first pattern initially carpet tape was tried but this did not have the adhesive quality required. Then expanding foam was used between the sheets and the jig. The sheets and Jig all needed to be clamped together whilst the foam cured. This was done with large wood clamps, sash clamps and ratchet straps.

Cutting Master Pattern Parts

Once the Jig with its foam is securely in the CNC machine the technician can Turn the CAD file into G-code which is the type of machine code the CNC understands (Lee, 1999). Considerations taken by the technician are; the size of the foam so the tool starts at its edge. A datum/ location starts point. Tooling lines to move around the foam in an efficient order that won't damage it. The speed of the head. The cutting tips used (Liang, 2016).

The technician would run a simulation cut of the process and this would visually aid their assessment of the job and give the run time to cut. A front pontoon would take 12.5 hours cutting time screen shots of the simulation can be seen in figure (12).

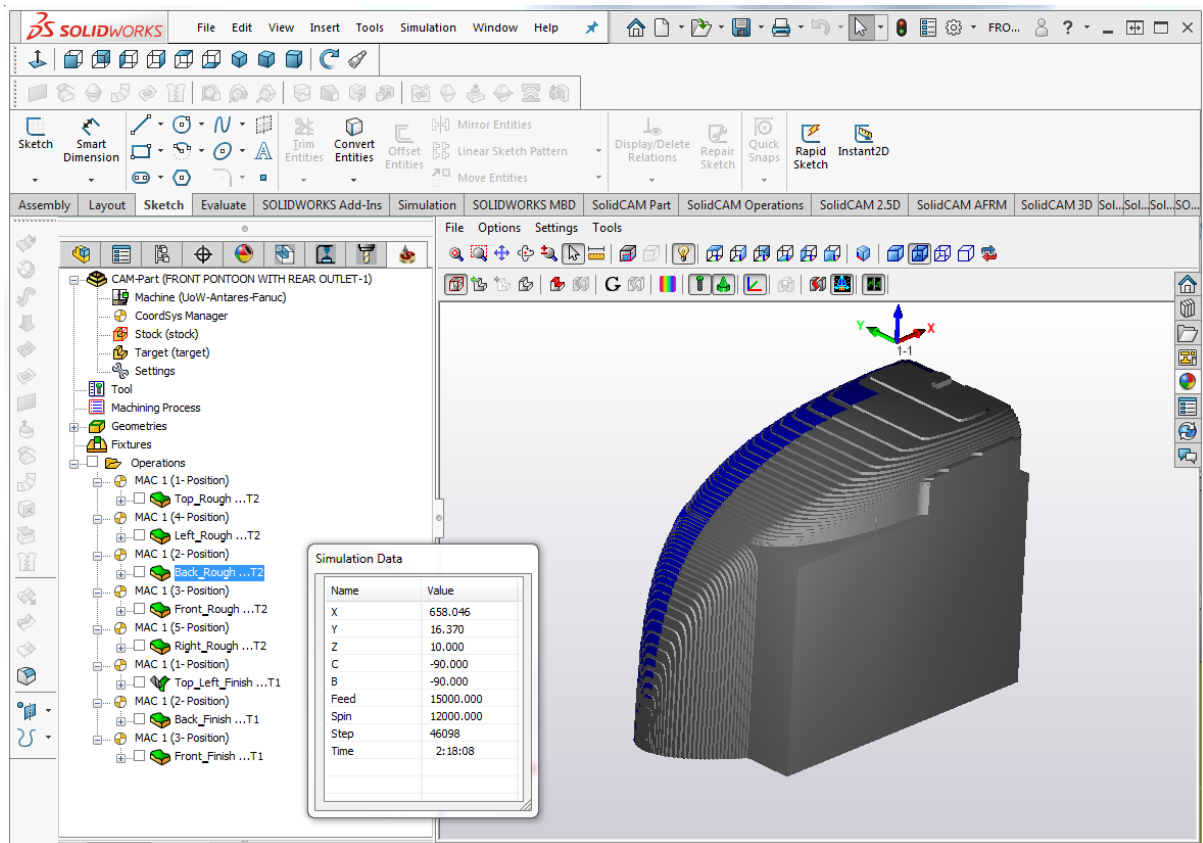


Figure 12 - partially cut foam block simulation

(Cooper, 2019).

Review of Master Pattern Creation

The strain on the group budget and the time delay for ordering parts for the project inadvertently lead to a positive of seeking sponsorship and using ingenuity to make do with other materials. This did add extra work to the project like making master patterns from insulation foam instead of going straight for negative moulds from model board but overcoming these obstacles taught us more about coping with real world non-ideal situations. This work to machine the master patterns brought forward the point that the parts would be created and lowered the project cost drastically.

George Jones - CAD Operations - Design

Table 5 - Work Completed (GJ)

TASK	COMPLETED WITH	HOURS
Initial Planning	All	10
Meetings	All	50
CAD Chassis Parts	All	6
Check Chassis Measurements	RJ	4
Research Tasks	ALL	8
Research Gunn	AM, RJ, NT, MH, SW, KT	2
Workshop Sessions	All	15
Thicken JHTT02 Surface Model	AM, MH	10
VIVA 1	ALL	10
Design Plan	-	5
Design GJ01	-	45
Additional Design Iterations	-	8
Meeting with AM	AM	2
Design GJ02	-	20
Design GJ03	-	4
Meeting with AM	AM	2
Negotiate Sponsorship	-	3
Additional Design Iterations	-	5
Finalise Design Meeting	AM, RJ, NT, MH, SW, EC, KT	2

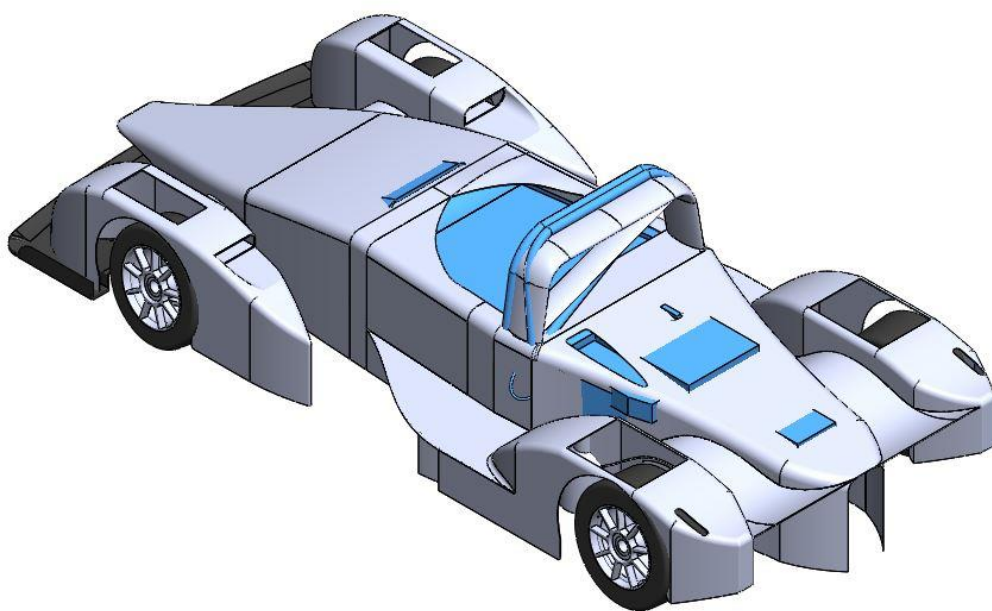
Total Hours: 211

Implementing the accurate chassis model for JHTT02 Fitment Analysis

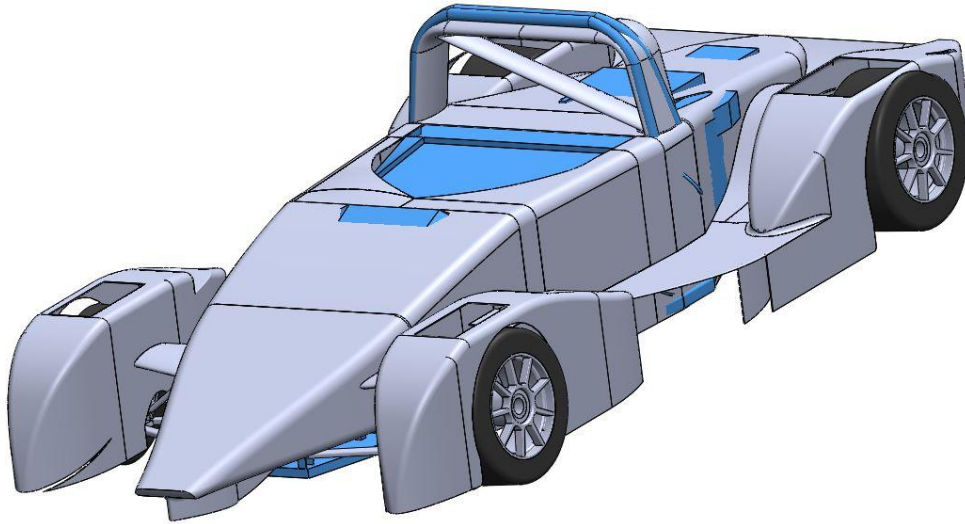
The group worked towards creating a full chassis assembly in Solidworks, by splitting the work load and following the established measurement procedure, intended for accurate results. The complete assembly was cross-examined with the MCR chassis and all inconsistencies were noted for future reference. The wheel alignment in the fully articulated chassis model was particularly problematic, as small discrepancies in suspension components are exaggerated to larger wheel attitude effects through wheel diameter (Campbell, 1981). The group assessed the severity of the problem and agreed to address these issues further into the project as necessary to avoid unnecessary delays (Marjolein CJ Caniels, 2019).

The groups attention turned to the JHTT02 concept (Hughes, 2016), intended for manufacture. The concept bodywork package was built on a chassis model of unknown accuracy, so it was critical to scrutinise the geometry of the proposed package, using the new chassis assembly (James, 2019). The entire JHTT02 concept was developed in one Solidworks part file, combining bodywork and chassis components. This resulted in failure of all reasonable methods to separate the individual bodywork components, without disrupting multiple sketches and features. A thickened surface model of the concept had to be created in Solidworks to simplify the problem (Lombard, 2013).

The model was converted to a surface, where individual faces and bodies were deleted systematically to separate the bodywork from the chassis structures. The surface model was thickened to 3mm before being overlaid to the chassis model.



(Isometric view of JHTT02 fitment)



(JHTT02 fitment assessment)

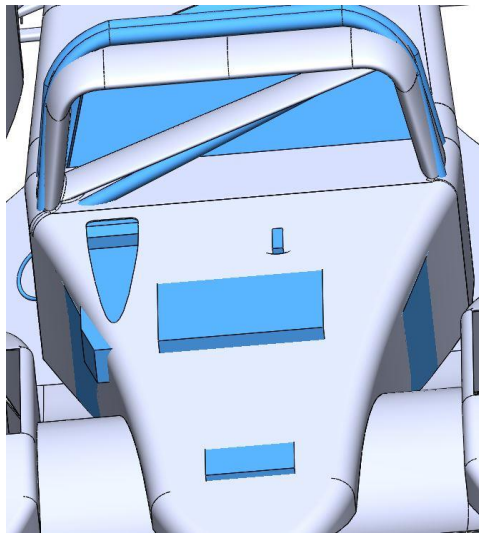


Figure 13 - Three Fitment Assessments

(JHTT02 rear clam collisions)

Areas of concern

- Upper nose cone / dash region too shallow with interference
- Front pontoons out of alignment (fore and aft)
- Roll hoop shroud too low and inaccurate with interference
- Rear bodywork sides - interference with chassis rails
- Rear bodywork upper - interference with gearbox, suspension, engine & air box
- Rear pontoons out of alignment (fore and aft)
- Suspension locations/geometries inaccurate

Design Plan

Due to the inherent complexity of the JHTT CAD design, the group decided the most viable solution was to rebuild the entire bodywork package. This decision was further justified by a necessity to produce three versions of the final CAD model, suitable for fitment, CFD and manufacture.

Assembly Method

A global coordinate system was developed to guarantee a precise fit when inserted to the chassis model. The selected origin location matched those of the concept and chassis, providing a simple cross compatible assessment tool. With the selected coordinate system established, a floor sketch was designed to map parameters for individual component boundaries and reference points. The system also bypassed the conventional approach of using Solidworks mates (Lombard, 2013), further reducing iteration times and model intricacy.

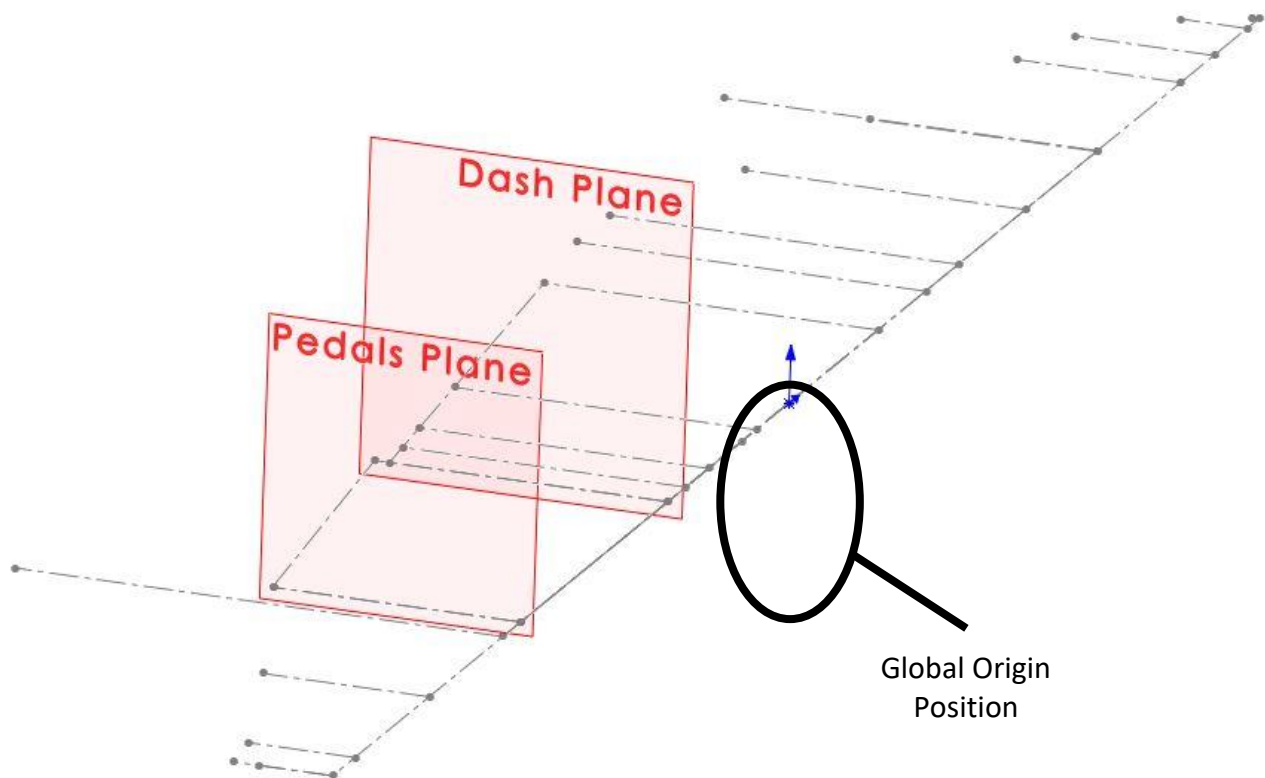


Figure 14 - Floor sketch for global coordinate system

Component Design Plan

To simplify the design phase of the project, the JHTT02 concept was visually assessed to split the package into independent components, with consideration to all geometric implications that may have hindered the chosen manufacturing process. Localised areas of aerodynamic interest such as the nose cone, front pontoons and rear deck profile were also isolated to improve iteration times during the performance development loop (Katz, 1995).

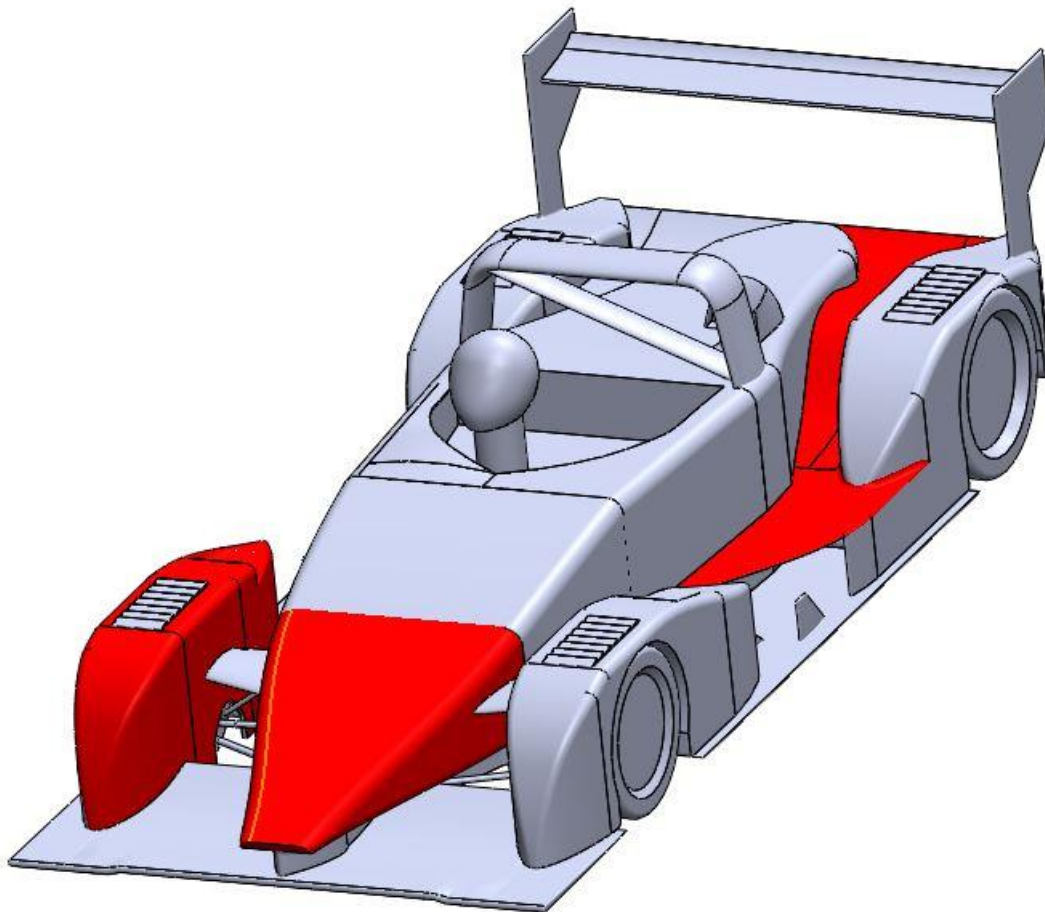


Figure 15 - Split components for independent designs

It was decided that the bodywork components central to the chassis tub would be constructed first, followed by each wheel pontoon. This meant a basic fitment check could be carried out before all other components were added.

Component Design Method

The global coordinate system was implemented to design each of the bodywork components. The Solidworks parts and features (Systems, 2019) were used extensively to ensure the most practical solutions were applied. Half parts were produced where applicable to further improve design efficiency. The JHTT model was continuously measured and compared through the construction of each component to remain consistent with the idealised concept.

All sketches, features and planes were organised by use of relevant names and any additional information specific to the part was embedded within the sketch/feature properties, such as tolerances (Peter Sydenham, 1989). File organisation was particularly important due to the quantity of parts and iterations required for the project, plus any future development to be undertaken.

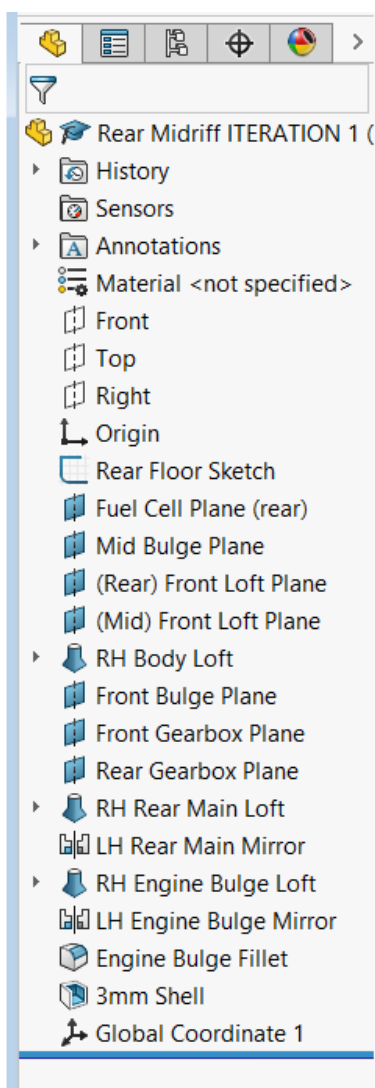


Figure 17 - Organised Design Tree

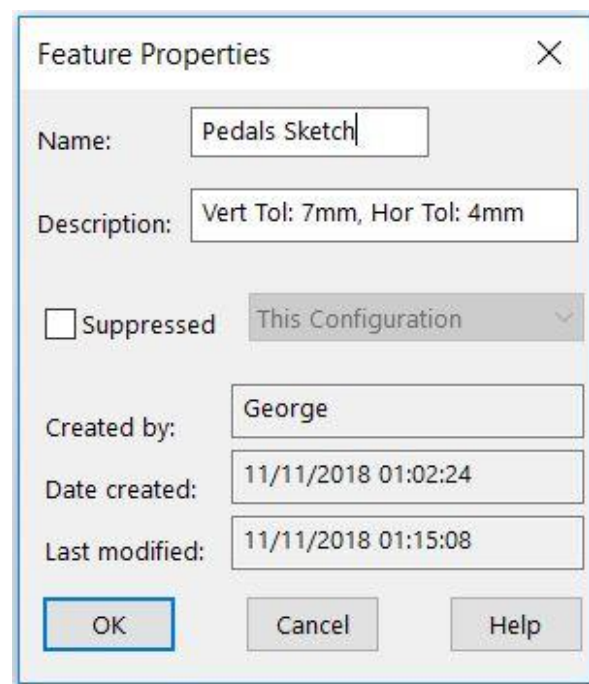


Figure 16 - Feature Properties, embedded tolerances

Design for Fitment

Central Bodywork

A central bodywork package (midriff) was first produced to enclose the chassis tub comprising three adjoining parts. This would be the reference point for all outboard components, so the proposed design was measured against the chassis model to ensure tolerances were satisfied before continuing.

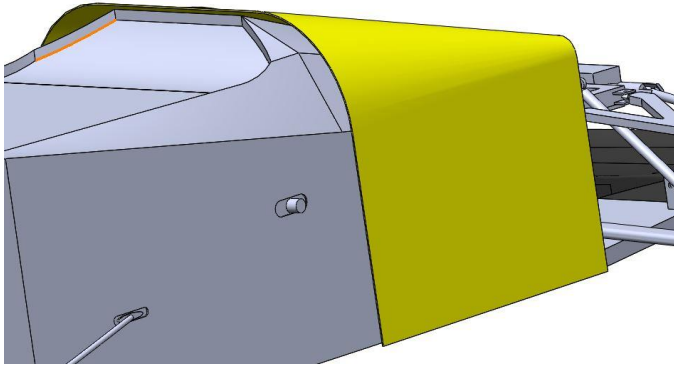


Figure 19 - Front midriff (upper nose) fitment

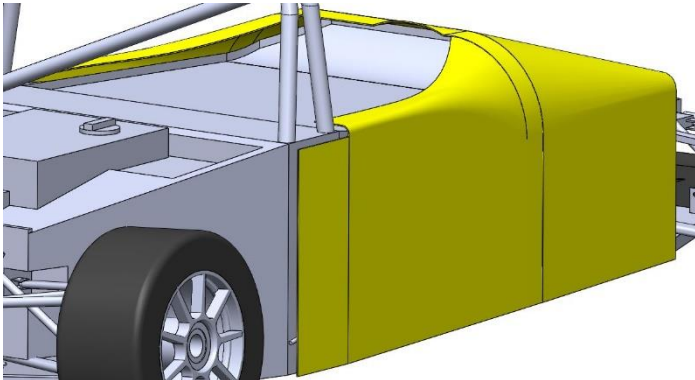


Figure 20 - Cockpit Fitment

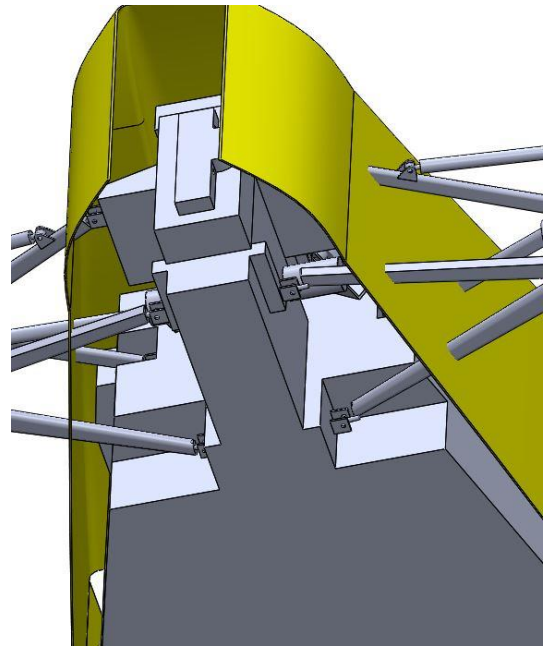


Figure 18 - Rear clam fitment

The concept bodywork was then overlaid for comparison. This confirmed a significantly tighter fitting midriff had been achieved whilst maintaining a suitable clearance for manufacturing tolerances.

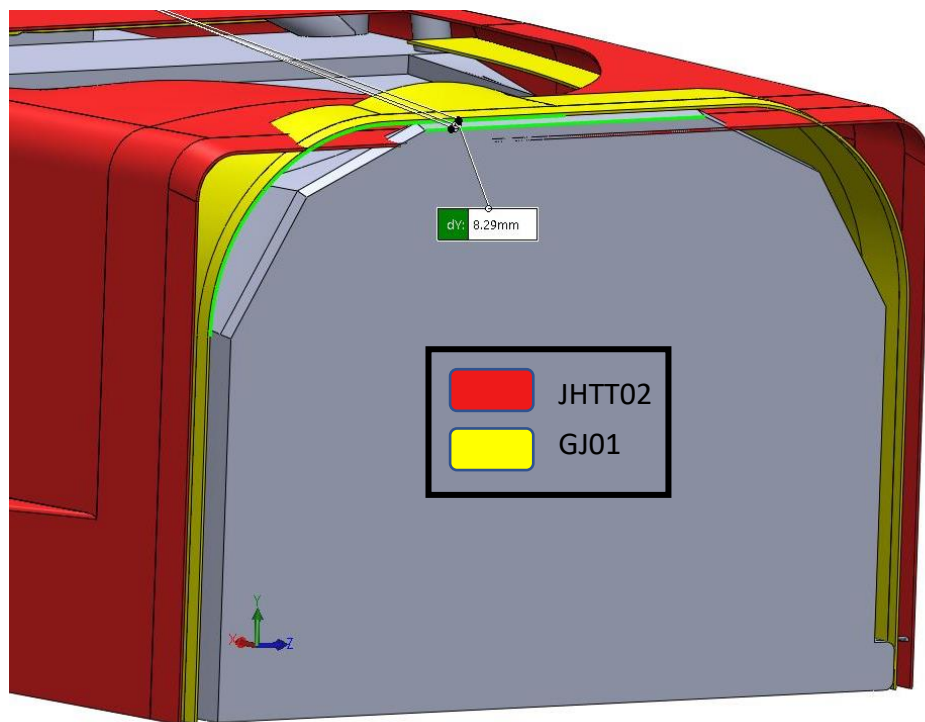


Figure 21 - Fitment comparison between JHTT02 concept and GJ01 design

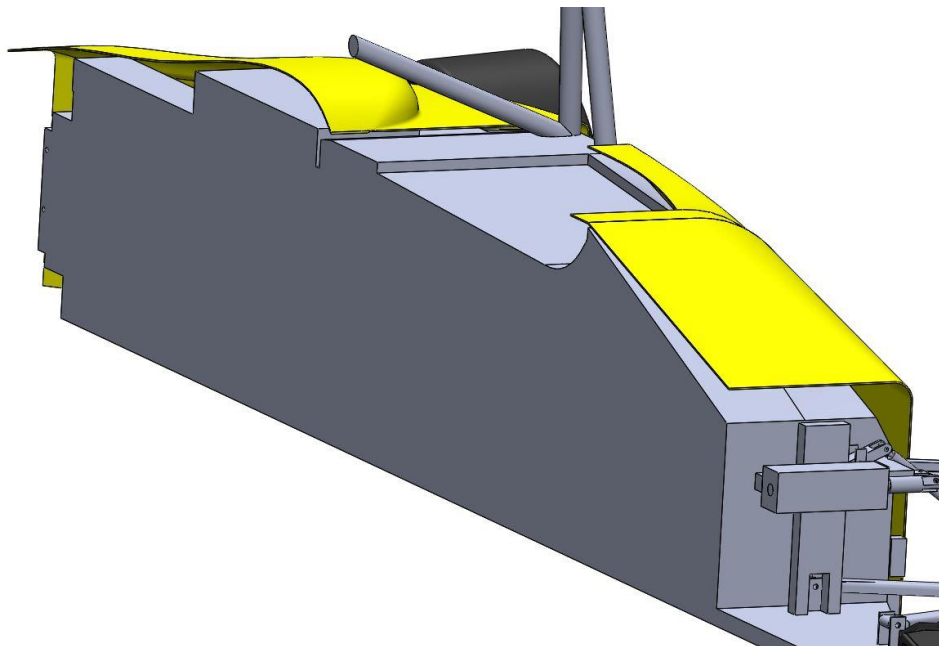


Figure 22 - Section view to illustrate bodywork fitment

Drag is a function of frontal area. This translates to an opportunity to influence the aerodynamic efficiency of a body in the early stages of design. In addition, the central bodywork profile can be shaped to reduce flow separation, which also increases drag. Flow separation occurs when the fluid detaches from the surface, in this instance, it may be caused by a sharp change in bodywork direction (Wilcox, 2007). This theory was noted for attention in future analysis.

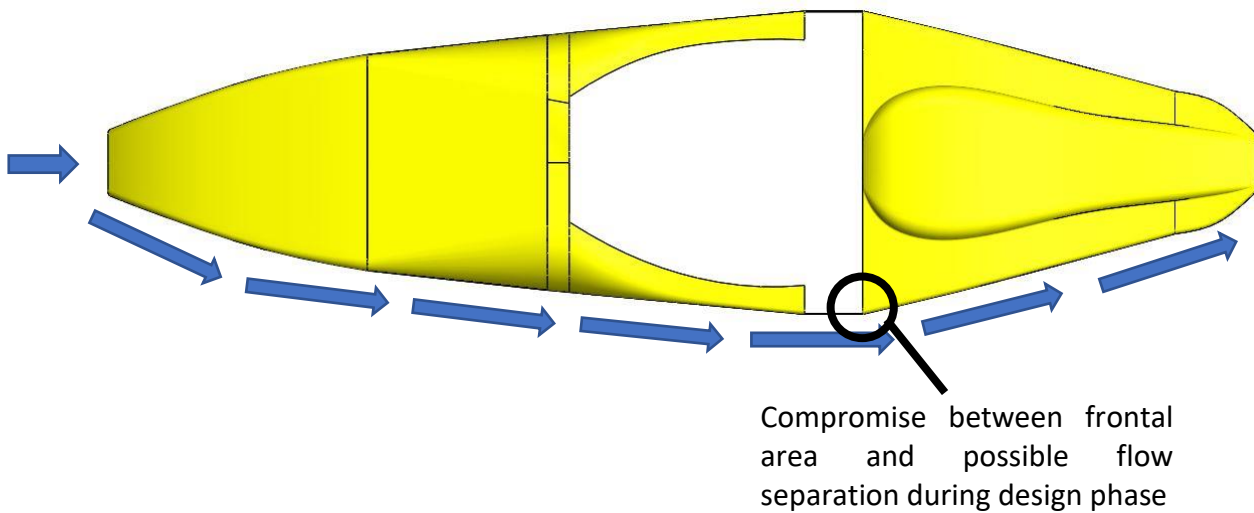


Figure 23 - Plan view detailing central bodywork profile with example of ideal flow attachment

Wheel Pontoons

The front right wheel pontoon was then sketched in reference to the global coordinate system. An initial design was produced that followed the basic shape of the concept so to ensure correct scale and fitment when applied to the chassis model. Finally, the contours were cut in the style of the concept with a spline tool.

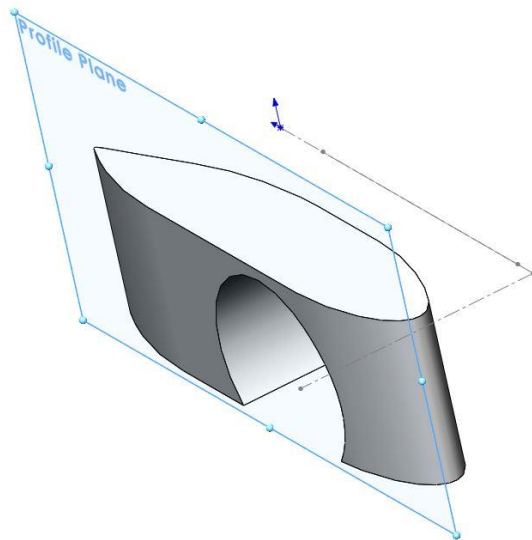


Figure 24 - Basic pontoon geometry

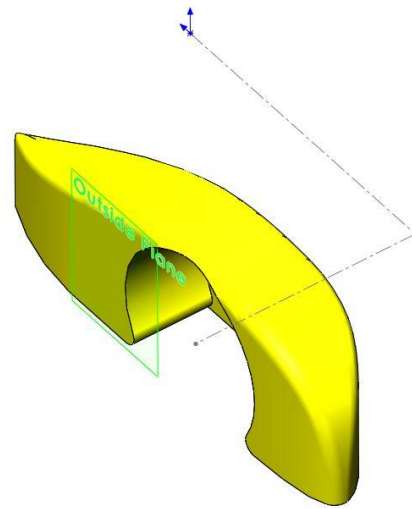


Figure 25 - Contoured pontoon profile

The rear pontoons required a slightly different technique. This was due to the addition of a rear deck surface, connecting the pontoons to the central bodywork. The deck was estimated to be under 5mm thick and perpendicular to both connecting surfaces, posing an element of uncertainty for its structural integrity. The design solution combined the external sidepod structure with the rear pontoon, creating a platform for the lower deck to rest upon if this was to be manufactured separately, whilst maintaining adequate simplicity for manufacture (Ullman, 2016).

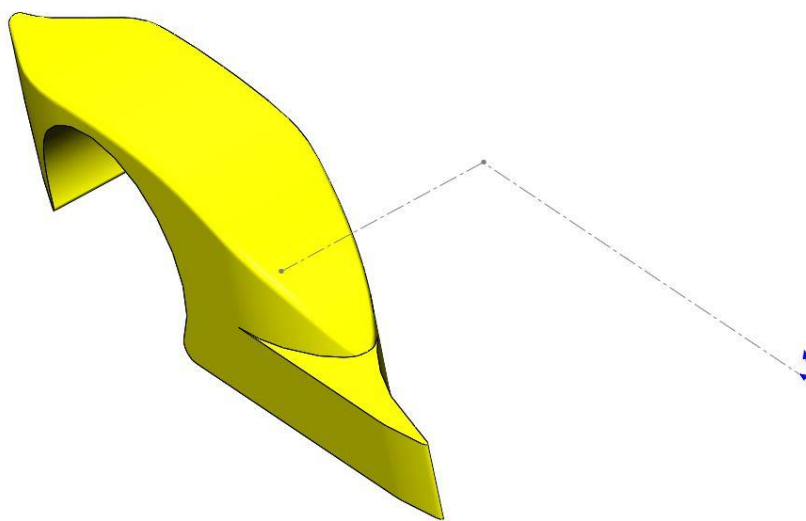


Figure 26 - Integrating sidepods to rear pontoon structure for additional deck support

Rear Deck Profile

The concept deck spline was replicated initially to complete the fitment design, with some improvements made during the aerodynamic development stage of the project. The complex profile was also created as an independent part to further simplify the manufacturing process.

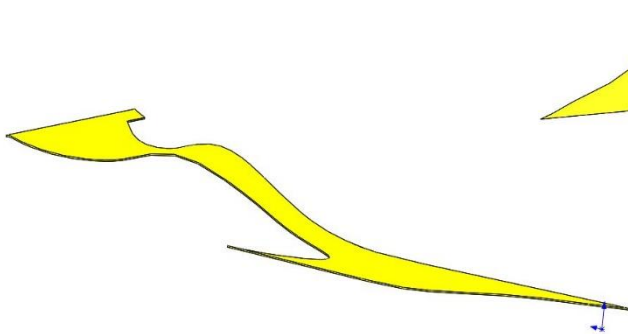


Figure 27 - Rear deck profile independently designed

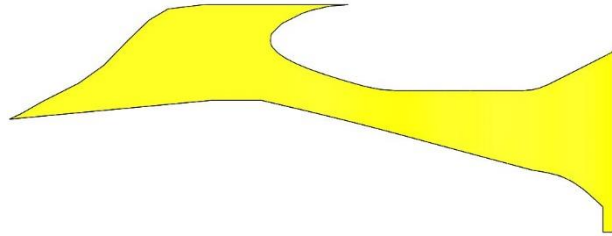


Figure 28 - Rear deck profile in plan view

Nose Cone

The JHTT02 upper nose cone protruded through the chassis when fitted to the model. Some alterations were required to replicate the straight nose. Multiple iterations were produced during the aerodynamic development phase to investigate any potential aerodynamic improvements (Bamsey, 1991).

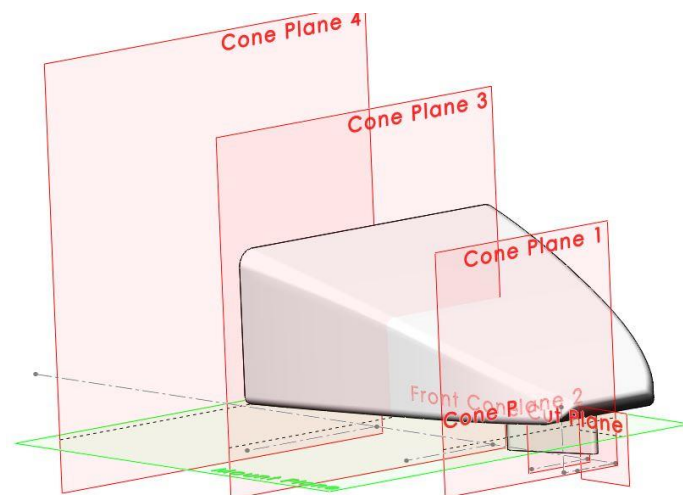


Figure 29 - Nose cone design structure

Fitment Model

An entire bodywork to chassis check was performed and tolerances were checked before any further bodywork development could occur. The current proposed splitter choice is the John Illy prototype. The splitter is readily available and closely follows the aerodynamic profile of the JHTT02 concept. The splitter can be considered one of the more difficult components to manufacture, so it is a great advantage for the group to implement the Illy prototype as a measure to further reduce costs, whilst providing a strong area for future development. The mate-free assembly method was also tested successfully with fully floating components situated in their precise locations.

Figure 30 - Floating components to illustrate alternative assembly technique

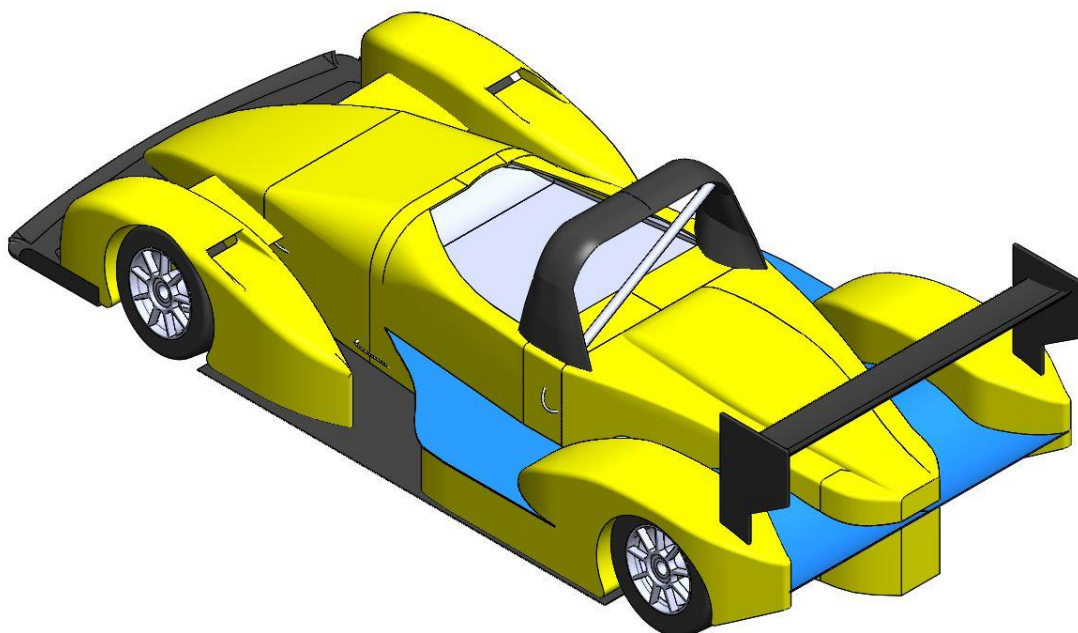
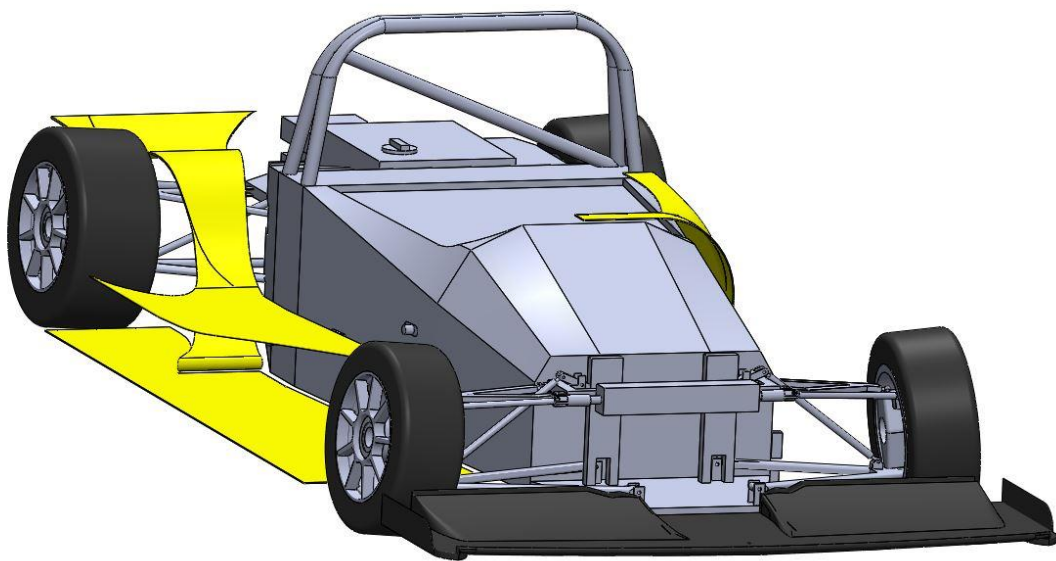


Figure 31 - Isometric view of Final Fitment Model

Aerodynamic Design

Initial CFD Preparation

An entirely separate assembly was required for the groups CFD investigation in addition to the previous fitment model. Components were independently modified to produce a simplified model suitable for meshing. The simplifications included additional thickening, sealing areas such as the cockpit with a replica driver and wheel geometry (Anderson, 2010).

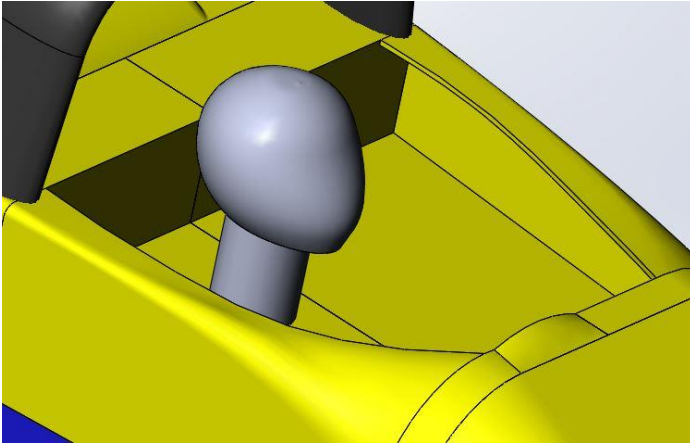


Figure 32 - Cockpit infill for CFD simplification

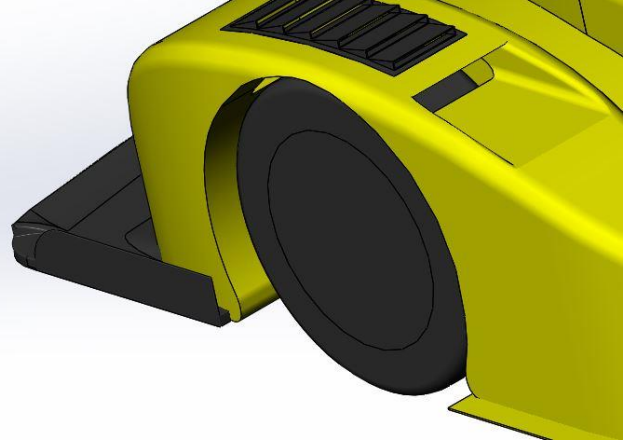


Figure 33 - Wheel simplification applied to CFD model

Some smaller components such as the roll hoop shroud and wishbone shrouds were created with conservative dimensions. This was necessary to establish an early indication of the aerodynamic profile when compared with the JHTT02 concept.

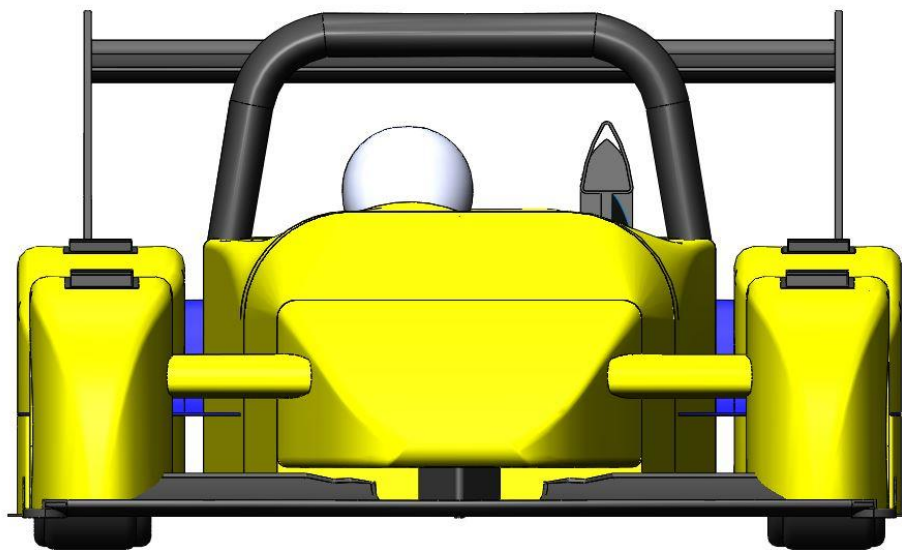


Figure 34 - Initial CFD model with coarse roll hoop and wishbone shrouds

Development Iterations

Some established areas for improvement around the fitment model were discussed so whilst the initial CFD tests were performed, further progress with the design was made.

It was decided to reuse the existing MSportEng roll hoop shroud to eliminate unnecessary costs at prototype level. The existing roll hoop shroud was measured, then created within Solidworks.

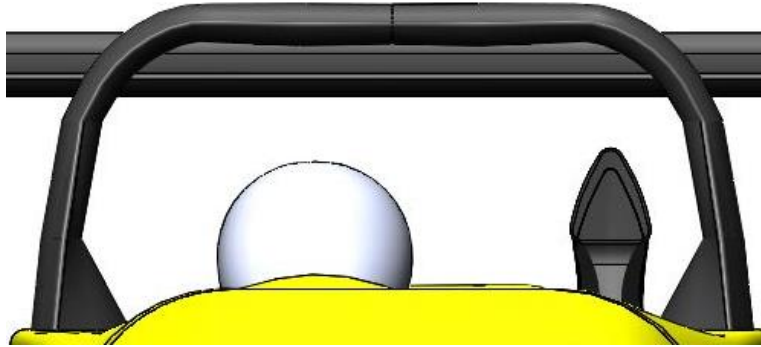


Figure 35 - Replica standard MCR roll hoop shroud

The front upper wishbone shrouds were improved by tapering the internal dimensions to suit the suspension pick-up points and the outer for full travel in bump and rebound. The shrouds were also increased in overall length to cover the lower wishbones when in plan view. This was of high importance due to regulations.

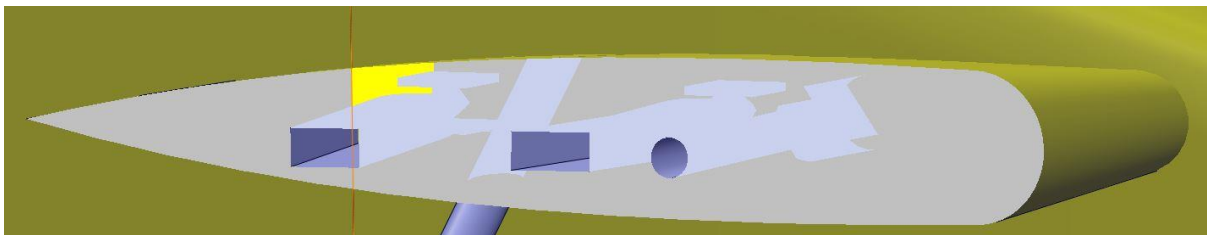


Figure 36 - Suspension fitment within tapered wishbone shrouds

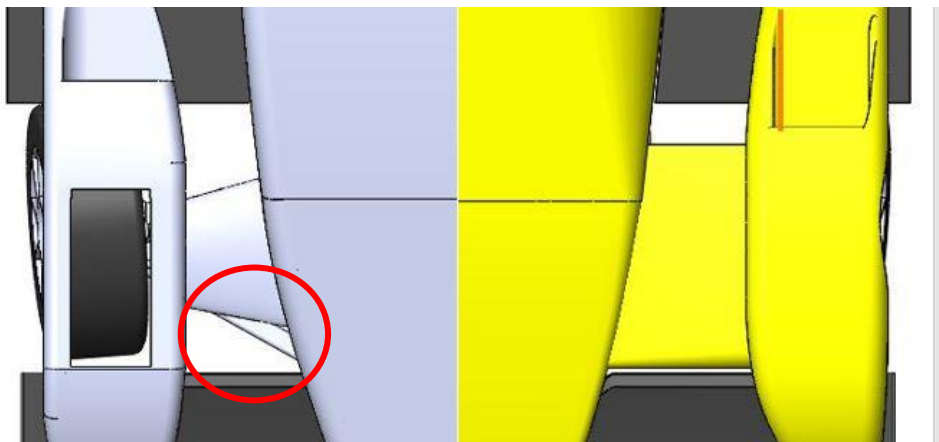


Figure 37 - Plan view comparison of JHTT02 (left) and GJ02 (right) wishbone shrouds

The rear deck profile was refined to reduce drag and achieve a tighter fitting package around the rear suspension components. A slightly longer diffuser section was also achieved, where the floor winglets carried over from the concept design interact.

The concept spline is significantly more aggressive than the developed version, as the suspension components within the concept package were not accurately placed.

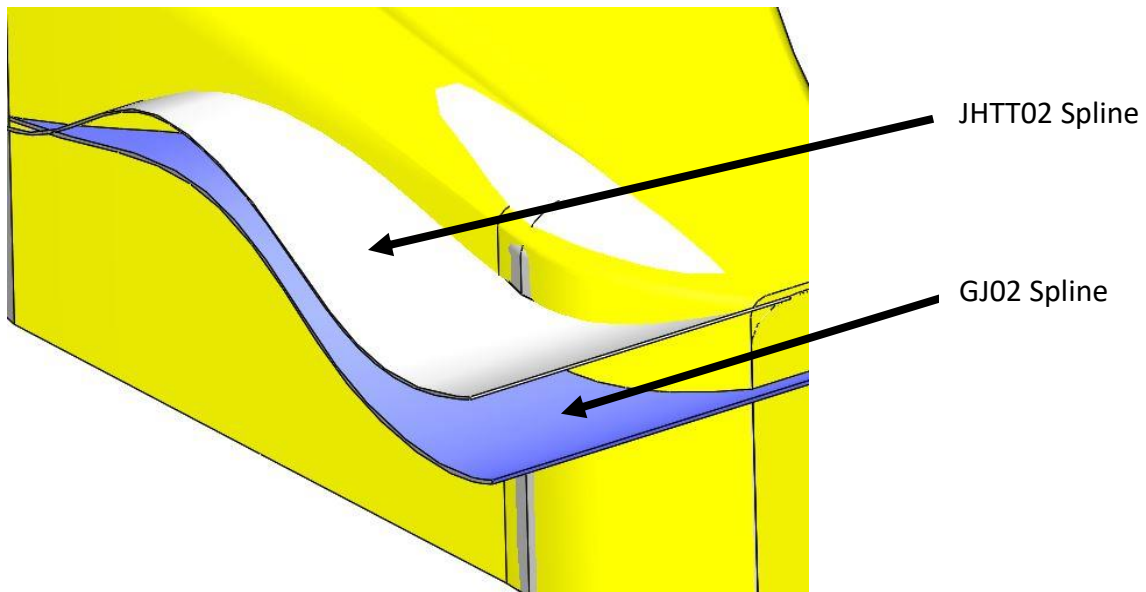


Figure 38 - Rear deck profile comparison between JHTT02 (upper) and GJ02 (lower)

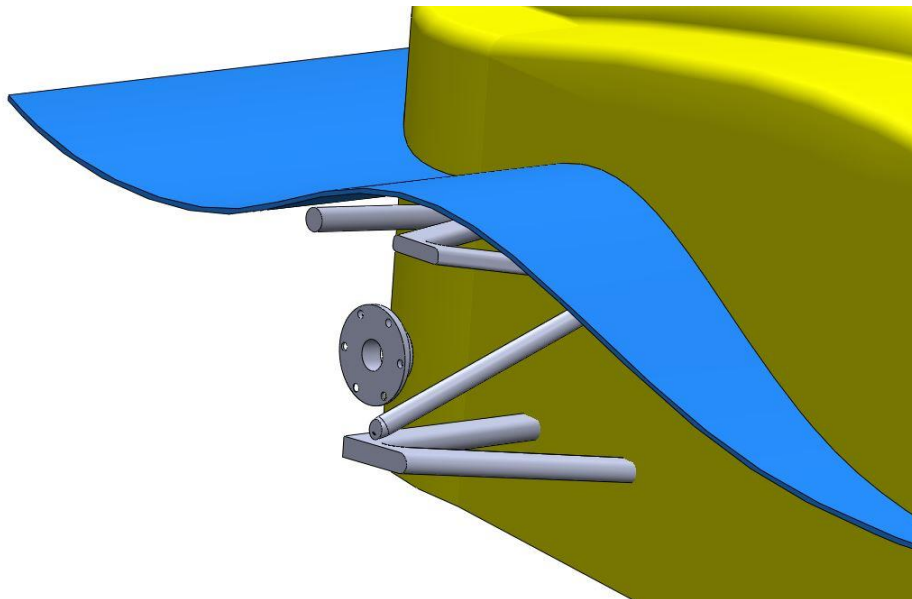


Figure 39 - GJ02 rear deck profile at full suspension compression

The nose cone was heavily developed through this project as it has a great influence on the aerodynamic properties downstream. Multiple early iterations were produced, with nose cone shapes being explored for a balance between aesthetics and performance. The two most appealing versions were fully integrated with a lower crash box structure to maximise aerodynamic efficiency. The high nose version was predicted to be the more difficult of the two to manufacture, due to its shape and complexity whereas the low nose iteration tended to simplified manufacturing techniques

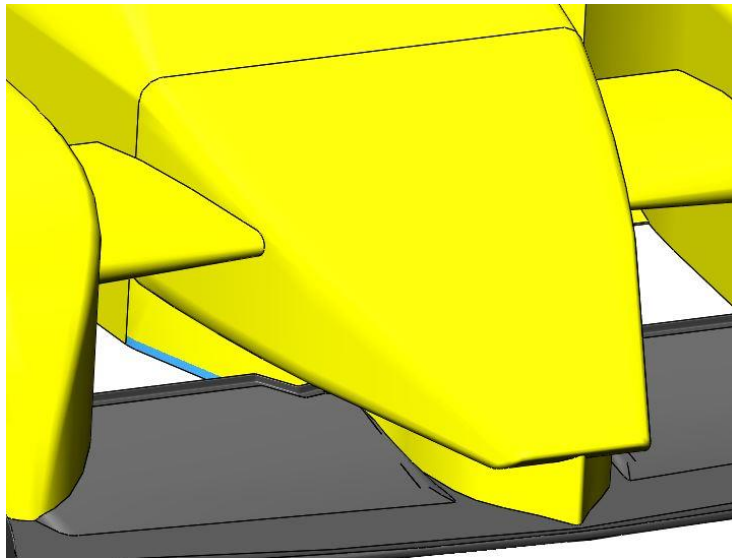


Figure 40 - High nose structure design with integrated crash structure shroud



Figure 41 - Low nose structure

Finally, the front pontoons were heavily altered through the design phase. The most notable adaptations through each iteration was to the leading edge. The overall target for the front pontoons was to reduce drag as much as possible, whilst enticing as much air as possible into

the sidepod region for cooling. The final iteration included an asymmetric leading edge to encourage these benefits and reduce the necessity of turning vanes included to the floor.



Figure 42 - Front pontoon leading edge design evolution (left to right)

Final CFD Design

The final design was locked down when a similar aerodynamic efficiency and centre of pressure was achieved to that of the concept. This gateway event allowed the continuation of the updated bodywork package into the manufacturing process within the project schedule.

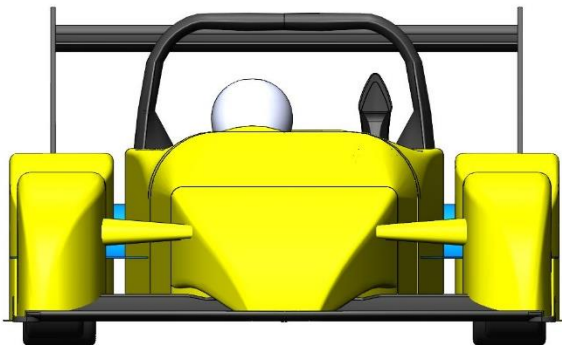


Figure 43 - Final CFD design front view

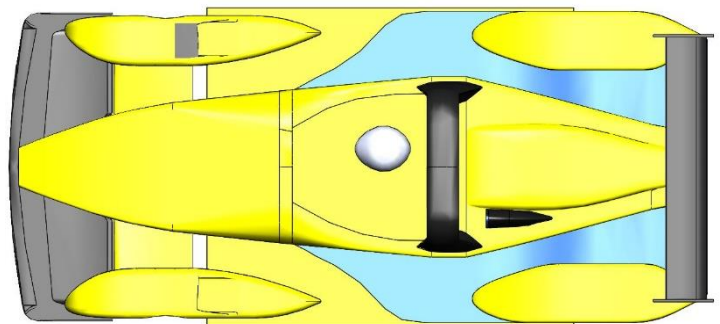


Figure 44 - Final CFD design plan view

Design Process Summary

The group decided from its experience of producing the accurate chassis model, to allocate one individual to oversee the bodywork design and rebuild. This decision was to mitigate the risk of conflicting parts and further potential delays (Martine Haas, 2016). The project aim was to manufacture the JHTT02 concept, so it was of great importance to reduce the re-design time by as much as possible, whilst maintaining a valid aerodynamic performance package.

As the priority for this project was to physically produce a prototype bodywork package, a necessary compromise was made for the development process. For this reason, it was even more important that the redesigned bodywork was developed with a versatile system. The design methods applied to this project enhance the possibilities for future improvements to the aerodynamic and fitment performance, based on real world application. With each component being designed independently, the scope for development can be focussed on specific areas of the car, without an obligation to rebuild the entire system. Further improvements to the aerodynamic package can include studies into the floor winglets and rear deck interaction, in addition to an entire bodywork optimisation investigation.

Ainsley Martin - Aerodynamicist

Tasks Completed

Table 6 - Work Completed (AM)

Task	Completed With	Hours
Meetings	All	50
Photo spy gun	George, Ryan, Max, Nick	4
Tibbott sessions	All	40
CAD part for chassis	All	5
Learn CFD	-	16
Research Aerodynamics	-	12
Fit and calibrate pushrods	Ryan, Max, Nick	4
CFD JHTT	-	5
CFD White Car	-	4
CFD Yellow Car	-	6
CFD John Iley Splitter on Car	-	4
Thicken part of car	George, Ryan, Max	1
Chassis Checks	Ryan	1
Viva 1	All	10
CFD New car	-	6
Meeting with George	George	2
CFD iteration 2	-	5
Meeting with George	George	2
CFD Iteration 3	-	6
Meeting with George (Lockdown)	George, Ryan, Max, Nick, Simon	2
CFD Notes	Max	5
Rake Attitude Study	Max	9
Ride Height Attitude Study	Max	9
Yaw Attitude Study	Max	9
Final CFD validation	Max	9
Viva 2 and Report	All	15

Total Hours = 241

Familiarising with CFD

At the start of the project, an investigation was done into aerodynamics and CFD. This included studying the basics of aerodynamics to allow the results of the CFD to be evaluated with some level of competency. This included reading books and research papers (*See aerodynamics bibliography*), talking to third years and attending lectures about aerodynamics. These continued throughout the year to keep progressing the understanding of aerodynamics throughout the project, allowing changes in the design to have a more factual basis to them. To understand how to use Ansys, videos online were used (SiriusCFD, 2012), including those provided by the group supervisor Tim Tudor. Also, Concept Designer John Hughes ran a session to show the basics of the software using the Ahmed body.

Before a full car model could be run a bluff body was used. This was done for two reasons, the first is a bluff body is a less complicated geometry, so it is easier to learn the basics of Ansys with, the second reason is there are many studies using the Ahmed bluff body. This allowed the results produced by the Ahmed body study to be validated, thus, validating the settings used. This allows these settings to be used for future run as they have verified by the software and now validated in the study.

After a few attempts, results were produced that were within an acceptable tolerance of results validated in a wind tunnel (Muhič & Štefanič, 2017). The knowledge gained during this stage of the project was used to run full car simulation models to gather aerodynamic data about the car as the design stage progresses.

JHTT02

The first full car model to be run was the JHTT02. This was done first as it is the car the project was based on. Furthermore, it is the car that Concept Designer (John Hughes) was most familiar with. This meant that he was able to answer any questions the group might have had regarding the settings inside ICEM or fluent. As this was a more complicated geometry compared with the Ahmed body there was some issues that arose such as meshing errors in ICEM and floating-point exceptions in fluent. Research was done online to find the cause of the issues and the best way to fix and prevent them. When the car was finally run to completion the results were compared with the results provided on the brief. These results showed a slight difference however that difference was negligible, this again proved that the settings being used could provide valid results.

With the run being complete a study could be done to observe the flow structures over the car. This was the first time being able to use the post processor to view a full car, where the flow structures are more intricate. Concept Designer John Hughes provided some screenshots of his completed CFD, showing the pressure contours on the car and planes through the car showing velocity contours. These screenshots were replicated inside the post processor to make sure they showed the same characteristics. When viewing the pressure contour the pressure distribution over the car could be seen. This showed area of low pressure under the wing and splitter and areas of high pressure at the front of the car and on top of the wing and splitter. When looking at the velocity contour through the car the turbulent air could be seen in the wake of the car, also seeing how the flow moved around the car. Streamlines were used to give a 3-dimensional view of the flow structure over the car. These were used to find the weak points of the provided design that could be altered throughout the project to improve the efficiency of the car.

Original MCR

3 investigations were done using the current design of the MCR bodywork. The first was done using the old 'White car' bodywork as it had both been externally run through CFD and additionally placed in MIRAs wind tunnel. This was another way of validating the results gathered through CFD as there are two sources with corresponding results. This model was the simplest to run out of the three due to the other 'Yellow car' model having some issues with the CAD resulting in small holes. External assistance was required to fix these issues to allow the model to be run more consistently with less errors in the meshing stage.

The results obtained from the 'White car' were not perfect (*as seen in Appendix 6a*), however they were accurate within a tolerance given the level of CFD knowledge at the time. The results showed a level of accuracy within the settings which could be refined as the project progressed.

The next car to be investigated was the 'Yellow car'. As this is the current car available at the university these results could be used to compare with either a straight-line test, where the car would be run in a straight line and pushrod sensors would measure the aerodynamic loading on the car, using the same pushrods with the sensors attached the aerodynamic loading could be measured at one of the cars races on a track with a long enough straight. This is less accurate compared with a straight-line test as there are more variables, however it is better validation than nothing. The final option would be to take it to a wind tunnel, this is not really a viable option due to the cost required for the wind tunnel and the university already has the data from a very similar bodywork in a wind tunnel.

As discussed previously there were some issues with the CAD, making the model difficult to run at the time. In hindsight the holes could have been fixed within design modeller however other students still had issues with doing it that way hence why the CAD model was fixed. Once it had been fixed the model was able to run with few issues, proving results close to those seen with the white car.

The final car to be testing was the 'Yellow car' model however the splitter was removed and replaced with a CAD model of the new splitter provided by professor of practice John Iley. This was done using the improved CAD model of the 'Yellow car'. This model was run in preparation for a straight-line test of the car with the new splitter attached planned by 'Team MCR'. This has been postponed until further notice due to mechanical issues with the car. This test will both be a way to validate CFD setting but also find the benefits of using the new splitter. Looking at the results of the CFD it shows a great improvement in aerodynamic efficiency compared with the current car.

New Bodywork

Once the new bodywork was completed a baseline was able to be established which future iterations would be compared to. To start with there were a few issues with the model, one issue was the airbox, there were 3 iterations tested. The first was the airbox removed from JHTT02 but due to the change in geometry this couldn't be used. The second was created by a member in the group although due to the way it was created it could not be used in CFD. The third iteration and the one that was used was provided by group supervisor Tim Tudor. This did have a hole in it however it was the best as it could easily be fixed within design modeller and produce results with no issues. There were a few other minor issues with holes in the body, however due to the way the model was designed with easy to modify part, these issues were quickly rectified, and the model was able to be run. Once the run was completed the results could be seen using the post processor. The lift, drag and centre of pressure (CoP) were investigated and compared with the baseline JHTT02. A meeting was organised with CAD designer (GJ), in which the pressure contours were viewed to see where the areas of high and low pressure occur on the car. Areas on the car where the aerodynamics could be improved were identified, using the post processor and different options for improvements were

discussed. Also, any problem areas were identified with the car such as the roll hoop being oversized and removing the louvres to improve the meshing quality. As the design was based on an existing model (JHTT02) it was known that the overall design proved significant aerodynamic gains over the original MCR bodywork. The new package retained most of the downforce produced, although this came with an increase of drag as the frontal area of the car had been increased to incorporate the suspension, wheels and engine. The task now for the group regarding the design was to streamline the bodywork to reduce the drag. The main areas of focus were the pontoons and engine cover and the previously mentioned roll hoop and louvres. The CoP was found to be too far forward, and this was taken in to account with the changes.

After the possible changes were discussed CAD designer (GJ) modified the bodywork and produced a second iteration. This iteration ran with no issue and results were produced quickly. The results showed both a decrease in drag and downforce, but the overall efficiency did improve showing the changes made to the car were beneficial. After this run was conducted some small fitment issues were discovered and had to be rectified for the third iteration. The wishbone shroud was slightly modified to give them a more neutral shape as previously they produced lift. They still are producing lift however this amount was reduced, and they create less drag. Another meeting was arranged with CAD designer (GJ) where the 1st and 2nd iteration was compared side by side. The good and bad aspects of both designs were compared to find the best changes for the 3rd iteration. A discussion was had about lowering the nose like the current design bodywork as it was hypothesised this would improve the airflow over the top of the car. It was agreed to test two different variations of the 3rd iteration where the only difference between them is the nose.

Between the 2nd and 3rd iteration a change to the settings used in CFD were made (*please see Appendix 6b for CFD settings used*), this was mainly done to reduce the number of elements from 20 million to 12 million which dramatically reduced the solution time. This was particularly important for the attitude study which was completed once the bodywork was finalised. The new setting was run using the Ahmed body to re validate them.

Once the 3rd iteration was completed the high nose variation was run through CFD while the low nose was being created. These were done at 0 rake. The results showed a decrease in efficiency from the 2nd iteration, however this will be due to changes made for fitment and cooling that were required for the bodywork to fit the car. The low nose was then tested and was found to have a greater efficiency than the high nose. Producing slightly less downforce with less drag and having a more optimal baseline CoP. There was a group meeting organised where the two options were discussed and after talking with the manufacturing team it was established that the low nose design was better aerodynamically and would be easier to manufacture, this made making the low nose as the final design an easy decision for the group.

Attitude Study

Once the bodywork was locked down an attitude study could be done on the finalised bodywork to establish how different attitudes effect the car. As many runs had to be completed to gather enough data to produce a valid range to compare to, the group decided that another member should learn how to use the CFD software to a level where they can run a full car and produce valid results. Team leader (MH) took up this role.

To get this done in the quickest time possible, it was decided that the level of knowledge should just be enough to run the full car however the need to understand the results is limited. A 'cheat sheet' was created to assist the group leader (MH) with his CFD runs and allow any other member of the group to run any modifications themselves without the requirement of the author.

The first study that was conducted was a rake study this was done at a ride height of 65mm. This was done using values from 0 degrees to 0.6 degrees. However, the results for 0.55 and 0.6 degrees didn't match up as expected and will have to be re-run. All the runs were done using the same settings to ensure comparable results. There was some variation in the results which could be due to some runs being done on Ansys 19 and some done on Ansys 16. This was rectified for future studies where Ansys 16 was used for all of them. From the results, 0.5 degrees of rake produced the greatest aerodynamic efficiency as seen in figure 45.

Table 7 - Aerodynamic Efficiency for Varied Rake

Rake Angle (deg)	cl	cd	Efficiency
0	-1.354	0.471	-2.875
0.2	-1.428	0.492	-2.902
0.3	-1.506	0.511	-2.947
0.4	-1.566	0.510	-3.070
0.5	-1.626	0.518	-3.139

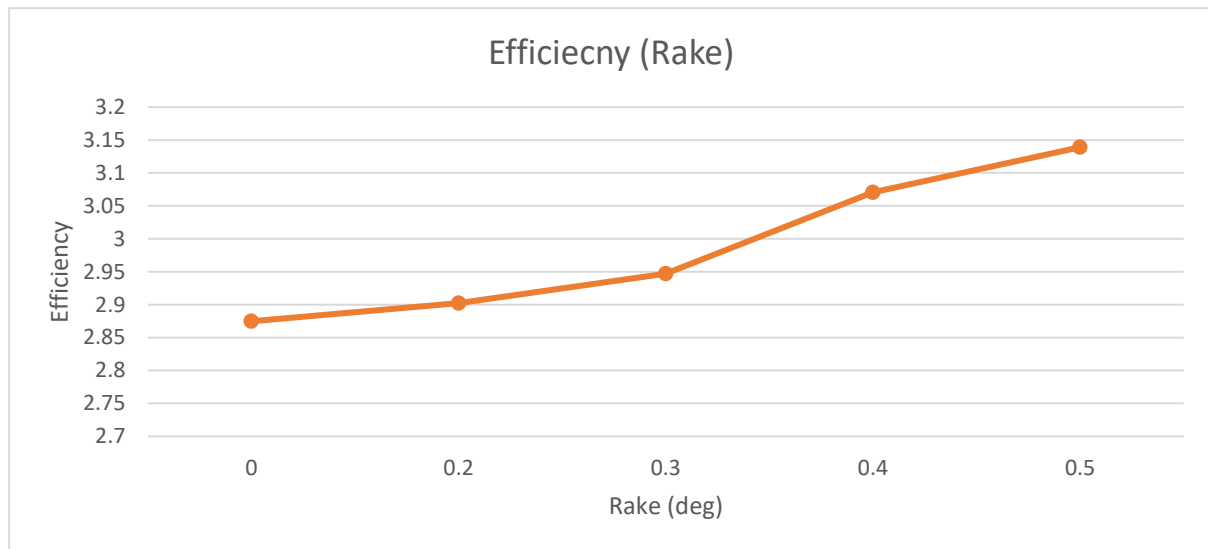


Figure 45 - Aerodynamic Efficiency for Varied Rake

The next study to be conducted was a ride height study. This involved changing the ride height of the car from 30mm to 70mm and finding out the implications of these changes. All these ride heights were conducted at 0.5 degrees of rake as the previous investigation showed this to be the most efficient. From the study, 50 mm produced the greatest efficiency as seen in (figure 46). The efficiency rose as the ride height rose up to 50mm, after this the efficiency started to drop off dramatically as the venturi effect under the car started reducing. Viewing the results in the post processor as the car becomes too low, air flow under the car is restricted due to the boundary layer of the splitter interacting with the boundary layer of the road, restricting the amount of air that can flow under the car, reducing the downforce produced by the car. When the car was raised up too much the underside did not create a venturi tunnel effect and the underside aerodynamics were not as effective.

Table 8 - Aerodynamic Efficiency for Varied Ride Height

Ride Height (mm)	cl	cd	Efficiency
40	-1.87	0.479	3.903967
45	-1.989	0.488	4.07582
50	-2.14	0.519	4.123314
55	-2.114	0.527	4.011385
60	-1.752	0.511	3.428571
65	-1.611	0.517	3.116054
70	-1.548	0.52	2.976923

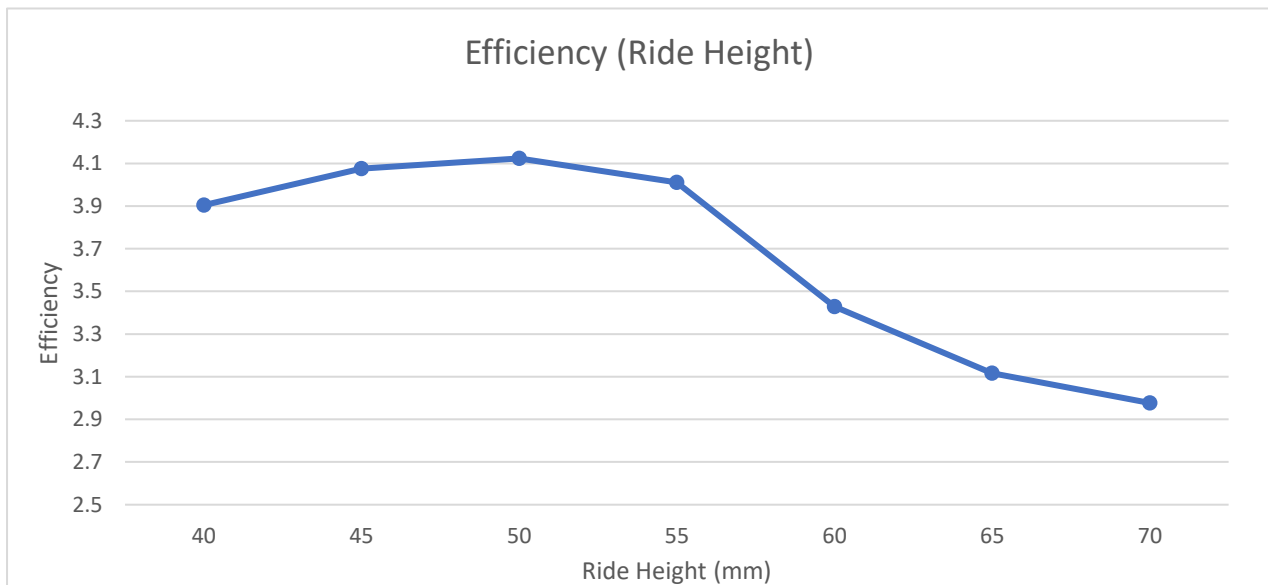


Figure 46 - Aerodynamic Efficiency for Varied Ride Height

Finally, a yaw investigation was done to ensure the car would retain some downforce as it turned around corners. This was done from -8 degrees to 8 degrees of yaw. The results showed the car maintained downforce as it went around a corner and did not enter a stage of stall when at maximum yaw. Due to some failures in the runs, full range of results was not gathered, and further investigation will be done to explore the results that were not completed at the time of writing this report.

From these studies the ride height has a smaller working range than the rake. As the car would go around a track the setup with the ride height will have to be considered as the car will squat down due to the gradient variation of the track and the aerodynamics forces acting on the car.

Towards the end of the project extra runs were completed to validate some of the results and to gather more data for some of the studies. One of these included running the car at 1 degree of rake. It was hypothesised that the flow would not stay attached under the car and reduce the downforce, however this was found not to be the case. The flow stayed attached over and under the car increasing the downforce and overall efficiency significantly. The floor winglets and rear deck are working harder increasing the downforce produced by them. Another interesting extra study conducted looking at how the car behaves when following another car. The results can be seen in Table 9.

Table 9 - Aerodynamic Data for Large Rake Angle

	cl	cd	Lift Force (N)	Drag Force (N)	Efficiency
1 Degree Rake	-1.914	0.522	-2002.04	545.81	3.66

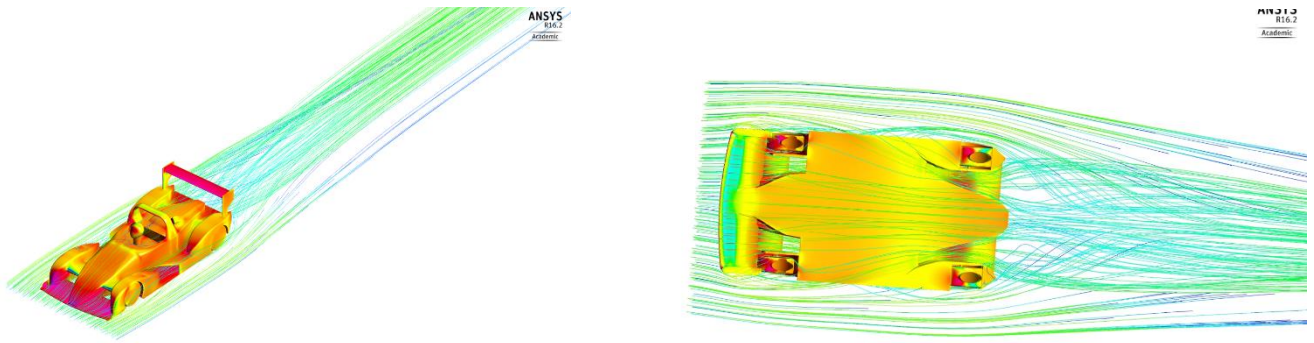


Figure 47 - Flow at Large Rake Angle

As the final design is based on the Gunn, both the cars used were GJ03 as it is the best way the group can simulate the bodywork behind the Gunn. The car loses some drag which is expected, however it does have a drop-in downforce. More studies can be done to see how the car behave at different distances behind the car and how the car behaves when travelling with another car. The results can be seen in figure 47 and 48.

Table 10 - Aerodynamic Data for cars together

	cl	cd	Lift Force (N)	Drag Force (N)	Efficiency
Lead Car	-1.850	0.521	-1907.22	537.26	3.55
Following Car	-1.617	0.488	-1666.74	503.05	3.31
% difference	12.59	6.33	12.59	6.33	6.76

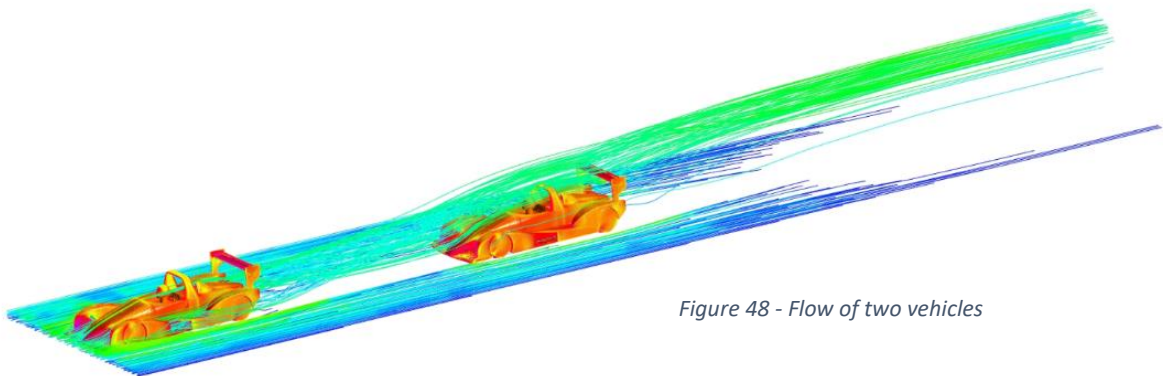


Figure 48 - Flow of two vehicles

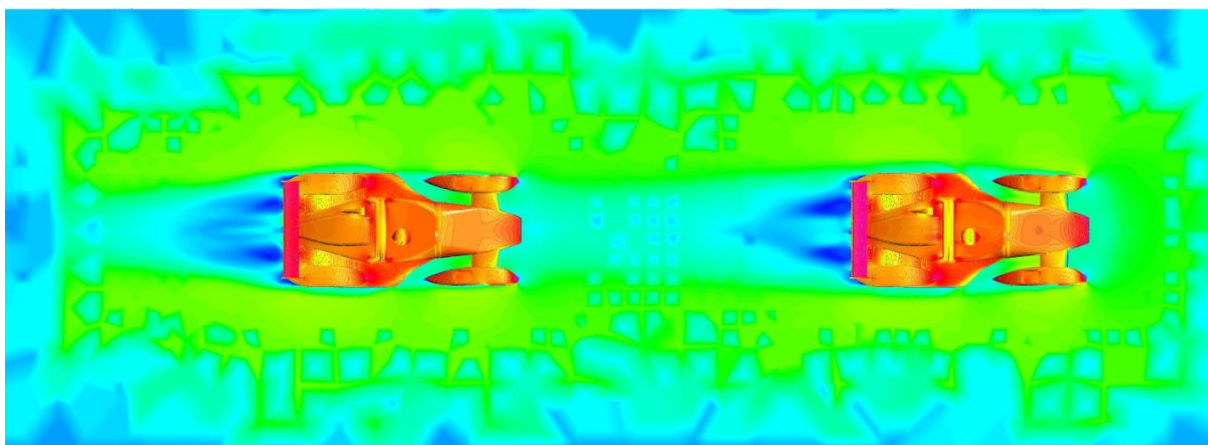


Figure 49 - Pressure for two adjacent vehicles

Over the summer more studies will be done with regard to the attitude to ensure a basic baseline setup (Rake and Ride Height) is ready for when the car is manufactured. Once the car is manufactured it will hopefully be taken to MIRA and tested in their wind tunnel to validate the CFD results.

Nicholas Thomas - Regulations Analyst

Work Overview

Within the group the authors main roles were two things. The first role was rules and regulations and the second was the splitting and attachment of the bodywork. For rules and regulations this was then cut into a number of tasks such as the author first had to research the rules and identify key areas that may concern the project, make a review of the Loaded Gunn TS11 and then through the whole project he evaluated the design through its changes to make sure that it complies with all the regulations that it is accountable for. Then the writer's other role was splitting the bodywork. This involved making a review of key areas that need easy access then designing the bodywork so that it can come apart easily. Along with these two main roles he also contributed by helping research manufacturing techniques and producing some parts on CAD for the chassis design.

Table 11 - Work Completed (NT)

Task	Completed With	Hours
Photographing the Gunn TS11	Ainsley, Ryan, Max, George	4
Plan Project	All	10
Group Meetings	All	50
Andy Tibbott Sessions	All	40
CAD Crashbox and Oil Cooler	-	6
Attach Crashbox and Oil Cooler	Ryan	2
Fit and Calibrate pushrods	Ryan, Max, Ainsley	4
Materials Research	-	7
Rules and Regulations Research	-	5
Gunn Review	-	4
Concept Bodywork Review	-	4
Viva 1	All	10
Check New Bodywork to Regulations	George	10
Assist with drafting Letter to regulators	Max	2
Meeting with George (lockdown)	George, Ryan, Max, Ainsley, Simon	2
Splitting Research	-	4
Designing Splitting	Ryan	25
Preparing Design for Manufacturing	Ryan	10
Assist Buck Making	Ryan	10
Final Viva	All	10
		Total=219

Research carried out

During the project the author researched several topics. One of which was the rules and regulations. It was found that the rules that affected the series the car is running in was the S2000 Duratec regulations (S.Morris, 2018) and MSA Yearbook 2018 (The Motor Sports Association, 2018) sections 2J, K and Q.

Another piece of research was conducted on materials, using many sources so that different methods along with the positives and negatives of each process and material could be investigated (McBeath, 2000; Aird, 1996). To add to that which material to use was also researched such as carbon, aramid or glass fibre. Each of these types also needed to then consider of which type of that fibre would then be used such as E-glass vs S-glass and what type of weave to use. This was then given to the materials/ manufacturing researcher (SW) to support their research on manufacturing which they used to make a decision of what manufacturing route to go down such as wet layup, pre-preg and resin infusion.

To add to that the writer also did research on the serviceability of the car this involved using personal experience of the race team, along with the checklist (see appendices) that the team use to check the car to help to decide where to split the car. From this it was found that there were two areas that would normally need easy access to. Of course, the rest of the bodywork would need to be accessed however they do not need to be accessed under normal conditions at a race weekend quickly for the spanner check. The two areas were the front end forward of the bulkhead and rear past the fuel tank. The front needed to spanner check the front suspension, springs, brake lines and clutch fluid. The rear needed access to check the rear suspension and associated parts and the gearbox, engine, airbox, ECU and rear wing mounts. The middle section doesn't need access as there is only pipes going through which don't need to be checked at weekend only after one which the team have more time to take the body apart to it is not so urgent to access.

(James, 2019)



Figure 50 - Current Bodywork Splitting

The writer also did research into similar cars so that they could see the methods and points at which they were split. A key point is the way which the Loaded Gunn TS11 had made its splits as this is a good base because the design is loosely based on it. Research was also done into Radical Sports Cars (Radical Sports cars, n.d.) as they also specialise in open cockpit prototype race cars which have a size and shape to the car. The research gave the author the sort of methods other manufactures used to split their bodywork up and how they attached together with things such as latches and aero clips. The group chose aero clips as they create less aerodynamic drag and the race team already have a number of them so they could use them instead of using up the already tight budget of around £3500.

Designs carried out

The designs the writer made was the splitting of the bodywork. To get the final split it went through 5 iterations of the design which was provided by the CAD Designer (GJ) and the chassis by other members of the group. The first iteration was very basic and did not include any method of attaching the body together. The first few iterations were concentrated on the front end splitting as there was more options for where the split lines could go.

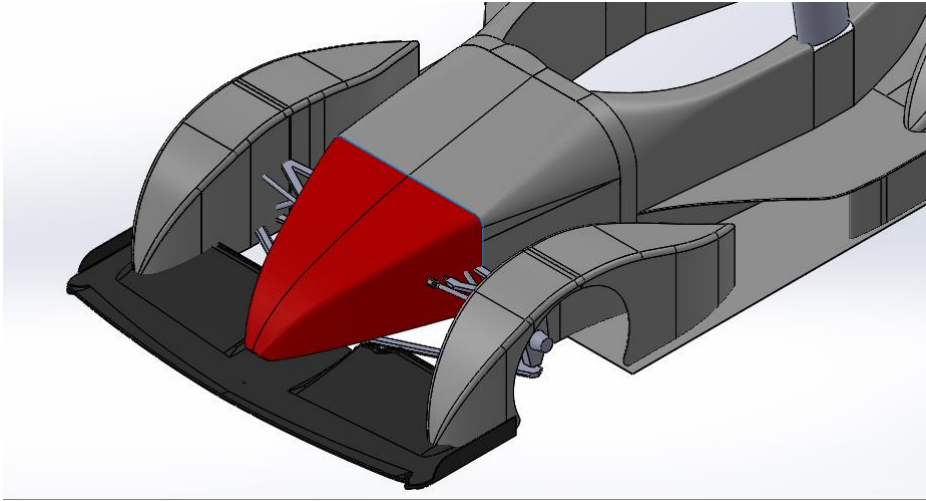


Figure 51 - Front Split Lines

Then as the process went through the bodywork also changed so the splits had to be adapted to the new bodywork. Therefore, next iteration was similar to the first as the front-end design was concentrated on but adapted with new splits to change with the new bodywork (Figure 53) taking them back rearward by around 157mm.

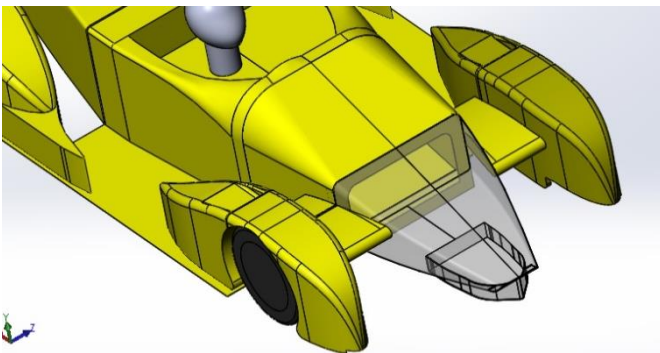


Figure 53 - New Bodywork Splits

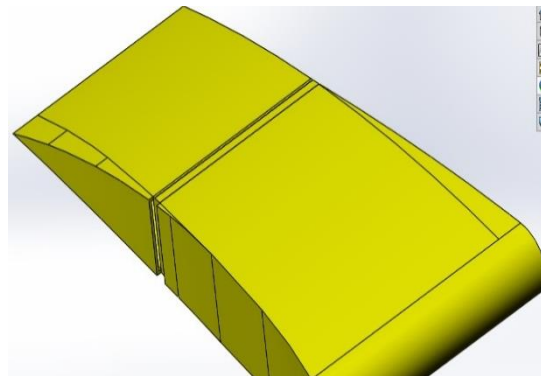


Figure 52 - Wishbone Shroud Flange

The second iteration also included the addition of a flange on the front upper wishbone shrouds (Figure 52). This was because this would be slid on and off when taking off the front section, so the flange made for easier location of the two halves. The shroud had to be there to cover the wishbones as the rules state that no suspension member can be visible from the X, Y, Z plane (S2000 5.6i). The flange overlapped by 10mm.

For the third iteration of the splits then included rear splitting and gaps for where the aero clips (Figure 54). In this iteration there was a 1mm tolerance left in between the sections. This was to allow for error in the building of the bodywork. This allows the bodywork to actually fit together as 2 things that are touching in CAD most likely to fit together in real life.

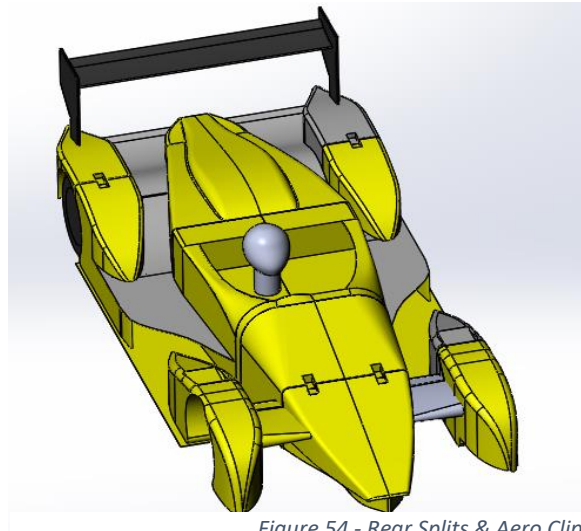


Figure 54 - Rear Splits & Aero Clips

For the final design the writer decided that on the front pontoon that the split should be moved more centrally. This was chosen as it is like the old MCR bodywork but also when pulling off the front bodywork it will come as one big section, so to clear the front wheels the split lines had to be moved forward to a more central position. The final iteration also includes an extra set of aero clips on the front pontoons as this would mean extra security and is also used on the Loaded Gunn TS11. The way the front shrouds came together also changed. Instead of having two flanges it had only one going under. This was chosen to simplify the design. Also, the writer believes that once made it will be easier to locate the two halves of the shrouds together.

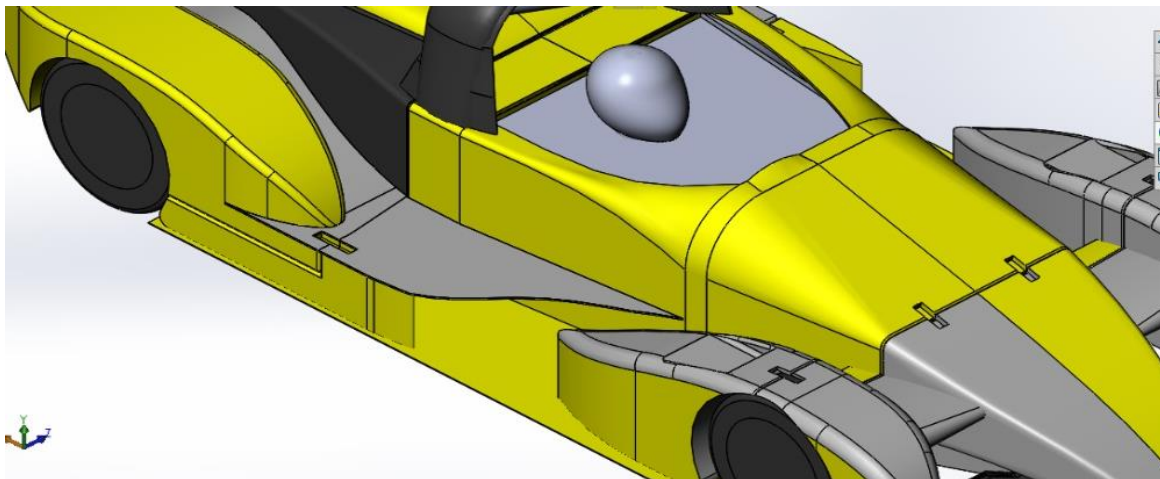


Figure 55 - Mid Section Splits

The main method in which that the author made the splits was to Cut and Extrude the split line, Cut and Extrude where the aero clips would go, Fillet and then create a flange of 35mm to create strength as splitting the part would make it weaker. The flange also allows smoother surface for the two parts to meet because otherwise they would rub against each other and break apart as the material the body is made out of is quite abrasive. The 35mm lip was also on the previous bodywork used so therefore should be suitable to use.

Then the writer added a fillet to the edges so that there is smoother air flow over the gaps rather than having sharp edges that could perhaps cause more turbulence than if there was a smoother edge. The old bodywork was measured for the size of holes it currently uses for the aero clips so that the design was accurate on the new bodywork. This is because once produced the bodywork will use the old aero clips which the group have multiple of, to save on costs as each set of 2 can cost up to £100.

Once the author had completed the initial splitting, the body was split it into the three sections as that made for easier manufacturing (Figure 56). Then the model was taken to the technicians at the composites workshop. They then advised that to make the manufacturing process easier that the author made blocks with in the cad model of the where the foam would be cut to produce the bucks. An example of this is below of the front half of the front pontoon (Figure 57).

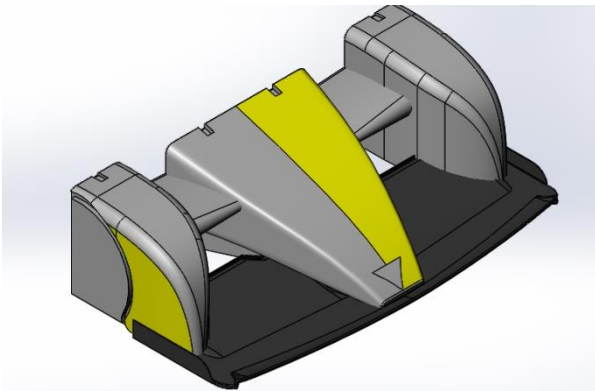


Figure 56 - Bodywork Front Section

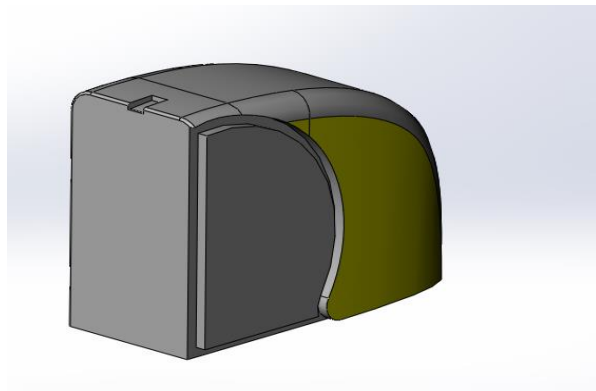


Figure 57 - Front Pontoon Split

As can be seen there is a 20mm wide by 20mm deep divot around where the cut line is. This is so that the technicians know where to set the CNS machine to cut along this line. This will speed up the manufacturing section as it means that the machine does not need to cut all the infill of the block but just the outside. To make the inner half the group will just create a liner which can be inserted at a later date in the manufacturing stage. This design was then passed onto the CAD designer- fitment (RJ) who then strated on making a frames for making a buck.

Once this was completed the author also did the same for the rear of the car. First by seperating the section from the rest of th ebody then removing parts which are not going to be machined in a block such as the wing and rear deck. The author then infilled any section that was not going to be machined. This again will help the technicians as it will reduce the time the CNS machiene needs to be running. It will also help with writing the G code as the the code would need to be adapted so it would miss that section. This is because the head wont actually be able to go into those areas so the code needs to be written to not go in them.

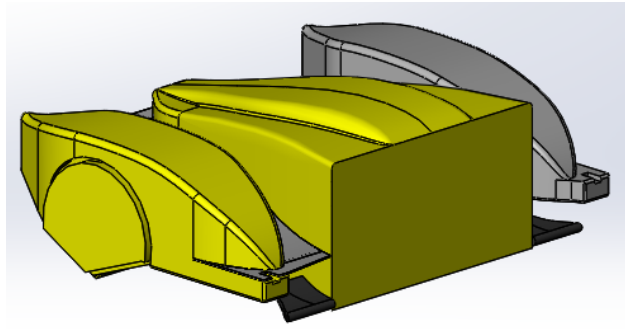


Figure 58 - Bodywork Rear Section

The author also split the mid-section as well for the same reason as stated above. So that that it saves the technicians production time etc.

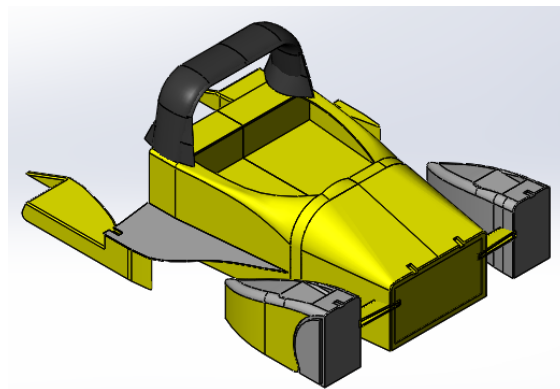


Figure 59 - Bodywork Rear Section

Another piece that the author created on CAD was the front crashbox on the current chassis (Figure 61). This was important as it was used by the CAD operator-fitment to completely make the chassis so that we could make the bodywork to the correct size. In addition, the oil cooler (Figure 60) was also made as that area of the design is got quite tight constraints so the group needed to make sure that the bodywork could fit the oil cooler. It also helped with looking into moving the oil cooler to another place in the car if the fit could be made better by moving it. The parts were measured with a Vernier Calliper and rulers and then producing them on CAD.

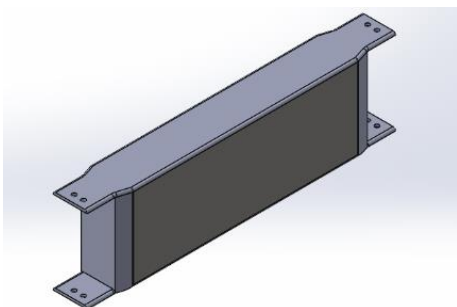


Figure 60 - CAD Oil Cooler

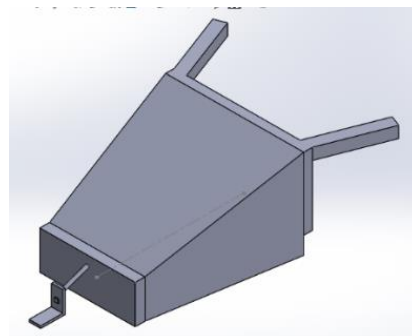


Figure 61 - CAD Crash Box

Analysis

From the rules and regulations, the author produced a set of boundaries which could be used to analyse the legality of the bodywork in the design package being used. This was several boxes and dimensions that the car could be put in to check that the bodywork was the correct size. First the wheelbase and track of the car was measured using a tape measure as the rules are based off those measurements. Then produced the boxes on CAD.

The author then made an initial review of the new proposed bodywork again using previous research on rules and regulations. It was found that there were several areas of concern on the initial design. One was that the body was not symmetrical forward of the main roll hoop (S2000 5.6c). This was however an unfounded concern as there is an allowance to this rule where as a windscreen or air deflector is allowed and the area of concerned was deemed as a windscreen by the group. There was also concern over the pushrods showing as all mechanical components must be covered if seen from the X, Y, Z plane (S2000 5.6i). The group got around this by using shrouds to cover the suspension members. There was also a concern that when looked at from the side the bodywork must be 20cm or higher for 70% of the body length between the axles. This was prevented by the author regular checking the design to see that the bodywork followed all the rules. At the beginning of the project there was also a consideration of the filler cap being exposed from the (MSA(K.6)) however the group decided not to change the roll hoop, so this ended up not being an issue as the current roll hoop already stops it being exposed.

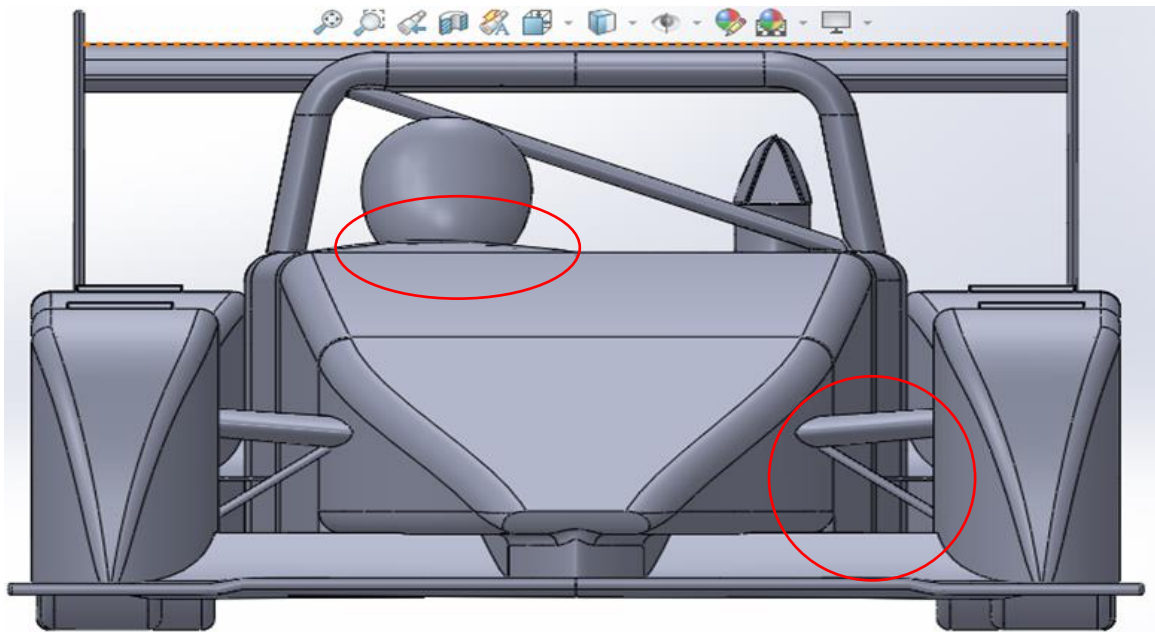


Figure 62 - Potential Legality Issues within the Bodywork

To add to that from the research, the author also conducted a review of the Loaded Gunn TS11. This was of high importance as the Gunn was the projects main rival within the series and is what the group were basing the group's bodywork on. From the review it was found that the Gunn was breaking several rules. One of which was that the bodywork was not symmetrical forward from the main roll hoop (S 2000 5.6(C)) and that the cockpit opening was not symmetrical along the longitudinal axis (S 2000 5.6(C.iii)). The writer then used this to inform the project leader (MH) on what to include in the letter to the regulators.

(Standing, 2018)



Figure 63 - Loaded Gunn Case Study 1



Figure 64 - Loaded Gunn Case Study 2

Simon Williams - Materials, Manufacturing

Introduction

This section of the report details the tasks covered by materials manager (SW) over the course of the project this year discussing the CAD work done at the beginning of the year, research carried out into different materials available, which resins work best with those materials, and the manufacturing processes that can be used to create parts with these materials. Also mentioned is the process of how the group went about making a final choice of material and process combination for the project to progress, and total material costings for buck manufacturing.

The processes carried out in the workshop sessions with Andy Tibbot each week will also be described, detailing the steps taken to create the various practice pieces made.

Table of work

Table 12 - Work Completed (SW)

Task	Time taken	Team members involved
Group meetings	50 hrs	All
CAD chassis (My tasks Bottom arms Suspension & steering pushrods)	13hrs	All
Materials research (Carbon fibre, Fibreglass Resins, Processes, Moulds, Parts)	40 hrs	Simon
External wiring CAD	8 hrs	Simon, George
Viva 1	10 hrs	All
CFD training	3 hrs	Ainsley, Max, Simon
Workshop sessions	40 hrs	All
Prices	10 hrs	Simon
Lock down bodywork meeting	2 hrs	George, Ainsley, Max, Simon, Ryan
Viva 2 and report	25 hrs	All

CAD chassis

To begin the project, an accurate CAD model of the MCR sports 2000 chassis was needed. The material manager's contribution to the chassis was to create the front lower wishbones, the steering arms, and the suspension pushrods. Technical drawings were made, and measurements taken from the vehicle using measuring devices such as a micrometre, ruler, and a set square. These were then used to create 3D part files on SolidWorks, the push and steering rods were also created in the same way. These parts were then uploaded to OneDrive for the CAD designer (GJ) could assemble the full chassis.

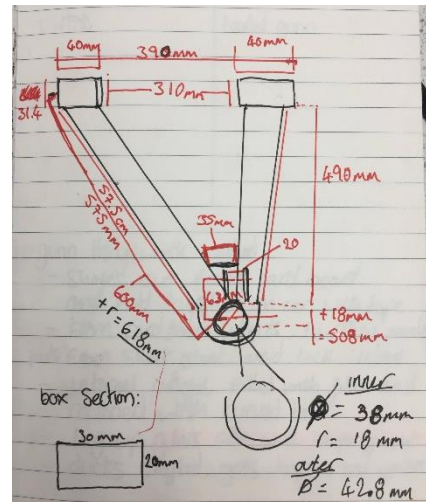


Figure 65 - technical drawing of the lower arm of the MCR sports 2000

Materials research

Once the chassis parts were designed and uploaded, the author's next task was to research different composite materials that could potentially be used to create the moulds and finished product from. The materials manager looked at carbon fibre, fibre glass, and Kevlar. The advantages and disadvantages of different weave patterns were analysed, considering the strength, weight, and cost of the materials.

Resins and other consumables, such as hardeners were also researched, looking at epoxy and polyester resins seeing which was best for each material, and process. Gathering this information helped the team decide on which way to take the project as regards to the overall strength of the new bodyshell, the costs, and timescale of manufacturing later in the project.

Manufacturing research

Different manufacturing processes available to the group were then analysed giving a base understanding of what was necessary in order to build the bucks, moulds, and final body work. A number of flow charts was created to display how these processes progress, which can be seen below.

Resin infusion

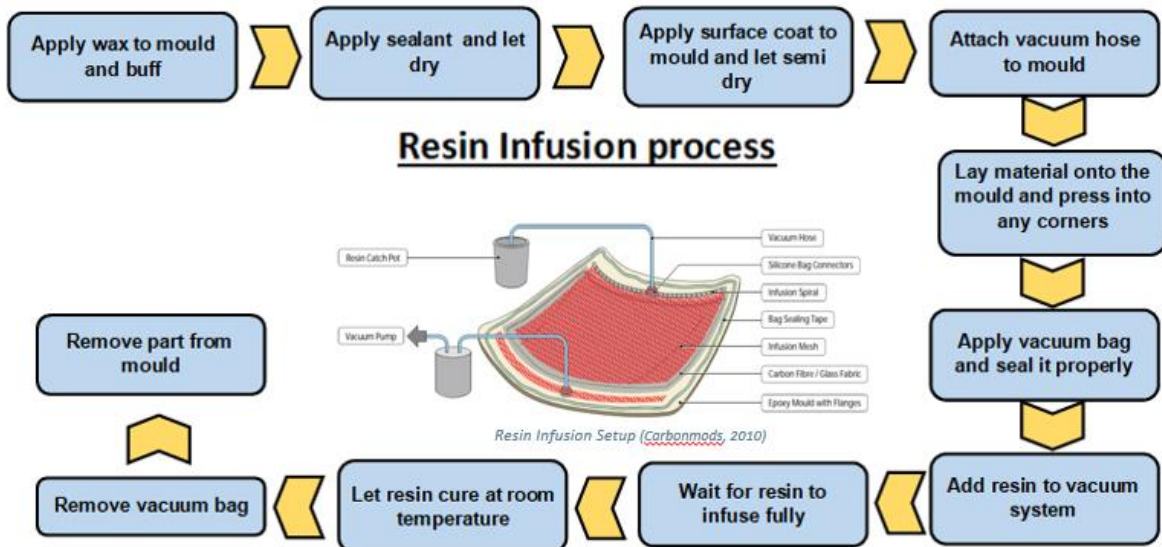


Figure 66 - flow chart showing the process involved in bladder moulding composite materials (Berg, 2009)

Wet layup

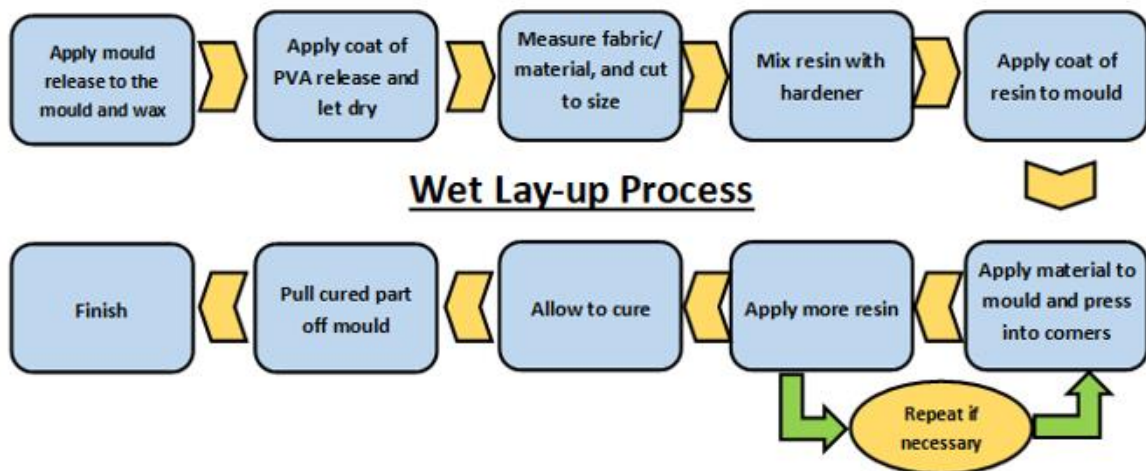


Figure 67 - flow chart showing the steps involved in the wet lay-up process (Stuart, 2010)

Resin transfer moulding

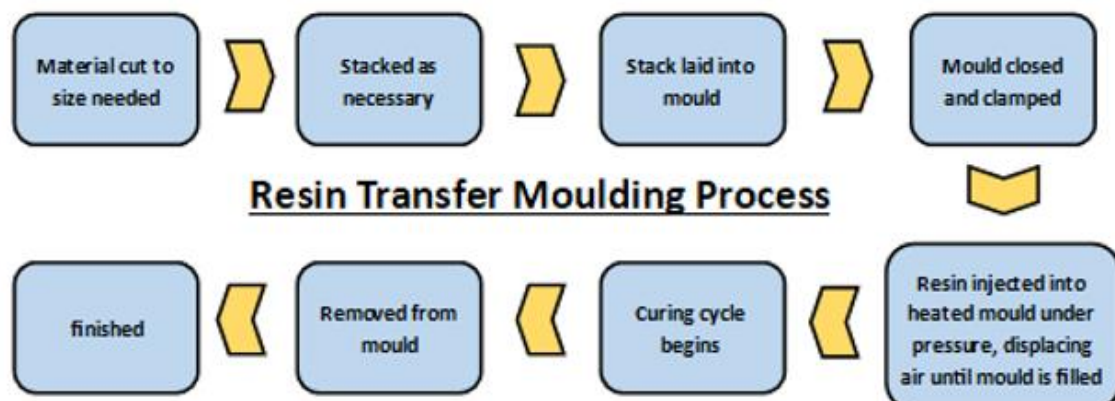


Figure 68 - flow chart displaying the process of resin transfer moulding (Laurenzi & Marchetti, 2012)

Prepreg process

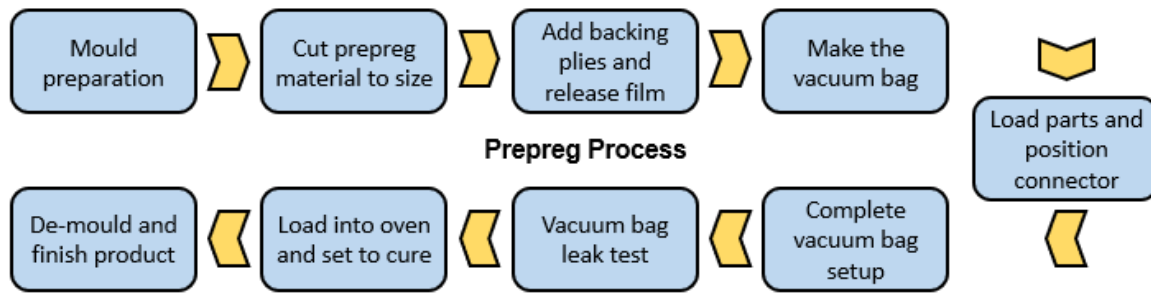


Figure 69 - flow chart detailing the steps involved in the prepreg process (Easy Composites, 2016)

Choices:

Once the group had a good base knowledge of the materials and processes available, a selection of five different combinations of material, resin, and process were made which would be suitable to what was needed to manufacture the final design. The choices considered overall strength, ease of manufacture, and costing. The five choices were as follows:

Choice 1:

2x2 twill glass fibre
EL2 epoxy resin
AT30 hardener
Wet layup process

Choice 3:

2x2 twill glass fibre
IN2 epoxy resin
AT30 hardener
Resin transfer process

Choice 5:

4 axial glass fibre
IP2 polyester resin
AT30 hardener
Resin infusion process

Choice 2:

2x2 twill glass fibre
IP2 polyester resin
AT30 hardener
Wet layup process

Choice 4:

Triaxial weave glass fibre
EL160 high temp resin
AT30 hardener
Resin transfer process

This selection was then presented to the composites technician (AT), who advised further which would be the best decision to make. It was decided that the group would construct the final body using choice five: 4 axial glass fibre with polyester resin, using the resin infusion process. Due to its overall strength, ease of manufacture, which could be carried out in house, and overall cost for materials. We also decided that smaller areas of the car such as vents and louvres may possibly be made from carbon fibre if funds allow after the shell is constructed.

Materials Pricing

Once the group had decided on materials to be used for the project, an estimation of prices for the materials was gathered. Using suppliers that were known to the University, a pricelist was compiled.

Table 13 - Materials Prices

Fibre glass	Price (all prices exc. VAT)	Source
1200g quadaxial glass fibre sheet 1m x 1.27m	£7.95	East coast fibreglass
Twill weave glass cloth 163g 1x1m	£3.40	East coast fibreglass
Carbon fibre	Price	Source
2x2 twill 3k 210g carbon fibre 1x1m	£21.50	Easy composites
Black stuff carbon fibre 2x2 twill 3k 200g 1x1m	£12.00	Easy composites
Resins	Price	Source
IP2 polyester resin 5kg	£32.95	Easy composites
IN2 epoxy infusion resin 1kg	£18.75	Easy composites
Model board	Prices	Source
PU80 low density board 1x1x0.1m	£131.75	Easy composites
PU240 medium density board 0.5x0.5x0.1m	£88.00	Easy composites
Miscellaneous items	Price	Source
VB160 Vacuum bag 150m	£150.80	Easy composites
Resin infusion spiral chord 10m	£3.50	Easy composites
Meguiars #8 mirror glaze mould release 310g	£11.75	Easy composites

Further CAD

as the project progressed and the CAD chassis model neared completion, it was found that certain areas of the body that had previously been ignored required extra attention for the new CAD body shell to fit properly. The author offered to measure up and complete any external wiring or objects that ran outside of the internal framework of the chassis. Technical drawings of each side of the car were made using a laser level, rulers, set squares, and micrometres, carefully locating where the wiring was in 3D space. The drawings can be found in figures 70 and 71.

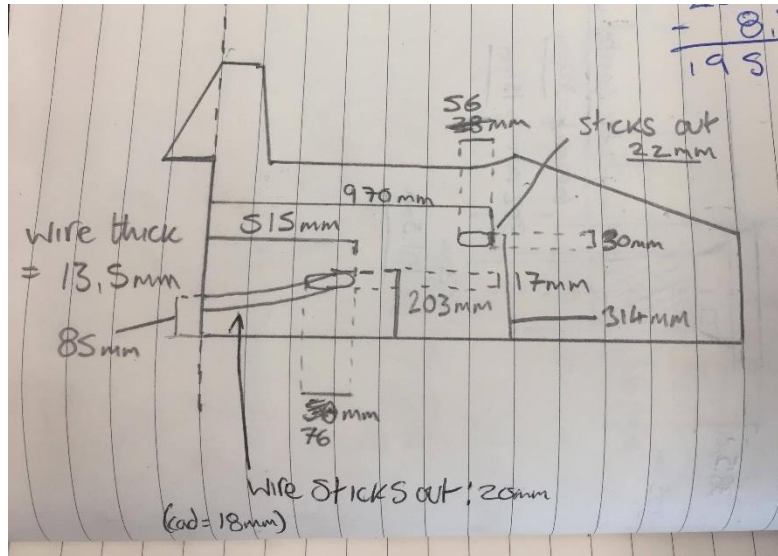


Figure 70 - technical drawing of the right side of the MCR car, detailing where wiring extruded from the chassis.

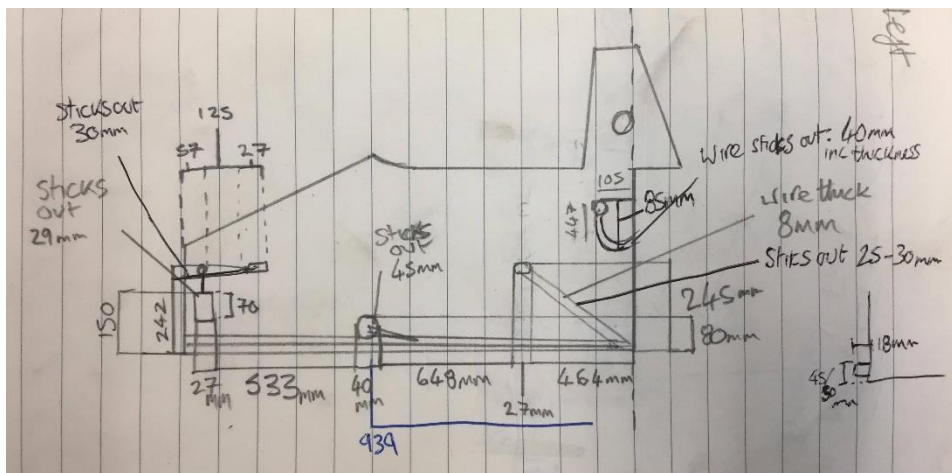


Figure 71 - technical drawing of the left side of the MCR car, detailing where wiring and other objects extruded from the chassis.

These items were then added to the CAD model using solid works and sent back to the CAD designer (GJ) to test fit the body shell once again.

Workshop sessions

The group initially created small shapes from different types of foam to establish which should be used for the manufacturing process. This allowed the author to practice sanding of the foam to an acceptably accurate degree. The shapes were then covered in high-build primer, a thick, paint-based substance that is easily sanded to fill any imperfections in the material (migwelding, 2008). Some foam samples dissolved upon contact with the primer. The polyurethane building foam survived the best so was chosen to use for the final outcome.

A profile of a car was produced on the CNC machine out of model board to practice the buck making process, this was sanded down for as smooth finish as possible. The author applied high build primer again and sanded this back to a smooth finish. The buck was then covered in three coats of clear gloss top coat, again, improving surface finish by filling any fine imperfections left on the surface from sanding. Finally, five layers of honey wax were applied to the buck and buffed back, this acted as the release agent, this reduces surface tension and allows the mould to detach freely (miller-stevenson, 2016).

Following this process, the author applied 20 layers of 0.4mm pre-preg carbon fibre sheet to the buck, beginning the mould making process. A heat gun was used to stretch and manipulate the material into place with no creases. The mould was then placed in a vacuum bag, sealed and put into the autoclave to cure.

The moulds were removed from the autoclave, separated from the bucks; then a layer of release agent was applied inside, before five more layers of finishing pre-preg carbon were applied, taking care not to crease the material. This was again put into a vacuum bag, sealed and placed in the autoclave.

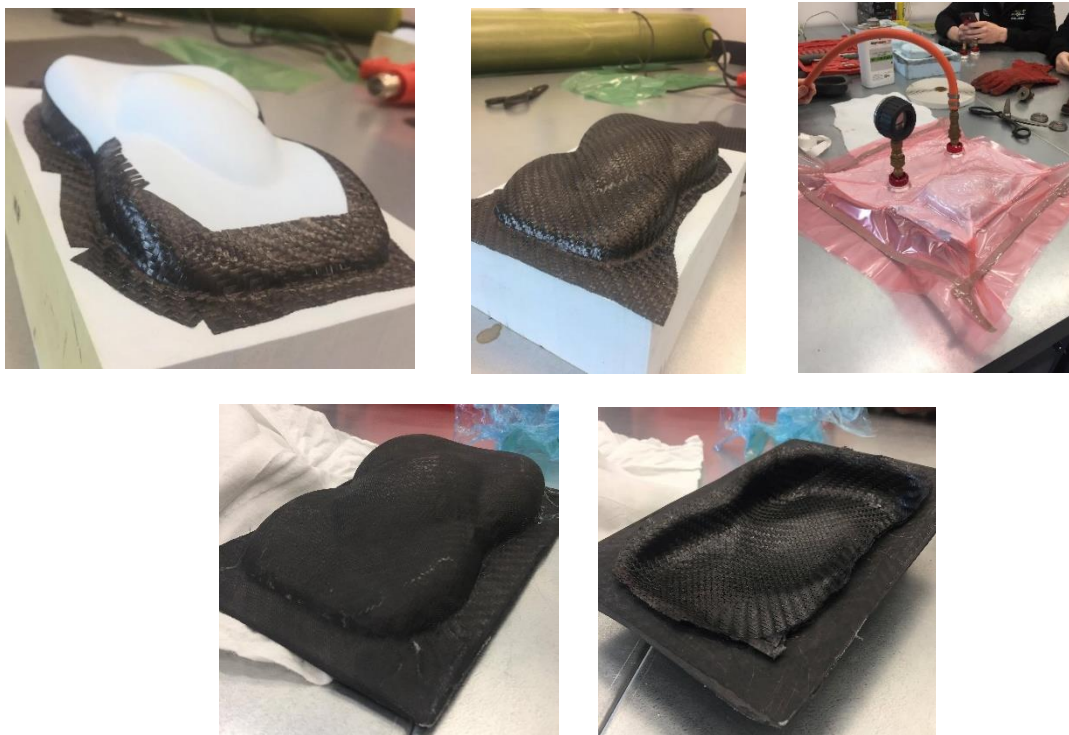


Figure 72 - pictures taken during the process of creating small prepreg carbon fibre moulds and parts in the workshop. 1 showing the layering up of the buck to create the mould. 2 showing the buck fully covered with twenty layers of carbon fibre. 3 showing the vacuum bagging process. 4 showing the cured mould. 5 showing the part layers being laid into the mould.

Buck manufacture

The group plans to create the bucks from the building foam previously mentioned. The sheets of foam will be glued together using polyurethane glue and held in a vice like structure made by CAD chassis manager (RJ) for support. The foam will then be cut down to the shape of the component by the workshop technicians (AT)(DC) using the CNC machine in the work shop. As previously discussed, a veil of fibreglass will need to be laid over the foam to increase its strength. This will then be sanded back, and a coat of filler applied to create a smooth layer with no cracks or pinholes. Once sanded, primer will be added layer by layer, sanding each layer back once it dries to create a smooth surface which will be sealed ready for layering the mould onto.

Due to size restrictions of the CNC machine and foam boards, the bucks will be split into smaller sections to create the moulds. The moulds will be made from these sections and joined together once created.

Mould manufacture

The primed buck will then be coated in mould release, and the process of laying up fibreglass chop sheet onto the buck will begin. 900g chopsheet is being used to create the bucks, using tooling resin which cures under its own exotherm, minimising any expansion. (Scott Bader, 2017) the wet layup process will be used to make the moulds, this method, although untidy and poor in terms of resin ratio control which doesn't particularly matter to the group, is the cheapest method to manufacture and will give a reasonably strong mould to work from, with each layer building overall thickness quickly. The thickness of the finished mould will enable it to be used multiple times afterwards to make any replacement pieces needed. once the corresponding moulds have been created, they will be joined together to create a large mould which will be able to create the part necessary in one single piece. (CFS fibreglass, Unknown)

The wet layup process that the group will use to create the moulds can be seen in Figure 72.

Flanges

The flanges mentioned in the above section will be crafted into the mould so once they are manufactured, they can be joined together to create a seamless full part single mould. This will be done by creating overlapping areas with slight recesses that will slide under or over the part it is to butt up against. These will then be sealed with resin and another layer of fibreglass to create a smooth surface which will not appear on the finished parts. (Ludlow, 1967) An example of this is shown below:

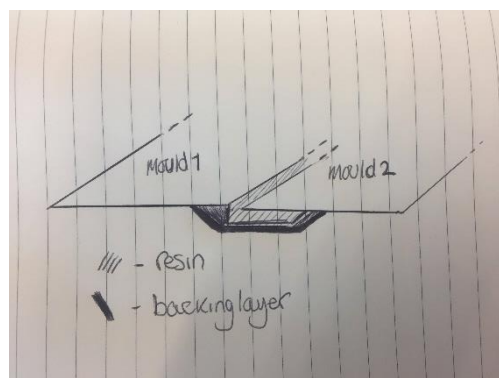


Figure 73 - basic sketch showing how two mould section will be joined together to create a smooth surface to create parts from.

Pricings

A pricelist of materials and any miscellaneous items needed for creating the bucks and moulds was created. This gave the group an estimate idea of the cost involved, and whether the target budget of £3600 was still achievable. Prices for certain items may need to be multiplied as per need.

Sandpapers (150mm disks)

80 grit (10 pack) x5£3.52 (toolstation)
120 grit (10 pack) x5.....£3.52 (toolstation)
240 grit (10 pack) x5£3.52 (toolstation)
320 grit (25 pack) x2.....£7.22 (CSM abrasives plus)

Wet and dry paper

p800 (50 pack)£21.95 (easycomposites)
1000 (50 pack)£24.25 (CSM abrasives plus)
2000 (50 pack)£13.25 (easycomposites)

Primers

Pattern coat primer (5kg each) x2£52.50 each (easy composites)
Hi gloss primer (5kg) x2£52.95 (easy composites)

Glue

Polyurethane glue 355ml (x5).....£13.40 each (axminster tool centre)

Fillers

Upol easy1 (3.5 ltr) x3.....£20.99 each (zoro.co.uk)
Onion board (20 sheets)£6 (Halfords)
Filler applicators (10 pack) x5£15 (mbfibreglass)

Fibreglass

900g (3oz) Chopped Strand Matt 37m² x2.....£158 ex VAT (east coast fibreglass)
glass fibre plain weave material 30m£114 ex VAT (east coast fibreglass)

Resins

Polyester resin (25kg) x2.....£95 (50kg resin)(easy composites)
Crystic RTR 4010 PA Tooling Resin (25kg) x7...£120 (east coast fibreglass)

Finishing compound

G3 compound (400g)..... £9.77 (advancedpaints.co.uk)

Mould release

Meguiars #8 mirror glaze (310g)£11.75 ex vat (easy composites)
(east coast fibre glass supplies, 2019) (toolstation, 2019) (CSM abrasives, 2019)
(Easy Composites, 2019) (axminster tools and machinery, 2019)
(Zoro, 2019) (Halfords, 2019) (mbfibreglass, 2019) (Advanced Paints, 2019)

Total items cost for creating moulds

The total for mould manufacturing equates to **£2030.08** + vat on certain items. Estimated total including VAT will be approximately **£2100**

The overall surface area of the new CAD body was around **28m²**, but as certain areas of the shell are not being made by the group, an estimated area of **22m²** was assumed. A thickness of 15-20mm is needed to create a strong mould that can be used repeatedly, so multiple layers of chopsheet fibreglass will be necessary to create each mould. Each meter squared of 900g chop sheet fibreglass requires 2kg of tooling resin, so **22 x 2 = 44kg**, this is the amount of resin required per layer.

So with four layers the overall amount of resin necessary will be:

44 x 4 = 176kg of resin needed, which is just over seven 25kg barrels of tooling resin

7 x 120 = £840 approximate total tooling resin costs.

Project budget and parts.

The total budget for the MCR project this year was **£3600**, with the cost for manufacturing the moulds including all the miscellaneous items needed being approximately £2030 the group is left with £1570 left for parts manufacturing.

The finished parts will be manufactured using 600g quad axial glass fibre, at a cost of £285 for 62m² from east coast fibreglass. Each full roll is enough for two layers of fibreglass. Resin needed for the manufacturing of the parts will cost £95 a tin (25kg) of which we will need two of, costing £190. the total cost for materials for parts manufacturing be £475, leaving the group with £1095 left for any strengthening materials such as Nomex core, and as a contingency fund for any unforeseen circumstances.

Analysis

Overall, the project has been an enjoyable task, and the workshops sessions with workshop technician (AT) have been an invaluable tool for the group in learning the processes necessary for creating the bucks and moulds. With an estimated £1095 left of the budget, mainly due to the sponsorship deal on the foam, the team will be able to use this money to create other areas of the body work that need improving also, such as the louvres and endplates.

Time wise, the project was hindered by having to redesign and refit the body in order to fit around the chassis. If this problem hadn't occurred, it is felt that the group would be able to have accomplished a lot more by now, but this has allowed the team to further develop the body and analyse any changes made in more detail, leading to a more refined product.

Kai Tang - Louvres

Work overview

The author will be conducting research on the viability of applying Louvres on the group projects current bodywork, looking into how much an effect a louvre has at dissipating high pressure air over the wheels and ventilate heat. A louvre exists in the race car the group is working on and the author is tasked to explore improvements, analyse and compare new designs to the existing one. Furthermore, a manufacturing method and costing of materials will need to be researched and considered whether the group will be able to procure new louvres under consideration of the overall budget and time for the race car.

Task allocation

Table 14 - Work Completed (KT)

Task	Completed with	Hours	Comments
Initial Planning	ALL	10	
Cad Chassis parts	ALL	20	
Meetings	ALL	40	
Workshop sessions	ALL	40	
Viva 1	ALL	10	
Measurement of wishbones and push rod to CAD shrouds		4	Some difficulties getting accurate measurements as they were awkward to take. Measurements were taken for team CAD designer. (G.J)
Research louvres		10	Books suggested by Project supervisor (Tim Tudor) and searched for other sources.
Measurements on current bodywork louvres		5	Some errors made and a couple tools were missing to remove the louvre.
CAD all test iterations		20	CAD up designs of the test iterations for adjustment of angles and number of air gaps
Draft analysis		6	Suggested analysis by composites technician. (Andy Tibbot)
CFD		2	Instructions to run CFD written by team leader and team aerodynamicist. (A.M)
Research manufacturing process		4	With some direction from team materials manufacture researcher. (S.W)
Viva 2 and report	ALL	10	
		181	

Research

As wheels rotate, the turbulent air pack in above the wheel creating positive pressure on top of the wheels. The air above flows through the pontoons or bodywork above the wheel at high speeds creating a negative pressure. "It is also the case that rotating wheels can act as pumps" (Mcbeath, 2015), pulling air into the wheel wells and pumped out the front. Thus, the high-pressure problem is accentuated, lift could be generated slightly and lead to lose of traction, grip and control.

By having a louvre located above the wheel, air can be pulled out by negative pressure above the wheel along the pontoon escaping through the vents as seen in Figure 74.



Figure 74 - Louvres on a Road-Going Vehicle



Figure 75 - Louvres and cutaways on a Race Vehicle

Cutaways can also be placed behind the wheel as seen in Figure 75 some also feature louvres, where turbulent air generated by the wheel (can also be known as 'Dirty Air') causing drag is escaping behind the wheel and allowed to follow the natural air flow as smoothly as possible around the car reducing its turbulent nature, turbulent air escaping from the wheel into smooth flowing air around the car can cause turbulence creating drag and slowing the car down. The goal is to reintroduce the 'Dirty Air' back into smooth flowing air along the side of the vehicle through the louvres which are angled to lessen the turbulence generated by the air around the face of the wheel.

Designs and experiments



Figure 77 - CAD
Louvre Plan View

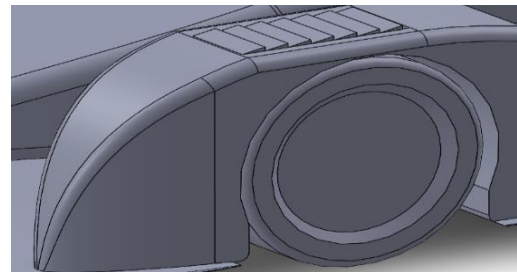


Figure 76 - JHTT02
Louvres

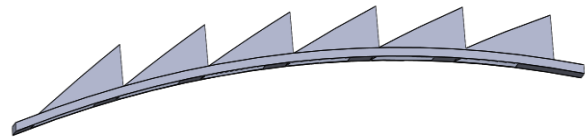


Figure 78 - CAD
Louvre Side View

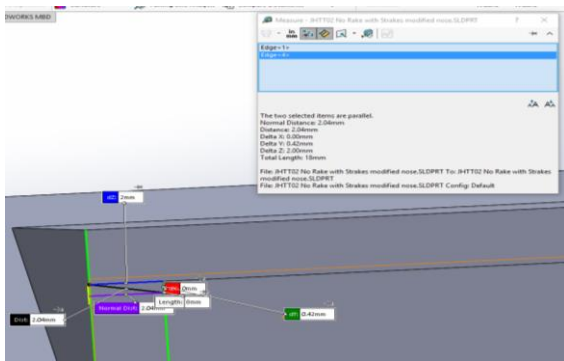


Figure 80 - CAD Measurements



Figure 79 - Original MCR Louvres

First the author took measurements of the louvre the current bodywork has in the workshop and transposed them into a cad file as seen above in figure 80; ready to include different test features such as adjusting the angle of which the air is let out of the louvre and the number of gaps that allow air to pass through. These test iterations will need to be designed in Solidworks and fitted onto a pontoon with a wheel as seen in figure 81 as an example so that it is ready to be verified on CFD with help of team aerodynamicist (A.M).

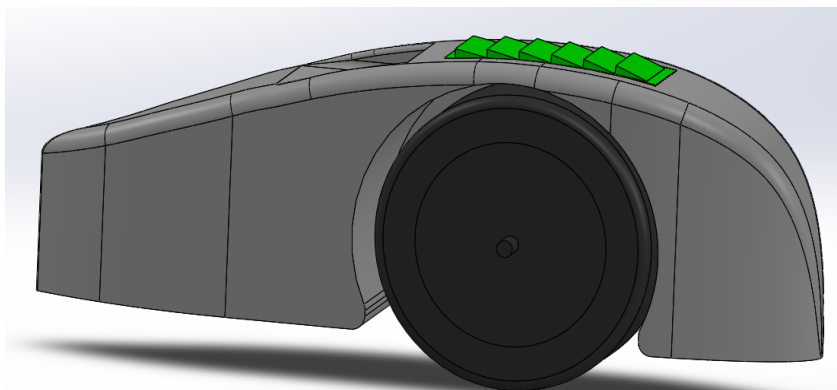


Figure 81 - original louvre on new pontoon

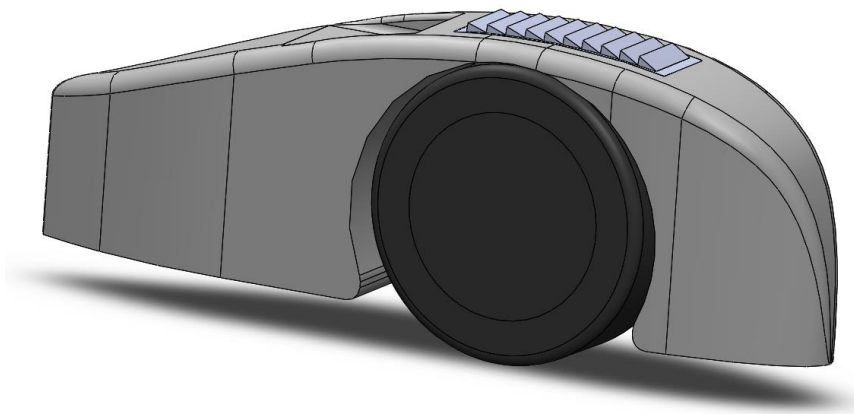


Figure 82 - New Iteration Pontoon

Analysis

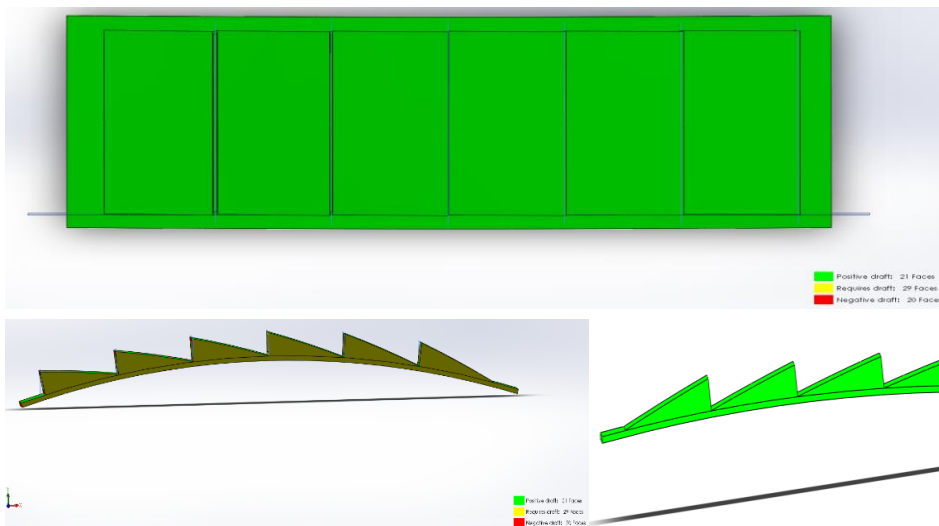


Figure 83 - Draft analysis from top view

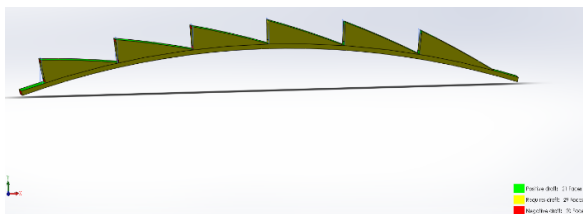


Figure 85 - Draft needed highlighted in yellow

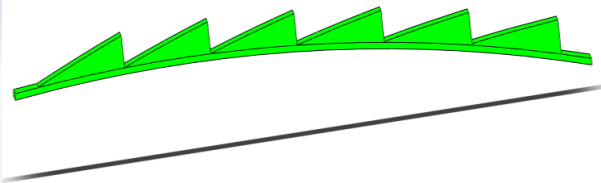


Figure 84 - Draft complete

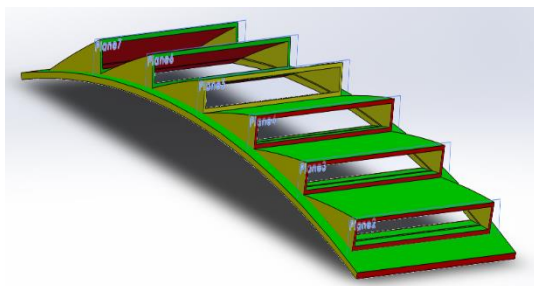


Figure 87 - Draft needed highlighted in yellow

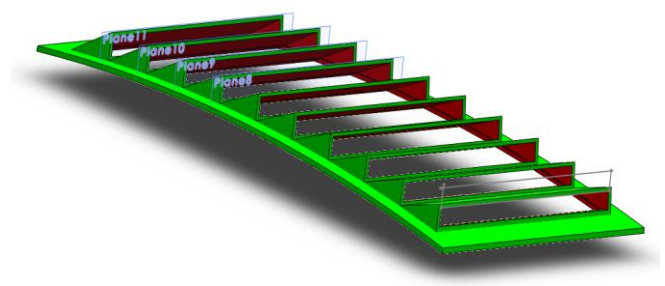


Figure 86 - Draft complete for 10 gap louvre

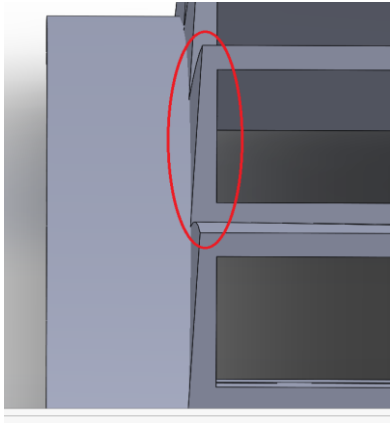


Figure 88 - Example of a drafted face and a non-drafted face within the same part

Drafting eases, the manufacturing process by angling certain faces of the part so that the component doesn't get trapped in the mould or cast. The author has allowed up to 3 degrees of draft as it is the recommended angle by Andy Tibbot. The draft helps the component to be lifted from the mould as the side faces such as figure 88 don't allow much friction between the mould and material. Draft Analysis in solid works helps illustrate this with colours depicting faces with positive, negative and areas which require draft in; green, red and yellow respectively as shown in figures 83-86.

Materials and manufacturing

Fibre glass, Aluminium and carbon fibre are some of the most common materials used for louvres in motorsports which can be made. The Author has decided upon using prepreg carbon fibre as the team has experience with handling the material as result of hours spent over in the workshop sessions. Although an alternative such as fibre glass can be used however that will require a wet layup process which the author hasn't had experience with and using wet lay-up, the process will also take longer as it is required to mix the epoxy resin. Wet lay-up process is also an option to consider for carbon fibre however using prepreg carbon fibre skips the steps as mentioned and will not need for an epoxy resin to be applied for every layer of carbon fire.

Aluminium is will be the quickest to manufacture as it can be machine cut however Dave Cooper has advised that there will be difficulties in fixing the material for the machine to be cut especially since a louvre isn't that large of a part/component compared to other parts of the bodywork the group is working on. There may also be issues with bending the louvre to shape uniformly

Thus, the author has decided upon using prepreg carbon fibre of which the material can be bought via Easycomposites website which lists a ~1.25m wide to 2m long roll of prepreg carbon fibre for £98.34

Materials	width/length/thickness	Price
Prepreg Carbon Fibre	1.25M x 2.0M x 0.00025M	£98.34
Fibre glass (wet lay-up)	1.0M x 2.0M x 0.00048M	£48
Aluminium	0.20M x 0.4M x 0.00003M	£4.39

Manufacturing technique

Starting with a CNC machine cut out of the mould from a desired cad design, begin the prepreg laminating process by applying a release agent onto the mould; this will ensure the mould and component will be more easily separated at the last stage.

Carefully apply a layer of prepreg carbon fibre over the mould and press down evenly to maximise contact between mould and material (on negative draft features of the mould, it may be necessary to cut incisions especially at tight corners to fully allow the material to cover avoiding creases). After applying the first half of the required layers, a debulking process will begin where the current mould and layers of carbon fibre are put under a vacuum via vacuum bag and held for 10 minutes to ensure all the air has been evacuated, this consolidates the material. Once vacuumed remove vacuum bag and continue to laminate the rest of the plys over; when all layers have been applied, vacuum seal the part and place in an autoclave so that it can be cured under high temperature and pressure.

After curing process is complete carefully separate the part from the mould and is ready to be sanded down smooth which completes the manufacturing process of which won't take more than two days to complete and assuming that 4 moulds are available, enough space to accommodate 4 louvres in the autoclave and at least 4 member of the team are present in making them, then all 4 louvres can be completed in that time frame.

Conclusions, review achievements and failures

A design has been made to allow ease of manufacture by using drafting on Solidworks and multiple iterations are made and ready to be verified on CFD given the time restrictions. However better time management could be had should the design phase was not over ambitious and made only what could be done at a reasonable time frame allowing enough data to be collected to check if any of the iterations could provide an improvement compared to the base louvre present in the current bodywork. A graph to show trends when comparing test iterations would have been made. The louvre investigation has improved the development of future louvres and established a manufacturing process that is realistic to the limited budget allowed to the team, time taken to produce and is able to be produced by any member of the team.

Ewan Carter - Wing End Plate Investigation

Table 15 - Work Completed (EC)

Task	Completed with	Hours
Initial Planning	ALL	10
Meetings	ALL	50
CAD chassis Parts	ALL	20
FEA Training	-	40
Workshop sessions with composites technician	ALL	40
VIVA 1	ALL	10
Learn CFD using CFD instructions	MH, AM	10
Create endplate test schemes	-	5
Rear wing position study	-	5
Slots study	-	5
VIVA 2 & Report	ALL	20
		TOTAL = 215

Rear wing endplate features

Before generating initial designs for the rear wing endplates, it was deemed crucial to first perform some research into what features an endplate-mounted rear wing endplate needs to have in order to function and perform as expected and in a manner to improve the performance of the rear wing.

Mounting points

For the wing to be able to be mounted upon the endplates, there needs to be a suitable support structure within the endplate to support the loads produced by the weight of the rear wing plus the loads produced by the rear wing at speed, which will be determined using computational fluid dynamics to determine the amount of downforce the rear wing produces and thus will transfer to the mounting points.

The endplate also needs to allow adjustments to the rear wing angle to suit the different circuits that the car will be raced at. This can be achieved in a number of ways, such as having a large number of holes based on the radius of the gap between mounting holes or by using slotted holes to allow infinite adjustments within the size of the slots.

Gills or slots

The first aerodynamic feature that will be investigated will be the addition of slots in the endplate above the location where the aerofoil mounts to the endplate. The theory behind this is that the slots will allow high pressure air from the top surface of the wing to mix with the lower pressure air moving along the side of the rear wing endplate (Mullen, 2017).

Test schemes

In order to perform computational fluid dynamics on the rear wings, the different schemes of rear wing endplates to be tested must have first been produced in computer aided design software. With the baseline wing assembly already having been provided, it was a case of modifying this to suit the two different schemes to be tested and then exporting them in a file format suitable for the CFD software.

Test scheme 1 – baseline

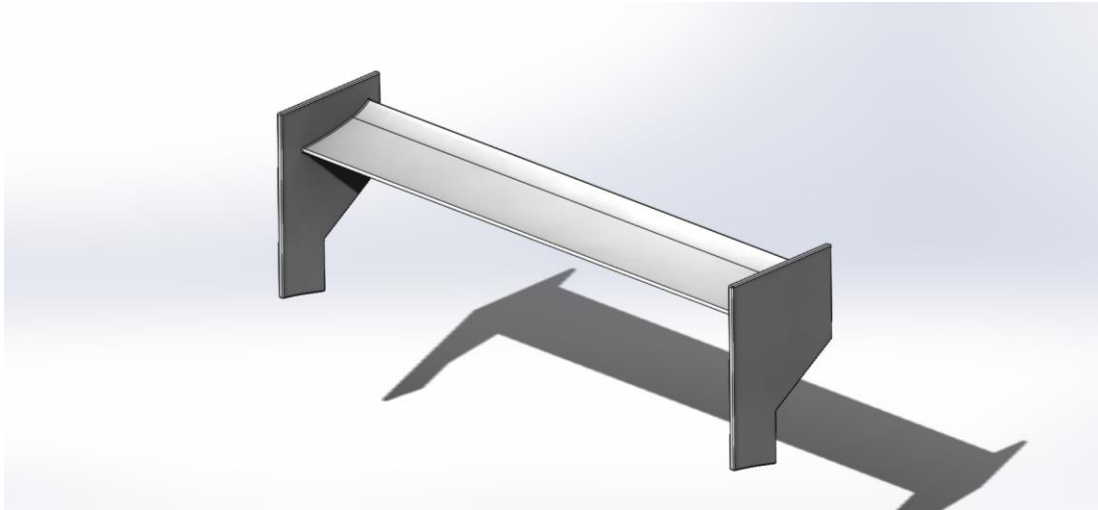


Table 16 - Test scheme 1 – baseline

The baseline scheme is the rear wing assembly as provided from the bodywork concept. This will be used as a benchmark for all the other concepts to compare results to.

Test scheme 2 – Aerofoil relocated

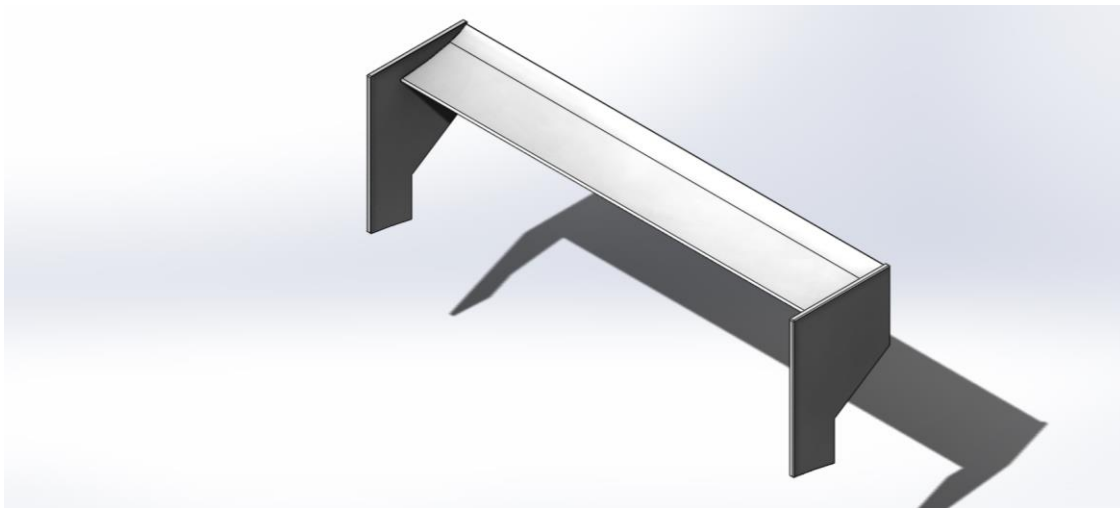


Table 17 - Test scheme 2 – Aerofoil relocated

This test scheme relocates the trailing edge of the aerofoil to a position 5mm forward of the trailing edge of the endplate and 5mm below the top edge of the endplate. In Isolation, this may not lead to any increase in downforce, but when applied to the car model and run in a full-car setting, this may produce more downforce than the baseline due to there being a reduced influence on the wing from objects upstream of it, for example the airbox and the driver's head.

Test scheme 3 – Aerofoil relocated and slots above the top surface of the aerofoil

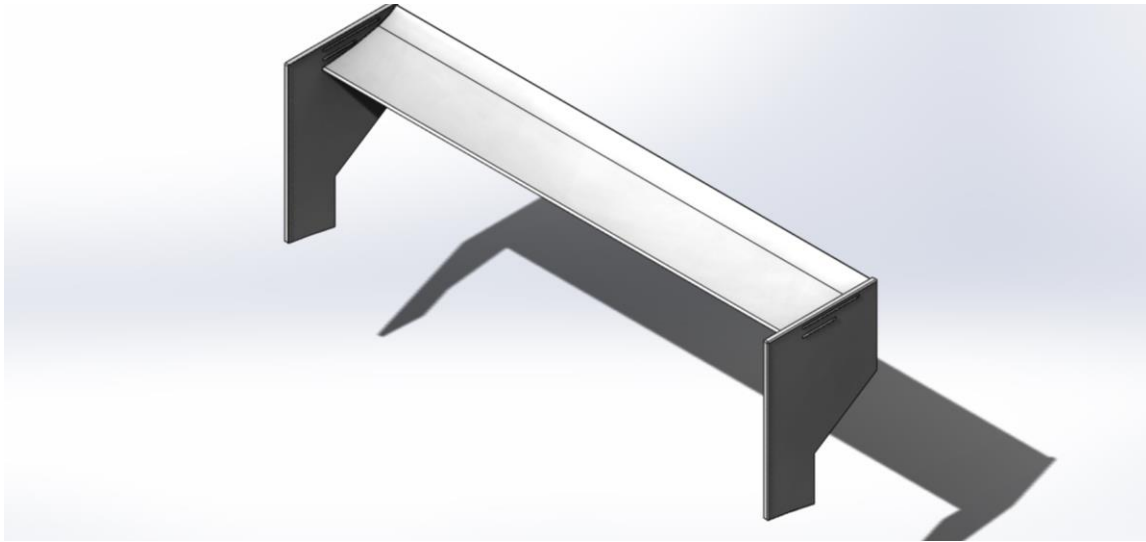


Table 18 - Test scheme 3 – Aerofoil relocated and slots above the top surface of the aerofoil

This test scheme uses the relocated aerofoil from Test scheme 2, but then adds a pair of slots above the top surface of the aerofoil. The slots are 6mm wide, with one being 25mm above the leading edge of the rear wing with a length of 100mm. The second one is 50mm above the aerofoil with a length of 175mm.

Test procedure

Before each scheme could be tested within CFD, each scheme needed the applicable steps taken to prepare them to be run. Firstly the CAD files were exported as a parasolid (.x_t) file which can then be used to create the domain within which the simulation will be run. The domain then gets the wing geometry subtracted from it to create the geometry that shall be run. The final step of creating the geometry is to name each face of the domain using a named selection with names that allow the final steps in FLUENT to automatically identify what each face is, for example the front of the domain is called the 'velocity inlet' to signify that this is where the simulated airflow will be coming from.

Once the geometry had been created, it can then be repaired to remove any errors present when creating the geometry. To follow on from this, the mesh can then be created by setting the scale factor to 0.5 and a max element setting of 1. Mesh type was set to "all tri" with the patch method set to patch independent as per recommendations from the group. Edge criterion was set at 0.06 due to the part being quite small relative to a full car. The mesh sizing was then set to 0.02 around the wing area to give a fine mesh around the areas that will be studied. Once this had been done and the mesh calculated, the mesh was then repaired to correct any errors or imperfections in the mesh.

With the models having been meshed, FLUENT could then be launched using a parallel process and four processes due to the PCs having quad-core CPUs in them. The model was set to viscous laminar with the K-epsilon model using non-equilibrium wall functions. Boundary conditions were set to have anything that the air comes into contact with, such as the wing assembly, be viewed as a wall or a solid object. The 'velocity_inlet' was set to have an air speed of 35 metres per second flowing over the part. This value was chosen as a reasonable average speed for an MCR race car which this assembly will eventually end up fitted to. The frontal area was then calculated and then used as a reference value for the calculations which were then calculated from the 'velocity_inlet'. Solution methods were set to second order upwind with the calculation scheme set to coupled.

In the controls section, the flow courant number was set to 50, with the momentum and pressures set to 0.25. The turbulent kinetic energy and dissipation rates were then set to 0.9,

with the turbulent velocity set to 0.95. The limits for the maximum turbulent velocity ratio were increased by multiplying the default value by 10000. The reports were then set up to output the coefficients of drag and lift to separate plots within the window, while also outputting the result to the console in FLUENT and write the result to an external file. The solution was then initialised using the hybrid initialisation to check if the calculation could converge on its final value. If this stage threw up any errors the whole assembly would need to be re-meshed.

Once the solution had been initialised, the calculation could then be run. Before this, the number of iterations for the calculation needed to be set. The value for this was set to 1000 to allow for a large enough number of iterations for the study to converge on its final value. Once the values had converged on their final value, the 3D viewer could then be used to create graphs for the pressure distribution along the length of the aerofoil at two points on the wing, both at the centre of the wing and near the endplate at 750mm from the centreline of the aerofoil section.

Results

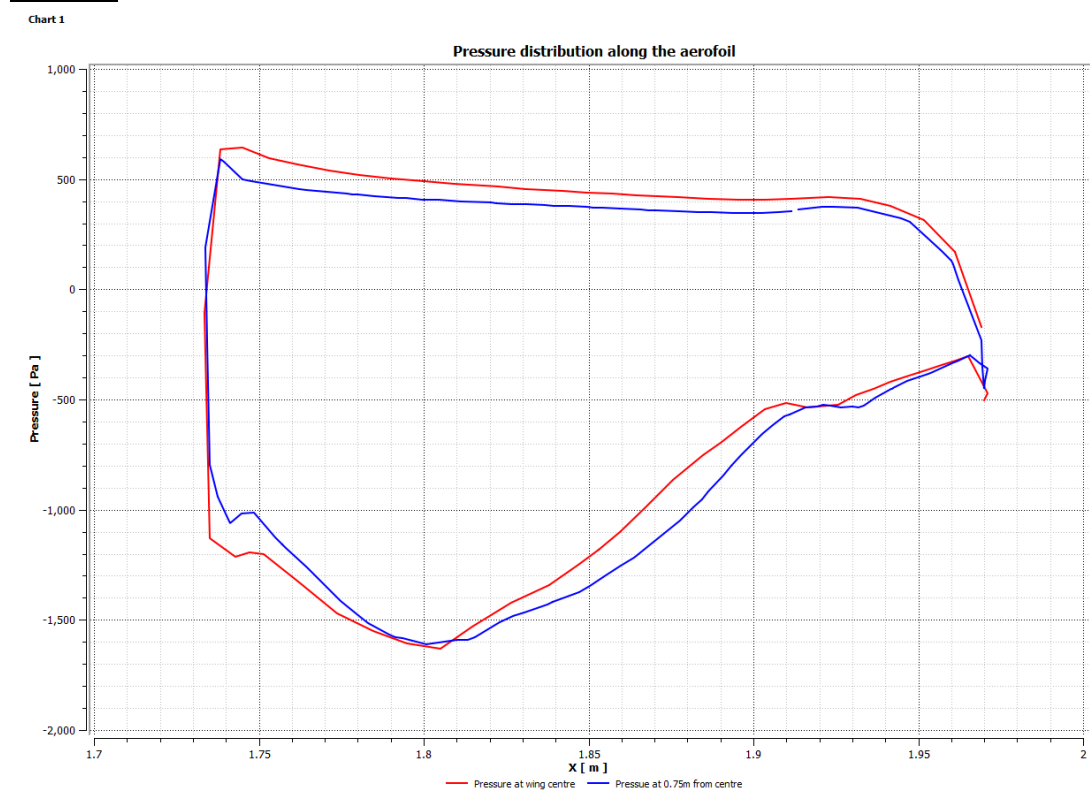


Figure 89 - pressure along the aerofoil for test scheme 1

Chart 1

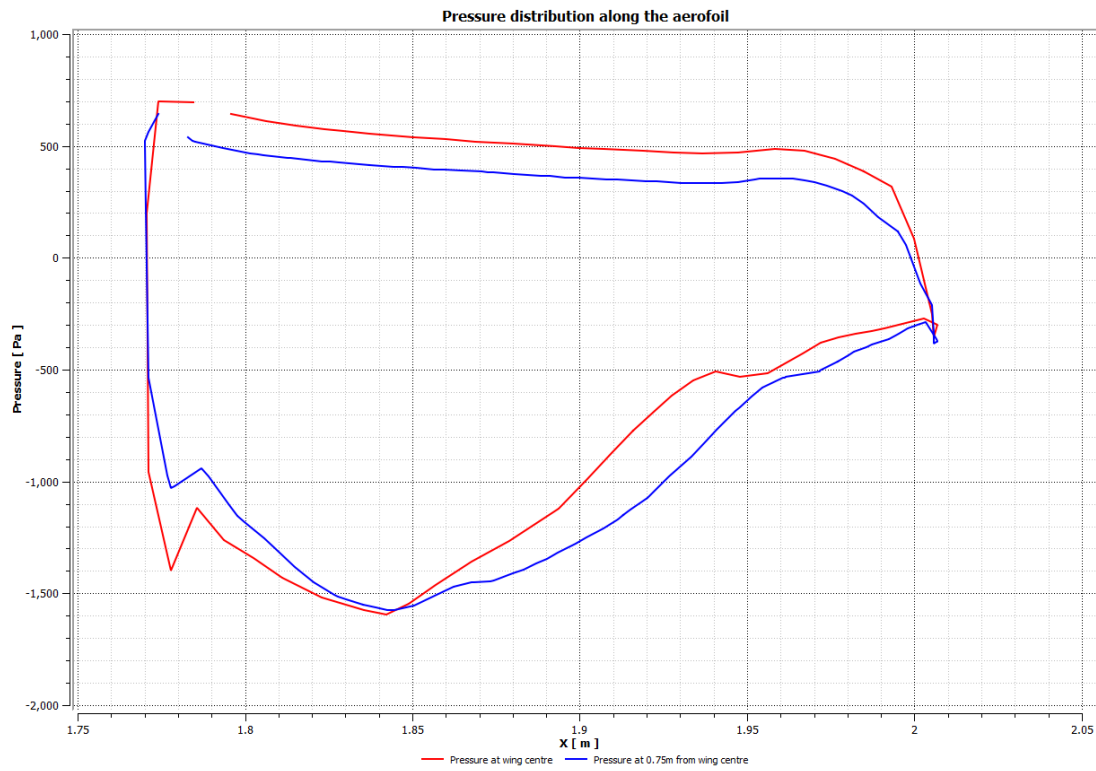


Figure 90 - pressure along the aerofoil for test scheme 2

WingCentrepressure

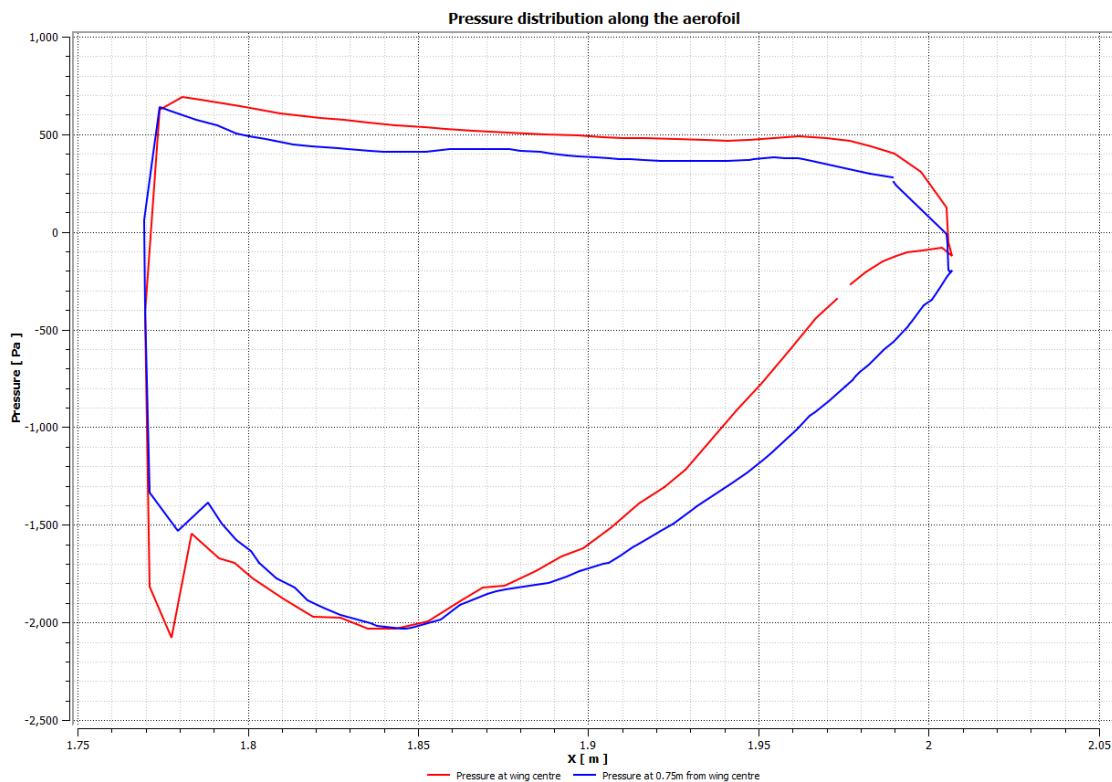


Figure 91 - pressure along the aerofoil for test scheme 3

From the figures above the pressures along the length of the aerofoil in pascals, taken at two points along the width of the aerofoil can be seen. The red traces in the plots above show the pressure in pascals at the centreline of the rear wing. The blue traces show the pressure along the length of the wing at 0.75m from the centreline of the aerofoil.

Taking into consideration the red traces from test schemes 1 and 2, it can be observed that test scheme 2 produced a higher localised pressure on the top of the aerofoil at the centreline compared to test scheme 1. The local pressure on the bottom surface is largely identical between the two schemes at the centreline, although test scheme 2 does have a larger spike in low pressure between 1.77 and 1.78m in the X axis, which is replicated in the graph for test scheme 3. This is due to a large low pressure zone on test schemes 2 and 3 which may have been caused by the action of moving the rear aerofoil upwards and rearwards on the endplate. Discounting this spike, the peak of low pressure between test schemes 1 and 2 are of a similar magnitude, although the location is roughly 0.05m further back on test scheme 2 compared to test scheme 1. Again, this makes sense because the aerofoil is positioned further back on test scheme 2 relative to test scheme 1 by roughly this amount. Because the Y coordinate is not being considered in these graphs, it could be expected that the locus of this pressure would be higher up in the Y axis compared to test scheme 1.

Comparing test scheme 2 to test scheme 3, the peak of high pressure at the centreline is about even between the two, with the distribution graph along the top surface sharing the same trends. Where the two differ is on the bottom surface of the aerofoil, where the trendline is largely the same shape, but the actual magnitude of the low pressure is much greater, giving a larger pressure difference between the two.

Considering the blue traces for test schemes 1 and 2, the location and peak pressures on the top surfaces between the two schemes is largely similar and follows the same trends, the only real difference being the location on the X axis, with test scheme 2 being set 0.05m further back. The other difference between the two is the difference between the pressure plots on the two plots. With test scheme 1, the two plots are close to each other and match for most of the shape, with the blue trace producing a lower pressure reading for the top surface. For the bottom surface at 0.75m from the centreline, the lower surface appears to produce a smaller low pressure zone than at the centreline up to 0.1m back from the leading edge of the wing, where the two traces intersect, and the centreline trace then produces higher pressure than the trace at 0.75m from the centreline.

Test case 3 follows largely the same trend as test schemes 1 and 2, although the overall shape of the graph is more rounded and the 0.75m from centreline trace follows the centreline trace more closely around the 1.85m mark on the X axis but diverges more than the other two test schemes as the study moves further back on the wing.

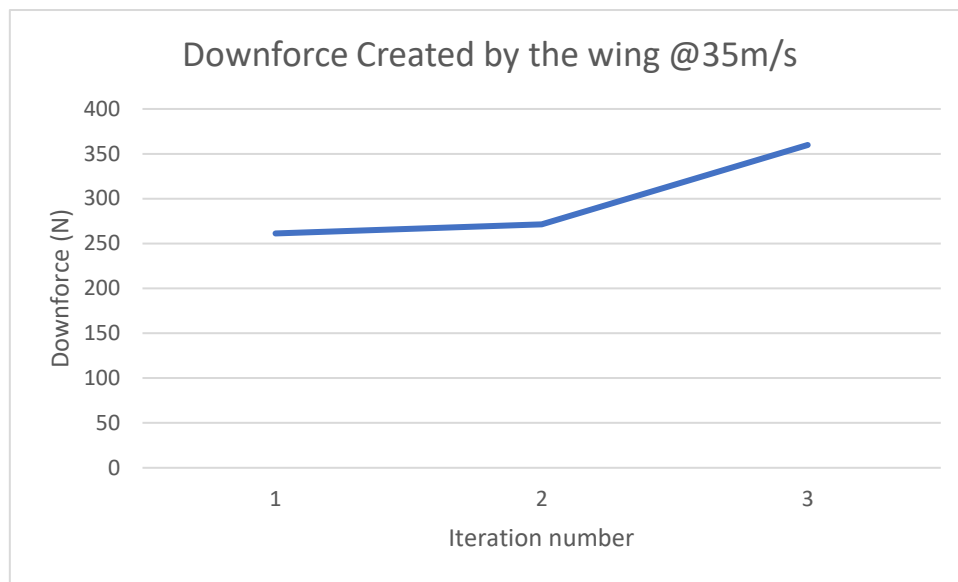


Figure 92 - a graph of the downforce created by each test scheme

From the graph above, the overall downforce produced by the aerofoils can be seen. This was calculated by taking the coefficient of lift data from the CFD calculations and first multiplying them by the frontal area of the rear wing assembly to produce a corrected value for CL that considers the frontal area of the rear wing assembly. This was then fed into the following equation to produce the Lift force produced by the rear wing assembly:

$$Lift = \frac{1}{2} * CL * air\ density * v^2$$

The term lift is used because downforce is simply a negative lift force. As the coefficient of lift produced by the CFD is negative, this then gives a negative value for the lift force which can be interpreted as downforce. To produce the graph above, the absolute values for the lift force were taken, so the sign doesn't matter.

Going off the plot above, the downforce increases with each different test scheme. The increase between test schemes 1 and 2 can be chalked down to moving the aerofoil upwards, giving a larger moment on the wing mount. The large increase between test schemes 2 and 3 is more difficult to explain. One explanation is that this is an anomalous result and could be mitigated by running another study on test scheme 3 specifically. Another explanation is that the shape of the slot, being a plain slot without anything blocking inward flow, is allowing air to flow from the outside of the endplate onto the top surface of the rear wing, creating a larger amount of high pressure on the top of the wing.

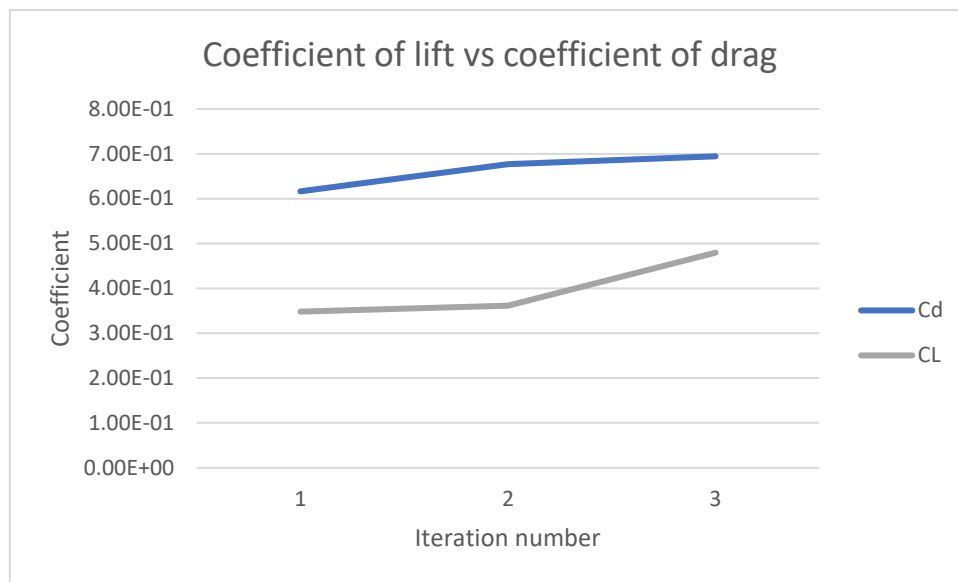


Figure 93 - A graph of coefficient of lift vs coefficient of drag for each test scheme

From the graph above, the Coefficient of lift and drag for each test scheme can be seen. The absolute values were taken for CL to give a positive value for CL. The CD in blue can be seen to increase proportionally with CL with the exception being for test scheme 3, where the CL appears to increase in a larger step than Cd.

Conclusion and further work

In conclusion, test scheme 3 appears to produce the largest gain in downforce, although the reasoning for this conclusion is based on potential errors within the testing methodology. The way to reduce the possibility that this result is anomalous would be to run the CFD testing again.

Moving forward, from here it would be beneficial to run CFD testing again to gather more data at the same speed and at higher speeds to calculate a more applicable value for the loading through the wing that the endplates will be experiencing. From this updated CFD with higher loadings, finite element analysis can be performed on potential production models of the endplates to decide how much deflection is acceptable on the endplate and decide on materials and production methods.

Overall Project Progress (MH)

Final Outcome

Initially, the group's final outcome was an entire, functioning bodywork package ready to be mounted onto the existing chassis and tested. As the project progressed, however, it became apparent that this was unrealistic due to the increased volume of work required. The initial bodywork package was expected to fit after minor adjustment, however, as discussed, a full redesign was required; this caused considerable delay to the group as the increased workload put the manufacturing phase on hold. Moreover, it was brought to the group's attention that the university's Computer Numerical Control (CNC) machine was missing a vital component and thus was unusable throughout the majority of the project. This encouraged the group to elongate the design development period, intentionally delaying the manufacturing phase and thus delaying the project. The group ensured ingenuity was used to make the best of these situations, a final outcome was still achieved and the project was still successful. The group learned more from these potential problems by dealing with them professionally and ensuring the project continued without delay as far as possible.

The final outcome developed, because of these delays, into what it is at the time of writing; the group aims to produce a buck for one front pontoon. By the end of the project, every stage of manufacturing up to producing the mould will have been completed for this component. The group aims to finish the project in a position where a mould can start to be made immediately, as all previous work has been completed. As mentioned previously, the buck has been produced and the revised final outcome has been achieved.

Future Plans

- Five members of the group have been accepted for an internship scheme during summer. This will allow any outstanding group project work to be completed. It is intended that the group use this time to complete the manufacturing phase of the project, resulting in a complete bodywork package produced, ready to race by August.
- It was decided by the group to prioritise getting to the stage where the manufacturing phase can begin immediately, therefore, the investigation into relocating the engine and oil cooling systems was not seen as a priority. Upon continuing this project into the summer, the group shall ensure this element of the car is thoroughly researched and a solution will be correctly implemented before manufacturing commences.

Overall Conclusion

This project allowed each group member to become more familiar with key types of engineering software such as Solidworks, as the components modelled tended to be quite complex and were expected to be accurate to within a small tolerance. Certain group members also had the opportunity through this project to learn the basics of the ANSYS CFD software. This helped to consolidate aerodynamic principles learnt in lectures and understand in more detail which direction the project was taking; specifically why the final bodywork package looked the way it did and how elements of the design influenced its aerodynamic properties.

This project also enabled the group to gain a deeper, more technical understanding of what is required from a composites-based structure. The materials and manufacturing research conducted and workshop sessions attended ensured every member of the group knew what was required from this area of this project; this knowledge can be transferred onto other composites-based projects in future care.

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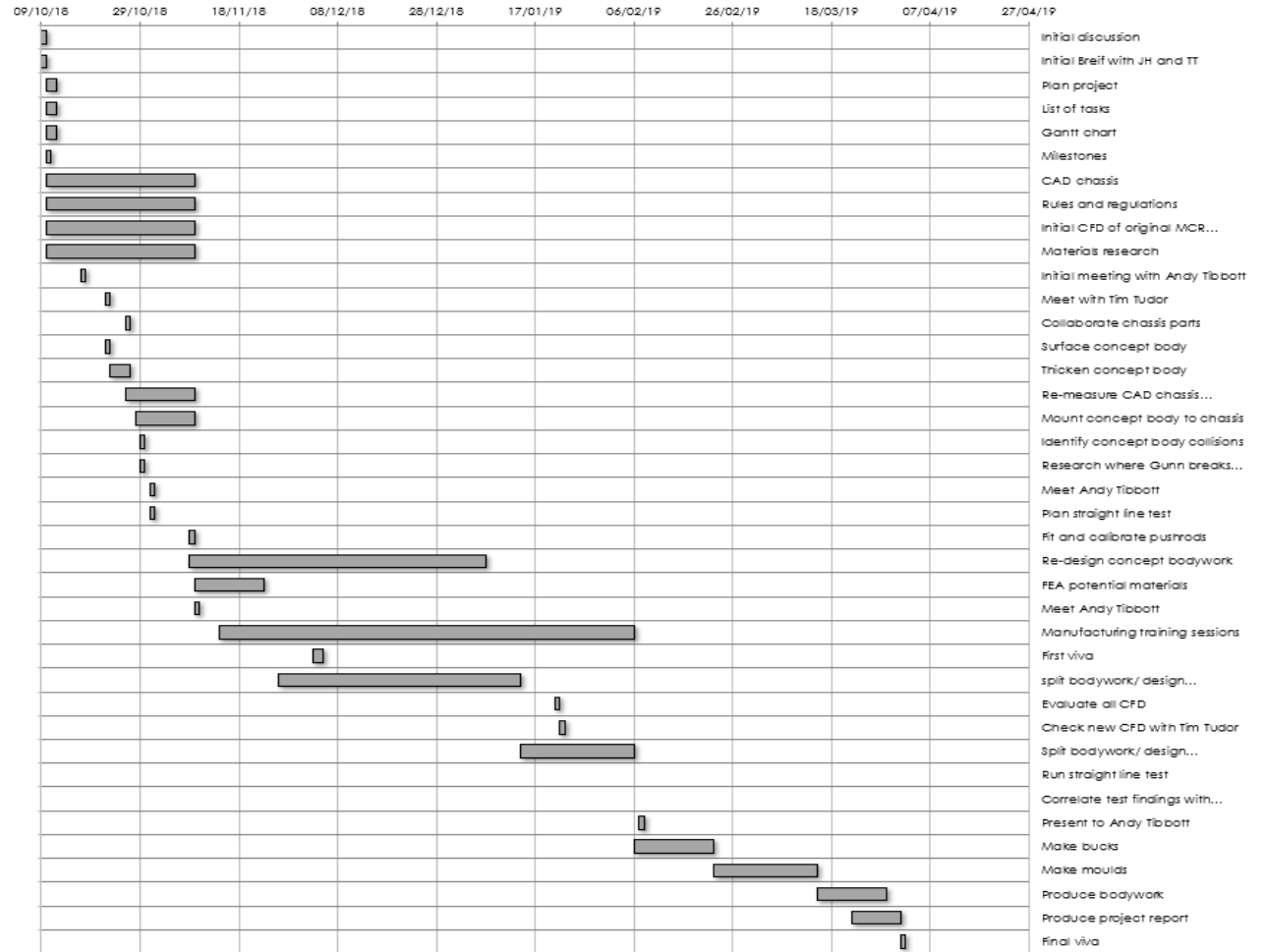
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Appendices

Appendix 1 - Overall Group Gantt Chart (MH, AM, RJ, GJ)

TASKS	RESPONSIBLE	START	END	DAYS
Initial discussion	All	08/10/18	10/10/18	2
Initial Brief with JH and TT	All	08/10/18	10/10/18	2
Plan project	All	10/10/18	12/10/18	2
List of tasks	NT, MH	10/10/18	12/10/18	2
Gantt chart	AH	10/10/18	12/10/18	2
Milestones	MH	10/10/18	12/10/18	1
CAD chassis	All	10/10/18	09/11/18	30
Rules and regulations	NT, EC, KT	10/10/18	09/11/18	30
Initial CFD of original MCR and concept body	AM	10/10/18	09/11/18	30
Materials research	MH, NT, SW, KT	10/10/18	09/11/18	30
Initial meeting with Andy Tibbott	All	17/10/18	17/10/18	1
Meet with Tim Tudor	All	22/10/18	22/10/18	1
Collaborate chassis parts	All	26/10/18	26/10/18	1
Surface concept body	RJ	22/10/18	22/10/18	1
Thicken concept body	GJ, MH, AM	23/10/18	27/10/18	4
Re-measure CAD chassis geometry	RJ	26/10/18	09/11/18	14
Mount concept body to chassis	GJ, RJ	28/10/18	09/11/18	12
Identify concept body collisions	GJ, RJ	29/10/18	29/10/18	1
Research where Gunn breaks rules	NT	29/10/18	29/10/18	1
Meet Andy Tibbott	All	31/10/18	31/10/18	1
Plan straight line test	RJ, EC	31/10/18	31/10/18	1
Fit and calibrate pushrods	RJ, MH, AM, NT	08/11/18	09/11/18	1
Re-design concept bodywork	GJ	08/11/18	07/01/19	60
FEA potential materials	EC	09/11/18	23/11/18	14
Meet Andy Tibbott	All	09/11/18	09/11/18	1
Manufacturing training sessions	All	14/11/18	06/02/19	84
First viva	All	03/12/18	05/12/18	2
split bodywork/ design fastening system	RJ, NT	26/11/18	14/01/19	49
Evaluate all CFD	AM	21/01/19	21/01/19	1
Check new CFD with Tim Tudor	AM	22/01/19	22/01/19	1
Split bodywork/ design fastening system	RJ, NT	14/01/19	06/02/19	23
Run straight line test	All	TBC	TBC	1
Correlate test findings with CFD of Iley splitter	AM	TBC	TBC	1
Present to Andy Tibbott	All	07/02/19	07/02/19	1
Make bucks	All	06/02/19	22/02/19	16
Make moulds	All	22/02/19	15/03/19	21
Produce bodywork	All	15/03/19	29/03/19	14
Produce project report	All	22/03/19	01/04/19	10
Final viva	All	01/04/19	01/04/19	1



UWTSD MCR AERO GROUP PROJECT

Wheel Louvres Project Specification

Task Leader: Kai Tang



www.mcrracecars.co.uk

Task Description

Currently the group have not looked into the design or adaptation of the louvres above the front wheels, or how they are mounted to the overall structure. Wheel louvres are used to increase overall downforce. An area of high pressure naturally exists above the wheels, and letting it flow out to the low pressure above the bodywork through the louvres helps to equalise the pressure, reducing the lift produced by the rotating wheels and thus effectively increasing downforce.

This is a key part of the overall aerodynamic package and detailed research and development could result in improvements in the performance gain achieved by the overall bodywork package produced.

Designing of the component - In-depth analysis of the design, dimensions and effects of the current component should be produced with a clear understanding displayed of how the current design is working well, as well as how it can be improved. Multiple new design ideas should be explored with benefits and drawbacks of each clearly documented, specifically regarding its aerodynamic benefits.

Materials - Data of aerodynamic loads experienced by this component is to be collected from the team aerodynamicist. From here calculations and simulations can be undertaken to establish the strength required and thus what materials can be used for manufacturing. Specific materials advice should be sought from technicians - specifically Andrew Tibbott regarding composites. A clearly laid out table of evaluation and comparison of potential materials should be produced, supported by correctly referenced and sufficiently detailed research and analysis.

Manufacturing - For each potential material choice, extensive research into the associated manufacturing process that is best both practically and financially should be explored, paying particular attention to the material chosen to produce the final outcome. Again - technicians can help with this and can be a valuable source of information. It could be researched how the production of this component relates to the overall production of the bodywork (if a composite material chosen - research bucks and moulds. Are they similar to those for the rest of the bodywork?)

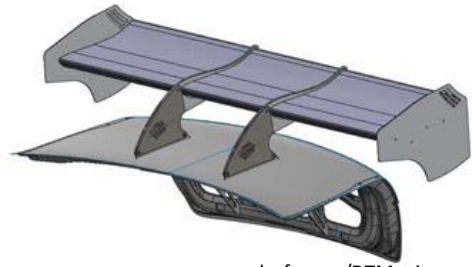
Cost and production time - As above, can this component be produced with the rest of the bodywork to save time? A detailed evaluation of costing should be produced much like it was for the overall bodywork by Simon Williams with correct, referenced figures for cost of materials (final and initially researched), and manufacturing costs.

It is expected that progress on these tasks will be relayed to the team at each meeting and much like for every member's tasks, these will be discussed and new objectives set for the following week. Remember this is still a *group* project task. Other members of the team can and should be contacted for ideas/support as much as necessary.

UWTSD MCR AERO GROUP PROJECT

Wing Endplates Project Specification

Task Leader: Ewan Carter



www.speedcafe.com/DTM-wings

Task Description

Currently the group have not looked into the design or adaptation of the endplates of the rear wing, or how they are mounted to the overall structure. End plates control vortices as the air moves around the end of the wing, thus limiting the drag found there known as induced drag. This leads to an increase in overall downforce produced.

This is a key part of the overall aerodynamic package and detailed research and development could result in improvements in the performance gain achieved by the overall bodywork package produced.

Designing of the component - In-depth analysis of the design, dimensions and effects of the current component should be produced with a clear understanding displayed of how the current design is working well, as well as how it can be improved. Multiple new design ideas should be explored with benefits and drawbacks of each clearly documented, specifically regarding its aerodynamic benefits.

Materials - Data of aerodynamic loads experienced by this component is to be collected from the team aerodynamicist. From here calculations and simulations can be undertaken to establish the strength required and thus what materials can be used for manufacturing. Specific materials advice should be sought from technicians - specifically Andrew Tibbott regarding composites. The above should be carried out for both the end plates themselves and the method in which they will be mounted to the wing. A clearly laid out table of evaluation and comparison of potential materials should be produced, supported by correctly referenced and sufficiently detailed research and analysis.

Manufacturing - For each potential material choice, extensive research into the associated manufacturing process that is best both practically and financially should be explored, paying particular attention to the material chosen to produce the final outcome. Again - technicians can help with this and can be a valuable source of information. It could be researched how the production of this component relates to the overall production of the bodywork (if a composite material chosen - research bucks and moulds. Are they similar to those for the rest of the bodywork?)

Cost and production time - As above, can this component be produced with the rest of the bodywork to save time? A detailed evaluation of costing should be produced much like it was for the overall bodywork by Simon Williams with correct, referenced figures for cost of materials (final and initially researched), and manufacturing costs.

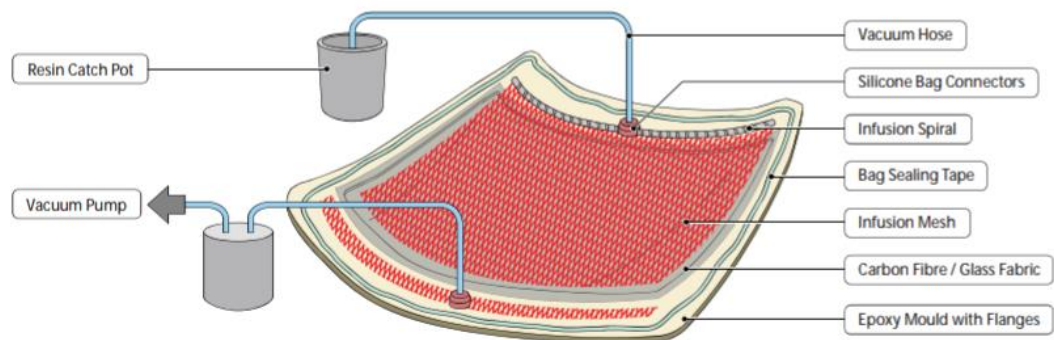
It is expected that progress on these tasks will be relayed to the team at each meeting and much like for every member's tasks, these will be discussed and new objectives set for the following week. Remember this is still a *group* project task. Other members of the team can and should be contacted for ideas/support as much as necessary.

Appendix 3 - Vacuum Resin Infusion Research (MH)

<u>Components Needed</u> (Carbonmods, 2010)	
<u>Vacuum bagging film:</u>	Used to form a bag to put component inside and seal up, forming the boundary of the vacuum.
<u>Bag connectors:</u>	These connect the bag to the vacuum hoses and the resin feed. These should be made from silicone as this makes removing resin overspill easier.
<u>Sealing tape:</u>	This tape has a putty-like texture creating a seal between bag & base.
<u>Vacuum pump:</u>	This will be connected to the system to remove all the air, creating a vacuum. This will be connected to a valve and vacuum hoses will take air from the bag to the pump.
<u>Resin catch pot:</u>	This is positioned between the component and the pump, preventing resin overspill being drawn back into the pump. This must be accessible and easy to empty.
<u>Vacuum gauge:</u>	A vacuum gauge is necessary to monitor level of vacuum within the system. Drops shown on the gauge help to identify leaks within the system.
<u>Tube clamp:</u>	This will be used to stop the flow of resin into the bagged component to allow for some lag in the system, retaining control of fill.
<u>Peel-ply:</u>	This is thin material and should line the component. It is easily removable and absorbs excess resin as well as texturing the finish of the component, increasing its ability to bond to other surfaces.
<u>Resin infusion spiral:</u>	Visually similar to cable spiral wrap. This tube allows resin to leave through the sides as well as the end, encouraging an even distribution of resin.
<u>Resin infusion mesh:</u>	This textured plastic mesh covers the component and helps the resin flow, encouraging an even distribution.
<u>Epoxy infusion resin:</u>	This process has to be carried out with low viscosity resin to ensure it does not boil when experiencing the vacuum. Epoxy infusion resin is most commonly recommended.

Diagram of Setup of Above Components:

Figure 94 - Resin Infusion Setup



(Carbonmods, 2010)

Background:

Resin infusion is a carbon fibre manufacturing process that produces strong, aesthetically pleasing parts. The use of a vacuum ensures an even spread and penetration of the resin, ensuring an optimum resin-to-reinforcement ratio, avoiding areas of excess resin or resin deficiencies, which would limit strength. This method also limits the amount of resin wasted, which is an important factor when working to a budget. The resin infusion process can take anywhere from an hour to multiple days depending on the size of the part. (Carbonmods, 2010; Easy Composites, 2015)

Table 19 - Resin Infusion Cure Times

(Carbonmods, 2010)

Temperature	20°C	40°C	60°C	80°C	100°C	120°C
Cure Time	24	11hrs	6hrs	4hrs	2hrs	1.5hrs

Moulds:

As stated previously, the best resin type for this process is epoxy resin. This means the optimal surface for the mould is also made from epoxy, either entirely or just as a surface layer. Alternative materials such as polyester are more likely to cause the resin to stick. (Carbonmods, 2010)

If another material must be used, a release agent can be applied generously to the component allowing easy removal from the mould. P.V.A is a good release agent but using this means time must be spent cleaning it off of the component, delaying the project. The mould should have mould flanges around the edges. These flanges are used to connect the spiral tubing, connectors and feed to the pump. (Richards, 2011)

Basic Steps of Vacuum Resin Infusion:

(Fibre Glast, 2017; Carbonmods, 2010)

Extra detail on the following steps and components can be found above

1. Prepare and create mould
2. Gather and prepare materials

3. Apply a layer of peel-ply
4. Apply a layer of infusion mesh
5. Position the resin feed spiral
6. Position and attach the resin feed connector
7. Position vacuum lines and vacuum pump connection
8. Apply vacuum bagging tape
9. Decide final position of bag, and correctly install and seal it
10. Connect and seal feed hose to resin supply
11. Connect and secure resin holding vessel
12. Connect resin catch pot
13. Connect vacuum pump
14. Clamp resin feed line to control flow until ready
15. Switch on vacuum pump
16. Read vacuum gauge and watch for any signs of leakages - fix as appropriate
17. Leave the system at full vacuum for a few minutes to insure vacuum can be held
18. Place correct amount of resin into the resin holding vessel
19. Unclamp resin feed line and allow resin to enter the system
20. Re-clamp resin feed line when around 2/3 of the part appears to be covered
21. The excess resin within the system at this point should be sufficient
22. Continue to monitor system, add more resin as necessary
23. Wait for resin infusion process to complete
24. Remove vacuum bag setup from component (quick sharp tugs effective to remove tape)
25. Remove all connectors from flanges
26. Remove infusion mesh and peel ply (some force may be required)
27. Carefully remove part from the mould
28. Clean, trim and finish the part

Appendix 4 - CFD Instructions for Ahmed Body (MH, AM)

Computational Fluid Dynamics (CFD) Basic Running Procedure

Steps based on Ahmed Body, but are transferable to other geometries.

These steps do not claim to fully explain CFD - this document has been produced to allow the reader to run an iteration on a given geometry quickly and correctly. For more information see ANSYS help pages or university tutorials.

Max Hart Ainsley Martin

Loading in and setting up Geometry

Component Systems - drop down menu (top left)

Drag 'geometry' box onto screen

Right click question mark

New DesignModeler Geometry (there may be a small wait)

File

Import External Geometry File

Select appropriate .x_l file

Generate ⚡

The model geometry should now appear in the 'Model View' Window

Sketch 

Ensure 'Sketching' is selected at the bottom of 'Sketching Toolboxes' window

Select rectangle tool and sketch around the body and feet. Don't intersect the line below geometry, draw slightly above dashed line

Click dimensions in 'Sketching Toolboxes'. Horizontal - click and define the full width and distance from back of geometry to back of box

Vertical - full height of box and distance from bottom axis line to bottom box line

Extrude

Define 'FD1, Depth' measurement, ensuring the sketch is selected in 'Geometry'

If the shape is symmetrical, 'Direction' can be left as 'Normal'

Alter the dimensions to roughly what is seen below. This is the *domain*

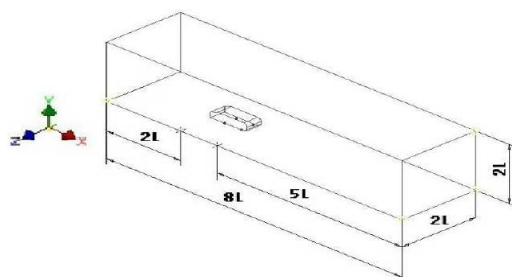


Figure 1 - domain dimensions

(Simanungkalit, 2016)

Generate 

Create drop down (Top left)

Boolean

Operation = subtract

Expand '2 parts, 2 bodies' in parts tree and use this to select the following:

Target Bodies= domain (shape being used)

Tool Bodies= Geometry (Top solid from '2 parts, 2 bodies')

Generate 

Click 'select faces' 

Right click, named selection

Name each of the faces of the domain as follows. Once a face is named, press F8 to hide it so it isn't selected twice. Click Generate after naming each face

Front = 'Velocity_Inlet'

Back = 'Pressure_Outlet'

Side by axis = 'Symmetry' ('Symmetry_Right if analysing full car)

Other side = 'Symmetry_Left'

Top = 'Symmetry_Top'

Bottom = 'Road'

Right click - show all faces

Tools - Freeze - Close (X in top right)

This is a good point to save the file

Integrated Computer-aided Engineering and Manufacturing CFD

(ICEM CFD) (ANSYS, 2017)

Component Systems.

Drag ICEM CFD to white geometry box previously defined (which should have a green tick) so red guidelines appear and a chain is formed.

Double click white model.

Expand 'parts'

Deselect all apart from 'Solid_1_1'

Expand geometry and check surfaces, uncheck curves

Click shaded cylinder icon at the top (Solids Simple Display)

Select repair geometry 

Set tolerance to 0.0002

Apply

Right click on parts

Create part

Name the part 'feet'

Click shining arrow (Select Entities) and click and drag to select the feet

Follow on-screen instructions for selection, middle mouse to confirm - press F9 to move body freely then F9 again to return to selection controls

Click dismiss

Repeat for 'car'

Click dismiss

Check Curves in 'Geometry'

Show curves and look at the domain isometrically (at an angle).

Go to geometry tab. Click 'create body' 

Rename to 'BODY' select special mouse button and select alternative corners e.g. top right of velocity_Inlet and bottom left of Pressure_Outlet assuming looking at the front of the car. Middle mouse to apply and dismiss.

Click mesh tab

Click Global Mesh Setup 

Scale Factor 1 - can set to 0.5 for twice as many elements but takes much longer.

Max element 1

Global Mesh Setup (currently on) - move to red logo (shell meshing parameters)

Mesh type = all tri

Mesh method = patch independent

Apply

Move to blue logo (volume meshing parameters)

Mesh type = Tetra/Mixed

Mesh Method = Robust (Octree)

Edge Criterion = 0.06 (use very small, ≈ 0.01 , for very thin geometry. Use higher, ≈ 0.2 , for thicker geometry)

Apply

Move to orange logo (prism meshing parameters)

Number of layers = 5

Move to next icon on the geometry tab (part mesh setup) 

Tick Prism for Car, Feet, Road and set all to Number of layers = 5

It is good practice to press enter after imputing each number to confirm its entry

Set size of mesh: Car = 0.01 Feet = 0.005

Apply and Dismiss

Click 'Create mesh density' 

Set size to 0.1

Select Density location from 'entity bounds'

Click arrow on box symbol (Select Geometry) and click and drag over the car, not the body.

Middle mouse and Dismiss

Click on geometry tab, click 'transform geometry' 

Select density box using  and clicking top left node to select entire box

Select 'scale geometry' 

Set scales to roughly same size as domain (figure 5) - rough scale factors $X = 1.8$, $Y = 1.6$, $Z = 1.6$. *Don't click enter until all values inputted.*

Set centre point to 'centroid'

Use 'translate geometry'  to ensure correct positioning

Select Mesh tab and click 'compute mesh' 

Mesh type and method will already be set

Click compute

Go to edit mesh tab and click 'display mesh quality' 

Criterion = skew

Apply

If Skew is large (bars don't increase in equal parts) - element size can be reduced to increase accuracy of results - speak to more experienced user if this does not solve issue.

Criterion = TGrid Skew

Apply

If skew is too large again here, global mesh size can be reduced to increase accuracy of results - speak to more experienced user if this does not solve issue.

Settings

General

Set processes to zero

Go back to mesh tab, 'compute mesh' 

Select 'prism mesh' 

Compute

Edit mesh tab

Select 'repair mesh' 

Click apply to repair any imperfections in mesh

ICEM CFD is now able to be closed and return to the Workbench program

Setting Physical Modelling Capabilities - Fluent CFD

Launch Fluent - drag from component systems to white 'model' box

Double click setup

Turn off Workbench Colour Scheme

Set processor to parallel

Set Processes to 4

Click OK to continue

From tree, expand models

Double click Viscous Laminar

K-Epsilon - select non-equilibrium wall functions

Click OK to continue

In Boundary Conditions

Check that for body and feet type = wall, and all symmetry sides type = symmetry

Double click Pressure_Outlet and check gauge pressure is 0

Double click velocity inlet, check that velocity specification method = magnitude & direction

Set velocity to desired value (35 m/s is good if unsure)

Set turbulent intensity to 1%

Click OK to continue

Reports

Projected Areas

Select Car and Feet

Set minimum feature size to 0.001m

Click compute to generate frontal area - *copy this value from the 'Area' box*

Reference Values

Compute from Velocity_Inlet

Paste in frontal area value

Methods (Solution Methods in Workbench 16)

Scheme = coupled

Pressure = standard

Momentum = First Order Upwind

Controls (Solution Controls in Workbench 16)

Flow Courant Number = 50

Momentum & Pressure = 0.25

Turbulent Kinetic Energy & Turbulent Dissipation Rate = 0.5

Turbulent Velocity = 0.8

Click limits

+ 4 zeros to Maximum Turbulent Viscosity Ratio

Click OK to continue

Report Definitions - (Monitors in Workbench 16)

New

Force Report - Drag

Name 'cd'

Select Body and Feet

Tick 'report file', 'report plot' and 'print to console'

Repeat this but for 'cl' (lift)

Initialisation (Solution Initialization in Workbench 16)

Click Initialise

If result says 'convergence tolerance not reached' this will hinder accuracy. Re-mesh may be required - speak to more experienced user if this does not solve issue.

Click Run Calculation (Sirius CFD, 2012)

Set number of iterations to 100

Click Calculate to continue

After 100 iterations change the following and run for another 100 iteration

Momentum = Second Order Upwind

Kinetic x2 = Second Order Upwind

Controls

Turbulent Kinetic Energy & Turbulent Dissipation Rate = 0.9

Turbulent Velocity = 0.95

Then run until converged

Appendix 5 - Original Splitter vs John Iley Splitter CFD

	cl	cd	Lift Force (N)	Drag Force (N)	Efficiency
Original	-0.343	0.428	-338	421	0.80
John Iley Splitter	-1.032	0.451	-1017	455	2.29

Appendix 6a - Table of Results

	cl	cd	Lift Force (N)	Drag Force (N)	Efficiency
JHTT02	-1.893	0.561	-1893	561	3.37
Iteration 1	-1.829	0.635	-1859.67	645.72	2.88
Iteration 2	-1.656	0.544	-1694.78	556.25	3.05

Appendix 6b - CFD Settings Used

Repair Geometry Tolerance	Global Mesh Max Element Size	Mesh Type	Mesh Method	Mesh Type	Mesh Method	Edge Criterion	Prism Layers	Density Boxes
0.00008	1.8	All Tri	Patch Independant	Tetra/Mixed	Robust (Octree)	0.2	4	1 at 0.1 and 1 at 0.5

Appendix 7 - Meeting Minutes (In Chronological Order)

The following are minutes from the main meetings of the project. Minutes from meetings that lasted less than 10 minutes or were a general chat/catch-up have been omitted. These are available to view upon request.

All minutes taken by Team Leader (MH)

MCR Aero Group Project

Minutes from Meeting · 30/10/18 · 0900-1200

Present:

Ainsley Martin
Ewan Carter
George Jones
Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams

Apologies:

Absent:

Kai Tang

Completed Since Last Meeting:

Furthered research on materials and started to create a test plan. Each member was asked to create a list of group tasks to compare in the meeting to make one master task list which shall be used as an overall project plan. A Precedence table template was drafted to fill out during the meeting.

Issues Arising:

- Compared individual group task lists.
- Discussed addition and removal of tasks.
- Discussed order of tasks.
- Precedence table was displayed & edited.
- Important events for critical path found.
- Individual Tasks identified.
- Tasks allocated to each member evenly.
- Car theoretically split to front, mid & rear.
- Three groups formed to oversee sections.
- Viva 1 discussed - agreed what team's goals were for this date and how to achieve them.

Conclusions Drawn:

Each member within the team now understands better what will be expected of them. This helps to efficiently further the project and helps each individual work on Mark Sandford's project which heavily relates to personal tasks within the group project.

The team understand what is expected of them for Viva 1 and how to be ready for it.

Targets for Following Meeting:

Each team member must carry on with their allocated tasks, at this stage this is generally research.

Carry on with completion of CAD model and CFD simulations.

Plan timetable of meetings and booking of meeting rooms for group project week next week and aim to have every group member in attendance.

Date of Next Meeting: 05/11/2017

MCR Aero Group Project

Minutes from Meeting · 05-11-2018 · 0900-1200

Present:

Ainsley Martin Maximilian Hart
Ewan Carter Nicholas Thomas
George Jones Ryan James
Kai Tang Simon Williams

Apologies:

Absent:

Completed Since Last Meeting:

Each member completed individual research on subject areas. Testing Plan completed, plans to finish CAD rolling chassis this afternoon (05-11-2018). Meeting rooms booked for entire week. Critical path analysis completed for overall project

Issues Arising:

- Discussed viva 1 further and targets for it.
- Discussion of 'dear Charlie' letters.
- Discussion of CFD tasks left to complete.
- Discussion of exactly what can be achieved (how much bodywork can be produced)
- Rolling Chassis group
- Team dispersed to carry out individual tasks (most of the time used doing this)
- Re-grouped to discuss what had been achieved
- Final building of rolling chassis

Conclusions Drawn:

The rolling chassis is now finalised, with research on materials and regulations furthered. Clearer targets set for overall project and Viva 1. 'Dear Charlie' letters now underway.

Targets for Following Meeting:

- Finalise rolling Chassis completely
- 5 Materials to FEA
- Start 'Dear Charlie' letters
- Start fitting bodywork to chassis.

Date of Next Meeting: 05-11-18

MCR Aero Group Project

Minutes from Meeting · 05-11-18 · 1300-1400 W/ T.Tudor

Present:

Ainsley Martin Maximilian Hart
Ewan Carter Nicholas Thomas
George Jones Ryan James
Kai Tang Simon Williams

Apologies:

Absent:

Completed Since Last Meeting:

Nothing - meeting followed immediately on

Issues Arising:

- Progress report
- Explanation of tasks completed to Tim
- Recap on CAD Chassis development
- Identification of problems/errors so far
- Talk of manufacturing processes - idea suggested to research low budget, alternative manufacturing techniques in case any issues arise with current plans.
- Suggestion to use one low budget method to make on pontoon to see how effective it would be.
- Discussion of pushrod calibration.

Conclusions Drawn:

The team are to organise better the roles of materials/manufacturing research as currently exactly what needs to be done by each person is slightly unclear.

Carry on research of alternative manufacturing methods

Targets for Following Meeting:

- Have pushrods calibrated ready for installation.
- Completed research of alternative manufacturing processes.
- Have CAD Rolling Chassis completed.
- Start to mount body onto completed chassis model.

Date of Next Meeting: 07/11/18

MCR Aero Group Project

Minutes from Meeting · 07-11-18 · 1000-1300

Present:

Ainsley Martin Maximilian Hart
Ewan Carter Nicholas Thomas
George Jones Ryan James
Kai Tang Simon Williams

Apologies:

Absent:

Completed Since Last Meeting:

- Progress made on rolling chassis CAD model.

Issues Arising:

- Split and organised materials research.
- Discussed dates for each task in project.
- Mounting of body discussed and potential issues mentioned.
- Strict target of 5 materials to be made for Friday to present to Andy Tibbott

Conclusions Drawn:

Materials and manufacturing research now clarified and separated between group members, so this can now be completed for next week.

Plans confirmed to meet Andy Tibbott with 5 materials for manufacturing.

Targets for Following Meeting:

- Have 5 materials to present - CRITICAL
- Progress made on materials research

Date of Next Meeting: 09/11/18 w/ Andy Tibbot

MCR Aero Group Project

Minutes from Meeting · 09-11-18 · 1430-1530

Present:

Ainsley Martin
Ewan Carter
George Jones
Kai Tang
Maximilian Hart
Nicholas Thomas

Ryan James
Simon Williams
Tim Tudor
Andy Tibbot
David Cooper

Apologies:

Absent:

Completed Since Last Meeting:

- Materials research progression - 5 materials found
- CAD rolling chassis completed

Issues Arising:

General catch-up and progress report with group, Tim Tudor and technicians. Materials research presented and confirmed by Andy Tibbot and discussion of how to progress. Practice session scheduled for 14-11-18.

Conclusions Drawn:

Materials research thus far correct and in right direction, carry on with what we have so far and make more technical and detailed.

Targets for Following Meeting:

- Source and bring in foam for practice session
- Carry on materials research
- Reduce list of 5 materials down to one or two

Date of Next Meeting: 12-11-18

MCR Aero Group Project
Minutes from Meeting · 12-11-18 · 1400

Present:

Ainsley Martin	Maximilian Hart
George Jones	Nicholas Thomas
Simon Williams	Ryan James
	Tim Tudor

Apologies:

Absent:

Kai Tang
Ewan Carter

Completed Since Last Meeting:

- 5 possible materials sourced and presented to Andy Tibbott
- Materials research progressed

Issues Arising:

- Check-up of progress
- Discussion with Tim about Andy Tibbot meeting booked to practice working on foam

Conclusions Drawn:

- Group on course, carry on with current work.

Targets for Following Meeting:

- Present better understanding of foam to be used for bucks after workshop session with Andy Tibbot and decide where to go from there.

Date of Next Meeting: 13-11-18

MCR Aero Group Project
Minutes from Meeting · 13-11-18 · 1100

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Simon Williams Ryan James

Apologies:

Absent:

Kai Tang
Ewan Carter

Completed Since Last Meeting:

- Task list compiled for making of altered bodywork CAD for roles to be assigned

Issues Arising:

- Discussion of progress so far
- CFD overview and progress report from A Martin
- Tasks for bodywork CAD model assigned to group members

Conclusions Drawn:

- The team members must work towards finishing their designated CAD tasks to have the bodywork completed by the following week.

Targets for Following Meeting:

- To have made headway with the CAD model by completing individual tasks

Date of Next Meeting: 14-11-18 w/Andy Tibbot

MCR Aero Group Project

Minutes from Meeting · 14-11-18 · 0900-1100

Workshop Foam Shaping Practice Session

Present:

Ainsley Martin Maximilian Hart
Ewan Carter Nicholas Thomas
George Jones Ryan James
Kai Tang Simon Williams

Apologies:

Absent:

Completed Since Last Meeting:

- General group project tasks carried on with and progress made, no specific tasks to report.

Issues Arising:

- Meet and have initial discussion with Andy Tibbot
- Health & Safety and task briefs
- Gathered 4 different types of foam
- Shaped foam into buck-like shapes using sanding blocks
- Sealed foam with primer filler for ease of sanding back further, to create smooth finish
- Discovered only one type of foam works, this shall be the one we go for
- Completed 3 coats of primer - to be completed next week

Conclusions Drawn:

The orange builders foam that Ryan James provided was the only one to not to be dissolved by the primer filler and thus this is the one that shall be used to create the bucks for the manufacturing process.

Targets for Following Meeting:

- Research and budget the foam that was decided to be used, implement this into materials research and look at purchasing more.

Date of Next Meeting: 19-11-18

MCR Aero Group Project

Minutes from Meeting · 19-11-18 · 1400-1500

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Kai Tang Ryan James
Simon Williams Tim Tudor

Apologies:

Absent:

Ewan Carter

Completed Since Last Meeting:

- CAD tasks to aid completion of bodywork redesign
- Manufacturing processes research & flowcharts
- Work on management assignment

Issues Arising:

- Update and catch up
- Talk of research on manufacturing processes
- Further flow charts of processes?
- Talk about what's expected for viva
- Discussion of budget
- Talk of securing budget through sponsorship etc

Conclusions Drawn:

- Good work so far, progress slightly slowed due to management assignment but still strong progress. The team know what needs to be done and how to go about it.

Targets for Following Meeting:

- Carry on with flowcharts for manufacturing processes
- Work to secure sponsorship for budget
- Work towards viva 1
- Carry on with CAD tasks to aid bodywork design

Date of Next Meeting: 26-11-18

MCR Aero Group Project

Minutes from Meeting · 26-11-18 · 1400-1500

Present:

Ainsley Martin
George Jones
Ewan Carter
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams
Tim Tudor

Apologies:

Absent:

Completed Since Last Meeting:

- Completion of planning - Management assignment

Issues Arising:

- Sing George happy birthday
- Planning of Viva - discuss timeslot
- Discuss components of viva

Conclusions Drawn:

Good work so far - focus now on viva planning mainly. Carry on with previous CAD work to enable bodywork to be created, good progress made thus far.

Targets for Following Meeting:

- Meet to plan and draft viva
- Prepare for further materials testing
- Make further progress with CAD parts for bodywork.

Date of Next Meeting: 27/11/18

MCR Aero Group Project

Minutes from Meeting · 27-11-18 · 1000-1200

Present:

Ainsley Martin
George Jones
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams

Apologies:

Absent:

Ewan Carter

Completed Since Last Meeting:

- Initial draft of Viva presentation made

Issues Arising:

- Full viva plan created with individual tasks assigned to each
- Interdependence of topics discussed
- Formatting of PowerPoint discussed
- Discussion of recent tasks completed

Conclusions Drawn:

Viva initial plans now set out, team has worked well to achieve this. Each member knows what is expected of them for the viva and to prepare sufficiently.

Targets for Following Meeting:

- Plan and format slides for viva and carry out any further research required
- Carry on with assigned CAD tasks for completion of bodywork.

Date of Next Meeting: 30/11/2018

MCR Aero Group Project

Minutes from Meeting · 30-11-2018 · 1200-1300

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Ewan Carter Ryan James
Kai Tang Simon Williams

Apologies:

Absent:

Completed Since Last Meeting:

- More planning of Viva

Issues Arising:

- Chosen design for PowerPoint and more work carried out on compiling completed slides. No evidence of FEA so far - this needs to be addressed.
- Finished compilation of all the slides and practice/rehearsals have begun.

Conclusions Drawn:

Viva presentation going well - now only FEA and some outstanding materials slides needed. Practice runs of the presentation need work - more rehearsals needed.

Targets for Following Meeting:

- Carry on with practice run-throughs of viva presentation

Date of Next Meeting: 03-12-2018

MCR Aero Group Project

Minutes from Meeting · 03-12-2018 · 1300-1800

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Kai Tang Ryan James
Tim Tudor Simon Williams

Apologies:

Absent:

Ewan Carter

Completed Since Last Meeting:

- Final slides submitted and compiled

Issues Arising:

- 1300-1400 - Run through with Tim Tudor to check presentation progress and ask for advice.
- 1400-1800 - Practice runs of presentation with critical peer marking to improve our performance.

Conclusions Drawn:

Good multiple runs through of presentation, with clear improvements. Having to allow time for FEA slides the group is under the time limit and the presenting flows well.

Targets for Following Meeting:

- More practice!!

Date of Next Meeting: 04-12-2018

MCR Aero Group Project

Minutes from Meeting · 04-12-2018 · 0900-1600

Present:

Ainsley Martin
George Jones
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams

Apologies:

Absent:

Ewan Carter

Completed Since Last Meeting:

- N/A

Issues Arising:

- Practice of viva!

Conclusions Drawn:

Hard to have a good idea on overall timescale as EC did not attend again, but overall good.

Targets for Following Meeting:

- Ensure all work is carried on after viva

Date of Next Meeting: 13-12-2018

MCR Aero Group Project

Minutes from Meeting · 13-12-2018 · 1300-1500

Present:

Ainsley Martin

George Jones

Kai Tang

Simon Williams

Maximilian Hart

Nicholas Thomas

Ryan James

Apologies:

Absent:

Ewan Carter

Completed Since Last Meeting:

- Debrief after viva and marks received

Issues Arising:

- Discussion of tasks to complete over Christmas, ensuring they are clearly set out and everyone is aware of what is expected of the group.
- Specific discussion on “dear Charlie” letters and how they should be written, and discussion of what is expected for FEA research.

Conclusions Drawn:

The group know exactly what to do over Christmas and can now work to manage time carefully and efficiently around Powertrain assignment and exam revision to ensure all work is completed.

Targets for Following Meeting:

- Discuss what was completed over Christmas

Date of Next Meeting: 08-01-2019

MCR Aero Group Project

Minutes from Meeting · 08-01-2019 · 0900-1200

Present:

Ainsley Martin
George Jones
Maximilian Hart
Nicholas Thomas
Ryan James

Apologies:

Simon Williams

Absent:

Ewan Carter
Kai Tang

Completed Since Last Meeting:

- As found in this meeting, 6/8 people completed the Christmas tasks.

Issues Arising:

- Discussion of tasks completed over Christmas and what progress was made.
- Discussion on what work was not completed.

Conclusions Drawn:

Work will be slow for a while whilst Powertrain assignment and exam revision takes priority. Outstanding Christmas tasks must still be completed.

Targets for Following Meeting:

- Carry on with as much work as possible around revision and assignment.

Date of Next Meeting: 22-01-2019

MCR Aero Group Project

Minutes from Meeting · 22-01-19 · 1400-1500

Present:

Ainsley Martin
George Jones
Ewan Carter
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams
Tim Tudor

Apologies:

Absent:

Completed Since Last Meeting:

- Work on completing all required CAD work for the first full CFD run

Issues Arising:

- Division of labour and ensuring each team member has a clear set of tasks.
- Ewan and Kai given individual briefs and told to focus on wing end plates and louvres respectively.

Conclusions Drawn:

Team knows exactly what to do individually and how to progress to create the CFD model.

Targets for Following Meeting:

- Have CFD model completed ready for aerodynamic analysis

Date of Next Meeting: 11-02-19

MCR Aero Group Project

Minutes from Meeting · 11/02/2019 · 15:00

Present:

Ainsley Martin
George Jones
Ewan Carter
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams
Tim Tudor

Apologies:

Ryan James

Absent:

Completed Since Last Meeting:

- More CAD iterations run on CFD. Tim Tudor has analysed new iteration ready for Ainsley Martin to compare results. Provisionally results are looking as good as, if not better than original geometry.

Issues Arising:

- Run through of Tim Tudor's CFD results and discussed changes to model, potential adaptations and future CFD runs.
- Discussion of Ewan Carter's progress with wing end plates - nothing to report.
- Discussion of Kai Tang's progress with louvres - nothing to report.

Conclusions Drawn:

Very pleasing results with CFD analysis so far, CL and CD and efficiency values are pleasing - however room for improvement.

Targets for Following Meeting:

- George to make more CAD iterations, Ainsley Martin to Run CFD, Max to complete CFD notes. Splitting and manufacturing research to be carried out and end plates and louvres to be investigated further.

Date of Next Meeting: 08-02-19

MCR Aero Group Project
Minutes from Meeting · 8-02-2019 · 10:00

Present:

Ainsley Martin	Maximilian Hart
George Jones	Nicholas Thomas
Ewan Carter	Ryan James
Kai Tang	Simon Williams
	Tim Tudor

Apologies:

Absent:

Completed Since Last Meeting:

- New CAD iterations to test on CFD

Issues Arising:

- This meeting was mainly for the purpose of getting the group up to speed on CFD advances. The CAD model was discussed, as well as how this was put into CFD and the results found. Discussion of future CFD runs and what to change.

Conclusions Drawn:

Good work thus far, more work to be carried out on the CAD model to input into CFD reflecting Tim Tudor's comments

Targets for Following Meeting:

- Team to carry on individual tasks to ensure CAD model is advanced to sufficiently run further CFD tests.

Date of Next Meeting: 14-02-2019

MCR Aero Group Project
Minutes from Meeting · 14-2-19 · 13:00

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Simon Williams Ryan James

Apologies:

Absent:

Ewan Carter
Kai Tang

Completed Since Last Meeting:

- More progress on CAD and looking to lock down design ready for manufacturing.

Issues Arising:

- Speak to Dave Cooper about CNC and CAM manufacturing.
- Discussion of splitting the body and what will be produced.

Conclusions Drawn:

The group now know where to split the body on the front. It was decided that the group will try to make the entire front section as one - not just pontoons. This will add strength and rigidity.

Targets for Following Meeting:

- Finalise splitting and lock down CAD design

Date of Next Meeting: 18-02-19

MCR Aero Group Project

Minutes from Meeting · 18-02-19 · 14:00

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Ewan Carter Ryan James
Tim Tudor Simon Williams

Apologies:

Absent:

Kai Tang

Completed Since Last Meeting:

- Completion of Dear Charlie letters and formatting of CFD notes.
- Individual projects - progress made
- CFD runs analysed for high and low nose iterations

Issues Arising:

- Dear Charlie letters checked again by Tim
- CFD results analysed and low nose chosen. Front end is now locked.
- Discussion of manufacturing processes into the future

Conclusions Drawn:

Front end of bodywork now chosen and CFD results analysed. Dear Charlie's now ready to be finalised and sent and CFD notes can be finalised also

Targets for Following Meeting:

- CFD final designs, have letters and CFD notes finished and send letters off. Start on splitting and ordering materials and manufacturing now.

Date of Next Meeting: 25-02-19

MCR Aero Group Project

Minutes from Meeting · 25-02-19 · 14:00

Present:

Ainsley Martin
George Jones
Ewan Carter
Kai Tang

Maximilian Hart
Nicholas Thomas
Ryan James
Simon Williams
Tim Tudor

Apologies:

Absent:

Completed Since Last Meeting:

- Bodywork now entirely locked down front, mid and rear
- CFD notes carried on
- Meeting with Andy Tibbot regarding materials
- Splitting and framework furthered.
- Dear Charlie letters now completed

Issues Arising:

- Talk of completing CFD notes
- Talk of completing CAD for push rod shrouds and any outstanding elements
- Planning of giving A Tibbot and D Cooper manufacturing info and ideas

Conclusions Drawn:

Bodywork now confidently locked down - team must now seriously focus on moving onto the manufacturing phase.

Targets for Following Meeting:

- Have CFD notes completed
- Complete any outstanding CAD
- More work on individual projects - wing and louvres
- Send off Dear Charlie Letters

Date of Next Meeting: 4-03-19

MCR Aero Group Project

Minutes from Meeting · 04-03-2019 · 11:00

Present:

Maximilian Hart
Ainsley Martin Nicholas Thomas
George Jones Ryan James
Ewan Carter Simon Williams

Apologies:

Absent:

Kai Tang

Completed Since Last Meeting:

- Research into splitting and manufacturing - full cost report of materials needed finalised.
- More CFD runs from AM, MH completed first CFD run and EC started learning CFD and applied it to wings and end plates.
- Previous meeting 2 hours ago discussed at length final report and viva, what's expected, individual tasks and how to go about it.

Issues Arising:

- Full discussion of what is expected from each member for the final report and viva.

Conclusions Drawn:

The team now fully understand what is required of them for the final viva/report.

Targets for Following Meeting:

- None - next meeting in 2 hours

Date of Next Meeting: 04-03-19 - 14:30

MCR Aero Group Project

Minutes from Meeting · 04-03-2019 · 14:30

Present:

Ainsley Martin Maximilian Hart
George Jones Nicholas Thomas
Ewan Carter Ryan James
Tim Tudor Simon Williams

Apologies:

Absent:

Kai Tang

Completed Since Last Meeting:

- Research into splitting and manufacturing - full cost report of materials needed finalised.
- More CFD runs from AM, MH completed first CFD run and EC started learning CFD and applied it to wings and end plates.
- Previous meeting 2 hours ago discussed at length final report and viva, what's expected, individual tasks and how to go about it.

Issues Arising:

- Recap of what each member has completed this week
- Discussion of materials costs
- Questions about report and viva asked and clarified - discussion further into how to go about this final task.

Conclusions Drawn:

Team to focus now on writing report and preparing final viva.

Targets for Following Meeting:

- Have an initial draft of at least part of each team member's report.

Date of Next Meeting: 11-03-19

MCR Aero Group Project

Minutes from Meeting · 11-03-19 · 14:00

Present:

Ainsley Martin	Maximilian Hart
George Jones	Nicholas Thomas
Ewan Carter	Ryan James
Kai Tang	Simon Williams
	Tim Tudor

Apologies:

Absent:

Completed Since Last Meeting:

- CFD advancements made
- No further group projects

Issues Arising:

- Updates on all group member's data
- Planned meetings for report and viva planning. Dates set and team made aware.

Conclusions Drawn:

Team to finish outstanding CFD runs and work towards report and viva ready for meetings discussed.

Targets for Following Meeting:

- Make considerable progress with report and prepare to plan final viva.

Date of Next Meeting: 14/03/19