TAYLOR'S UNIVERSITY

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School of Engineering

PRJ60303
Multidisciplinary Engineering Design

A Study of Attributes of an Air Intake Affecting its Efficiency and Performance

Project Supervisor

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Abstract

For this semester 3, we are doing air intake and also some research on what is air intake. We have come out a proposal which consist of several sections to show about what are we doing.

Air intake is an opening on a car capturing air for operation of an internal combustion engine. It is a very important parts that need tons of brainstorming in order to manufacture an intake. A new design of the air intake is necessary as the old intake did not have sufficient documentation to reliably test for performance and also the weight of the intake is too heavy.

In this proposal, we face new challenges such as members lack of knowledge on air intake, lack of materials that build up the intake and also dynamics calculations for the dimensions of air intake. But all of these challenge can be done by researching, meeting of members to execute ideas and also seeking help from seniors and supervisors.

We have our valid reason on why are we taking this project for our Multidisciplinary project. It is because we have found out the problems the original air intake manufactured by the seniors and we are offered to improve the air intake by creating a new one. Therefore, we volunteer to take up this important role and help out as much as we can to the Taylor's Racing Team.

We also insert what we plan for these 14 weeks and the responsibility of everyone so that we do not left out everyone or one people do all and the rest do nothing. Everyone in this group have to contribute something to improve this proposal and get it done on time.

1.0 Introduction

The Formula SAE (FSAE) is a student design competition organized by the SAE International to allow engineering students from universities to design and manufacture an open cockpit style race car. FSAE has set rules [1] to ensure that students participating in the event produce a safe car to ensure that there are minimal injuries if an accident were to occur.

Taylor's University has a racing team named Taylor's Racing team. The team is using a 2006 Yamaha R6 engine. The engine requires a new air intake because the old intake in place is too heavy at 5 kg due to mistakes made by the seniors during manufacturing. Reducing the weight of the air intake but maintaining similar or better capabilities will allow the overall performance of the car to improve.

Figure 1. Picture of TR16, the FSAE car for Taylor's Racing Team in the year 2016 [2]

Figure 2. Picture of the Old Air intake in the chassis of TR16

The objective of this project to find out about how the attributes of an air intake affects the performance of the engine within the FSAE rules and regulations. An air intake is a component where it directs air into the engine to be mixed with fuel. Most production vehicles have air boxes that have filters that filter out the air before directing the air into the engine. In an FSAE car, the air intake has the option to route the air intake to feed the air from the side of the chassis, or through the top of the chassis, below the roll hoop.

Figure 3. A simple design of a side feeding plenum

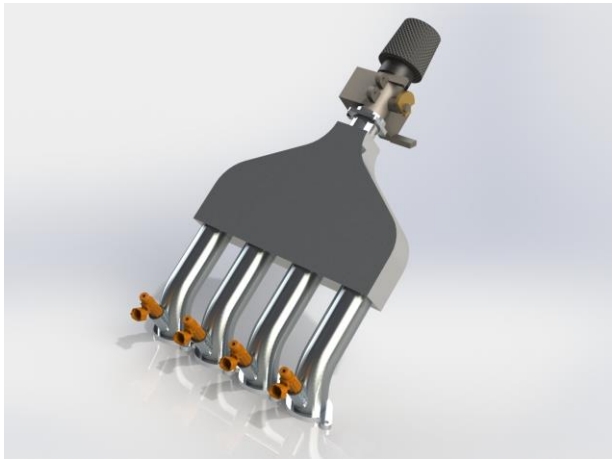


Figure 4. A simple design of a top feeding plenum

The rules and regulations for FSAE states that air intake needs to have a 20mm restrictor between the plenum and the engine [3]. This is to ensure that teams do not turn in with dangerous and overpowered cars that will be unsafe for the tracks they will be running on.

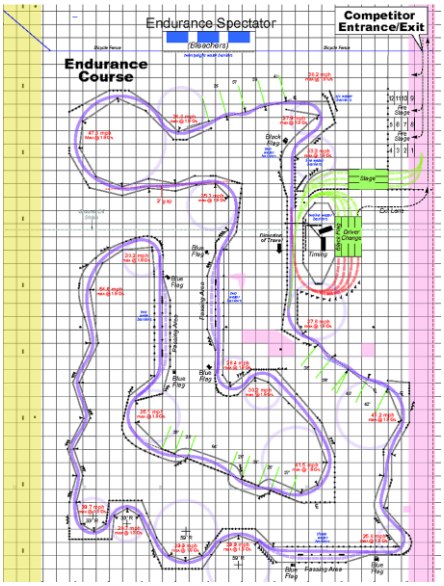


Figure 5. Figure showing the FSAE track for FSAE Lincoln 2014 [4]

Some of the attributes that we will be looking into in this project is the runner length and layout, the plenum volume and the type of materials used in the construction of the air intake.

The runner length affects the performance of the air intake due to Helmholtz Resonance Theory. The theory suggests that after an intake stroke has ended, the valves on the cylinder closes, causing the air to bounce off the valves creating a resonance. This resonance, with the Helmholtz resonance calculation, can be calculated just right for the resonance to bounce back to the valve of the engine just in time as the valves open again for another intake stroke at a certain RPM. This helps to force more air into the cylinder, boosting performance at the calculated RPM. The runner's performance can also be affected in a negative way if the runners are bent to aggressively due to packaging. This may cause some major energy loss between the throttle body and the runner of the intake. It may signify that the intake design has choked air, reducing the potential of the engine to produce more power than able to.

The intake manifold or plenum is where the engine draws air from the environment and supplies it to the individual cylinders.The plenum is also responsible for evenly distributing the reservoir of air to each cylinder. Poorly designed plenums will have an uneven pressure distribution, with some of the cylinders receiving more of the available air supply. Therefore, the design of the plenum is essential for the cylinders to receive sufficient airflow. Several factors can affect the ability of the plenum to properly supply air to the engine, including the volume, shape and size. Due to the flow rate limitations from the restrictor, the plenum is vital in determining how much power output the engine can push out. The side effect of increasing the volume of the plenum is the presence of throttle lag. This effect can be overcomed by the driver if proper vehicle testing is taken place to allow the driver to get use to the throttle response and adapt their driving style around it.

Different materials have been used to produce an air intake by FSAE teams around the world. Some use aluminium sheets, some use carbon fibre composites, some use molded plastic and some are experimenting with 3D printing materials. It is important that the right material is used for the plenum to ensure that the plenum does not break during race week. The temperature of the engine during operation may cause certain materials to lose structural properties and break. Adequate material testing is required to conclude a suitable material to be used for constructing the plenum that is lightweight yet cost effective.

SWOT Analysis

The reason we come out a new FSAE air intake is because we want to improve the efficiency of air entering the combustion cylinder for better combustion. There are numbers of challenges to be conquered while designing a new FSAE air intake.

Strength	Weaknesses
Every individual in the team are passionate about the project given. Although our knowledge in FSAE is limited but we are willing to learn and take the challenge. Furthermore, we have sufficient tools in the lab (e.g: CNC machine, 3D printer, etc) for us to work with our FSAE air intake model. This allows us to have a smooth process as we do not have to source or rent any other tool outside the campus.	We have limited knowledge about the mathematics behind it. For example, calculating the air turbulence inside the plenum and the velocity of air goes through the runner. Moreover, we are the only group who is doing a different kind of project, so we do not have any sample references from other groups.
Opportunity	**Threat**
We are very glad that the seniors from TRT has assisted us in designing and building this FSAE air intake. We do have some documents about FSAE air intake that given by the seniors to read through to know more about the anatomy of an air intake and the mathematical relations behind it.	The time period for the FSAE air intake to be designed and build is quite short due to the car has to be done and tested up to 44 km in July and send to Australia in November. We are able to schedule more testing and design amendment if the time period given is longer.

Table 1. SWOT Analysis

Objective

The project is part of the Multidisciplinary Engineering Design Module for semester 3 students. Several objectives are to be achieved at the end of the project.

Specific: To design and manufacture an air intake that is optimized for the 2006 Yamaha R6 engine at 9000 RPM for the Taylor's Racing Team.

Measurable: To improve the engine performance through the air intake that results in a faster and more fuel efficient car.The improvement will be measured through physical tests as well as Computational Fluid Dynamics (CFD) simulations.

Achievable: To produce a working prototype of the air intake that can be presented and allows the car to achieve a significant performance boost.

Relevant: To address one of the 14 grand challenges of engineering, specifically to Restore and Improve Urban Infrastructure[5]. A more fuel efficient car will reduce costs as well as the fossil fuels consumed.

Time-bound: To accomplish our objectives to design and manufacture an optimized air intake within the time constraints and be able to present the final product within 14 weeks.

Concept

Technological feasibility	The air intake will be designed and simulated in Solidworks and ANSYS. Both are famous industrial grade software that are available to use in the computers in Taylor's University Campus
Economic viability	Most of the materials required for the manufacturing of the prototype can be obtained from the campus labs or from the Taylors Racing Team. Therefore, since the prototypes are all 3D printed using Polylactic Acid (PLA), the cost of manufacturing is reduced.
Impact on Environment	The material PLA is a biodegradable thermoplastic made from renewable resources. The carbon footprint from using this material is small and also environmentally friendly.
Sustainability	The proposed design changes will allow any damaged or faulty parts to be replaced or switched out without the need to build a new intake from scratch. This will save up on cost long-term wise and reduce material wasted on manufacturing.
Legal and Ethical	Safety precautions are taken when constructing the prototype. The designs used in this project are designed and fully modelled by the team members, with care taken that no single part is plagiarized from external sources.

The air intake that we will be designing needs to help and accomodate the 2006 Yamaha R6 engine that the Taylor's Racing Team possesses.

There are many factors to consider when designing the air intake which involves different disciplines of engineering to accomplish.Since the challenge is to improve the performance of the air intake using these factors, different variables will be considered during the design phase. Each design will test a different variable and various tests will be conducted to observe what changes occur.

For most of the designs, 3D printing will be used to manufacture the prototypes to simplify the production phase as well as reducing the amount of time used in this phase of the project. This is because manually producing these designs would take a significant amount of time which would be detrimental to our project as it decreases the time for testing. To use the 3D printing machine, a file would need to be converted to a STL file format to allow the machine to read the file.

The new design will include connecting flanges that will allow the individual parts of the intake to be replaced and exchanged. This will save up on overall cost as repairs and maintenance can be done easily and faulty components can be switched out instead of fully manufacturing a new intake.

The testing phase will be done with a combination of computer-aided engineering software as well as physical testings of the various designed prototypes. Among the software to be used are ANSYS and Solidworks simulation. Physical tests using a flow bench to analyse the flow rate through the intake will also be done.

Approach

Methodology

The team will need to understand the fundamentals of an FSAE air intake before starting out their designs of the air intake. An FSAE intake for a naturally aspirated engine consists of a throttle body, a restrictor, a plenum and also a set of runners to the individual cylinders.

The team will have to think about each of the attributes and think about how to optimize the design to benefit the engine used. Material testing is needed to decide if materials such as carbon composite or 3D printing plastic is feasible as a material for the air intake.

Runner tuning can be done by using the Helmholtz Resonance theory[6]. A correctly tuned runner can help boost the output power of the engine as the resonant pressure wave meets the opening of the intake valves as the engine starts a new intake cycle.

Plenum Tuning can be done by calculating the maximum flow rate of the engine. The flow rate of the intake is restricted by the 20mm air intake, therefore the engine will starve of air at high RPM when the plenum volume is not sufficient.

FSAE teams around the world have used different materials to manufacture their air intake. Some use aluminium, some use carbon composites, and some use 3D printed plastics. Each materials have its downsides and its upsides. For example, 3D printed PLA is strong in normal room temperature, but it might not withstand the heat the engine is radiating which may result in the material warping at high temperatures.

The old intake weighed in at about 5 kg. Most of the weight comes from the use of block aluminium CNC into their desired parts. This also wastes a lot of material as CNC cuts out the materials it does not need. The new intake will take advantage of tubings and also thin aluminium flanges to reduce the amount of material wasted and also reduce the weight of the intake.

Design

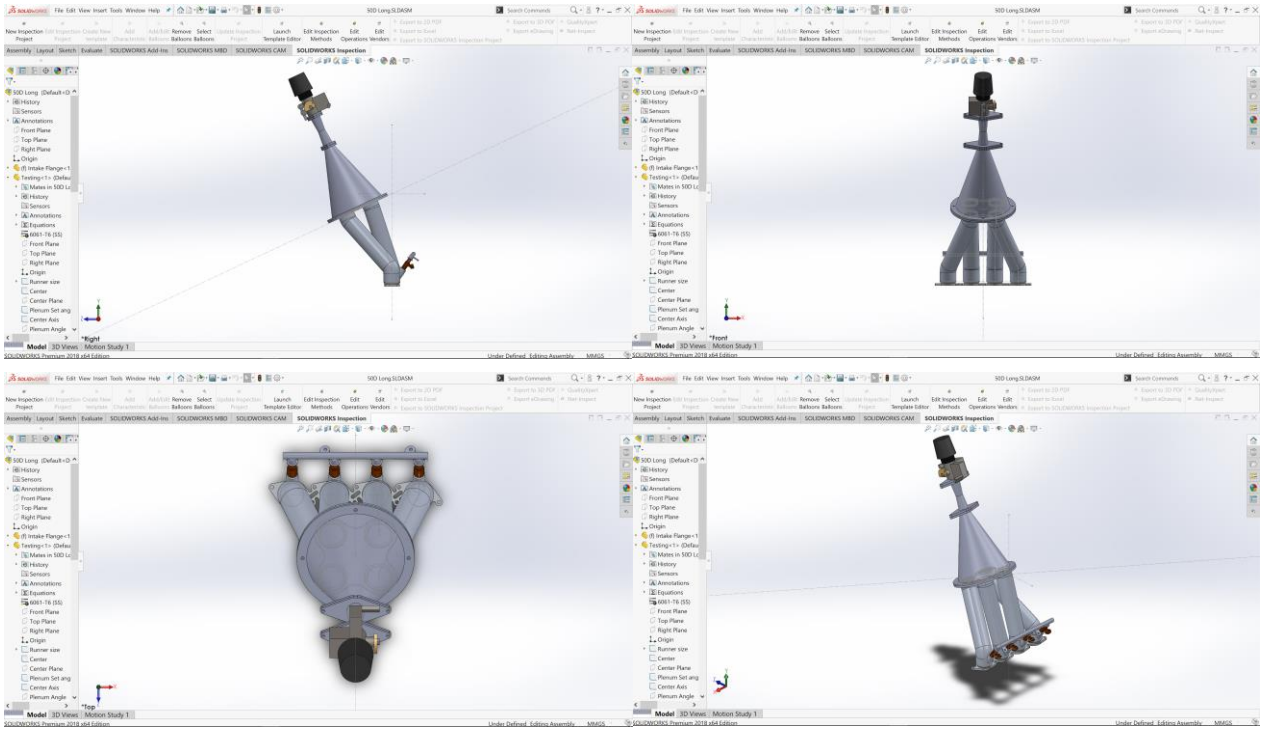
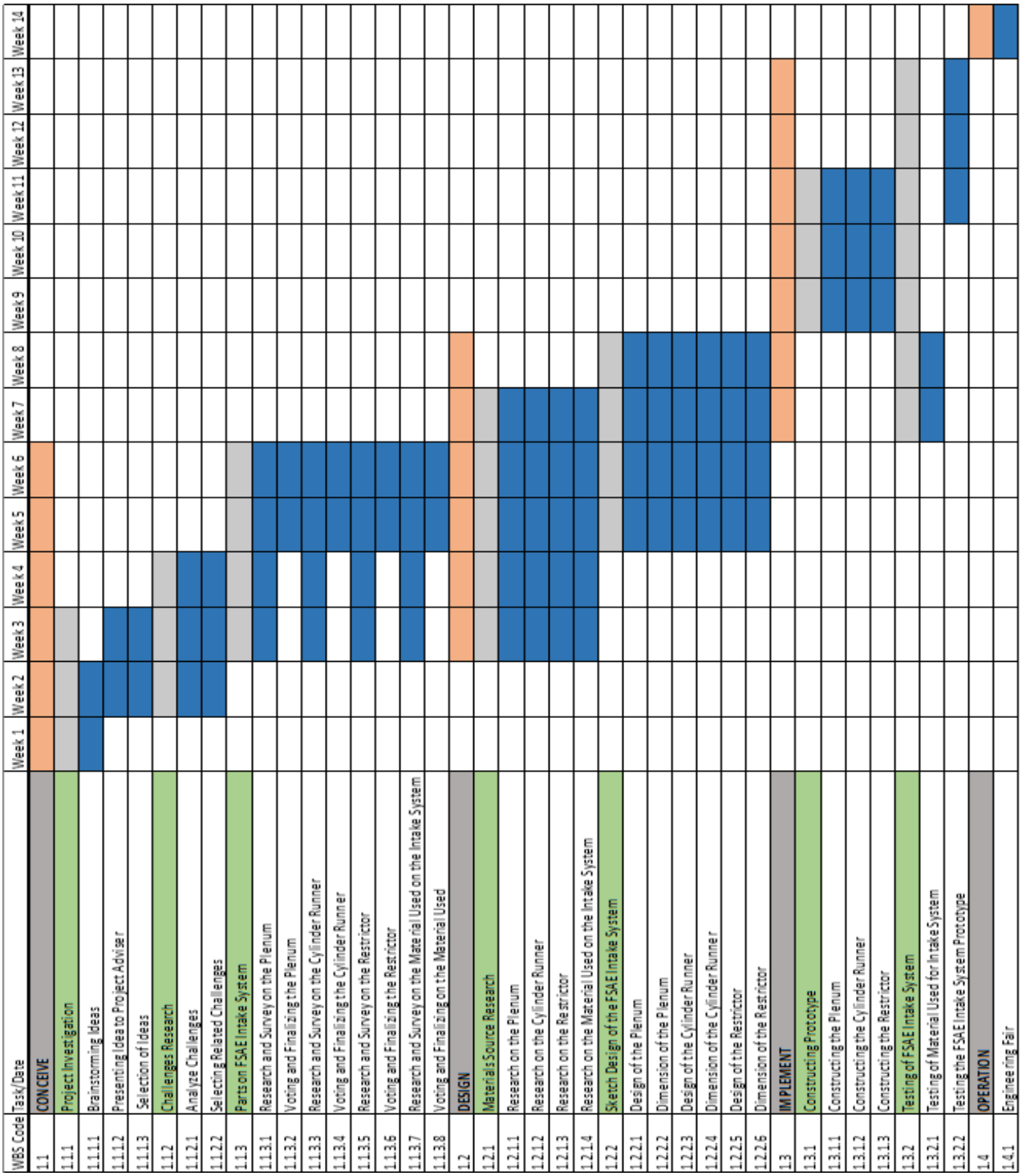


Figure 6. One of the currents designs of the air intake

One of the proposed designs of the air intake. This design has flanges between the runners and plenum as well as the plenum and restrictor to allow for easy changes in case of damage to the parts. The restrictor is the standard 20mm standard set by the FSAE committee. The runners have a circular configuration instead of a linear configuration to allow airflow to distribute more evenly.

Project Management

Gantt Chart



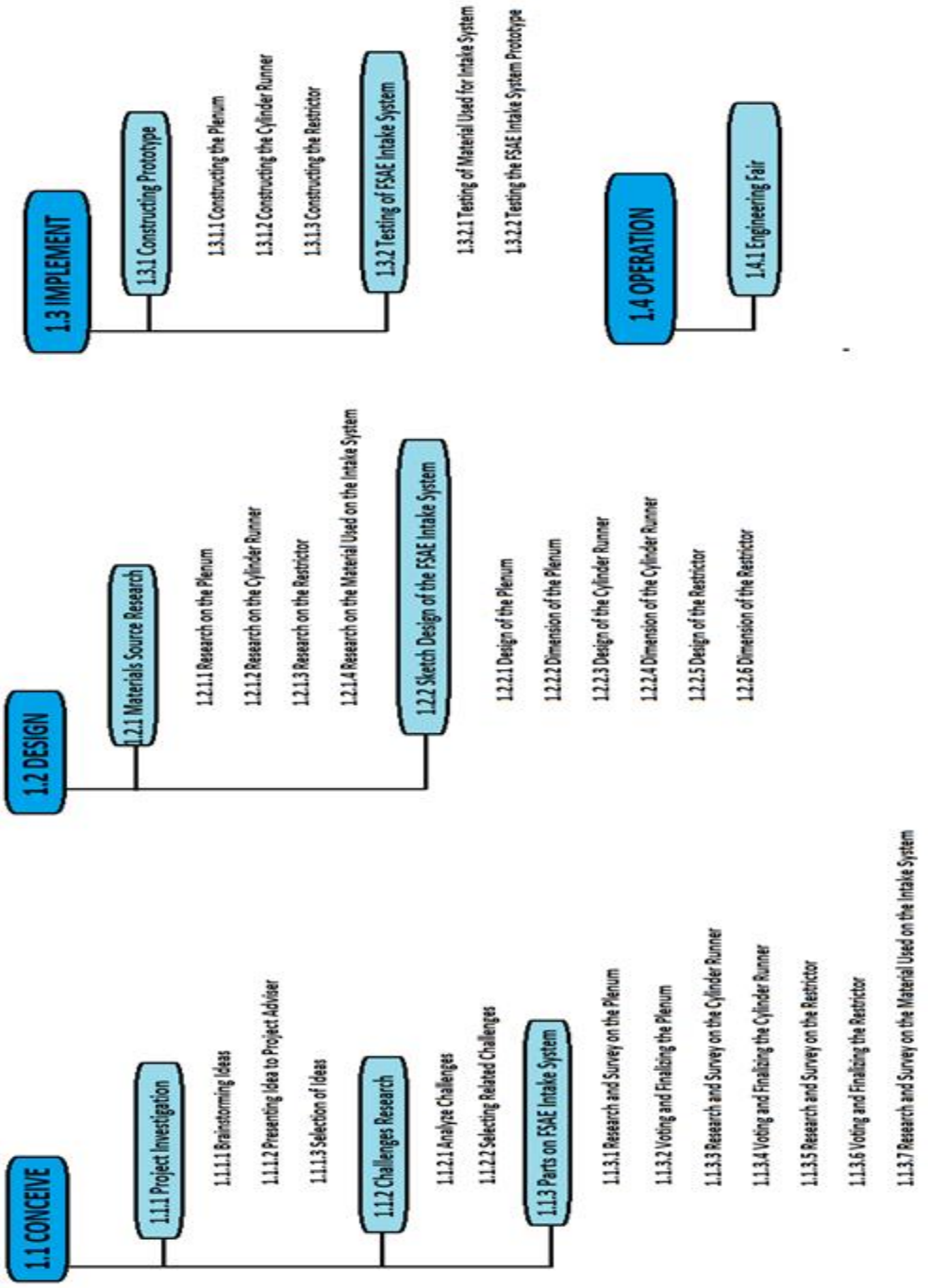
Linear Responsibility Chart

WBS Code	TASK	Person In Charge					
		JT	SL	JL	ZF	MZ	NA
1.1	CONCEIVE						
1.1.1	Project Investigation						
1.1.1.1	Brainstorming Ideas	6	6	6	6	6	6
1.1.1.2	Presenting Idea to Project Adviser	6	6	6	6	6	6
1.1.1.3	Selection of Ideas	6	6	6	6	6	6
1.1.2	Challenges Research						
1.1.2.1	Analyze Challenges	6	6	6	6	6	6
1.1.2.2	Selecting Related Challenges	6	6	6	6	6	6
1.1.3	Parts on FSAE Intake System						
1.1.3.1	Research and Survey on the Plenum	6	2	3	4	5	1
1.1.3.2	Voting and Finalizing the Plenum	6	6	6	6	6	6
1.1.3.3	Research and Survey on the Cylinder Runner	3	1	5	6	4	2
1.1.3.4	Voting and Finalizing the Cylinder Runner	6	6	6	6	6	6
1.1.3.5	Research and Survey on the Restrictor	3	2	6	5	4	1
1.1.3.6	Voting and Finalizing the Restrictor	6	6	6	6	6	6
1.1.3.7	Research and Survey on the Material Used on the Intake System	1	5	4	2	3	6
1.1.3.8	Voting and Finalizing on the Material Used	6	6	6	6	6	6
1.2	DESIGN						
1.2.1	Materials Source Research						
1.2.1.1	Research on the Plenum	6	2	3	4	5	1

1.2.1.2	Research on the Cylinder Runner	3	1	5	6	4	2
1.2.1.3	Research on the Restrictor	3	2	6	5	4	1
1.2.1.4	Research on the Material Used on the Intake System	4	6	1	3	2	5
1.2.2	Sketch Design of the FSAE Intake System						
1.2.2.1	Design of the Plenum	6	5	6	6	6	5
1.2.2.2	Dimension of the Plenum	6	5	6	6	6	5
1.2.2.3	Design of the Cylinder Runner	6	5	6	6	6	5
1.2.2.4	Dimension of the Cylinder Runner	6	5	6	6	6	5
1.2.2.5	Design of the Restrictor	6	5	6	6	6	5
1.2.2.6	Dimension of the Restrictor	6	5	6	6	6	5
1.3	IMPLEMENT						
1.3.1	Constructing Prototype						
1.3.1.1	Constructing the Plenum	6	6	6	6	6	6
1.3.1.2	Constructing the Cylinder Runner	6	6	6	6	6	6
1.3.1.3	Constructing the Restrictor	6	6	6	6	6	6
1.3.2	Testing of FSAE Intake System						
1.3.2.1	Testing of Material Used for Intake System	6	6	6	6	6	6
1.3.2.2	Testing the FSAE Intake System Prototype	6	6	6	6	6	6
1.4	OPERATION						
1.4.1	Engineering Fair	6	6	6	6	6	6

6 Person in charge ~ 1 Assistance

Work Breakdown



Conclusion

As a conclusion of this proposal, we are redesigning our air intake for the Taylor Racing Team (TRT), this is because there are mistakes found out in the previous design of the air intake which is the weight of the intake (5kg) and it is ‘overweight’ for the race car,so all we have to do is to manufacture a new air intake that is lighter than the original intake and either keep the quality or make it even better.

All of the air intakes in the world have slight different of design but similar calculations that contains of runner, plenum, restrictor and throttle. It is easy to design the intakes but measurement and materials use must be in considerations due to the mathematical solutions behind it. Not only that, research had been made in order to calculate the dynamic parts of intake so that the same error will not be done again. The materials also had been research so that the final intake should not be too heavy and also must withstand certain pressure and does not break easily.

Every of our group members has done a very great job in designing and also researching on the basic concepts of air intake. It is also because of our teamwork, we have different designs of air intake which gives different outcome for the racing car. But we will be choosing the best design with the best output for the racing car and manufacture it for Taylor’s Racing Team.

Gantt chart and linear responsibility charts has been plan accordingly and it is very organized so that everyone knows what is their roles and when should all of us hand in our projects in time so that we do not delay the project.

References

[1]*2017-18 Formula SAE Rules*. SAE International, 2018.

[2]*Picture of TR16, the FSAE car for Taylor's Racing Team in the year 2016*. 2017.

[3]*2017-2018 Formula SAE Rules*. SAE International, 2017, pp. 81-83.

[4]*Course Design Feedback & Discussion - FSAE Lincoln*. 2014.

[5]"Grand Challenges - Restore and Improve Urban Infrastructure", *Engineeringchallenges.org*, 2018. [Online]. Available: http://www.engineeringchallenges.org/9136.aspx. [Accessed: 18- Apr- 2018].

[6] M. Thompson, "Non-Mechanical Supercharging of a Four-Stroke Diesel Engine," MS Thesis, The Ohio State University, 1968