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GEOMETRY DESIGN OF RACING EXHAUST SYSTEM ON L12B ENGINE

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ABSTRACT
Geometry design of a special racing exhaust for the L12B engine has been done. This exhaust system is different from the previous standard exhaust system, the dimensions of this new racing exhaust system have been re-engineered to meet the specification of the racing exhaust system by stripping the catalytic converter, resonator and muffler to make free and faster fluid velocity. The diameter of the exhaust pipe is made to have a width of 1.5 inches rather than 1.75 inches which it is standard. Based on the results of CFD simulation measurements on the sample exhaust, the 1.5-inch exhaust pipe diameter resulted in an average fluid flow velocity of 15.43 m/s, while the 1.75-inch exhaust diameter width resulted in an average fluid flow velocity of 12.79 m/s.

KEYWORDS: Fluid velocity, Scavenging effect, Volumetric efficiency, Backpressure, Computational Fluid Dynamic

1. INTRODUCTION
The world of racing/motorsports is a sport that combines the power of humans and machines to compete with each other on a racing track or circuit. The world of racing includes both car racing and motorbike racing, both of which require the physical fitness of a human being and the prime condition of the racing vehicle used, discussing the prime condition of a racing vehicle, then what is meant is how high the performance and reliability of each component installed on these vehicles (Hidayanti, F., Adi, K. A., and Wati, E. K., 2020).

These components include engine parts such as pistons, crankshafts, camshafts, connecting rods to the engine cooling components of the intercooler, components that are useful for control, such as suspension components which are divided into tie rods, suspension arms, steering racks, and even coil-over and its condition because it will affect the overall performance of the vehicle, the components that are useful for the exhaust process are also considered for their performance and physical condition, one of the components that is part of the exhaust component is the exhaust system or exhaust (Bajwa, A. U., Patterson, M., and Jacobs, T. J., 2020).

The demand to produce high-performance vehicles has made the world of racing/motorsports competition for research and development among racing teams, race car engineers and other engineering engineers, to competition among automotive manufacturers. R&D in the world of auto racing is one type of unofficial research competition in the automotive world that is still ongoing. One of the vital parts of R&D in the world of car racing which is still the prima donna for engineers to improve car performance is research in the development of racing exhaust systems or exhaust that is devoted to car racing (Sawicki, B., & Scherer, M., 2020).

The reason why until now the development of a racing exhaust system is still a vital research sector is due to the complexity in designing and designing a racing exhaust system. The complexity in designing a racing exhaust system is caused by differences in engine performance characteristics used in each racing car, each type of car engine has different characteristics and engine performance parameters regarding engine timing, engine cooling, combustion process, and exhaust process.

This difference will have a direct impact on the exhaust process, which results in a difference in fluid velocity of the residual exhaust gas to be discharged from the combustion chamber to the exhaust system (Shafie, N. A. M., Said, M. F. M., Aziz, A. A., Latiff, Z. A., Yamin, A. K. M., & Tamaldin, N., 2017).
A racing exhaust system or racing exhaust that can improve the performance of a car engine is a racing exhaust that is made according to the characteristics. In accordance with the engine performance parameters, so that the exhaust can work properly according to engine characteristics, it is necessary to design engineering in the design of a racing exhaust such as the dimensions of length and dimensions (Puškár, M., Kopas, M., Puškár, D., & Šoltésová, M. ,2020).

The width of the exhaust pipe diameter, the difference in the dimensions of the length and width of the exhaust pipe can affect the characteristics of the exhaust gas fluid flowing in the exhaust and it is necessary to test the fluid flow velocity in order to get an exhaust that matches the characteristics of the car engine used whereas in this world there are many types of engines cars in circulation, even though they have the same displacement, the same number of cylinders or the similarity in the structure of the engine arrangement, it is certain that no engine has the same characteristics between one engine and another (Hanada, N., Hiraide, A., and Takahashi, M., 2009).

Therefore, the reason why research on racing exhaust systems is still very complex is that each type of engine requires a different type of exhaust system or exhaust design and dimensions, so it is logical that all the cars in the world are either racing cars or cars. Commuter cars must have different or inhomogeneous exhaust system designs and dimensions, and this has an impact on high R&D research costs in the racing exhaust system development sector.

2. MATERIALS AND METHODS

Real-life phenomena related to fluid mechanics have yet to be solved analytically, so a problem-solving approach through a numerical approach is used to solve the problem. The reason why until now there has been no numerical solution to the fluid case is that fluid cases are still very complex and there are still many fluid phenomena that cannot be explained by current science, such as examples to date if you want to solve cases. Streamline aerodynamics on an airfoil, of course, it will use the Navier-Stokes equation. However, the simple Navier-Stokes equation which is the law of conservation of mass, energy and momentum is still too complex and too long the calculation process to be digested by human numeracy if it is still done. Then it will potentially have a higher error value due to human error than numerical error. Therefore, until now solving fluid equations using the Navier-Stokes law still cannot be solved analytically.

The energy conservation equation in this study is written as:

$$\frac{\partial}{\partial t}\left(pe+\frac{1}{2}pv^2\right)+\frac{\partial}{\partial x}\left(pue+\frac{1}{2}puv^2\right)+\frac{\partial}{\partial y}\left(pve+\frac{1}{2}pvv^2\right)+\frac{\partial}{\partial z}\left(pwe+\frac{1}{2}pwv^2\right)= k\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial xz^2}\right)-\left(u\frac{\partial p}{\partial x}+v\frac{\partial p}{\partial y}+w\frac{\partial p}{\partial z}\right)+\mu\left[u\frac{\partial^2 u}{\partial x^2}+\frac{\partial}{\partial x}\left(v\frac{\partial v}{\partial x}+w\frac{\partial w}{\partial x}\right)+v\frac{\partial^2 u}{\partial y^2}+\frac{\partial}{\partial y}\left(u\frac{\partial u}{\partial y}+w\frac{\partial w}{\partial y}\right)+w\frac{\partial^2 u}{\partial z^2}+\frac{\partial}{\partial z}\left(u\frac{\partial u}{\partial z}+v\frac{\partial v}{\partial z}\right)\right]+2\mu\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial u}{\partial y}\frac{\partial v}{\partial x}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial v}{\partial z}\frac{\partial w}{\partial y}+\frac{\partial^2 w}{\partial z^2}+\frac{\partial w}{\partial x}\frac{\partial u}{\partial z}\right]+pug_x+pvg_y+pwg_z \qquad (1)$$

This results in if you want to do research related to fluid mechanics, then the research is carried out experimentally which of course takes very high time and cost, this is done due to compensation for the difficulty of deriving the Navier-Stokes equation analytically, through this the approach is numerical becomes one of the things that are considered in solving cases related to fluid mechanics (Munson, B. R., 2015).

There are two types of exhausts that are known, first is a standard exhaust which includes a catalytic converter, resonator and muffler, second is a racing exhaust that does not use the 3 components of a standard exhaust, so it is called a straight pipe exhaust system. In this study, racing exhausts will be further investigated according to the title and purpose of this study, so the research methodology begins with a pre-research phase with direct observation of the racing performance of the research object on the Sentul circuit, which is then followed by a research phase at the headquarters of the EnginePlus Motorsports racing team.

Step in this research:

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1. Direct observation at the Sentul circuit on the object of research, namely the L12B engine race car owned by the EnginePlus Motorsports team (Honda Brio Satya).
2. Analyze the performance directly and study the behaviour of the object of research owned by EnginePlus Motorsports and compare its performance with cars owned by other competitors during the qualifying and race session.
3. Collect quantitative data in the form of records of travel time per lap or lap time and qualitative data in the form of feedback from drivers, mechanics and team leaders on car performance.
4. Draw the initial hypothesis based on the results of direct observation and the data obtained.
5. Examine the condition of the research object after the race at the Sentul circuit.
6. Evidence was obtained that the exhaust was still standard and required further modification.

3. RESULTS AND DISCUSSION

The sample exhaust design stage begins with the process of drawing a 3D model using the FreeCAD software, which is open source and free to use and is quite popular among novice researchers and engineers. The drawing process starts by drawing a 3D model of the exhaust head, where the exhaust head is the first part of the entire exhaust system.

The exhaust head is the part that directly attaches to the exhaust manifold which is in the engine block as well as the first entry point for the flue gas residual combustion when the exhaust process is being carried out, for the L12B engine the shape of the exhaust manifold is shaped like in Figure 1, so that the exhaust form automatically head on the exhaust system or exhaust that is made must be made the same shape. Although basically the shape of the exhaust head can be changed in design and size, changing the size and geometry of the factory standard exhaust head is a very risky thing and can make the exhaust gas flow choked up and backpressure occurs, in addition to the regulations for the ISSOM Honda Brio Speed race. A challenge that prohibits changing the shape of the standard car exhaust head (Figure 1).

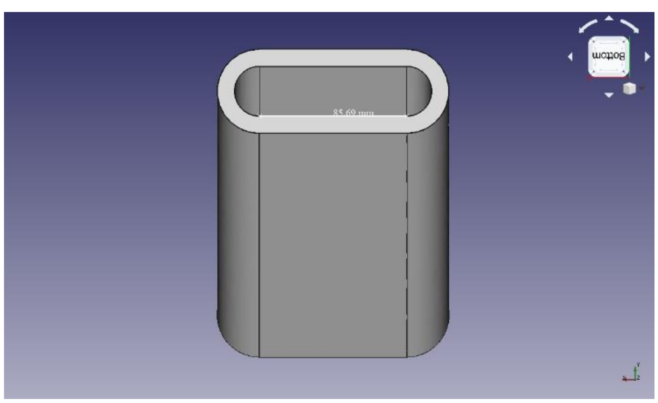

Figure 1: 3D Exhaust Head Model

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The geometry of the exhaust head on the L12B engine is made the same as the actual size, which has a diameter of 85.7mm.

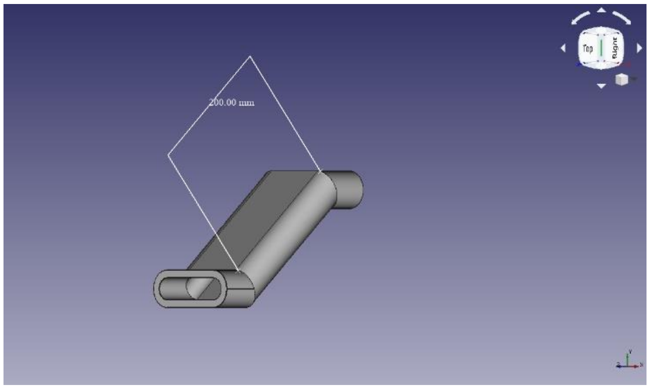


Figure 2: 3D model of the overall exhaust head downpipe

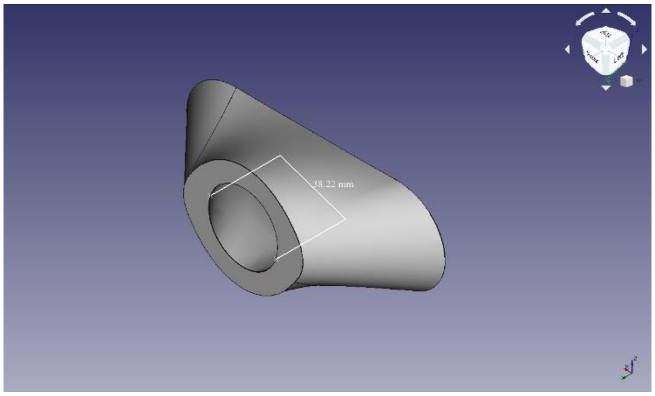


Figure 3: 1.5-inch sphere to round joint

The sphere to round joint is a link that also changes the shape of an oval into a circle. This shape is made the same as the original exhaust system or factory default exhaust for the L12B engine. There are two spheres to round joints that are made, measuring 1.5 inches (38.1mm) and 1.75 inches (Figure 2 – Figure 3).

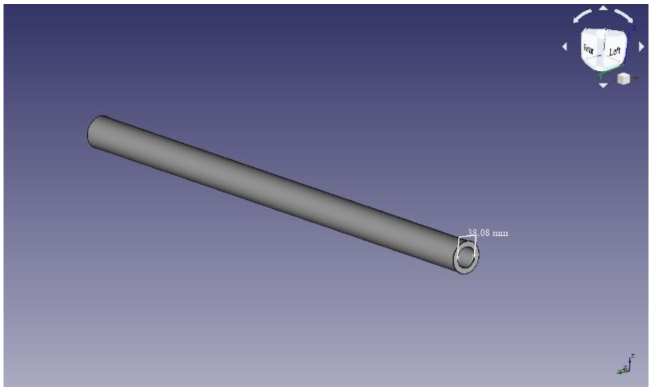


Figure 4: Section exhaust pipe with a diameter of 1.5 inch

According to Figure 5, the exhaust pipe section of the entire exhaust system or exhaust is the independent variable in this study and a different diameter will be made for the exhaust pipe section as a variation in this research. There are two types of variations in the diameter of the exhaust pipe, namely 1.5 inches (Figure 4) and 1.75 inches (Figure 5). The difference in diameter between the two exhaust pipes will affect the flow rate of the exhaust gas fluid, which is the dependent variable in this study.

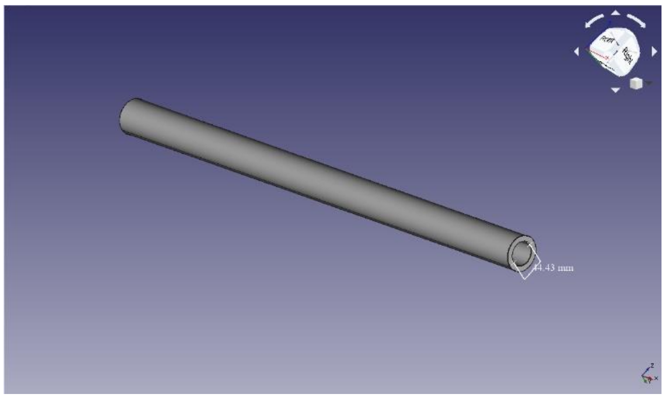
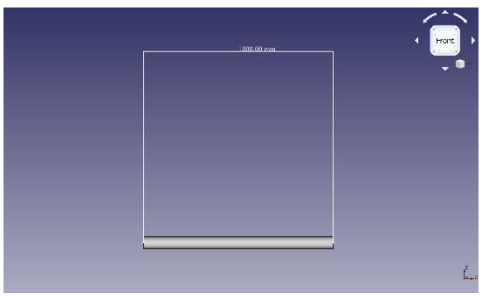


Figure 5: Section of the exhaust pipe with a diameter of 1.75 inch

a



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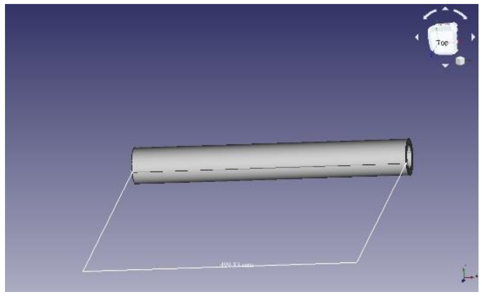
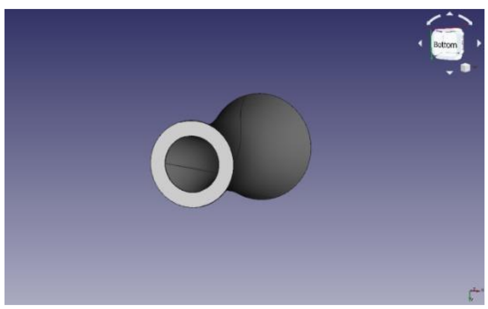


Figure 6: Difference in length for straight pipe (a) 1.000 mm and (b) 500 mm

The length of the exhaust pipes also varies from 500 mm, 1,000 mm, to 1,500 mm (Figure 6 – Figure 7). The difference in the length of the exhaust pipe results in a difference in the fluid character of the exhaust gas, thus affecting exhaust performance and impacting on changes in overall engine performance.

a



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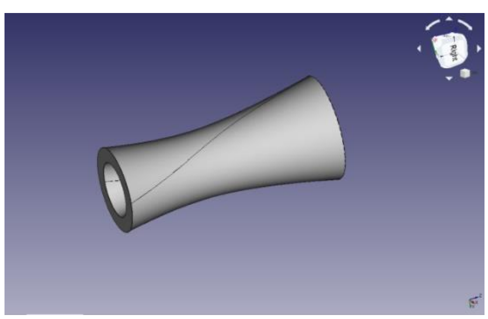

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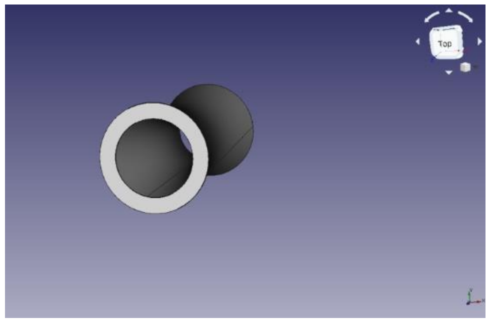

Figure 7: Exhaust tip (exhaust tip), varied with Megaphone (a) front surface of megaphone exhaust pipe 1.5 inches in diameter, (b) megaphone exhaust pipe length 1500 mm, (c) rear megaphone exhaust pipe 2 inches in diameter

Megaphone functions to equalize pressure from inside and outside of the exhaust so that the backpressure effect that blocks the flow of exhaust fluid to be discharged into the air is minimized. Backpressure has a devastating impact on exhaust performance and can damage the exhaust leading to damage caused by a failure of the engine's heat pulse to be discharged by the exhaust. Megaphone exhaust is usually used for cars that have a rear engine placement (Rear Engine), although the L12B engine is specifically designed to be placed at the front of the car (Front Engine), but to find out the results, a CFD simulation is carried out to analyze the velocity of fluid flow in the exhaust using a megaphone component. All components made are then put together into one part to form a complete exhaust as in Figure 8.

Figure 8: Racing exhaust designed from the assembly of several components made. The head exhaust section is used as fixed parts or fixed variables, and the research parts section, which consists of regions 1, 2 and 3 are independent variables.

In addition to all these components being put together as in Figure 9, a fixed variable in the form of the exhaust head is also made into a fixed part or fixed variable so that it does not undergo further modification. In contrast, in the exhaust pipe section it is used as an independent variable, this independent variable is the research part or part under study, so that the exhaust pipe underwent further modification

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in the different width of the exhaust pipe diameter between 1.5 inches and 1.75 inches. In addition, the research parts section also distinguishes the exhaust pipe installation configuration, an explanation of the exhaust pipe installation configuration can be seen further in Table 1.

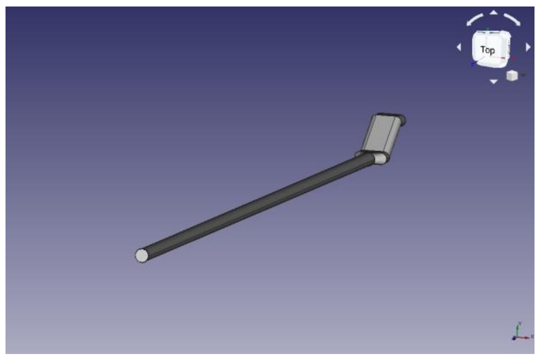
Table 1: Table of a configuration of exhaust pipe installation in each region and alias name of each exhaust

Exhaust System	Diameter (inch)			Sample
	Region 1	Region 2	Region 3	
1	1.50	1.50	1.50	Sample A
2	1.50	1.50	1.75	Sample B
3	1.50	1.75	1.50	Sample C
4	1.75	1.50	1.75	Sample D
5	1.75	1.75	1.50	Sample E
6	1.75	1.75	1.75	Sample F
7 (with *smooth joint)*	1.50 (1m)	1.50 (1m)	1.75 (1m)	Sample Special A
8	1.75 (1m)	1.50 (1.5m)	1.75 (0.5m)	Sample Special B
9	1.50 (1m)	1.75 (1.5m)	1.50 (0.5m)	Sample Special C
10	1.50 (1m)	1.50 (1m)	2.00 (1m)	Sample Special D
11	1.50 (1m)	1.50 (1m)	1.75 (1m with megaphone)	Sample Special E
12	1.50 (1m)	1.75 (1m)	2.00 (1m with megaphone)	Sample Special F

On Table 1, it is explained that 12 types of 3D exhaust models have been made using CAD software, then explained in detail the configuration of the exhaust pipe installation in each region in Figure 9, for example, an exhaust sample A starting from region 1 to region 3 of the exhaust pipe Installed is a pipe with a diameter of 1.5 inches entirely, but in the exhaust sample B in region 1 and region 2, a 1.5-inch diameter pipe is installed and in region 3, a 1.75-inch diameter pipe is installed, so in other words, at the end or exhaust tip the exhaust tip-sample B is enlarged in diameter (Figure 8).

Mufflers 7 to 12 are given special sample names because the six exhausts use components with different designs from exhaust 1-6. They have thus obtained 12 types of specially made exhaust for the L12B engine where all these exhausts will be further analyzed with CFD software.

a



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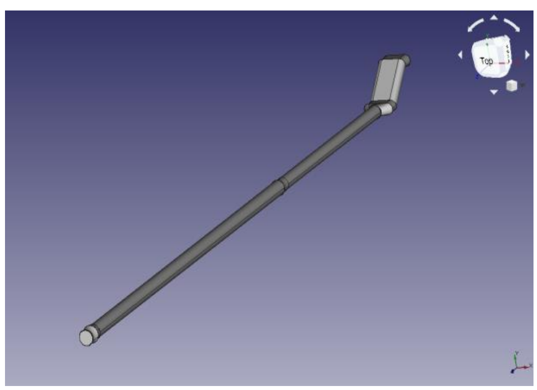

Figure 9: Design differences at the exhaust tip between the straight-pipe exhaust and the megaphone (a) a straight pipe exhaust sample A and (b) a megaphone exhaust sample special F

Figure 9 shows the 3D results of the exhaust made by FreeCAD software, the first exhaust is a straight-pipe exhaust system and the second exhaust is a megaphone exhaust system, specifically the second exhaust is a pure 3D experimental design that has never been applied to a car with the front engine placement. (Front Engine). The two exhausts in Figure 11 have different characteristics from the character of the exhaust fluid so that their performance is also different.

In this study, 12 of 3D models of exhaust samples have been successfully made where all the exhausts have the same maximum dimension length of 3m but have differences in the configuration of the diameter of the exhaust pipe which is the independent variable of this study, where the result is a difference in flow velocity. The fluid in each of the twelve 3D exhausts made is the dependent variable of this study.
The main purpose of making sample exhausts is to test the initial hypothesis which concludes that differences in the diameter of the exhaust pipe can affect the fluid flow velocity and the characteristics of the exhaust gas fluid flowing in the exhaust.

4. CONCLUSION

Utilization of CAD software in the geometry design of l12B engine-specific racing exhaust proved effective and appropriate in meeting the research timeline. In the 3D design process, the exhaust model using CAD software proved that the difference in exhaust pipe diameter between 1.5 inches (Sample Exhaust A) was able to produce an average fluid flow speed of 15.43 m/s, while for 1.75 inches (Sample Exhaust F) it was only able to produce an average fluid flow speed of 12.79 m/s as measured by CFD simulation software.

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