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Numerical Simulation of the Effect of Flow Velocity and Inlet Position on the Pressure Drop in the Exhaust Manifold

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Velocity
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ABSTRACT – The exhaust manifold, also known as the exhaust header, is an important channel in the combustion chamber of a car. The exhaust manifold's role is to collect exhaust gas from various exhaust channels and direct it to the catalyst and car exhaust muffler for filtering. This research was conducted to see the pressure loss in the exhaust manifold at different speed conditions and different inlet positions on an engine with 4 cylinders. The speed variations used were 0.4, 0.6 and 0.8 m/s while the inlet position variations used were 1 and 3 and 2 and 4. The method used was numerical simulation. Geometry is created in the CAD software, then proceed with creating a mesh and setting boundary conditions. The results obtained show that the greater the flow rate, the greater the pressure drop. Based on the inlet position, positions 2 and 4 tend to have a greater pressure drop than positions 1 and 3 at each of the same speed. The largest pressure drop is 1.5438 Pa at a speed of 0.8 m/s with inlet channels 2 and 4.

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INTRODUCTION

The exhaust manifold, also known as the exhaust header, is an important channel in the combustion chamber of a car. The exhaust manifold's role is to collect exhaust gas from various exhaust channels and direct it to the catalyst and car exhaust muffler for filtering. This filter serves to minimize the content of CO_2 and other harmful gases, so that when the exhaust emits exhaust gas, the gas released can reduce the causes of air pollution. Unfortunately, there are still many motorists or automotive lovers who are not aware of the existence of this exhaust manifold component. Thus, many cases of exhaust manifold damage and cracks occur. As a result, it not only damages the air and the environment, but also reduces the performance of car engines.

Flow velocity (v) is the distance traveled by the flow of water in the channel in unit time. Usually the speed v is expressed in units of m/s. The flow velocity in the channel is uneven. The closer to the edge of the channel or the bottom of the channel, the smaller the flow velocity [1]. The velocity distribution on the channel cross-section depends on several factors, including the shape of the cross-section, the channel roughness and the presence of bends.

Pressure drop is the term used to describe the drop in statistical pressure from within a system (eg flow in a pipe) to another point of lower pressure. Pressure drop is also the result of the frictional forces of the fluid flowing in the pipe, which is caused by the resistance of the fluid to flow. Pressure drop is the result of forces on the fluid flowing in the pipe, which is caused by the resistance of the flowing fluid [2]. The flow of fluid through the pipe causes fluid friction with the pipe wall which causes a pressure drop and fluid flow velocity which affects the use of energy to flow it [3-4].

The exhaust is generally called the exhaust manifold. Exhaust channel is usually placed at the bottom of the suction channel. The exhaust channel functions to channel the remaining combustion gases in the cylinder out through the exhaust pipe and silencer. To prevent gas leaks, the exhaust surface associated with the cylinder head is given a gasket. In a sports car or racing car, the placement of the suction channel with the exhaust channel is separated. The suction channel is placed to the right of the machine, or vice versa.

The inside of the exhaust channel is equipped with a heat control valve to heat the mixture in the suction channel. The heat contained in the exhaust gas mixture contained in the exhaust is circulated around the intake duct. The heat control valve works with the help of a bimetal and is regulated based on changes in the exhaust channel [5].

The use of exhaust manifolds is commonly used on four-wheeled vehicles and above due to the complex design of the engine block so that the exhaust manifold is here to provide a solution. The function of the exhaust manifold is to collect and distribute exhaust gases from the combustion engine, muffle the sound of engine explosions, and make the engine work more efficiently. The purpose of this study is to determine the effect of flow velocity on the exhaust manifold pressure drop and also to determine the effect of inlet location on pressure drop. The limitation of the problem in this study is that the type of exhaust manifold used is a Single-Outlet Manifold and uses the Computational

Fluid Dynamics simulation method. Computational fluid dynamics (CFD) provides qualitative (and sometimes even quantitative) predictions of fluid flow in mathematical models (partial differential equations), software tools (solvers, pre-processing and post-processing), and numerical methods (discritization techniques and solutions).

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METHOD

The research method was carried out using CFD software. CFD software is a software that is used to simulate fluids using numerical methods. Calculations are performed by the computer in the form of iterations through this software. In this study, there is a way of working of CFD software, namely modeling a geometry, applying meshing, entering boundary conditions, processing each interaction between elements until convergence conditions, and analyzing the results of the simulation. The variables used in this study consist of independent variables and dependent variables. The independent variables are flow velocity (0.4 m/s, 0.6 m/s, 0.8 m/s) and inlet location (1 and 3, 2 and 4). Dependent Variable is Pressure Drop (Pascal).

The exhaust manifold geometry with an inlet and outlet diameter of 85 mm was made using CAD software and then simulated with CFD software as shown in the figure 1 below. In this study, the sizing mesh used was a small element size of 0.005 m for the exhaust manifold parts as shown in the figure 2.

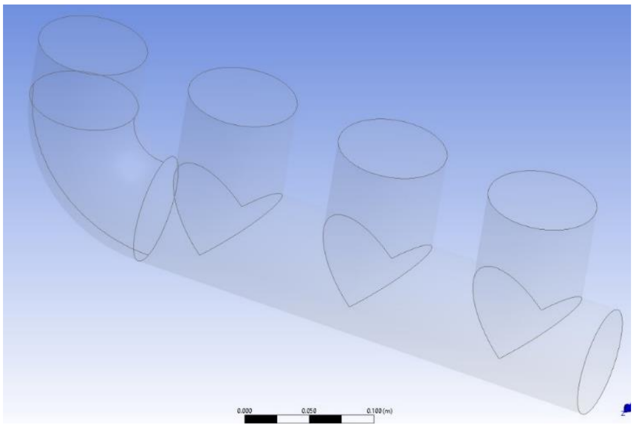

Figure 1. Exhaust Manifold Geometry

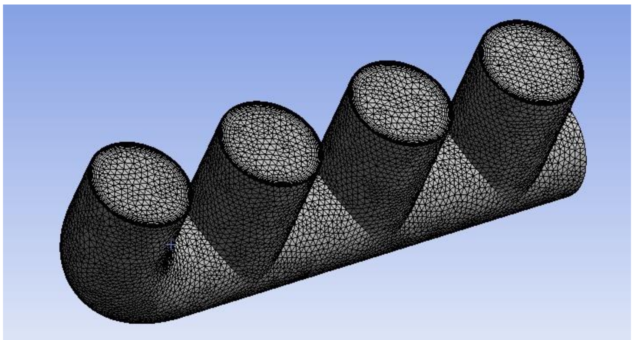

Figure 2. Meshing appears on the right side

The boundary conditions included in this geometry are shown in table 1 as follows.

Table 1. Boundary Conditions.

Indicator	*Boundary Condition*	Input Value
Wall	*Wall*	*No slip*
Output	Pressure-Output	-

Inlet 1	[1] Velocity-Input [2] Wall	[1] 4 m/s, 6 m/s, 8 m/s [2] *No slip*
Inlet 2	[1] Wall [2] Velocity-Input	[1] *No slip* [2] 4 m/s, 6 m/s, 8 m/s
Inlet 3	[1] Velocity-Input [2] Wall	[1] 4 m/s, 6 m/s, 8 m/s [2] *No slip*
Inlet 4	[1] Wall [2] Velocity-Input	[1] *No slip* [2] 4 m/s, 6 m/s, 8 m/s

RESULTS AND DISCUSSION

The results of the data obtained in the single output exhaust manifold simulation results are shown in table 2 as follows.

Table 2. Simulation Results.

Inlet Position	Velocity (m/s)	Inlet Pressure (Pa)	Outlet Pressure (Pa)	Pressure Drop (Pa)
1 and 3	0.4	0.797	0.4211	0.3759
1 and 3	0.6	1.744	0.9387	0.8053
1 and 3	0.8	3.0037	1.589	1.4147
2 and 4	0.4	0.96119	0.5626	0.39859
2 and 4	0.6	2.156	1.2805	0.8755
2 and 4	0.8	3.7759	2.2321	1.5438

Analysis of the Effect of Flow Velocity on Pressure Drop

The analysis of the effect of flow velocity on pressure drop with three variations of speed used, namely the speed of 0.4 m/s, 0.6 m/s, and 0.8 m/s. In the experimental results, it can be seen that the Pressure Drop value is higher when the speed is increased. This happens because there is a faster exhaust gas so that the resulting pressure is higher in the exhaust manifold according to Bernoulli's principle, when the flow rate increases, the static pressure of the gas tends to decrease. The pressure difference between the inlet and outlet creates a high pressure drop. This can be seen in the pressure comparison images shown in Figures 3, 4 and 5.

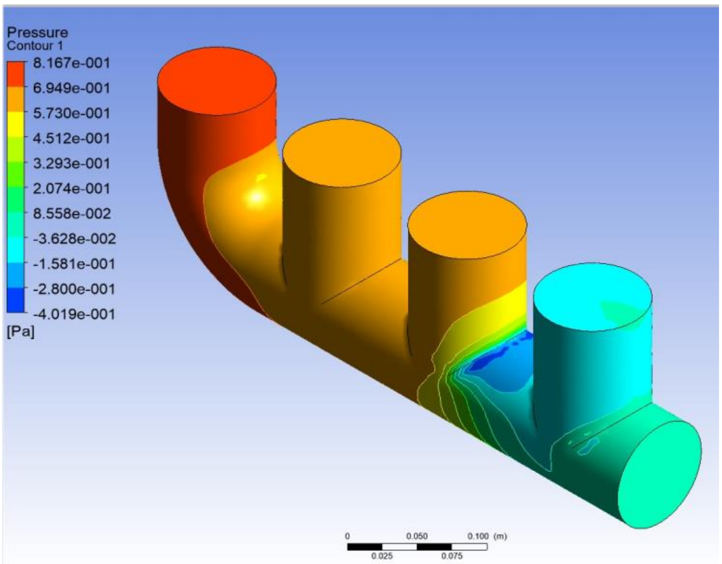

Figure 3. Contour Pressure velocity 0.4 m/s

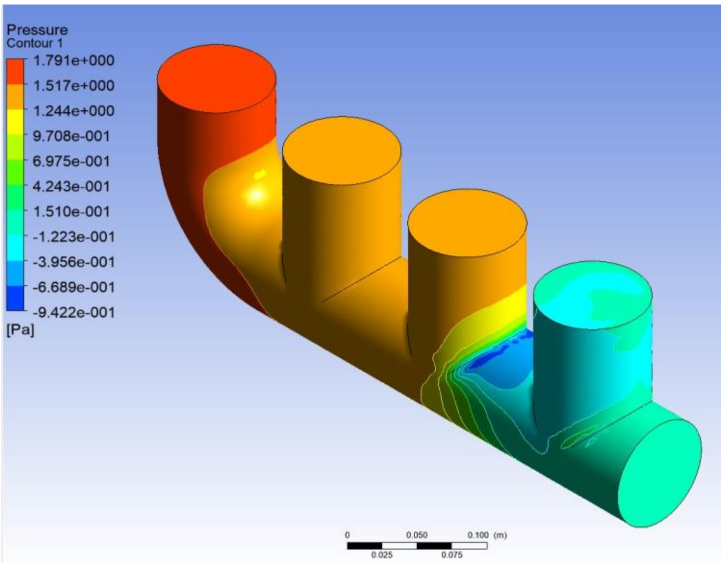

Figure 4. Contour Pressure velocity 0.6 m/s

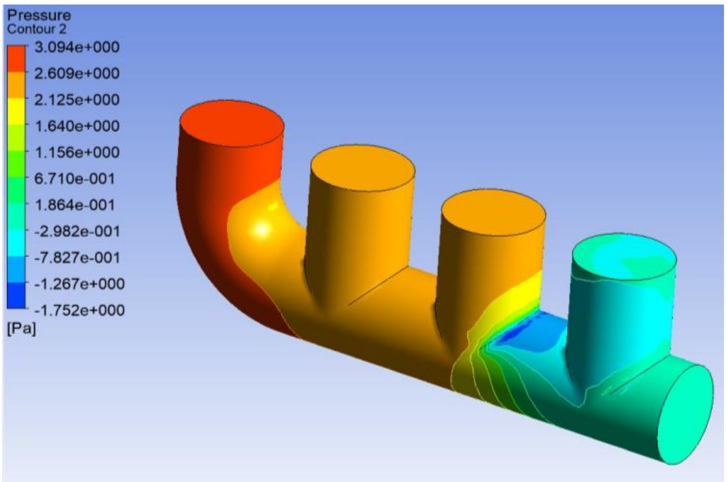

Figure 5. Contour Pressure velocity 0.8 m/s

Analysis of Inlet Position Effect on Pressure Drop

The analysis of the influence of the inlet location on the pressure drop with two variations of the inlet location used, namely the location of the inlet 1 and 3 and 2 and 4. The incident when some inlets are closed and others are open shows how the exhaust manifold works when a valve is closed and another valve is open during processing. burning. With this phenomenon, it certainly causes an unstable pressure distribution. Therefore, it is reviewed using a simulation if two of the four inlet valves are closed and the others are operating. There are results that valves 2 and 4 when open have a higher pressure drop than when inlet valves 1 and 3 are open. This is because there is a bend at inlet 1 which causes lower pressure so that the speed distribution is better than if only opening inlets 2 and 4. This can be strengthened by a comparison image of the simulation results of inlets 1 and 3 as well as inlets 2 and 4 shown in Figures 6 and 7 as follows.

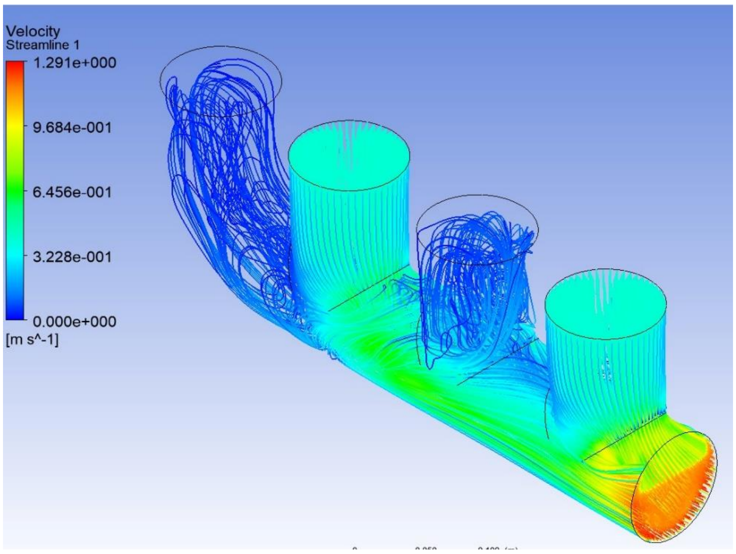

Figure 6. Simulation results with inlet 2 and 4

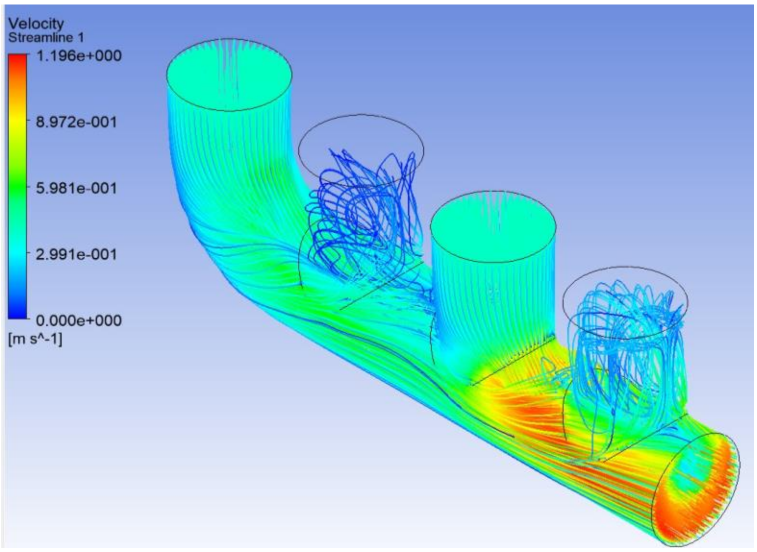

Figure 7. Simulation results with inlet 1 and 3

CONCLUSION

The conclusions drawn from the exhaust manifold simulation using Ansys software are as follows. Flow rate affects the pressure drop in the exhaust manifold. The pressure drop values at flow velocities of 0.4 m/s, 0.6 m/s, and 0.8 m/s are 0.376 Pa, 0.805 Pa, and 1.41 Pa, so that the greater the flow velocity at the exhaust manifold, the greater the pressure drop value.The location of the inlet affects the pressure drop on the exhaust manifold. The value of the pressure drop at inlet locations 1 is equal to 3 and 2 is equal to 4 at a speed of 0.6 m/s which is equal to 0.805 Pa and 0.88 Pa, so if you look at inlet 1 and 3 the value of the pressure drop is greater lower than if the inlet is through inlet 2 and 4.

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