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NUMERICAL STUDY OF VARIABLE LENGTH EXHAUST PIPE IN SMALL ENGINE

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ABSTRACT

Small engines, with capacity not exceeding 150 cc, can be divided into two types: two-stroke and four-stroke engines. The exhaust pipe has significant influences on the performance of the engine. Thus, it is necessary to study factors that affect the exhaust in order to improve the performance of the engine. For this early stage, it would be appropriate to conduct the research by using simulations since they only require minimal resources and can be conducted in a short period. The objective of this study is to conduct the simulation for determining the required velocity and pressure in the exhaust pipe. The comparison is done between parameter values from different configuration of exhaust pipes; the most appropriate configuration is then proposed. Three types of exhaust pipe is proposed using computer software and simulations are carried out using ANSYS Workbench 15.0. Results show that the velocity and pressure fluctuate according to the diameter and length of the exhaust pipe. Model 3 exhaust pipe configurations have been selected as the most suitable exhaust pipe for obtaining the maximum pressure and velocity.

Keywords: small engine, exhaust pipe, exhausts gas.

INTRODUCTION

The efficiency of a small engine is influenced by several factors. One of the important factors is the design of the exhaust pipe. A lot of research have been conducted previously for determining the best configuration of the exhaust pipe in order to improve engine efficiency. However, almost all researches are focused only on large capacity engines. There are only a small number of studies that have been conducted on small capacity engines.

The exhaust pipe is used to flow out exhaust gas from the system. The diameter and the length of the exhaust pipe have significant effects on the flow of the gas. It is noted that the exhaust gas flow is difficult to analyse. However, the study can be done based on only its main characteristics such as pressure, velocity and temperature. All these characteristics can be studied extensively by using computer software such as ANSYS.

There are several factors that influence the characteristics of the exhaust gas such as the diversity of size, shape and length of the exhaust pipe. These effect of these factors are determined based on engine power. It is important to carry out the study in order to determine the best option of the size, shape and length of the exhaust pipe for optimizing the performance of the engine.

The objective of this study is to compare the pressure and gas velocity in several types of exhaust pipe. Each pipe has different sizes, shapes and lengths. Then, the best configuration that fits the exhaust pipe is determined. This study is focused only the exhaust pipe in a small engine.

LITERATURE REVIEW

Most of the exhaust manifold are made of cast iron and have been designed according to the inlet manifold heat. It is to assure that the heat can be supplied and evaporation processes can occur in the inlet manifold. For an internal combustion engine, the flow of exhaust gas will pass to exhaust manifold through the exhaust valve. Exhaust manifold plumbing system will enhance the flow of exhaust gas directly through the exhaust pipe [1].

The exhaust gas that flows through the exhaust pipe will create the negative pressure pulse, which is reflected back at the exhaust valve. The negative pressure pulse is generated as soon as the valve is opened; this phenomenon will cause large pressure difference across the valve. This problem will cause the resulting gas to flow out quickly and increase the load imposed between the cylinder and the resulting gas mixture in the engine. Several modelling and simulation works have been done to study the effect of geometry structure of the exhaust pipe in the heating process [20]. However, the data is still too limited for us to elaborate the phenomenon sufficiently.

Design of the variable inlet and exhaust systems has significant influence on the overall engine performance. The verification of the best design of inlet and the exhaust system can be done through computational simulation. This method is selected since it requires low cost to produce highly repeatable data compared to experimental method. In this research, the model uses zero-dimensional phenomenon in the cylinder and one-dimensional phenomenon in the engine inlet and exhaust systems. This engine model can be optimized based on the impact of input parameters, exhaust systems, and engine performance. Proper size for the inlet and exhaust pipe system can be determined accurately from this investigation [22].

Exhaust gas pipe acts as a conductor when it is purged out of the engine system. This gas reduces engine noise and also removes dust from the engine system. Mainly the materials used for the construction of the exhaust system are the ordinary carbon steel or stainless

ARPN Journal of Engineering and Applied Sciences

steel. Recently, there are several researchers that have developed a surface layer of mild steel with ceramic/ metallic materials for protection against heat and corrosion of reinforcement degradation. It is noted that operating temperature of the exhaust line can be in the range between 250 to 1150°C. However, slow movement, high mobility, and termination by motor engine can cause the temperature gradient exceeds this range and can cause failure at the exhaust pipe.

In addition, temperatures between 730°C and 1150°C can cause changes in the microstructure in of ferrous alloy exhaust and also changes in response to corrosion, thermal degradation, and performance pressure levels. Exhaust condensate, exposure to road salt and dynamic excitation system can also lead to failure of the pipe. Failure that may occur is cracking and leaking in pipes [25]. Therefore, the exhaust system of even small engines is a worthwhile problem to solve.

METHODOLOGY

Figures-1-3 show the models of exhaust pipe used in this study. Each of the models has their own dimensions especially in diameter and length of the pipe.

All three models of exhaust pipe are designed using the Solid Works software. The design of exhaust pipe is similar to that of Yoshimura's brand of exhaust pipes [4].

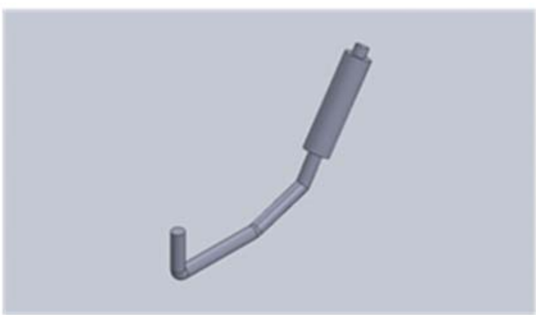

Figure-1. Exhaust pipe model 1.

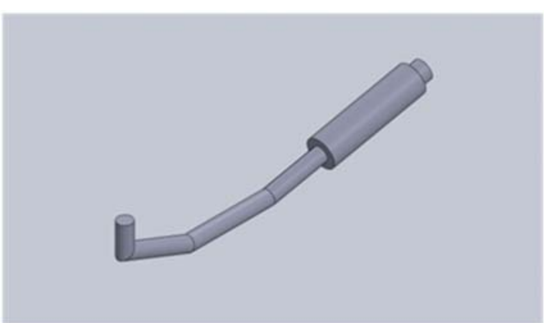

Figure-2. Exhaust pipe model 2.

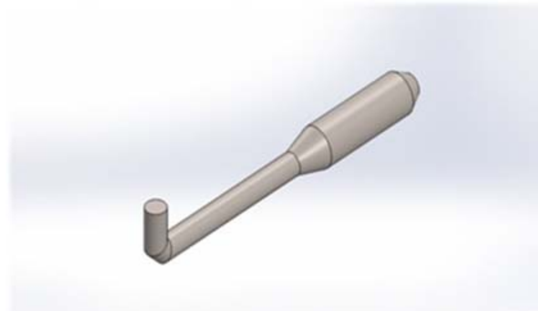

Figure-3. Exhaust pipe model 3.

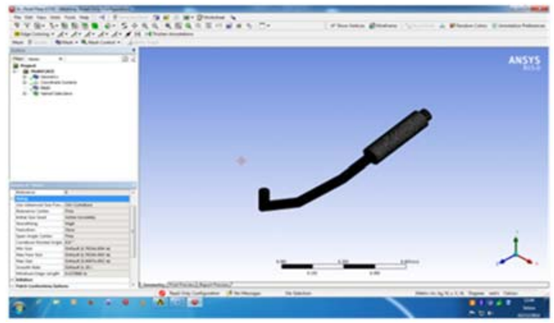

Figure-4. Meshing geometry using ANSYS CFX.

Table-1. Parameter of the mesh process.

Relevance center	Fine
Initial size seed	Active assembly
Smoothing	High
Transition	Slow
Span angle center	Fine
Curvature normal angle	8°

Table-2. Result of the mesh process.

Nodes	152170
Elements	779719

Table-3. Parameter value in Solver Control.

Min. iterations	100
Max. iterations	300
Residual target	0.001

Tables-1-3 show the parameters of mesh process, the result of the mesh process, and the parameter values used in the solver control, respectively. Node and element values depend on the value of the normal curvature angle; the values increase as the angle decreases. Node and element values have been determined from the results of early simulation runs.

The temperature of exhaust gas is set to 500°C or 773K. At the inlet part of exhaust pipe, the value of speed

ARPN Journal of Engineering and Applied Sciences

is set to 60 m/s^{-1} and at the outlet part, the value of pressure is set to zero. However, the phenomenon of backpressure always occurs in exhaust pipe. In order to remove this problem, relative pressure is set to be 0.2 psi. At the solver control, all the values are set according to Table-3.

RESULTS AND DISCUSSIONS

Figures-5-7 and Figures-8-10 show the velocity and pressure contours for all exhaust pipe models, respectively. Significant differences are seen for the contours of the velocity and pressure between all exhaust pipe models. The differences are mainly influenced by the size and the length of the exhaust pipe. It can also be seen that the maximum value of the velocity and pressure in exhaust pipe 1 is higher than the maximum values for the other exhaust pipes. However, the temperature is almost constant for all exhaust pipes.

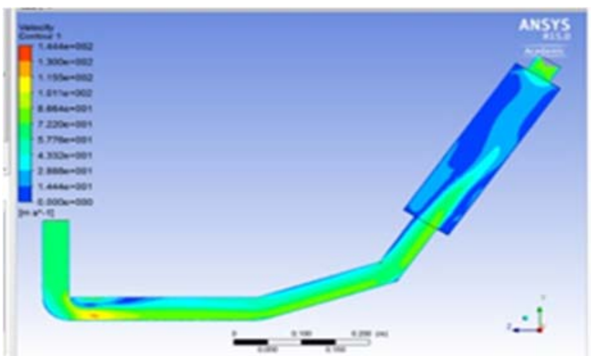

Figure-5. Velocity contour of exhaust pipe 1.

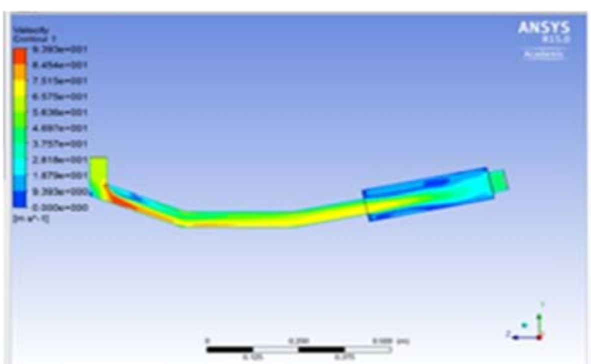

Figure-6. Velocity contour of exhaust pipe 2.

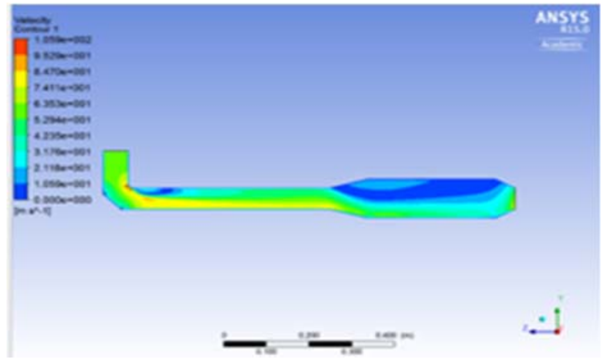

Figure-7. Velocity contour of exhaust pipe 3.

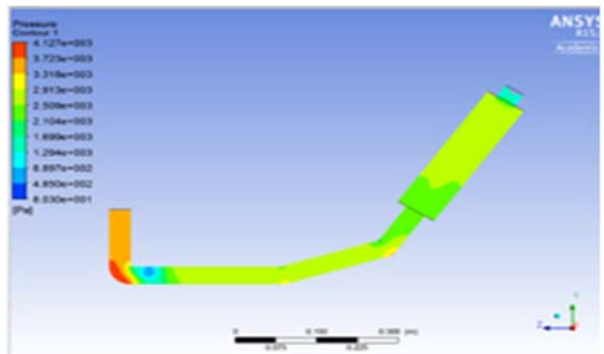

Figure-8. Pressure contour of exhaust pipe 1.

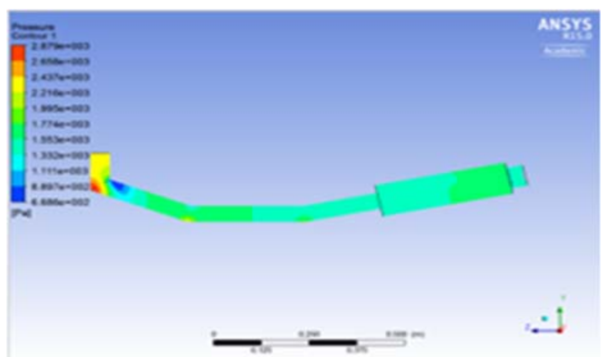

Figure-9. Pressure contour of exhaust pipe 2.

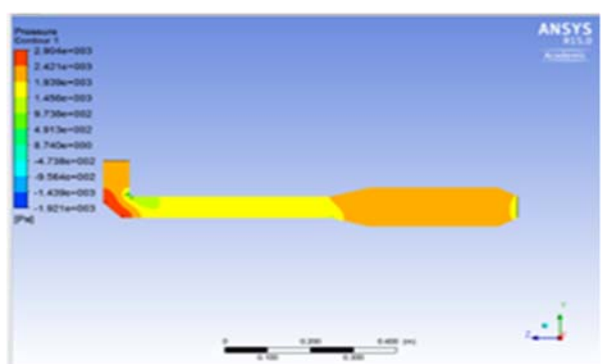

Figure-10. Pressure contour of exhaust pipe 3.

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The bends of the piping for exhaust pipe 1 has reduced the speed of the gas flow from the exhaust manifold and has allowed the system to retain some amount of pressure at the back end. The results are a little different when compared to the configurations of exhaust pipe 2 and exhaust pipe 3, both of which are progressively straighter than the predeceasing design. In these two setups, the exhaust gases go straight through the pipes without much resistance, producing higher speeds and lower pressures.

It also seen that from Figure-8-10, the resulting pressure is different at every corner in the exhaust pipe. According to pressure contour, the critical point occurs at the elbow manifold where the pressure is the highest in the region. This opens up the possibility of tuning the exhaust design to meet differing objectives.

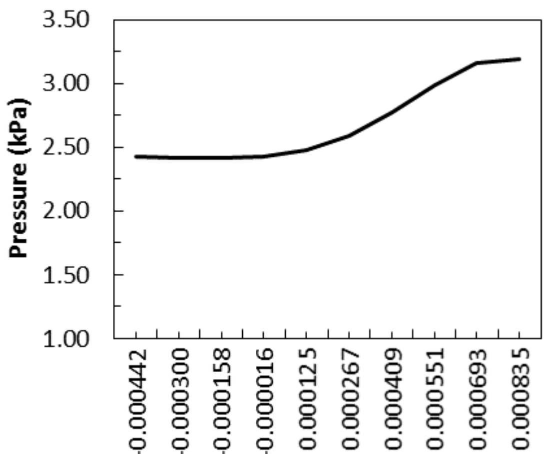

Figure-11. Pressure vs plane X for exhaust 1.

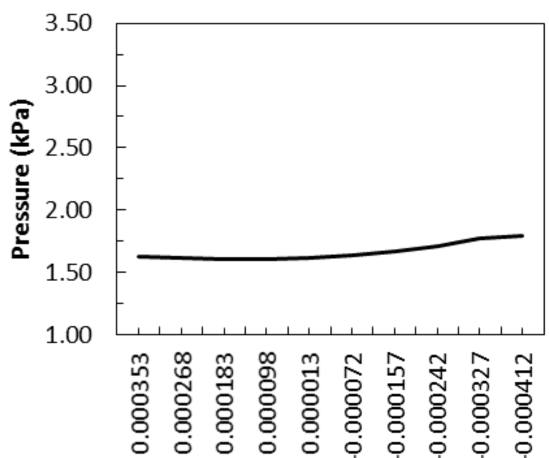

Figure-12. Pressure vs plane X for exhaust 2.

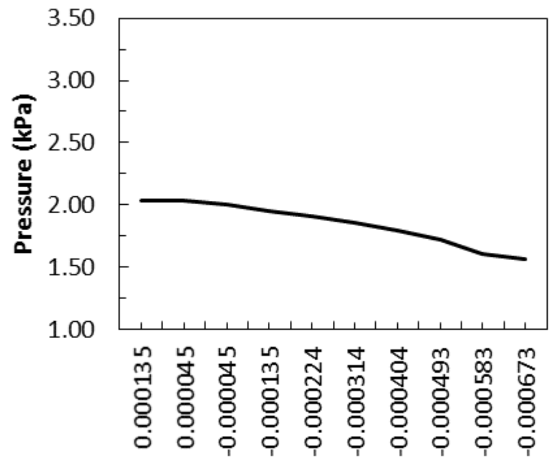

Figure-13. Pressure vs plane X for exhaust 3.

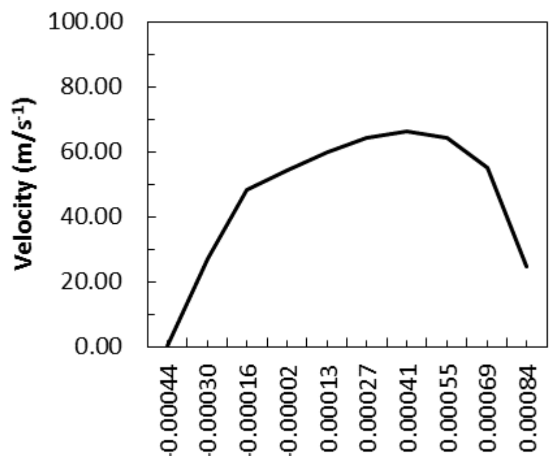

Figure-14. Velocity vs plane X for exhaust 1.

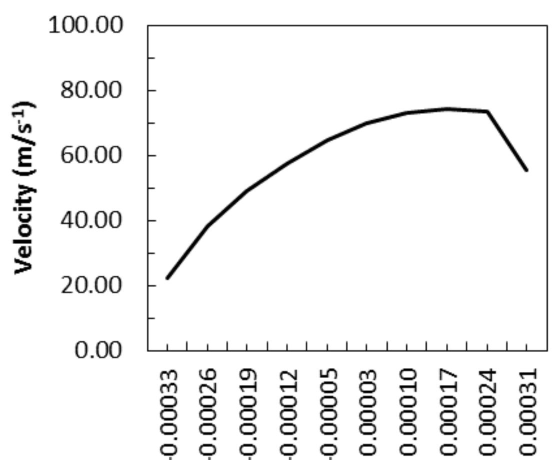

Figure-15. Velocity vs plane X for exhaust 2.

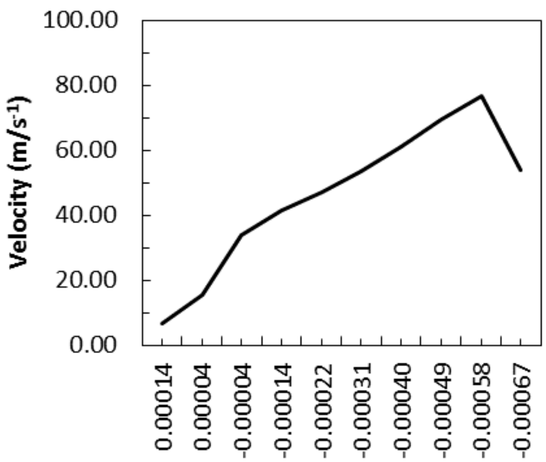

Figure-16. Velocity vs plane X for exhaust 3.

Figures-11-13 show the resulting pressure for models 1, 2, and 3, respectively. For model 1, the maximum pressure generated in the exhaust pipe is 3.2 kPa and the minimum pressure is 2.5 kPa. For the model 2, the maximum and minimum pressures are 1.8 kPa and 1.6 kPa. The model 3 has the maximum pressure 2.0kPa and the minimum pressure 1.5 kPa. As expected, model 1 produces higher pressures compared to the other two.

Figures-14-16 shows the velocities for all exhaust pipes. As shown in the figures, the velocities of all models are almost the same, except for exhaust pipe 1 which has a discernibly lower velocity characteristic compared to the other two designs. The resulting velocity increases until reaching at a maximum value before decreases after the point. The maximum velocities for pipe 1, pipe 2, and pipe 3 are 68m/s, 75m/s, and 78m/s, respectively.

According from the results, it is shown that the exhaust pipe 1 gives the best results compared to the exhaust pipe 2 and 3, if the design requirement targets the retention of pressure in the exhaust. However, if the objective is higher exhaust speeds, it has been shown that the exhaust gas can flow out easier and faster in the exhaust pipes 2 and 3 so that the exhaust gas velocity can be increased.

CONCLUSIONS

Simulation has been done to study the effect of exhaust pipe configuration on the pressure and velocity of exhaust gas. It was found that the exhaust pipe model 1 provide better pressure than the design of the exhaust pipe 2 and 3. However, the velocity of the exhaust gas flowing in the exhaust pipe is almost similar for all models.

The characteristics of the phenomena that occur in the exhaust pipe can be identified via simulation. Although the results are not accurate as the actual situation, but simulation studies continue to be used to obtain information for a future study.

Although the phenomenon of reverse pressure prevailing in the exhaust pipe shape and has a constant temperature between the two models, but the diameter and length corresponding to the exhaust pipe can produce optimum engine efficiency.

In conclusion, the exhaust pipe diameter and length affect the efficiency of small engines such as motorcycle engines. The value of the exhaust gas velocity and pressure is also influenced by the diameter and length of the exhaust pipe.

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