Analysis of airbox performance improvement for Modenas model by geometrical analysis

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Abstract. Airbox system consist of filter element which greatly influenced the quality air into the engine system. The main objective of this study is to improve the performance of airbox system that attached in MODENAS CT115S engine system. Airbox, an empty air chamber, accumulates the outside air and feed it to the cylinder of the engine for combustion process and contains filter element. The function is to provide cleaner air for greater combustion rate and cleaner emission. The performance of airbox can be influenced by changing the location of the filter element and the geometry of airbox. By changing these parameters, the performance of the airbox system can be enhanced. In this study, the geometry of the airbox inlet has been changed in terms of shape and size. The inlet shape for Design 1 in round shape with a diameter of 43.60 mm. Meanwhile for Design 2, the geometry of airbox inlet was changed to a rectangular shape. Between these two designs, Design 1 provides a better result in terms of mass flow rate (10.41 kg/s), velocity (9.84 m/s) and pressure difference (83.44 kPa). By increasing the performance of airbox, the performance of engine can be increased.

1. Introduction
The iteration of engine performance is the major concern in the automotive industry. The aim of this study is to improve the performance of airbox for MODENAS CT115S engine system in terms of mass flow rate, the velocity of the air and the pressure difference of airbox. Airbox system is one of the components
in the engine system. The airbox is a void chamber at the inlet of most ignition engines. The airbox gathers the air from surrounding and feed it to the admission hoses in every intake part. The Airbox needs to supply clean air to the carburetor before the mixing process. The supply air and the fuel are mixed before being introduced into the cylinder for the combustion process. The specific amount of air is provided according to the type and application of the engine. Different types of engine application required different amount of air [1]. For the normal engine, a stable and continuous air flow is needed to provide comfortable driving. Meanwhile, for the racing application, a greater amount of air is entailed in order to produce greater combustion rate and generates the better amount of torque and power of the engine [2].

Pressure difference also known as pressure drop is the vital parameter in constructing the new design of airbox. In intake system, the capacities of pressure drop inside the airbox system can be accomplished by redesign geometry of the airbox design. The air from airbox will be used for overall intake system, which includes the cylinder head and intake port. From this study, the geometry of the airbox is redesigned and simultaneously, the mass flow rate, air velocity and pressure difference are investigated [3].

### 2. Methodology

This study involves three stages namely sketching, designing and analysis. For first two stages, Catia V5 software was used. For analysis, Ansys Fluent 14.5 was used as the simulation tool. The airbox model consists of inlet part, body part and outlet part. All these parts were measured carefully before the sketching process. The dimensions were measured as accurate as possible in producing benchmarking result for comparison purpose. The first drawing was the actual design, which acts as benchmarking.

![Figure 1. Airbox CATIA model.](image.png)

For improvement of design, two designs were proposed. Both designs have different geometry of inlet part, with different shape and size of inlet part. The volume of airbox remained constant and the diameter of outlet part was verified but the round shape of outlet part remained. Table 1 describes detail design for all the designs.
TABLE 1. The design detail of airbox.

| Parameter          | Actual Design | Design 1 | Design 2 |
|--------------------|---------------|----------|----------|
| Volume (l)         | 1.53          | 1.53     | 1.53     |
| Inlet Dimension    | 43.56 × 18.53 | Ø 43.60  | 33 × 35  |
| Outlet Dimension   | Ø36.60        | Ø43.60   | Ø36.6    |

For Design 1, the shape proposed was in round shape, with a diameter of the design was 43.60 mm. The volume of Design 1 is kept constant as the actual one, (1.53 l). The diameter of the outlet part was increased from actual dimension of 36.60 mm to 43.60 mm. For Design 2, the volume of the airbox and the diameter of outlet part were kept constant. The geometry of the inlet part was changed to a rectangular shape, with a dimension of 33 mm × 35 mm. This dimension was selected in order to investigate the effect of different shape of the inlet part and dimension changes to both intake and outlet part.

After the sketching and designing stage, the analysis was carried out by using Computational Fluid Dynamic (CFD) module in Ansys Fluent 14.5 in order to scrutinize the flow characteristics for all the designs including the actual one. Before the simulation, the best description of meshing was selected to avoid error during the analysis. The selected meshing is shown in Figure 2 and Figure 3.

Figure 2. The existing design of Airbox.
The streamlines of airflow inside the airbox were observed for each airbox design. Besides, the velocity profile was also examined together with mass flow rate, velocity magnitude and the pressure difference during post processing.

3. Results and Discussions

3.1 General Flow Field

Figure 4 shows the performance of flow field inside the airbox system. The flow described the motion of dirty air from the atmosphere that been drawn into the airbox. The inlet acts as the starting point and the outlet part set as the output point. The air flow circulated inside the airbox produces streamline profiles and path line as the result of the simulation. The result of streamlines of air flow can be seen in Figure 4. From the results, Design 2 produces better air flow streamlines compared to the other designs, with the number of streamlines greater than others.
Figure 4. The airflow streamlines of airbox; a) Existing Design; b) Design 1; c) Design 2

Figure 5. Streamlines colored by velocity magnitude for; (a) Existing design; (b) Design 1; (c) Design 2
4. Result Analysis
The analysis of mass flow rate, velocity and the pressure difference determines the improvement percentage and the best design. The value of mass flow rate for all designs is different to each other influenced by the design of airbox. For the original design, the maximum of mass flow rate occurred during medium valve lift. For the improvement designs, both have maximum flow rate during low valve lift. Figure 6 represents the result of mass flow rate for all designs.

The value of mass flow rate for the original design was 8.46 kg/s, which was the lowest one. For Design 1 and Design 2, the mass flow rate was 10.41 kg/s and 9.73 kg/s respectively. The variation of geometrical design influenced the result [4]. Design 1 has round shape with the diameter of both inlet and outlet is similar, (43.06 mm) and the improvement rate was 23.05%. Design 2 improved the value of mass flow rate by 15.01%. Design 1 was the best design in enhancing the flow rate value.

![Mass Flow Rate versus Airbox Design](image)

**Figure 6.** Mass flow rate comparison between the existing air box and new designs.

Velocity magnitude were constant at the inlet for all the designs. All designs experienced the same trend, with the outlet velocity magnitude decreased compared to the inlet. The differences between inlet and outlet were calculated and the smallest difference percentage was chosen as the best design.

Figure 7 represent the results for velocity magnitude for all designs and shows the constant velocity magnitude of 10m/s for all analysis. Pressure differences and the geometric design produce the friction in the air and cause the changes of velocity for the outlet of every air box. The result gives the value of velocity, which is the most approximate to 10m/s is the best result of the analysis.
Figure 7. The comparison of velocity magnitude among the airbox.

The outlet velocity magnitude for the original one was the lowest one, with velocity dropped from 10 m/s to 8.022 m/s (19.78%). For Design 1, the velocity at the outlet was the highest with the value of 9.84 m/s. The difference percentage was only 1.6%. Meanwhile, the outlet velocity for Design 2 was 9.58 m/s, 4.2% drop from inlet velocity. The velocity drop was due to the existing of friction acting on air flow inside airbox and when the air flowing out from the outlet [5]. The value of friction was different according to the design of airbox. The round shape improves the flow of airflow and reducing the friction that acts on the movement air [6].

Performance of the airbox was also analyzed in term of pressure difference. The initial pressure at the inlet was set at the atmospheric pressure, 100 kPa. After the simulation completed, the value of pressure at the outlet was obtained for the pressure drop calculation. For existing design, the outlet pressure was 73.97 kPa, with the pressure difference was 26.03 kPa. For Design 1, the pressure at the outlet was 83.44 kPa and the outlet pressure was drop by 16.56 kPa. The outlet pressure for last design, Design 2 was 81.25 kPa, with the pressure difference was 18.75 kPa. From all these values of the pressure difference, Design 1 recorded the lowest pressure difference among all the designs.
5. Discussion

The changes of inlet geometry influence the value of mass flow rate, velocity magnitude and the pressure difference that produced by airbox system. Basically, the inlet with round shape can enhance the air the flowing into the system. This is because the air flow is smoother compared to other shapes. It is really important to improve the air movement to enter the airbox system through inlet part by reducing the obstacles, sharp edge and friction. This is because all these blockages can reduce the amount of air that will be supplied to the overall engine system for the combustion process. When the amount of air reduced, the combustion rate will be dropped [7]. Therefore, it is important to generate the sufficient of air mass flow rate to be supplied for the combustion process.

By adjusting the inlet geometry to round shape and has similar diameter with outlet part, the pressure difference can be reduced [8]. This is because the pressure is needed to push the air from airbox to the cylinder effectively. If the pressure difference is too big, the required pressure to drive the air from airbox to cylinder is not adequate. Therefore, the small pressure difference is entailed in order to ensure the sufficient pressure for the engine system. To get 100% efficiency of the airbox is difficult since the losses occurred when the air passed through the element system inside airbox system [9].

6. Conclusion

By redesign inlet geometry to the round shape and the dimension was 43.6 mm for both inlet and outlet, the performance of airbox was enhanced. The value of mass flow rate, velocity magnitude and pressure difference for air that passing through the airbox were increased compared than the other design. This is because the round shape for inlet part reducing the friction, smoother the air flow entering the airbox, minimizing the air losses and increase the overall performance. The greater amount of air that supply to the cylinder from airbox will generate greater combustion rate and boost the overall engine performance. Design 1 was the best design among all airbox designs.

![Outlet Pressure versus Airbox Design](image-url)
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