Chapter 16
Design of Micro Turbocharger Runners for Automotive Application

Khairul Shahril, Mohamad Wardi, Shahril Nizam, Muhammad Najib, and Ishak A. Azid

Abstract The turbocharged system is one of the essential components that works in the engine system. It uses exhaust gas to control a turbine. This spins an air compressor that pushes in the cylinders with extra air (and oxygen), allowing them to burn more fuel every second. The intake air system for a motorcycle turbocharger must be correctly configured to minimize the output losses caused by the runner manifold with the regulated air exhaust turbine rule regulation. The paper presents the analysis of the runner manifold configuration parameter design against the engine output and then enhances the traditional runner manifold performance. This research begins with the development of the runner manifold design and modelling, and the runner manifold will use air flow simulation software to be used for simulation purposes. The parametric analysis was carried out to study the effect of the runner manifold parameter design on the engine output after designing the reference engine model. The optimization process was then carried out to achieve the goal of progress that had already been set before the optimization was carried out. The findings show an improvement in speed and pressure of up to 65.20 and 88.09% at the optimal operating range of engine speed.

Keywords Exhaust manifold · Runner · Simulation · Modelling

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16.1 Introduction

In this globalization era, to progress the automotive application is very important because of the growing economy in every country. The expanding automotive technology provides more development opportunities for other activities that cannot be archived before this. The motorcycle turbocharger, where a turbocharger is used for the forced induction of an internal combustion engine, is one example of an automobile application. The aim of a turbocharger, like a supercharger, is to increase the mass of air entering the engine in order to produce more fuel. Turbocharger use among motorcycle riders across Malaysia has recently increased in demand due to the advantages and satisfaction of turbocharge users.

Even with a turbocharger, a motorcycle cannot yet achieve one hundred per cent efficiency due to air pressure and velocity loss through the exhaust stroke process which channelled right after it exits the cylinder head straight to the turbocharger turbine, basically this part that channelled throughout from the exhaust port manifold to the turbine wheel in turbocharger is called the runner. The exhaust manifold is one of the most critical components of an internal combustion (IC) engine [8]. Hence this project is focused on designing the runner around exhaust manifold in order to increase the turbo productivity of air pressure inside the runner more sufficiently while maintaining volumetric efficiency of manifold runner flows. The power of the engine greatly depends on the amount of air that can be delivered through the intake. The solution that is used to overcome this problem is to design the tapered runner that has three different parameters which are the elbow diameter, manifold length and tapered diameter [10].

16.2 Literature Review

In order to gather all the available sources related to design of micro turbocharger runners for automotive application in one place and to assess them in terms of theory, engineering assessment and other external factors, the previous study that has been done related must be studied in order to have evidence and source that can assist in the project. There are a few main keys that can obtain the idea for the feature of this project in order to progress the modelling method and analyse method of the runner. These main keys are design theory and air flow behaviour.

16.2.1 Design of a New Improved Intake Manifold for F-SAE Car

The output velocity should be high with an even distribution to each cylinder to achieve the maximum mass flow rate for efficient working of the engine. But there

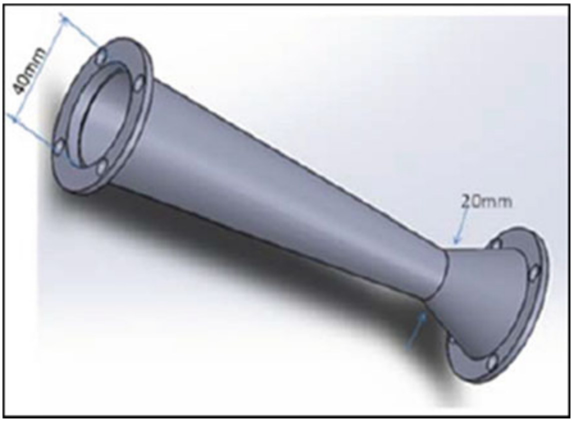

Fig. 16.1 Final design of restrictor [3]

is a low mass flow rate attributable from higher pressure losses distributed along with the air fuel mixture to each runner that affects the efficiency of IC engine. The performance of the intake manifold must be improved to improve the performance of the internal combustion engine, since the efficiency of an IC engine is highly dependent on the performance of the intake manifold [6].

The geometry of the runner and plenum must be improved to minimize pressure losses in order to demonstrate the efficiency of the model and to improve the performance of the intake manifold, so that high mass flow rate and even fuel/air distribution to each runner must be achieved by using computer simulation on the established model. The example of the model is shown as in Fig. 16.1 [6].

By changing the venturi and throat diameters, the pressure–velocity characteristics of the venturi are not affected too much. But the diameters influence the duration of the venturi non-aerated flow area [3].

16.2.2 Simulation Analysis of Spark Ignition Engine Intake Manifold for Better Performance

The authors of the paper present the research that explores the impact on the engine efficiency of the intake design parameter and then enhances the performance of the previous intake manifold system. This study begins with the development of the Honda CBR 600RR engine model and intake manifold device model to be used for simulation purposes using the GT-Power engine simulation software. The parametric research was conducted after designing the reference engine model to study the effect of the intake manifold parameter design on the output of the engine [9].

Parametric study is performed on the reference intake manifold system for the main purpose to investigate and identify the relationship of the effect of changing the design parameter of intake system towards the performance of the engine and to

Table 16.1 Design parameter values for parametric study [9]

Design parameter	Present values	Selected values
Plenum volume	2.3 L	1 L
		3 L
		4 L
		5 L
Runner length	247.6 mm	100 mm
		150 mm
		200 mm
		300 mm
Runner opening diameter	44 mm	30 mm
		40 mm
		50 mm
		60 mm

ensure that this research is producing relevant data compared with previous research from the literature review findings. The parametric study was carried out for the purpose of determining a suitable range of the design parameters and acts as a guide when performing the optimization at a later stage. Table 16.1 shows the design parameter values to be analysed [9].

The optimization process was then carried out to achieve the goal of progress that had already been set before the optimization was carried out. The results show an improvement in the target operating range of engine speed to 4.83 and 4.45% of the torque and air flow rate, respectively [9].

16.2.3 Air Flow Behaviour on Different Intake Manifold Angles for Small 4-Stroke PFI Retrofit Kit System

In order to deduce the angle at which the air flow conduct is stronger in the intake manifold for a small 4-time PFI retrofit kit device, the author investigates the airflow behaviour. Six intake manifold angles were investigated using the simulation tool CFX (software fluid dynamic) which are 30°, 60°, 90°, 120°, 150° and 180° as shown in Fig. 16.2 [5].

The high intake multiple angles provide better air flow inside the intake manifold based on the shown results. This is because the flexible manifold has lower air resistance. The results of this study showed that 180° is the best choice for multiple angles of input due to better air flow behaviour [5].

Optimization focuses specifically on the optimal configuration of the following parameters: elbow diameter, manifold length and tapered diameter [4]. Valve timing, valve diameter, valve lift profiles, exhaust multi diameter, tube inlet and exhaust tubes

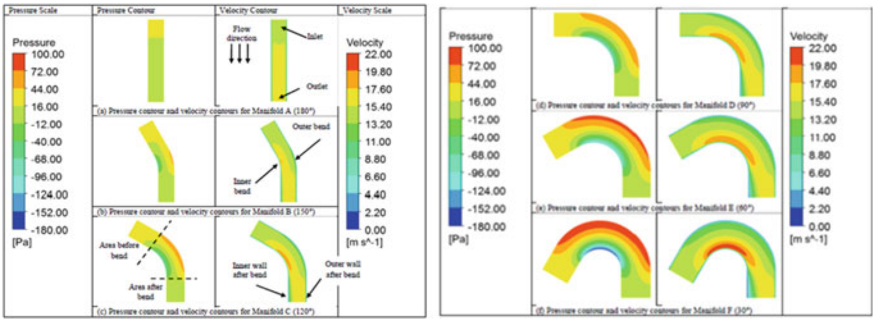

Fig. 16.2 Pressure and velocity contours plots for all intake manifold models continue [5]

lengths and tube junction geometry are parameters which improve the performance significantly [2, 7].

For the prediction of process output and efficiency of multiple systems, flow distribution and pressure drop are vital [11]. One of the important factors that governs the engine output is airflow inside the intake manifold, so the flow phenomenon inside the intake manifold should be completely optimized to generate more engine power with better combustion [1].

16.3 Methodologies/Experimental Set-Up/Model Set-Up

This paper aims to explain the flow map, which consists of a research framework that is essentially the work outline, conducive to the design of turbocharger runners. Next is the method of achieving or approaching something, particularly a systematic or established one, which is a specific procedure. Modelling is the method of project design and step-by-step design in CAD, divided by two parts that are modelling and analysis, while the air flow simulation shows the properties and the simulation process in the analysis and also the calculation involving flow rate and velocity in this paper.

16.3.1 Methodology Process

A methodology process is an approach with a defined set of rules, methods, testing operations, deliverables and processes to do something that typically serves to solve a particular problem. There are two parts of the methodology in this project: the first part is modelling and the second part is simulation of analysis.

16.3.1.1 Modelling

For this research, the modelling was performed using the 3D modelling SolidWorks software to visualize how different geometries affect parameters such as the length of manifold. The 3D modelling is performed at the engine full load condition. The modelling was done to study the result of the parameter differences by improving the design and geometry of every runner part in the exhaust system on the turbocharger performance. The explanation of this research is as below:

(a) Construct a 3D model of the present exhaust manifold system using SolidWorks.
(b) Create a component modelling using SolidWorks 3D as shown in Fig. 16.4.
(c) Assemble the developed complete part and both intake and exhaust system to form a complete manifold runner for the simulation purposes (Fig. 16.3).

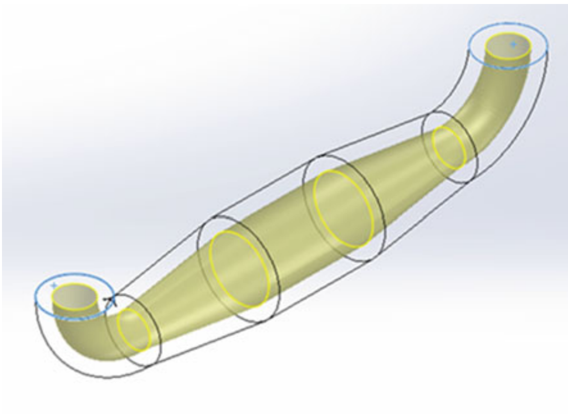

Fig. 16.3 Remove material inside by using shell function

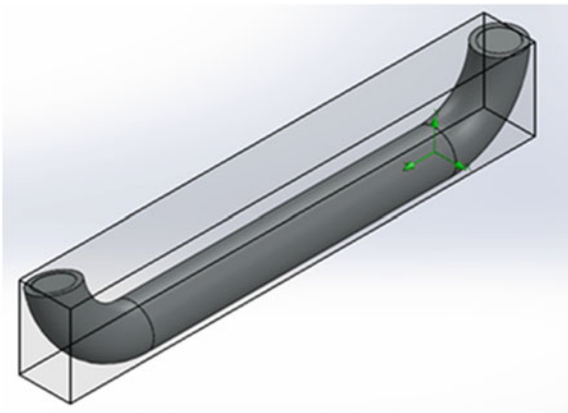

Fig. 16.4 Computational domain of current runner

16.3.1.2 Simulation Analysis

For this research, the simulation was performed using airflow simulation in SolidWorks to visualize how different geometries affect parameters such as the elbow diameter of the runner and to achieve a certain result that will optimize the design. The simulation analysis is performed at the engine full load condition as shown in Fig. 16.5. The simulations were done to investigate the impact of the parameter variations by optimizing the design and properties for the manifold system on the turbocharger system performance. The explanation of this research is as below:

(a) Develop engine model for this research using the airflow simulation software.
(b) Run the simulation on the complete system with properties to obtain the performance result of the air flow velocity and pressure.
(c) Perform a parametric study on the exhaust manifold system.
(d) Analyse the results from the parametric study and perform the optimization towards the parameter of the intake manifold system by using the method based on the second journal.
(e) Review the results after implementing the optimization values of the parameter on the present exhaust manifold system.

16.4 Results and Discussion

After running the optimization process using the simulation air flow method according to the proposed setup in order to achieve the desired target, the values for each of these three design parameters were obtained through the optimization results performed earlier. Figure 16.5 shows the optimizing design which combines the best of the three parameters. Figure 16.6 shows a clear wireframe design to make a view of the inner design and Fig. 16.7 is a simulation on flow trajectories velocity and pressure and the contour for pressure and velocity.

The elbow diameter is the first design parameter where an elbow offers a change in the direction of material flow. This causes the device to lose pressure due to impact, friction and re-acceleration. Manifold length second parameters were one of the important characteristics when concerning intake and exhaust manifold runners. The shape of the runners themselves is perhaps similarly as important. Tapered diameter third parameter is where a process of providing the slope between two surfaces objects with the use of the tapered pipe.

In the first parameters, i.e. elbow diameter, the best velocity would be design ED9 with 65.24% increase whereas for the best pressure it would be design ED9 with 88.09% increase. For the second parameters, i.e. the manifold length, the best velocity would be for design ML15 with 2.05% increases meanwhile the best of pressure would be for design ML1 with 6.13% increases diameter which the best velocity would be for design TD3 with 2.24% increases and for the best pressure would be for design TD4 with 6.91% increases. However, the design TD3 with 6.84%

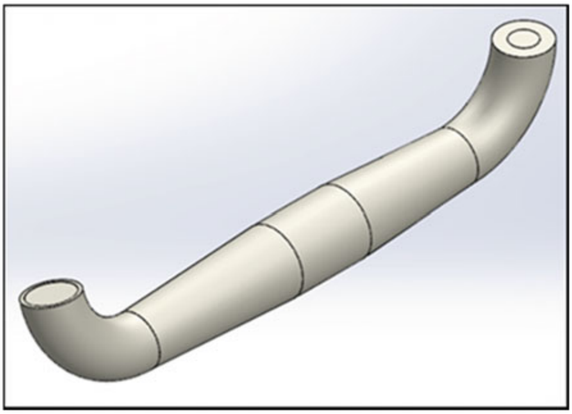

Fig. 16.5 Final design of MW

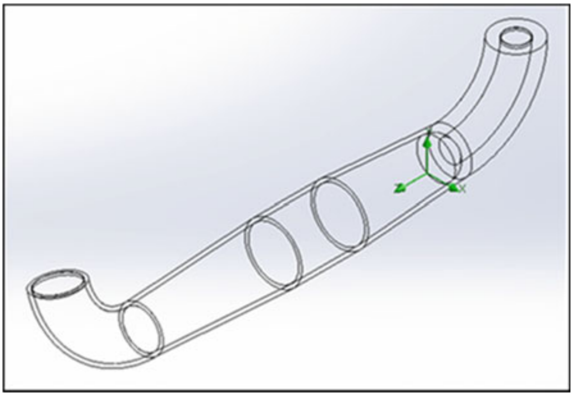

Fig. 16.6 Wireframe of MW

was selected due to higher velocity value. But the design ML15 with 5.60% was selected due to higher velocity value. Last parameter is tapered as the percentage increases for each parameter but the most significant affecting the result analysis would be the first parameter which is elbow diameter that increases velocity by 65.24% and the pressure by 88.09% which turn into main influence to the air flow inside the runner. Table 16.2 shows the data or result of the final design.

16.5 Conclusion

In conclusion, the correlation between each design parameter and the engine output is clearly established by the parametric analysis. The targets for the optimization also were successfully achieved. The improvement of air flow velocity is significant with the highest increment of about 65.24% at design ED9 whereas for the pressure, the most significant improvement also occurred at design ED9 with 88.09%

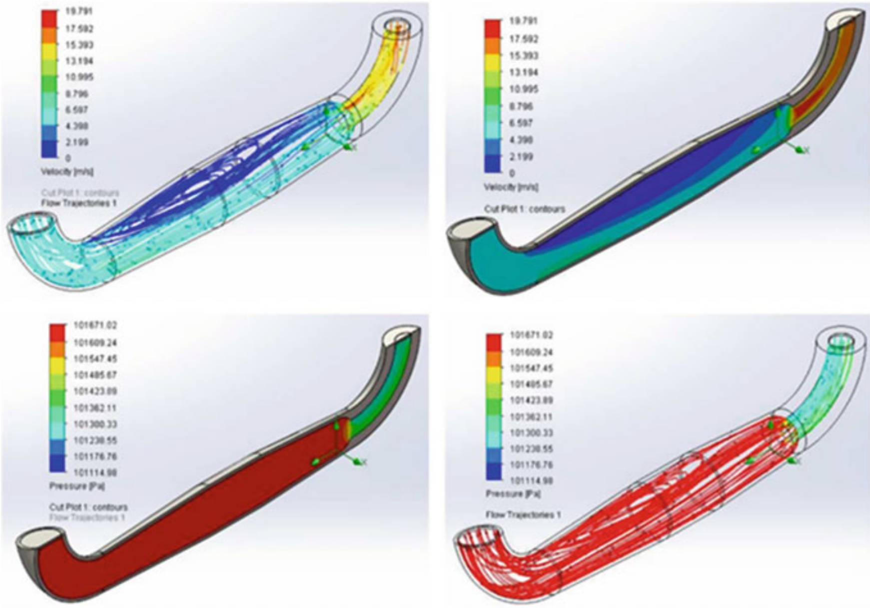

Fig. 16.7 Velocity and pressure of flow trajectories and contour

Table 16.2 Result of final design

Goal Name	Unit	Value	Averaged value	Minimum value	Maximum value
SG Av dynamic pressure 1	[Pa]	28.57	28.57244015	28.57122358	28.5744519
SG Av dynamic pressure 2	[Pa]	240.59	240.5640328	240.3140754	240.8081782
SG Av velocity 1	[m/s]	5.58	5.580028426	5.580028426	5.580028426
SG Av velocity 2	[m/s]	16.09	16.09739693	16.09355366	16.10185785

increment. The most significant parameter affecting the result analysis would be the first parameter which is the elbow diameter that increases both velocity and pressure which turn into the main influence on the air flow inside the runner. To conclude, the overall performance of the engine for the improvement at the runner manifold of the turbocharger has been successfully achieved through the implementation of the optimization approach.

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