Iran University of Science and Technology

Automotive Science and Engineering

Journal Homepage: ijae.iust.ac.ir

ISSN: 2008-9899

# Comparing the effects of geometric changes of the input and output manifold on engine performance

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**ARTICLE INFO**

**Article history**:
Received : 17 Nov 2020
Accepted: 3 Mar 2022
Published: 6 Mar 2022

**Keywords**:
Intake manifold
Outlet manifold
Geometry parameter
Diesel fueled engine
GT SUITE

**A B S T R A C T**

Many efforts have been made to increase power and reduce emissions from internal combustion engines. For this purpose, the internal combustion engine subsystems are examined via many studies, and the effective parameters in each of them are analyzed. One of these subsystems is the air inlet and outlet to the combustion chamber, the most important part of which is the manifold. In the present study, using one-dimensional modeling of the OM457 heavy diesel engine in the GT SUITE software environment, the effect of geometric parameters of cylinder runner's length - cylinder runner's transverse distance as well as plenum's depth on the performance and the emissions of this engine has been investigated. During this study, it was concluded that increasing the volume of the plenum not only improves the engine's output but also reduces the emission of pollutants produced. Also, increasing the length of the cylinder runner increased the engine power. The change in the transverse distance of the cylinder runners did not have a significant effect on the power and pollutants of the sample engine. It was also observed that in similar geometric changes, the effect of changing the input manifold is significantly greater than the output manifold level.

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https://doi.org/10.22068/ase.2022.579

## 1. Introduction

The internal combustion engine is still the most common source of power for heavy-duty vehicles. But the comfort that internal combustion engines provide is not without compensation and cost. The main input of these cars is fossil fuel, which is a limited and non-renewable source. Burning fossil fuels emits greenhouse gases, which in turn causes global warming [1]. Due to this and the strictness of environmental organizations, it has forced automotive factories to compete to build and optimize vehicles that meet the needs of the user. And optimal act, also in the field of pollution. One of the main and important systems in the power generation process in the engine is the process of fluid entry and discharge, before and after the combustion process, which has a significant role in pollution as well as engine performance. This system, the most important member of which is the inlet and outlet manifolds, needs a lot of analysis due to its complex geometry and oscillating fluid flow[2].

One of the first researches and studies of fluid flow in manifolds can be referred to the studies of Bartent (1927) and Watmo (1937) which studied the effect of fluid pressure and velocity in carburetor engines of that time. This was the beginning of research on manifolds and the effect of its geometry on the output power as well as pollutants of internal combustion engine[4].

Among these researches, we can mention the research of Kakai and Farrokhzadeh[5], during which they chose the optimal geometry for an XU7 engine from among the twenty available geometries. Also in 2011, Porter et al.[6] were able to show that by changing the length of the cylinder runners and the volume of the plenum and other geometric parameters, the engine output and the torque can be increased. Among the researches on the effect of manifold geometry on the specific fuel consumption of the engine, we can refer to the research of Samuel et al.[3] they showed that by changing the length of the inlet cylinder runners, fuel consumption can be reduced as shown in Fig. 1, while also having a higher output power.

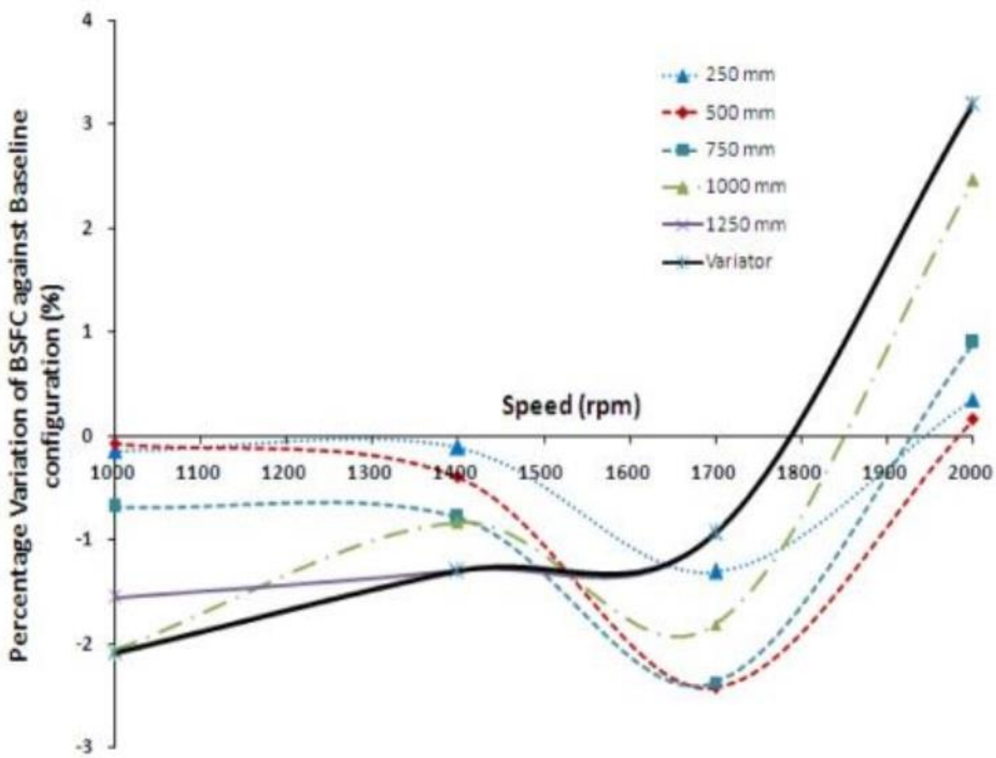


**Figure 1:** The effect of cylinder runners length on fuel consumption during the research of Samuel et al.[3]





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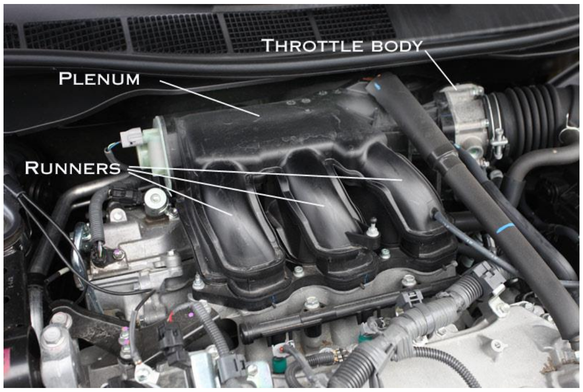


**Figure 2:** The location of geometric parameters studied in manifold analysis

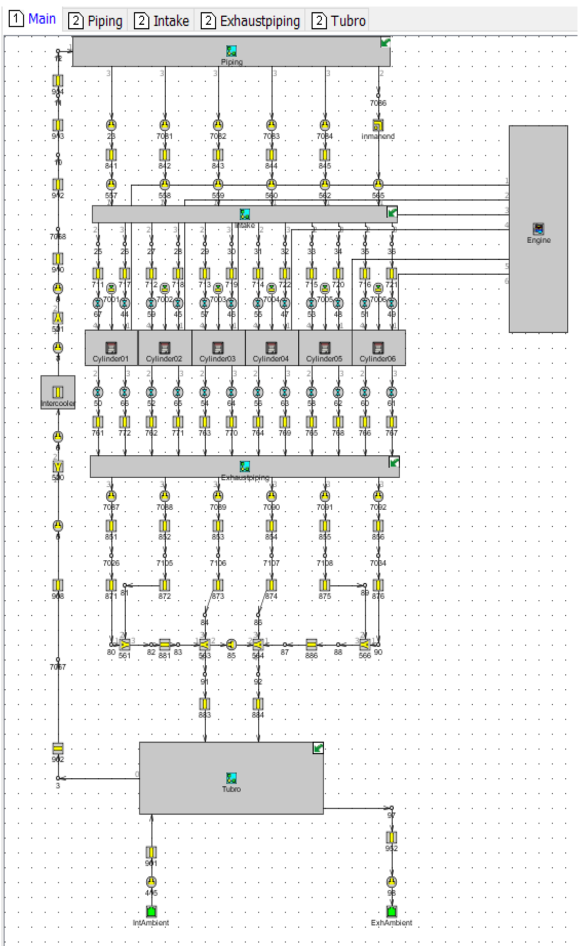


**Figure 3.** OM457's map modeled in the present study in GT SUITE software

Khalkhali et al.[7] in 2016, Also analyzed some selected geometries for the input manifold during a one-dimensional study and analytical cycle, and then entered the optimal manifold's geometry dimensions as input for analyzing the engine under consideration, during which it was observed that the engine output increased. According to the mentioned contents, for each engine, according to its conditions, it is necessary to analyze and study the geometric parameters of the input and output manifolds. Therefore, during the present study in the sample engine, the effect of inlet and outlet manifold geometric parameters (such as cylinder runner's length - cylinder runner's transverse distance and plenum's depth which are showed in Fig. 2 on the output power of the engine as well as pollutants obtained during the combustion process has been investigated.

## 2. The engine's parameter and the case study

As mentioned, the engine under study in the present study is the OM457 engine made by Mercedes-Benz, which is in the category of heavy diesel engines. Table 1 presents the specifications of this engine.

The model used for analysis in the GT SUIT software is the model used in the study of Afshari et al.[9], which the engine's map is shown in Fig. 3. Its validation has also been confirmed by reviewing and comparing the engine output parameters with the data of the engine released by manufacturer as mentioned at their study. Table 2 presents these values and the values provided by the manufacturer at 2000 rpm, which is the maximum output power of the engine, and its error percentage is calculated.

**Table1.** Specifications of the examined motor, OM457 [8]

| | |
|---|---|
| Bore (mm) | 128 |
| Stroke (mm) | 155 |
| Displacement (CC) | 11/967 |
| Compression ratio | 18.5 |
| Rated power | 260 kW @ 2000 rpm |





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| | |
|---|---|
| Maximum torque | 1.6 kN.m @ 1100 rpm |
| Mean effective pressure | 13.03 bar @ 2000 rpm<br>18.2 bar @1100 rpm |
| Valves layout | 2 intake and 2 outlet valves for each cylinder |

**Table 2.** Model simulation results and engine information

| | provided by the manufacturer | model simulation result | error percentage |
|---|---|---|---|
| **Rated power (kW)** | 260 | 260.52 | 0.2 |
| **Mean effective pressure (bar)** | 13.03 | 13.081 | 0.4 |

As shown in Table 2, the error percentage of the model is less than 1%, so this model is reliable.

## 3. Simulation results

Now, knowing the accuracy of the model under study, the parameters of the manifold such as cylinder runner's length - cylinder runner's transverse distance and plenum's depth for this engine are reduced and increased respectively. The results such as engine's output power and the diagram of Pressure-percentage of unburned fuel and nitrogen oxides in terms of crank angle for all states are presented in these changes made for the inlet and outlet manifolds.

### 3.1. Changes along the cylinder runner's length in inlet and outlet manifold

The length of the main cylinder runner's length of the OM457 engine in inlet and outlet manifold is equal to 14 cm. To investigate the effect of this parameter, we first set the length of the cylinder runner to 13 and then to 15 and simulate the engine. By applying the above change, the diagram of Fig. 4 presents the pressure (bar), the mass ratio of unburned fuel and NOx (ppm), respectively.

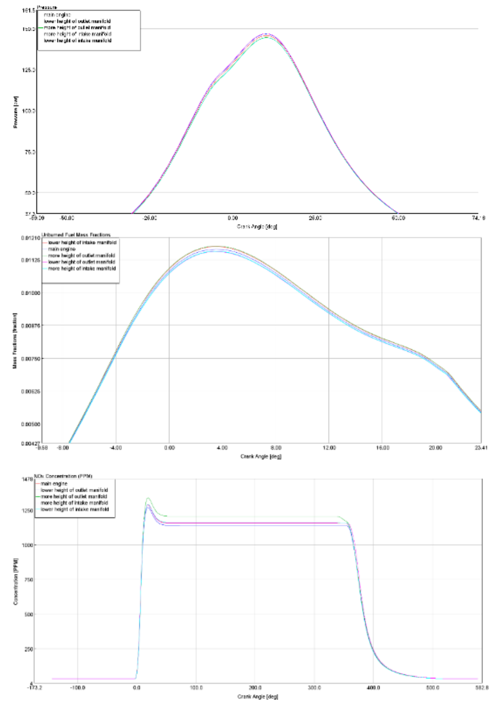

**Figure 4.** A: Pressure, B: mass ratio of unburned fuel, C: amount of NOx at each crank angle with change along the cylinder runner's length in inlet and outlet manifold

Table 3 also shows the changes in engine output power after the change along the cylinder runner's length in inlet and outlet manifold.

**Table 3.** engine output power after the change along the cylinder runner's length in inlet and outlet manifold

| | Power (kW) @ 2000 rpm at each cylinder |
|---|---|
| Main engine | 43.42 |
| Lower cylinder runner's length in inlet manifold<br>(percentage of changes) | 43.38<br>(-0.09%) |
| More cylinder runner's length in inlet manifold<br>(percentage of changes) | 43.46<br>(+0.1%) |
| Lower cylinder runner's length in outlet manifold<br>(percentage of changes) | 43.42<br>(0%) |
| More cylinder runner's length in outlet manifold<br>(percentage of changes) | 43.43<br>(+0.02%) |





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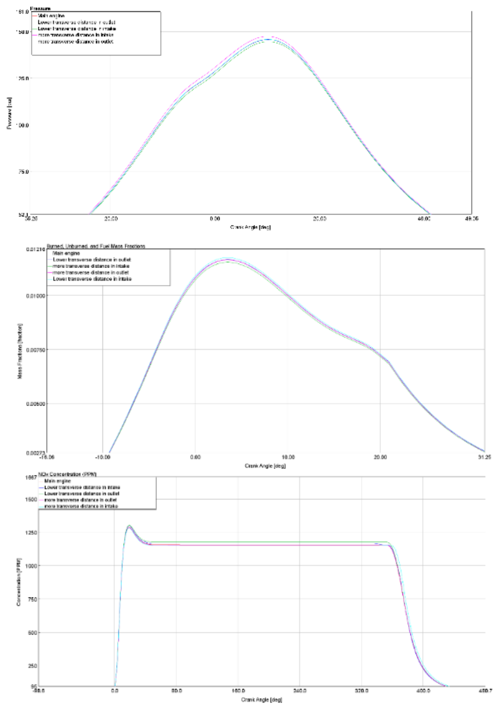

**Figure 5.** A: Pressure, B: mass ratio of unburned fuel, C: amount of NOx at each crank angle with change along the cylinder runner’s transverse distance in inlet and outlet manifold

**Table 4.** Engine output power after the change along the cylinder runner’s transverse distance in inlet and outlet manifold

| | Power (kW) @ 2000 rpm at each cylinder |
|---|---|
| Main engine | 43.42 |
| Lower cylinder runner’s transverse distance in inlet manifold<br>(percentage of changes) | 43.39<br>(-0.06%) |
| More cylinder runner’s transverse distance in inlet manifold<br>(percentage of changes) | 43.45<br>(+0.09%) |
| Lower cylinder runner’s transverse distance in outlet manifold<br>(percentage of changes) | 43.44<br>(+0.02%) |
| More cylinder runner’s transverse distance in outlet manifold<br>(percentage of changes) | 43.42<br>(+0.01%) |

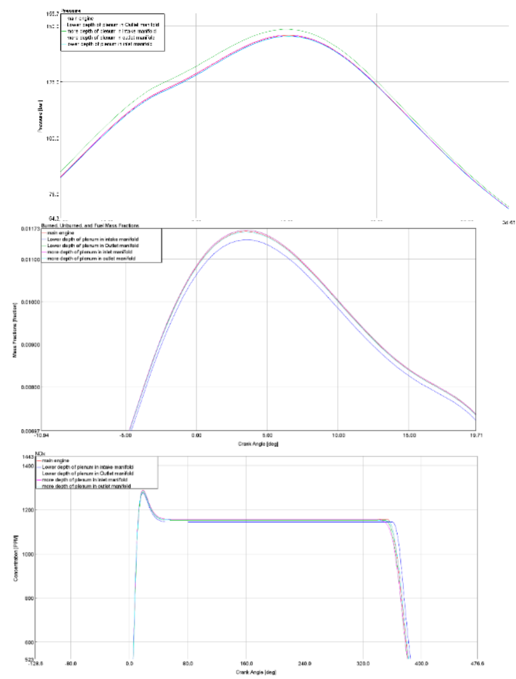

**Figure 6.** A: Pressure, B: mass ratio of unburned fuel, C: amount of NOx at each crank angle with change along the depth of the plenum in inlet and outlet manifold

### 3.2. Changes along the cylinder runner’s transverse distance in inlet and outlet manifold

The transverse distance between the two-cylinder runner in the OM457 engine is equal to 12 cm. In the continuation of the present study, to investigate the effect of this parameter, we consider this distance to be once equal to 13 and once equal to 11 cm. By performing the simulation, we get the results according to Fig. 5 and Table 4. It should be noted that by changing the transverse distance, the length of some cylinder runner will change by 3 to 4 cm.

### 3.3. Changes along the plenum’s depth in inlet and outlet manifold

Like the last two sections, in this section we examine the effect of the volume of the plenum in intake and outlet manifold on the performance of the engine. The depth of the plenum in this engine is equal to 112 mm. To check this parameter, we consider this depth once equal to 100 and again equal to 120 mm, and the results like the previous sections are presented in Fig. 6 and Table 5.

**Table 5.** engine output power after the change along the depth of the plenum in inlet and outlet manifold

| | Power (kW) @ 2000 rpm at each cylinder |
|---|---|
| Main engine | 43.42 |
| Lower depth of the plenum in inlet manifold (percentage of changes) | 43.25 (-0.4%) |
| More depth of the plenum in inlet manifold (percentage of changes) | 43.9 (+1.04%) |
| Lower depth of the plenum in outlet manifold (percentage of changes) | 43.44 (+0.03%) |
| More depth of the plenum in outlet manifold (percentage of changes) | 43.41 (0.02%) |

## 4. Conclusions

In this section, the results of the second part of the present study will be analyzed and the results obtained from the simulations of the sample engine with the mentioned geometric changes will be expressed.

- As the length of each cylinder runner in the inlet manifold increases, the pressure inside each cylinder and the output power of each cylinder increase. This result is in Full compliance with the results obtained in previous studies, such as Priyadarsini's study in the 2011[10]. In the sample heavy-duty diesel engine, this increase in power is significant to the point where the output power is increased by a 0.1 percent increase in cylinder runner length by 5, meanwhile the NOx pollutant as well as unburned fuel did not change significantly.

- With increasing the width of the inlet manifold (cylinder runner’s transverse distance), the engine power increases slightly (8% change in the transverse distance of the cylinder runner will lead to a change of 0.07 % in the output power.) The output pollutants do not change significantly during the change of this parameter.

- By increasing the depth of the plenum chamber in the inlet manifold, due to the decrease in turbulence of the fluid and its pressure, an increase in output power was observed (7% increase in the depth of the plenum, will cause an increase in the output power by 1.1 kW), unburned fuel is also reduced, which in turn reduces pollutants such as soot and unburned hydrocarbons. The NOx pollutant did not change significantly.

- According to the above results, increasing the volume of the plenum in intake manifold has priority in improving the performance and reduction of pollutants of the OM457 engine, and then increasing the length of the cylinders runner is also a good solution. The change in the width of the inlet manifold, or in other words, the change in the transverse distance of the cylinder runners, has no economic excuse for reviewing and analyzing its geometry, as well as construction costs.

- By changing the geometric parameters of the output manifold, despite the presence of turbocharging in the engine, we do not see a significant change in the output power and pollutants of the engine. Therefore, to increase the output power and reduce engine pollutants, change in the inlet manifold is a priority and a change in the output manifold is not reasonable.

## Reference

[1] A. Haines, A. McMichael, K. Smith, I. R.-T. Lancet, and undefined 2009, “Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers,” *Elsevier*.

[2] J. Heywood, “Internal combustion engine fundamentals,” 1988.

[3] K. A. J Samuel, NS Prasad, “Effect of Variable Length Intake Manifold on a Turbocharged Multi-Cylinder Diesel Engine,” *SAE Tech. Pap. 2013- 01-2756*, 2013.





[ DOI: 10.22068/ase.2022.579 ]

[4] D. Winterbone and R. Pearson, “Theory of engine manifold design: wave action methods for IC engines,” 2000.

[5] A. Mohammadebrahim and A. H. Kakaee, “Intake Manifold Optimization of XU7 Engine to Improve Volumetric Efficiency,” *J. Engine Res.*, vol. 20, no. 20, pp. 3–11, Oct. 2010.

[6] M. A. Porter, “Intake Manifold Design using Computational Fluid Dynamics.”

[7] A. Khalkhali, M. S.-I. J. of Engineering, and undefined 2016, “Intake manifold flow assessment on a 3-cylinder natural aspirated downsized engine using CFD and GT-SUITE,” *ije.ir*.

[8] O. H. Euro, “Technical Data : OM 457 LA Technical Data : OM 457 LA,” pp. 2–6, 2009.

[9] D. Afshari, A. Afrabandpey, and R. Aghamohammadi, “Deploying Variable Valve Timing System in ’OM457’Diesel Engine to Reduce Specific Fuel Consumption and Its Impact on Emissions,” *researchgate.net*.

[10] Priyadarsini, “Flow analysis of intake manifold using computational fluid dynamics,” *Int. J. Eng. 2016, Undefined*, 2016.



[ DOI: 10.22068/ase.2022.579 ]