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Effects of modified intake surface to gasoline engine performance with the use of LPG

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Abstract

Indonesia observes a yearly rise in motor vehicle possession. Failure to consider alternate fuels in these trends may result in the depletion of gasoline. Out of the potential alternatives, Liquified Petroleum Gas (LPG) appears to be the most favorable. The sole issue lies in the elevated engine temperature and subsequent decrease in performance caused by its utilization. To address this vulnerability, it is advisable to employ a cooling injection method, such as water injection. Nevertheless, the rise in exhaust emissions linked to water injection highlights the necessity for optimization. This study aims to optimize coolant injection systems by conducting experiments with different modifications, such as conventional intake surfaces, dimple intake surfaces with gaps, and dimple intake surfaces without gaps. The gapless dimple inlet surface demonstrates superior performance in terms of exhaust emissions, power, and torque compared to both conventional inlet surfaces and slotted dimple inlet surfaces.

Keywords:
LPG fuel, emission exhaust, dimple intake, standard intake, cooling injection.

1 Introduction

Owners of motor vehicles in Indonesia are increasing day by day. A survey in 2017 shows motor vehicles in Indonesia amounted to 138,556,669 units, a very significant increase from 2015, which still amounted to 121,394,185 units [1]. The more vehicles running on the road, the more gasoline is used. Unless we find alternative fuel oils, humans soon run out of nonrenewable gasoline fuel. The type of gas fuel that has a high possibility of being used as an alternative fuel is Liquified Petroleum Gas (LPG) [2]. The price of traveling 100 km on LPG fuel is way more efficient than that of gasoline fuel. However, the use of LPG as a vehicle fuel still has many shortcomings so far [3]. The addition of LPG gas fuel to a diesel engine increases the exhaust gas temperature [4], which is compared straight to the greater amount of LPG gas fuel being mixed [5].

One of the technologies used to overcome engine heat is the addition of a cooling injection system. Water injection is an existing type of this system [6]. Intake manifold water injection is an effective way to control engine temperature. Despite such a breakthrough, the use of water injection in vehicles also has weaknesses. A considerable amount of water and methanol mixture does not burn in the engine [7]. The fuel mixture particles that do not receive enough oxygen to react may cause an incomplete combustion process to occur, thereby potentially increasing CO and HC levels [8].

Optimization of the water injection system is needed to overcome these problems. This study aims to optimize the water injection system with variations in the intake manifold so as to make the fuel mixture more homogeneous [9] additionally emphasized that the key to getting efficient combustion is to have sufficient vortex/mixture in the combustion chamber before ignition [10].

The functional signals come into play until the defuzzification layer, where the least squares method regulates the outcome parameters to minimize inaccuracies. The backward pass applies gradient descent to refine the parameters. Surface plots are used to depict the impact of input parameters on the GRG value. Performance evaluation revealed that the ANFIS projected data had a strong correlation with experimental data, boasting an overall correlation coefficient of 0.99415. The optimal operating conditions were determined to be an injection pressure of 194.32 bar, 1 LPM LPG flowrate, and 1.13 BP, resulting in an optimum GRG of 0.835084 [11].

Another study shows a fraction of exhaust gas is directed towards an intercooler, from where partially cooled gases are drawn into the inlet manifold for combustion. A noteworthy experimental study demonstrated that combining optimal part-cooled EGR flow rates with magnetic fields can significantly enhance LPG combustion characteristics, resulting in improved fuel economy of 13.8% and brake thermal efficiency of 3.9%. This combined approach also addresses one of the major drawbacks of LPG combustion, namely the increased emission of oxides of nitrogen. Additionally, the applied magnetic field can counteract any destabilizing effects on combustion stability caused by the recirculation of exhaust gases [12].

2 Research Methods/Materials and Methods

This research was conducted experimentally with variations in the intake manifold surfaces. The variations of intake surface are standard intake surface, dimple intake surface with gap, and dimple intake surface without gap. This research uses a motor vehicle with a 100 cc, 4 stroke, 1 cylinder engine as in previous research [13]. While the fuel used is 3 kg of LPG fuel from Pertamina, due to its affordability and practicality. The design of the dimpled intake surface with a gap and the dimpled intake surface without a gap can be shown in Fig. 1.

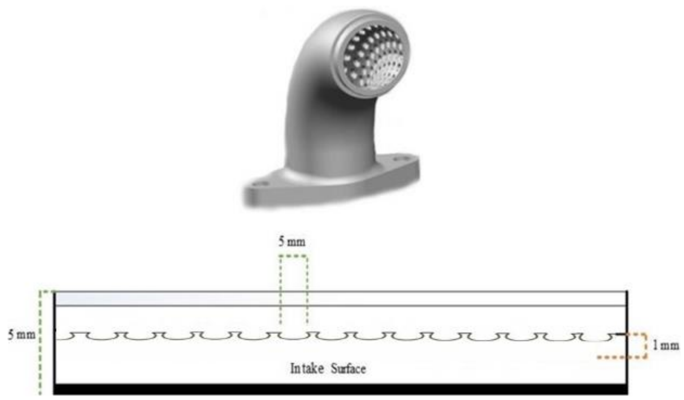

Fig. 1. Dimpled intake surface without gap.

Fig. 1 displays the specifications of the dimpled intake surface without a gap. The diameter of dimple ports is 5 mm, with 1 mm of depth, while the gap between ports is tight. While the thickness of an intake surface is 5 mm. For comparison, the design of a dimpled intake surface with gap can be seen in Fig. 2.

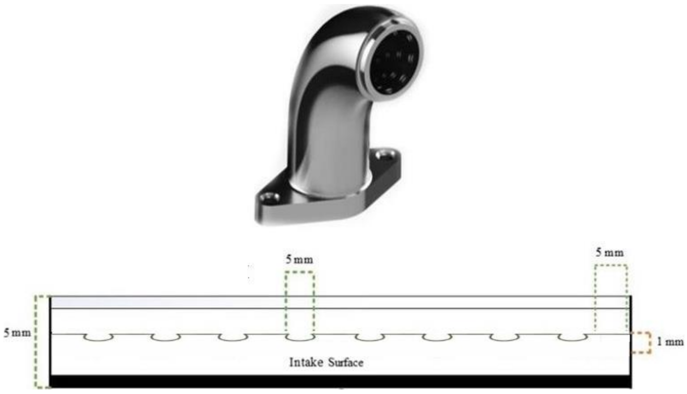

Fig. 2. Dimpled intake surface with gap design.

Fig. 2 shows the specifications of the dimpled intake surface with a gap. The dimple port has a diameter of 5 mm with a 1 mm depth, while the gap between the ports is 5 mm.

2.1 Power and Torque Test Preparation

To determine the amount of power and torque produced by the engine, a measuring instrument called a prony brake is used (please use italics) [14]. The basic principle of prony brakes is to utilize frictional resistance on the brakes. The magnitude of resistance can be obtained from the heavy load supported by the lever. Fig 3. shows the schematic of the prony brake on the machine.

Upon obtaining the load measurement results from the prony brake, it is necessary to calculate the torque value. The torque calculation is as Eq. 1.

$$T = F \times L \quad (1)$$

Description:
F = Torque (Nm)
L = Condenser length of prony brake (m)
F = Object centrifugal force (N)

After obtaining the torque value, only then can the power generated by the engine at each RPM be calculated. The calculation of power using torque is as Eq. 2.

$$P\ (kW) = 2 \times \pi \times N\ (rev/s) \times T\ (Nm) \times 10^{-3} \quad (2)$$

Description:
P = Power (kW)
T = Torque (Nm)
N = Engine speed (rev/s)

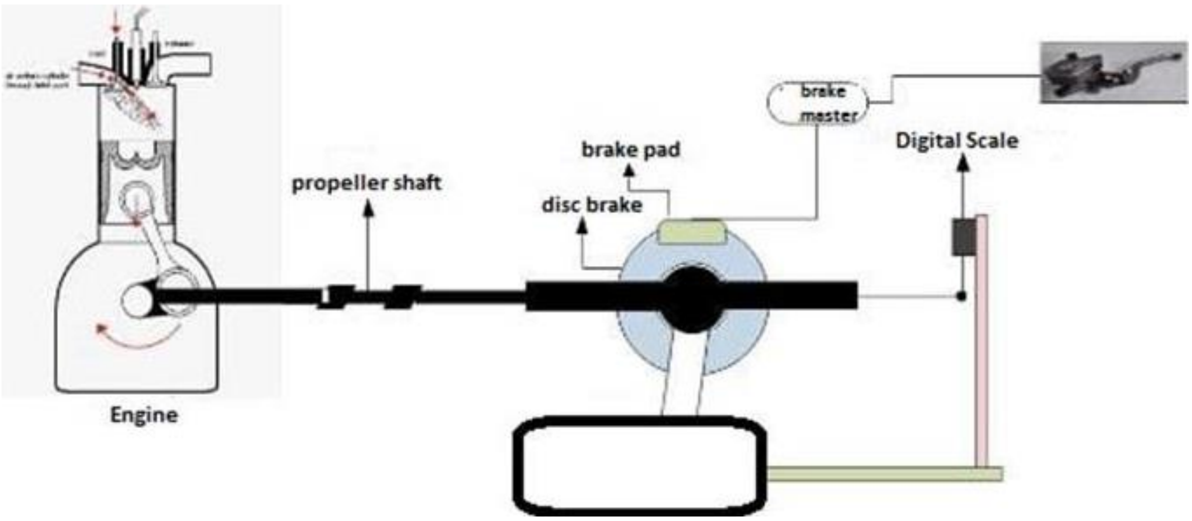

Fig. 3. Schematic installation of prony brake.

3 Results and Discussion

To determine the comparison of exhaust gas emissions of Hydrocarbon (HC) and Carbon Monoxide (CO) in motor vehicles with LPG fuel, the researcher made an exhaust gas emission table (Table 1). This is useful for determining how the big the effect of adding a dimpled intake surface.

Table 1. Exhaust gas emission

Exhaust emission	Standard intake surface	Dimpled intake surface with gap	Dimpled intake surface without gap
HC (ppm)	0.8	0.57	0.55
CO (%)	1327	1145	1048

The graph generated from the variation in intake surface shows the exhaust gas emissions of HC and CO at idle RPM. The results of the experiment research show that a dimpled intake surface without a gap has a lower exhaust emission than the standard intake and a dimpled intake with a gap as shown in Fig. 4 - Fig. 5.

3.1 Power and Torque Test

To find out the power produced by the engine, researchers made a table to compare the variation in intake surface. This is useful for determining how the big the effect of adding a dimpled intake surface. Power data collection was carried out three times. The results can be shown in Table 2.

Table 2. Power output

Engine speed (RPM)	Power output (kW)		
	Standard intake surface	Dimple intake surface with gap	Dimple intake surface without gap
3000	3.25	2.86	2.52
4000	3.84	3.81	3.96
5000	4.64	5.23	5.42
6000	5.97	6.34	6.53
7000	6.27	6.07	6.11
8000	5.84	5.38	5.53

Fig. 6 shows the results of power output from the standard intake manifold at low rotation (3000 RPM) is 3.25 kW bigger than the power output from the dimple intake surface with a gap of 2.86 kW and a dimple intake surface without a gap of 2.52 kW. But in the next rotation up to 6000 RPM, dimple intake surface without gap has increase power output. At 6000 RPM dimple intake surface without gap has biggest peak power 6.53 kW, while standard intake surface and dimple intake surface with gap 5.97 kW and 6.34 kW. This was due to the use of a dimple intake surface without gap at high RPM; the mixture of LPG fuel and water injection is more homogeneous so as to produce maximum power [15].

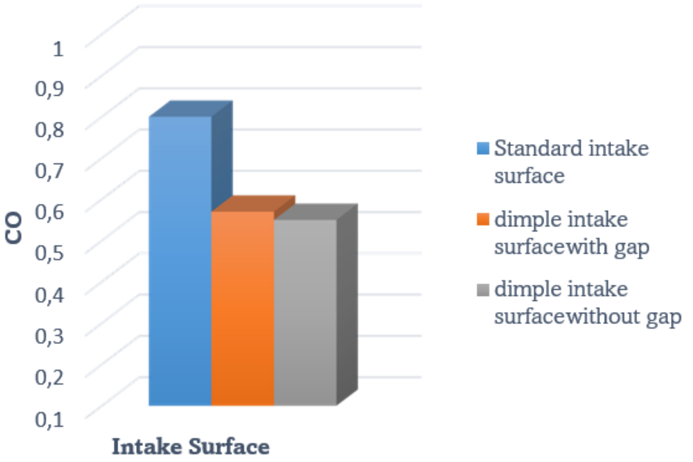

Fig. 4. Carbon monoxide emission exhaust.

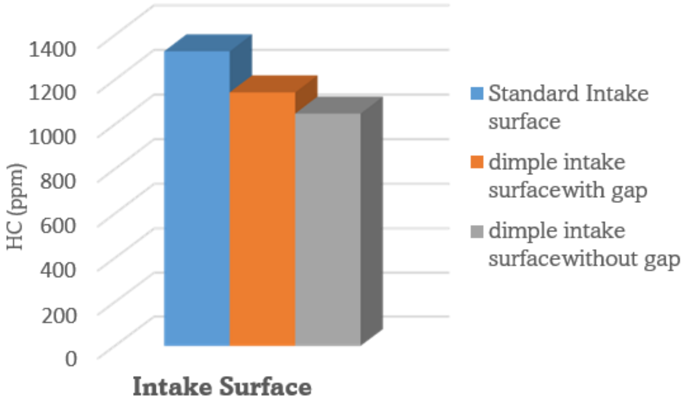

Fig. 5. Hydrocarbons emission exhaust.

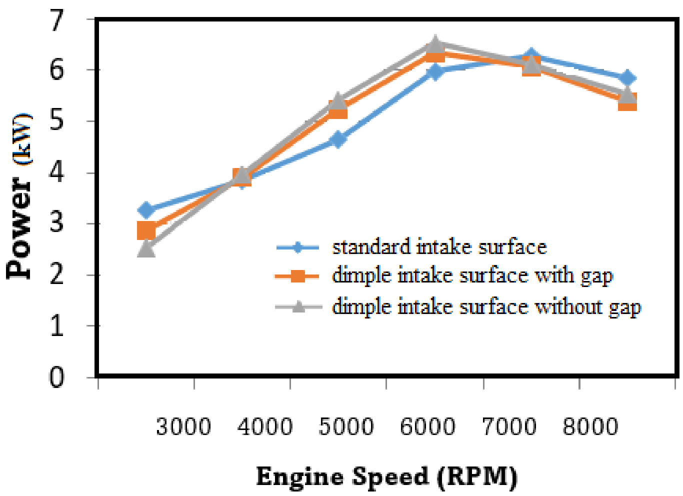

Fig. 6. Power graph of variation intake surface on engine speed.

To find out the torque produced by the engine, researchers made a table to compare the variation of the intake surface. This is useful for determining the big size of the effect of adding a dimpled intake surface. The torque data collection was carried out three times. The results can be shown in Table 3.

Fig. 7 shows the results of torque output from the standard intake manifold. Similarly, the engine power results, at 3000 RPM, torque output is 3.20 Nm bigger than torque output from engine which uses a dimple intake surface with a gap of 3.13 Nm and a dimple intake surface without a gap 2.92 Nm. But in the next rotation up to 7000 RPM, the dimple intake surface without a gap increases torque output. At 7000 RPM dimple intake surface without gap has the biggest peak torque of 6.29 Nm, while the standard intake surface and dimple intake surface with a gap are 6.17 Nm and 6.18 Nm, respectively. This is due to the use of a dimple intake surface without a gap at high rotation; the mixture of LPG fuel and water injection is more homogeneous so as to produce maximum torque.

Table 3. Torque output

Engine speed (RPM)	Torque output (Nm)		
	Standard intake surface	Dimple intake surface with gap	Dimple intake surface without gap
3000	3.20	3.13	2.92
4000	3.64	3.78	3.99
5000	4.75	5.23	5.52
6000	5.98	6.09	6.57
7000	6.17	6.18	6.29
8000	5.62	5.88	6.03

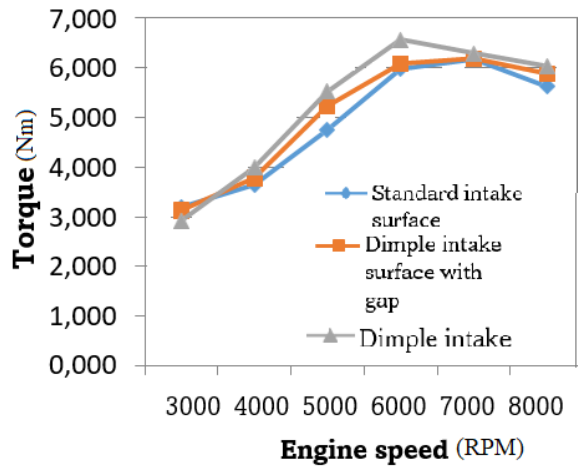

Fig. 7. Torque graph of variation intake surface on engine speed.

4 Conclusion

After analyzing the findings of a study conducted to optimize the cooling injection system and intake surface variation in a four-stroke LPG fuel engine, several conclusions can be drawn.

The experiment demonstrated that the dimpled intake surface, without gaps, results in a more uniform fuel and air mix, resulting in lower exhaust emissions. Specifically, the HC content produced by the dimpled surface was measured at 1048 ppm, while CO was at 0.55%—notably lower than the standard intake surface. The standard intake surface, which produced HC at 1327 ppm and CO at 0.80%, was far worse than the dimpled intake surface without gaps. In comparison, the dimpled intake surface with gaps produced HC at 1145 ppm and CO at 0.57%.

A dimpled intake surface without a gap was the key to optimal power and torque production. The resulting power output of such an arrangement was 6.5 kW at 6000 RPM, with a torque of 6.5 Nm at the same speed. This combination proved to be highly effective in reducing exhaust gas emissions and increasing power and torque on a 4-stroke LPG fueled-engine.

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