Jurnal
Teknologi

Full Paper

Characterization of Perodua Myvi K3-VE I4 Engine Performance Using Exhaust Gas Recirculation (EGR)

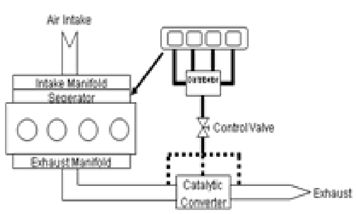
Article history
Received
31 January 2015
Received in revised form
30 April 2015
Accepted
31 May 2015

M. Hanif Mat Muhammad*, A. Qaiyum Hanafiah, Aman Mohd Ihsan Mamat

Automotive Research and Technology Centre (ARTeC), Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

*Corresponding author
mhanif76@salam.uitm.edu.my

Graphical abstract



Abstract

Internal combustion engines are the main power source for automobile vehicles. As current emission regulations becomes more stringent, more fuel efficient and less polluting engines are becoming the focus of car manufacturers. This paper presents the study of improving the performance of K3-VE I4 internal combustion engine that is used in the Perodua Myvi for the Perodua Eco-Challenge 2013. The strategy was to use an EGR system to reduce Brake Specific Fuel Consumption (BSFC) while maintaining or increasing the engine power. The effects of different location of EGR on the engine performance were tested on a chassis dynamometer. The sensitivity of the engine performance and gas emission were studied since EGR implementation plays a major role in influencing NOx emission. The performance parameter such as engine power and BSFC were then analysed. The result shows that a significant increase of power can be achieved and a reduction of around 56% was obtained on the BSFC. While the best NOx reduction was around 93%. These improvements are obtained at low RPM that corresponds to Perodua Eco-Challenge's objective.

Keywords: EGR, engine performance, NOx, ICE

1.0 INTRODUCTION

Currently, many researches are focused on improving engine performance while reducing fuel consumption. This is due to severe regulations on emission such as the EURO 6, allowing only 1.0 g/km of carbon monoxide (CO) and 0.06g/km of nitrogen oxides (NOx) to be emitted [1]. By creating more fuel efficient engines, less fuel will be used resulting in reducing atmospheric pollution. One of the strategies to increase the engine performance is by using the exhaust gas recirculation (EGR) system [2]. Other method used involves implementing swirl generator to create high velocity evaporation and air intake tank to increase intake pressure [3,4].

In the EGR system, downstream exhaust gas is recirculated into the intake manifold. Thus, some of the unburned fuel can be re-used in the engine. Exhaust gas recirculation system on gasoline engine is primarily to reduce throttling loss at part load range in order to reduce fuel consumption and secondly, to reduce NOx emission level [5]. This reduces the oxygen (O2) concentration and dilutes the intake charge, and reduces the flame temperature inside the combustion chamber which will simultaneously reduce the NOx formation [6].

NOx is well known to form at high temperatures and in an oxygen rich environment. NOx consist of nitric oxide (NO) and nitrogen dioxide (NO2) which are both dangerous to humans and the environment. The emission of internal combustion engine contains more NO than NO2, but NO will be oxidized quickly after entering air, transforming into NO2. The formation of NOx originates from thermal reaction of N2 and O2 in the air in high temperature combustion. NO is formed inside the combustion chamber in post-flame combustion process in high temperature region, three principal reactions described by extended Zeldobich Mechanism [7]:

$$N_2 + O \leftrightarrow NO + N$$
$$N + O2 \leftrightarrow NO + O \quad (1)$$
$$N + OH \leftrightarrow NO + H$$

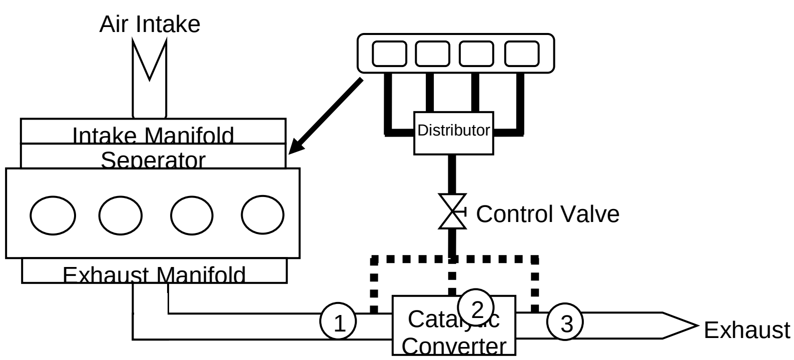
In this study, the objective of the EGR implementation is to reduce the fuel consumption and at the same time to increase the engine power at low RPM for city driving. This correlates to the objective of Perodua Eco-Challenge 2013 (PEC2013) where the car is driven in an urban track with obstacles to gain the longest distance with a specified amount of given fuel. However, NOx emission will also be studied seeing as they affect the environment directly.

The characteristic of exhaust gas is different along the exhaust pipe due to the presence of catalytic converter. In order to determine the best position to increase the engine performance, three exhausts tapping: one before the catalytic converter (Tapping 1); second in the middle of the catalytic converter (Tapping 2) and finally after the catalytic converter (Tapping 3) were investigated and analysed. The effect of several EGR valve opening (EGR concentration) on the engine performance and fuel consumption were measured on the chassis dynamometer. Gas analyser were used to analyse the emission effect.

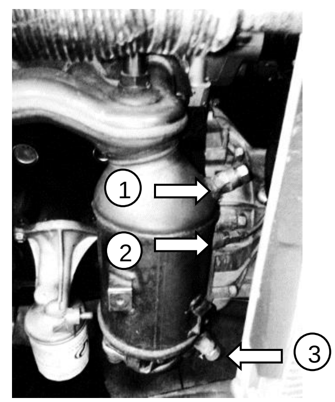
2.0 EXPERIMENTAL SETUP

2.1 EGR Setup

Exhaust gas were collected from three different point of interest one at a time and will be redirected into the distributor. The distributor will distribute the exhaust gas into each intake hole through the separator. The fresh air intake will mix with the recirculated exhaust gas before entering the combustion chamber in between the intake manifold and the engine intake hole. A valve is located between the tapping point and the distributor to control the flow of the recirculated exhaust gas. All this can be seen in Figs. 1a and 1.b. For the experiment, the car used a UK spec Myvi with 1.3L K3-VE I4 engine. Table 1 shows the summary of the engine specifications.



a. EGR flow diagram



b. Position of Tapping

Figure 1 EGR Setup

Table 1 Engine specifications for 1.3L K3-VE, UK spec Myvi

Engine Type	Water-cooled, 4-cycle, in-line 4-cylinder
Valve Mechanism	DOH DVVT
Total Displacement	1298 cc
Maximum output	64 kW @ 6,000 RPM
Maximum Torque	116 Nm @ 3,200 RPM

Table 2 Experimental Parameter

Parameter	Value
Start RPM	2000 RPM
Finish RPM	6000 RPM
System master	Master on front
Wheel diameter	580 mm
Drive ratio	5.012

2.2 Data Collection

Two equipment were used to collect the necessary data for the experiment; a dynamometer to collect power and torque data of the car engine and a gas analyser to collect exhaust gas emission data. Chassis dynamometer with direct coupling was used to eliminate wheel slip effect. Parameter of the experiment was setup into the Dynapack dynamometer software as per Table 2. Data for 2250 RPM to 5000 RPM was recorded for every run. Fuel consumption is monitored using a graduated modified beaker as an external tank. Each run is repeated five times and the average result is used as the final values.

3.0 RESULTS AND DISCUSSION

Before the EGR experiment, a baseline test was performed for data comparison. For each tapping, different opening of the valve was tested; this was also to evaluate the influence of exhaust gas quantity.

3.1 Performance Analysis

The main objective of the EGR system is to optimise the Brake Specific Fuel Consumption (BSFC) without reducing power.

3.2 Tapping 1

Fig. 2 and 3 compares the engine Power and BSFC to the baseline data. The power curve shows that overall power increase occurs below 3250 RPM for different EGR valve opening. Maximum engine power increase of 85% was recorded at 2500 RPM. A significant improvement of the BSFC is observed during low engine speed operation for the three valve opening. This result correlates with another finding by Deepak et al. [9], where at higher RPM, more fuel is injected while the amount of oxygen is reduced and in turn changes the air fuel ratio which reduces the BSFC. A maximum reduction of BSFC is documented approximately 56% at the engine speed of 2750 RPM.

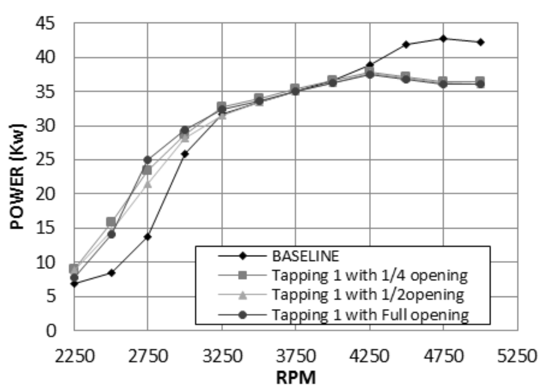


Figure 2 Comparison of Engine Power between Baseline and EGR Tapping 1

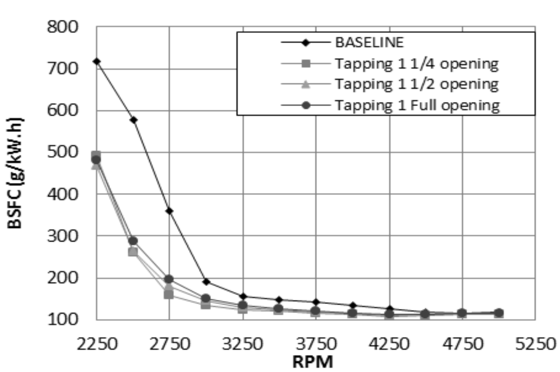


Figure 3 Comparison of BSFC between Baseline and EGR Tapping 1

3.3 Tapping 2

In the middle of the catalytic converter, ¼ opening of the valve only reduces engine power; this can be seen in Fig. 4. Nevertheless, an increase in engine power can be seen before the 3250 RPM mark for the other two openings. Here a gain of 67% in engine power can be observed at 2500 RPM with full opening of the valve. In Fig. 5, BSFC has the same characteristic as in Tapping 1, but the ¼ opening becomes impractical after 2500 RPM. Best reduction in BSFC is 50% for full opening at 2500 RPM

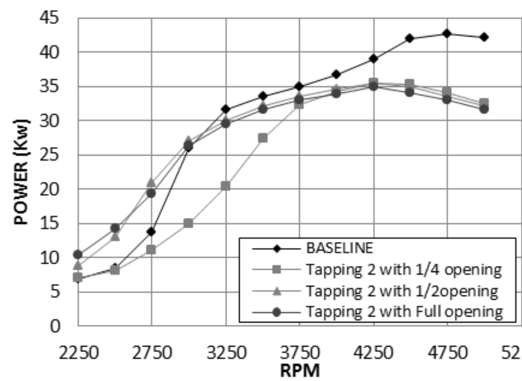


Figure 4 Comparison of Engine Power between Baseline and EGR Tapping 2

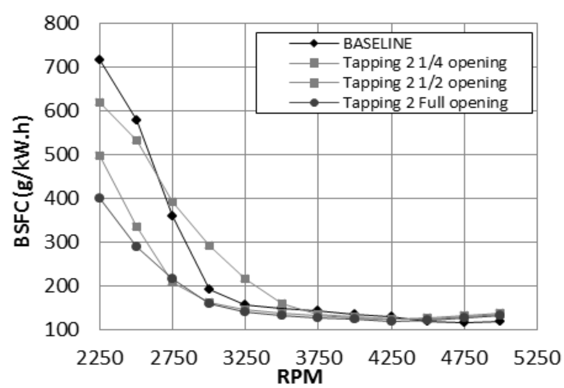


Figure 5 Comparison of BSFC between Baseline and EGR Tapping 2

3.4 Tapping 3

From Figs. 6 and 7 the engine power and BSFC for ¼ valve opening has very similar trend with the tapping at position 2. This time the maximum engine power improvement and BSFC saving is observed during full valve opening at 2500 RPM. The achieved engine power is very significant and the BSFC has reduced as much as 54%.

In order to profit the best increase in engine power and reduction in BSFC, the system should only operate at low RPM, from 2750 RPM and below.

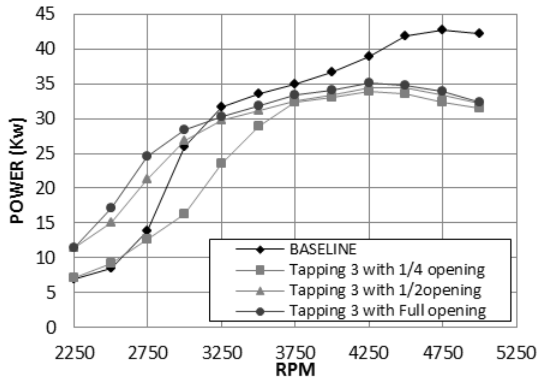


Figure 6 Comparison of Engine Power between Baseline and EGR Tapping 3

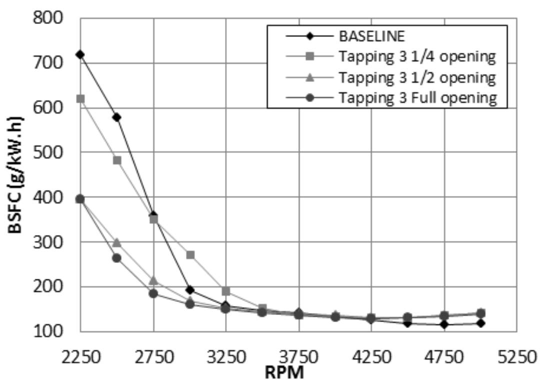


Figure 7 Comparison of BSFC between Baseline and EGR Tapping 3

3.5 Emission Analysis

From multiple research before this, it is shown that the effect of EGR will reduce the amount of NOx emission, the more percentage of EGR used will reduce NOx [8,9,10]. From Fig. 8, 9 and 10, the overall trend show a decrease in NOx measurement as the engine RPM increase, except for the quarter opening at tapping 2. Since the quantity of O2 is insufficient at high RPM like explained before, this reduces the flame temperature and thus reduce the amount of NOx [8]. The value reveals an increase in value for almost all the EGR opening for any valve opening compared to the baseline. For Tapping 1, the best was with the full opening of the valve but only between 1000 to 3000 RPM. Tapping 2 show no improvement of NOx emission compared to the baseline and recorded a maximum increase of NOx. The third tapping give best result with ¼ valve opening with a decrease of 93% in NOx emission at 2000 RPM

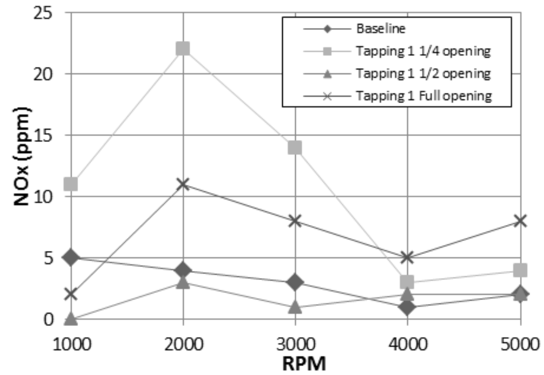


Figure 8 Comparison of NOx between Baseline and EGR Tapping 1

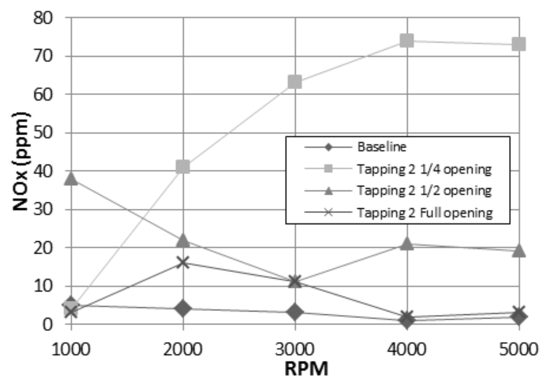


Figure 9 Comparison of NOx between Baseline and EGR Tapping 2

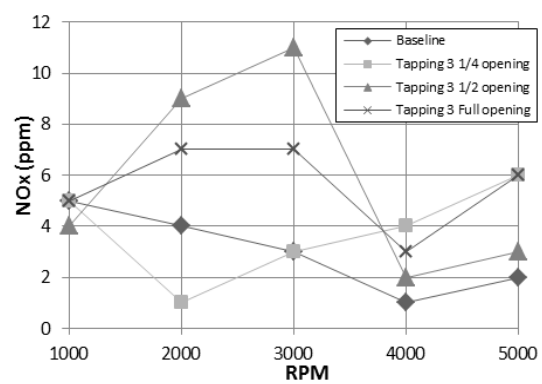


Figure 10 Comparison of NOx between Baseline and EGR Tapping 3

4.0 CONCLUSION

mprovements of the Power and fuel consumption succeeded for under 3000 RPM, this is still valid for city driving where there a lot of stop-and-go and meets the purpose of PEC2013. Improvement gain is 100% in term of engine power and around 56% of reduction in BSFC. Using Mass Specific Index (g/kW.h) as comparisons for NOx to the baseline would have been better since the EGR recirculate some of the exhaust gas. But this requires the mass flow rate of the exhaust gas which was unable to be measured with the chassis dyno setup.

Acknowledgement

The authors would like to acknowledge the Faculty of Mechanical Engineering Universiti Teknologi MARA for supporting the project and and Perodua Berhad for organizing Perodua Eco-Challenge 2013.

References

[1] Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information (Text with EEA relevance), *Official Journal of the European Union*, (2007), L 171/2-15.

[2] Lapuerta M, Hernandez J. J. and Gimenez F. 2000. Evaluation of exhaust gas recirculation as a technique for reducing Diesel engine NOX emissions. Proceedings of the Institution of Mechanical Engineers Part D, *Journal of Automotive Engineering*. 214: 85–93.

[3] Idris Saad, Baria, S. and Hossaina, S. N. 2013. In-cylinder air flow characteristics generated by guide vane swirl and tumble device to improve air-fuel mixing in diesel engine using biodiesel. *Procedia Engineering*. 56: 363 – 368.

[4] Muhammad, M. H., Badrulhisam, N. H., Hanafiah, A. Q., Abdullah, N. R. and Mamat, A. M. I. 2014. Characteristic of K3-Vei4 Engine Performance using Swirl Generator, Air Intake Tank and EGR Modification, *Paper presented at Automotive Innovation Green Energy Vehicle Conference*, Pahang. 65-74.

[5] Haiqiao We. 2012. Gasoline engine exhaust gas recirculation-A Review. *Applied Energy*. 99: 534-544.

[6] Rajput, R. K. 2005. *Internal Combustion Engine*, Laxmi Publications, New Delhi.

[7] Heywood J. B. 1988. *Internal Combustion Engine Fundamentals*, McGraw-Hill, New York.

[8] Hussain, J., Palaniradja, K., Alagumurthi, N. and Manimaran, R. 2012. Effect of Exhaust Gas Recirculation (EGR) on Performance and Emission characteristics of a Three Cylinder Direct Injection Compression Ignition Engine, *Alexandria Engineering Journal*. 51: 241–247.

[9] Deepak A., Shrawan K. S. and Avinash K. A. 2011. Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine, *Journal of Applied Energy*. 88: 2900–2907.

[10] Abd-Alla, G. H. 2002. Using exhaust gas recirculation in internal combustion engines: a review, *Journal Energy Conversion and Management*. 43: 1027–1042.