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VALVE TRAIN INVESTIGATION FOR CNG ENGINE APPLICATION

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ABSTRACT

Compressed natural gas (CNG) beyond doubt has better emission byproduct as compared to petrol for compression ignition engines [1]. For greener environment retrofitted or converted vehicle was introduced into the automotive market. This work investigates whether the valve overlap period affects the vehicle engine performance. From the study, it was found that for a single overhead camshaft engine, the valve overlap period does affect the engine performance. The results show that retrofitting the present vehicle without modifying the valve overlap period is not suitable for CNG. It reduces the engine performance by about 9% for part open throttle conditions as compared to petrol. The present overlap duration should be increased for better performance.

1.0 INTRODUCTION

An automotive internal combustion engine can function as a very powerful air pump and the more efficiently the air moves through it the more power the engine produces. The camshaft is the mechanical switching device that opens and closes the engine valves allowing air to enter and exit the engine combustion chambers. Thus, it is one of the key components of the engine system. Camshaft is usually the first engine component to be adjusted and modified in search of horsepower or economy. Camshafts differ in design for several reasons, but the two main factors are the extent of 'duration' and 'valve lift'. The 'duration' is the time the valve opens and is measured in degrees of crankshaft rotation. Duration determines the "rpm potential" of the engine and power band. However, longer duration means that the engine is not efficient at low rpm but will give better performance and increase torque at higher rpm. The "lift" is the distance the valve opens and is measured in thousandths of an inch of travel. The more the lift, the more is the air/fuel mixture that can enter and exit the engine combustion chambers, thereby producing more torque.

As mentioned earlier, valve 'duration' plays an important role in the engine performance. However, one must remember that there are two types of valve in an internal combustion engine - the intake and exhaust valves. The 'duration' relation between these two valves also plays an important role in the engine performance. Hence, one has to take full advantage of this valve 'duration' relationship to get the best engine performance - thus, the introduction of variable valve timing on petrol engine in the automotive industry. This is to meet customer expectations for vehicle with improved performance coupled with reduced fuel consumption, but at the same time meeting the exhaust emission legislation [2]. Porsche's VarioCam systems, for example, advances its valve timing and creates more overlap and earlier closing time than normal, yielding additional torque [3].

Hence, this pilot project is to investigate the engine performance with regard to valve 'duration' relationship, specifically its valve overlap fuel period for compressed natural gas (CNG) as its fuel and petrol as the control results. The engine used was PROTON model 4G15-SOHC (single overhead camshaft) – which is a carburetted engine.

2.0 THEORY ON ENGINE VALVE TIMING

The clearing out of the exhaust gases from the cylinder is improved by opening the exhaust valve before the piston has completed its power stroke and then delaying the closure of this valve until the piston has swept some amount of the cylinder on its exhaust stroke. Similarly, to improve the filling of the cylinder with a fresh charge, the inlet valve is designed to open just before the piston reaches TDC (top dead center) on its exhaust stroke. The inlet valve then remains open for the full induction stroke and the early part of the piston's compression stroke.

The angular crank movement, which occurs when the inlet or exhaust valve opens before TDC or BDC (bottom dead center), is referred to as the valve lead angle. While the crank movement after an inlet or exhaust valve closes after TDC or BDC, is referred as the valve lag angle. The total angular movement when both inlet and exhaust valves open simultaneously in the TDC region is then known as the overlap period (Figure 1) [4].

In its simplest form, when the inlet valves open the exhaust valves close at TDC on the piston's outward induction stroke; correspondingly, when the inlet valves close the exhaust valves open at BDC on the outward exhaust stroke. All the valves close during compression and power stroke.

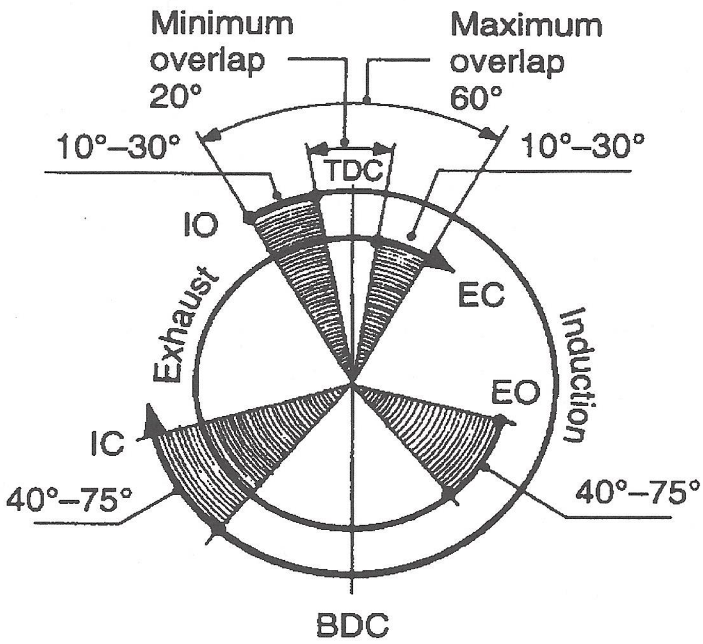


Figure 1 Range of valve leads and lags [4]

3.0 EXPERIMENTAL SETUP

The experiment was conducted to study the performance and characteristics of an engine that was operated at *constant throttling* condition. The engine speeds were varied between 1200 rpm to 4500 rpm. It was carried out under part throttle conditions in the range of 30% to 45% throttle opening. Wide-open throttle was not possible due to equipment limitation. Two types of fuels were used in this experiment, petrol and CNG. The investigation was carried out for three different types of camshaft valve overlap period. The first camshaft was taken from a standard PROTON engine with (S) valve overlap period while, the second and third have longer (+S) and shorter (-S) valve overlap periods, respectively. This standard camshaft (S), is to serve as an indication for our further work in optimisation of camshaft design for CNG application, while petrol was used as a controll experiment.

Table 1 Camshafts Specifications

Camshaft Identity	Camshaft part number	Intake/Exhaust overlap angles
(-S)	003151019-2	22°/48°
(S)	202240749-3	26°/67°
(+S)	010121823-6	34°/71°

Table 1 shows the intake and exhaust overlap angles where, camshaft (S) is the standard PROTON model 4G15-SOHC-carburetted engine while camshafts (–S) and (+S) were manufactured locally by MatSpeed Automotive Development Sdn. Bhd., Shah Alam, Selangor.

4.0 EXPERIMENTAL RESULTS

The experimental results were recorded and analyzed. The main results in this experiment are the power and the torque curves. These two curves are the characteristic curves for the engine performance.

Figures 2a and 2b show the results for the engine installed with camshaft (-S) and fuelled with CNG and petrol respectively; while Figures 3a and 3b show the power curves for the same engine installed with camshaft (S); and Figures 4a and 4b show the power curves for the same engine installed with camshaft (+S). Similarly, Figures 5 through 7 show the engine torque curves.

Table 2 44 % Part Open Throttle – CNG / Petrol

Valve Overlap	**Max. Power [rpm]**		**Max. Power [kW]**		**Torque [N.m]**	
	CNG	**Petrol**	**CNG**	**Petrol**	**CNG**	**Petrol**
$22^o/48^o$ (-S)	2625	2625	9.0	11.0	32.74	40.02
$26^o/67^o$ (S)	2550	2550	10.25	11.25	38.38	42.13
$34^o/71^o$ (+S)	2500	2500	11.0	12.25	42.02	46.79

Figure 2a. Power curve for CNG engine equipped with camshaft intake/exhaust overlap angles of $22^O/48^O$

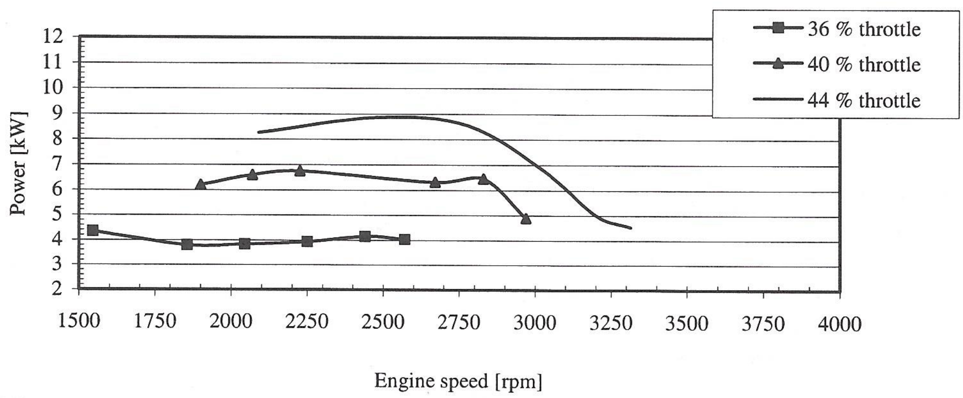


Figure 2b. Power curve for PETROL engine equipped with camshaft intake/exhaust overlap angles of $22^O/48^O$

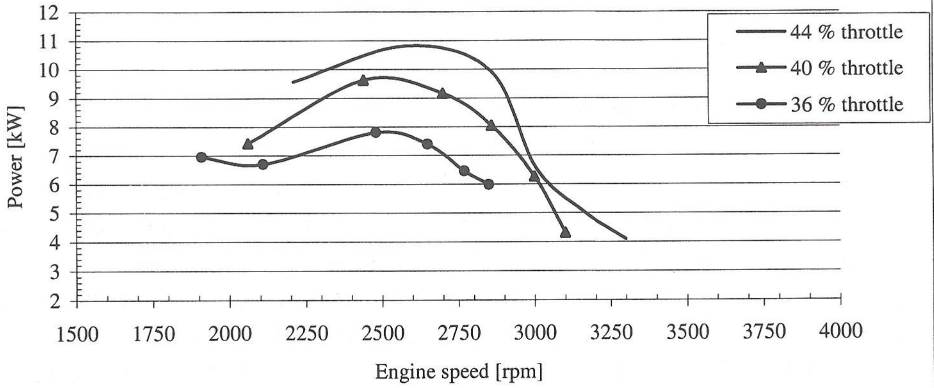


Figure 3a. Power curve for CNG engine equipped with camshaft intake/exhaust overlap angles of having $26^O/67^O$

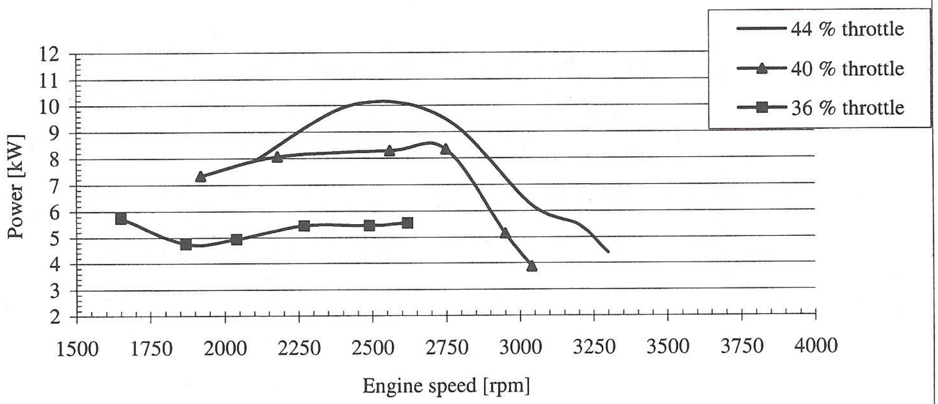


Figure 3b. Power curve for PETROL engine equipped with camshaft intake/exhaust overlap angles of having $26^O/67^O$

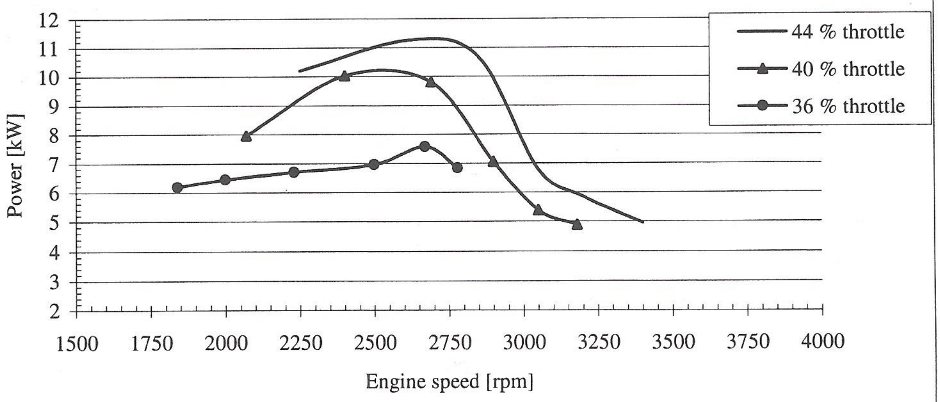


Figure 4a. Power curve for CNG engine equipped with camshaft intake/exhaust overlap angles of having $34^{O}/71^{O}$

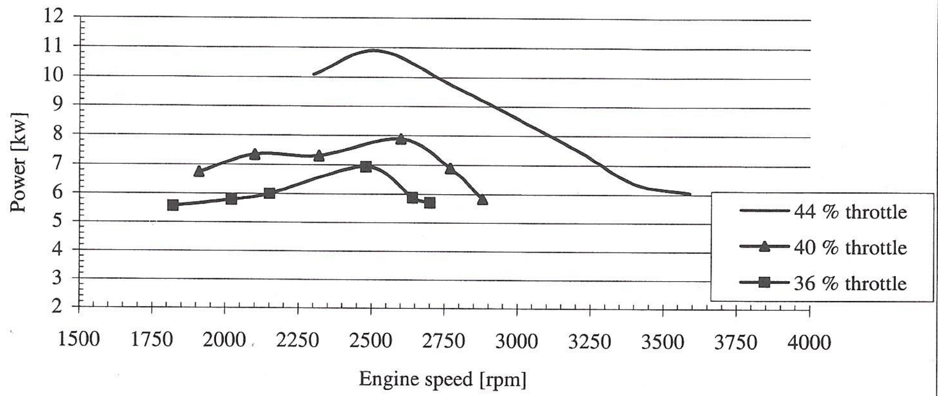


Figure 4b. Power curve for PETROL engine equipped with camshaft intake/exhaust overlap angles of having $34^{O}/71^{O}$

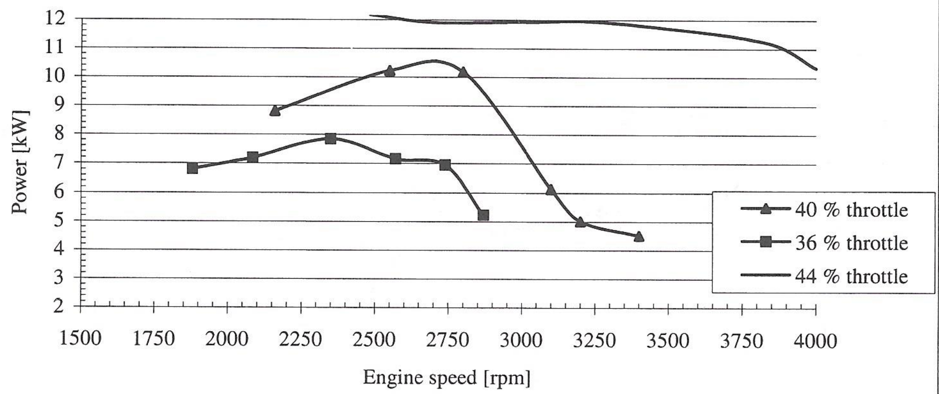


Figure 5a. Torque curve for CNG engine equipped with camshaft intake/exhaust overlap angles of $22^{O}/48^{O}$

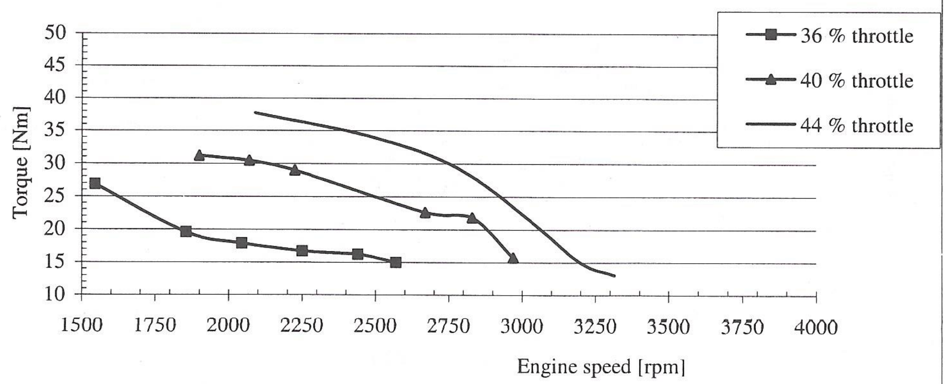


Figure 5b. Torque curve for PETROL engine equipped with camshaft intake/exhaust overlap angles of $22^{O}/48^{O}$

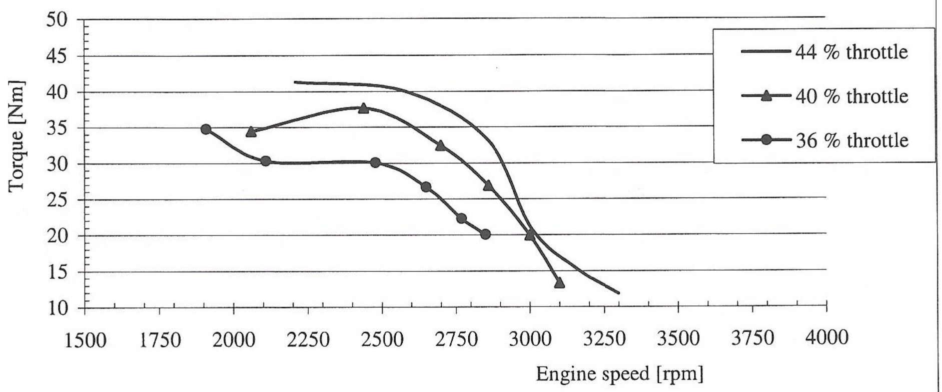


Figure 6a. Torque curve for CNG engine equipped with camshaft intake/exhaust overlap angles of having $26^{O}/67^{O}$

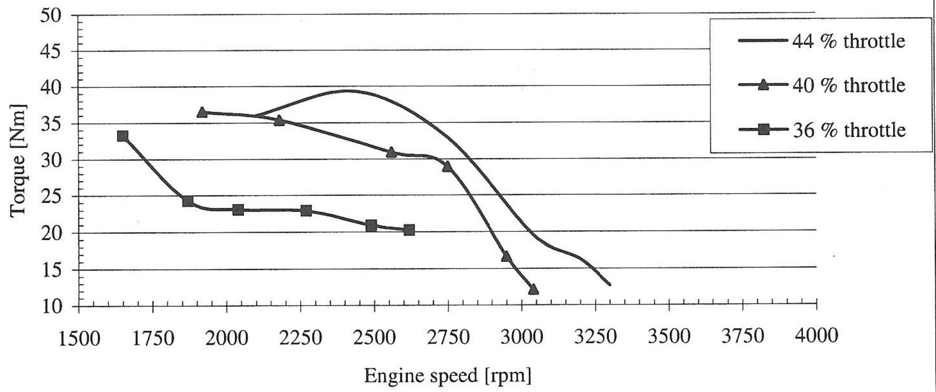


Figure 6b. Torque curve for PETROL engine equipped with camshaft intake/exhaust overlap angles of having $26^{O}/67^{O}$

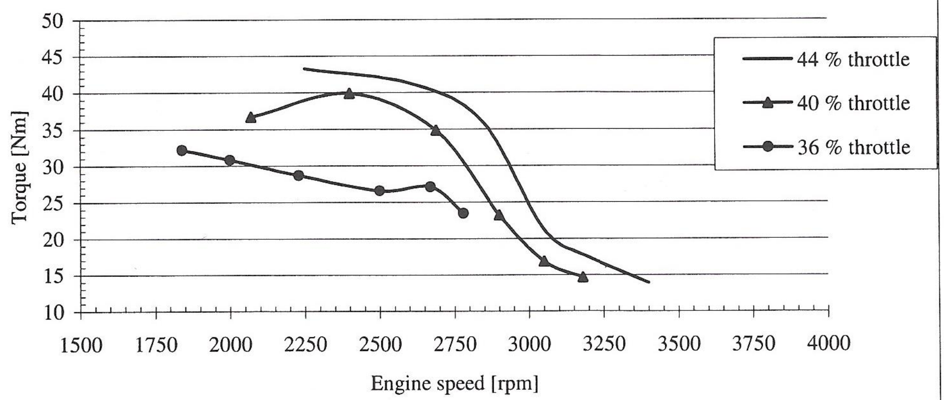


Figure 7a. Torque curve for CNG engine equipped with camshaft intake/exhaust overlap angles of having $34^{O}/71^{O}$

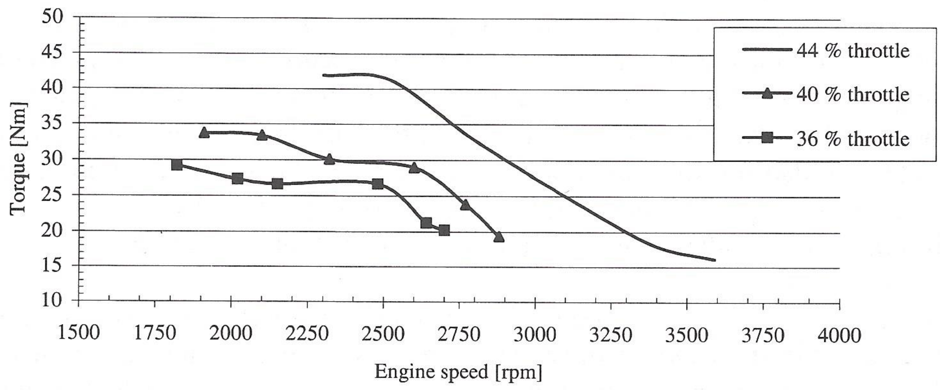
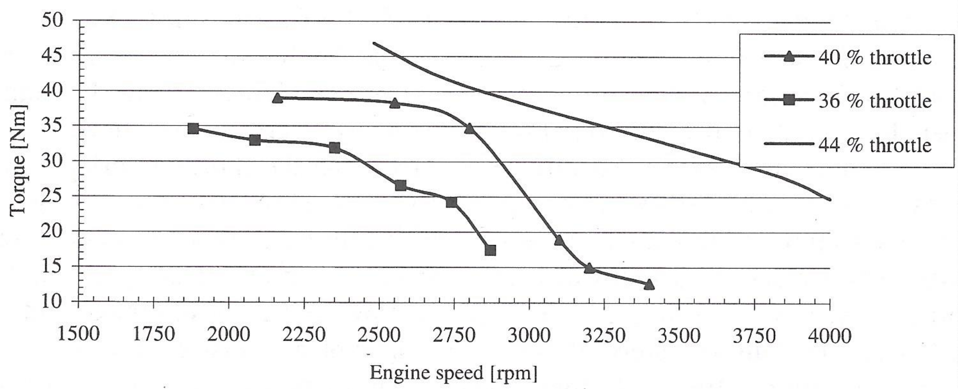


Figure 7b. Torque for PETROL engine equipped with camshaft intake/exhaust overlap angles of having $34^{O}/71^{O}$



5.0 DISCUSSIONS

In general the results show that for part open throttle, an increment in camshaft overlap angle shifts the engine rpm maximum power band to the lower region for both fuels accompanied by increase of engine power. Table 2 shows the summary of maximum power and the accompanied torque for part open throttle of about 44%. It shifted from about 2625 (9 kW) to 2500 (11 kW) engine rpm. Since, power is directly proportional to the product of torque and engine rpm hence, torque will also increase with increment of camshaft overlap angle as shown by Figures 5b, 6b and 7b. Interesting phenomena seem to take place for both petrol and CNG i.e. maximum power takes place at the same engine rpm. It clearly indicates that maximum power increases with overlap duration valve timing. For this case, maximum power increases by about 11.36% for both CNG and petrol. Unfortunately, the results were not conclusive enough to predict the peak engine performance due to limited dynamometer capacity. As for the standard camshaft, the results show that CNG fuel causes about 8.89% of power loss as compared to petrol. This finding justifies the researchers' prediction that the present engine design is not optimised and thus needs some modification for use with CNG fuel. Although it does function reasonably well, it is not economical for mass production. It is also interesting to note that, for part open throttle of about 44%, the engine is also not optimised with petrol which is why some automotive car manufacturers introduce the variable valve timing [5]. As a whole, CNG maximum power is always lower than petrol; camshaft (-S) 18.18%, (S) 8.89% and (+S) 10.20%.

The results also show that, power for smaller part open throttle of about 36%, the standard camshaft (S) produces about 5.0 kW and the camshaft with lower overlap duration (-S) produces about 4.0 kW are almost independent of engine rpm. i.e. power is almost constant with engine rpm. These characteristics are not favourable for automotive applications where engine torque reduces almost linearly with increase of engine rpm. As for the standard camshaft (S), a power lost of about 26.67% is experienced as compared to petrol. Power loss is even greater for shorter overlap duration i.e. about 48.84% for camshaft (-S).

The results also show that, CNG is not suitable for the standard camshaft S and at part open throttle. About 29% power loss is experienced using the standard camshaft as compared to petrol. Power loss is even greater for shorter overlap duration (camshaft (-S)). In this project, it shows that the shorter overlap duration causes about 49% power loss as compared to petrol. However, when using CNG, longer overlap duration (camshaft (+S)) gives better performance as compared to petrol. In this work, 33.3% power increment was experienced using CNG. These indicate that, CNG is suitable to be used for low power consumption with long overlap period. Unfortunately, these results are not conclusive enough for high power applications. Hence, further research has to be carried out to obtain the optimum overlap duration.

6.0 CONCLUSION

The current retrofitted PROTON model 4G15-SOHC-carburetted engine is not suitable to be used with CNG fuel without modifying its valves overlap timing. The retrofitting exercise causes a reduction of about 9% in engine performance for part throttling condition as compared to petrol.

The results provide valuable information to our automotive industry. This would mean that a tremendous amount of savings can be made if a full investigation on the effect of valves overlap duration on engine performance can be carried out in order to ascertain the most optimum over lap duration for retrofitted vehicles.

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