# Effects of Variable Length Intake Manifold on Performance of Gasoline Engine using GT Power Software

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***Abstract*— Volumetric efficiency is an air inducted into the engine intake of internal Combustion engine (Spark Ignition Engine) systems that have great impact on performance characteristics of the engine. Different intake manifold lengths will have different impacts on volumetric efficiency of the engine and consequence upon this, performance characteristic of the engine will be greatly affected. Performance characteristics such as Brake Torque (BT), Brake Specific Fuel Consumption (BSFC) and Brake Thermal Efficiency (BTE) can either increased or decreased. Thus, it is obvious from the above statement that the impact of different intake manifold lengths on the performance characteristics of the Internal Combustion Engine (ICE) is still relatively unclear. Therefore, the current reports aimed to investigate the impact of different intake manifold length on performance characteristics of the ICE (Spark Ignition Engine) engine. This research was conducted using simulation strategy with the aid of GT-Power software and the technical parameters such as stoichiometric mixture (λ=1.0), different range of engine speed (N=1000-5000rpm), wide open throttle (WOT), and Maximum brake torque timing (MBT-spark timing) etc. The results showed that, increase in engine speed brings about increment in performance characteristics of the Spark Ignition engine (i.e. increase in Volumetric Efficiency, increase in Brake Torque and increase in Brake Thermal Efficiency) under the part and full load condition. While decrement was obtained under idle load condition of the engine. Thus, it can technically be concluded that different intake manifold length is an effective strategy to enhance the performance characteristics of Spark Ignition engine under the part and full load condition.**

***Keywords*— Intake Manifold Lengths; Volumetric Efficiency; Brake Torque; Brake Specific Fuel Consumption; Brake Thermal Efficiency; Stoichiometric combustion strategy with MBT-Spark Timing.***

## I. INTRODUCTION

There are lots of factors that influence the performance characteristics of engine, among which are engine speed, air fuel ratio, throttle position and intake manifold length which is not clearly understood [1]. However, the impact of the aforementioned factors on the performance characteristics of the ICE is clearly understood with the intake manifold length been the obvious exception. Different intake manifold lengths have different impact on the intake charge of the system (increase or decrease of volumetric efficiency) which alternately affect the performance characteristics of the engine [2]. Numerous research has work or conduct research investigation towards optimization of performance characteristics of Spark Ignition engine S. N. Soid et al 2015 [3] conducted a “Simulation Studies on the Performance of Small Engine Fuelled by Methane and the Effect of Various Valve Timings”. The results shows that increasing in valve overlap the volumetric efficiency also increases which lead to increasing in torque, power, bmep and peak pressure [4]. In addition, Jusoh, M.F, and Jufriadi 2016 [5] studied on “Variable throttle opening effects on the performance and emission of spark ignition (SI) engine”. The results show that at engine speed 4000 rpm at all condition of throttle opening is appropriate than at engine speed 4500 rpm although the different between both of speed is small. Also, Dileep Namdeorao Malkhede and Hemant Khalane 2015 presented “The effect of intake length on volumetric efficiency for wider range of engine speeds”. The result shows that volumetric efficiency was found to be a function of both engine speed and intake length, more so at higher engine speeds [6]. Next, M.F. Muhamad Said, Z. Abdul Latiff, et al 2014 analyzed of “Variable Intake Runner Lengths and Intake Valve Open Timings on Engine Performances”. The result shows that by advancing the intake valve open timing, the brake torque and volumetric efficiency increased at high engine speeds. However at low engine speeds, they reduce significantly [7].

In furthermore, Haibo.C, Shou.Z, Haizhen.H, and Zhaocheng.Y 2013 conducted a “Simulation Analysis of the Impact on Gasoline Engine Power Performance by Optimizing the Structure of Intake Ports”. The results then show that the length of intake ports influence the pressure wave in take intake port is inversely proportional to the resonance frequency, which means the longer the pipe is, the smaller the resonance frequency is, and then the lower engine velocity the resonance point moves to [8]. Also, H. Bayraktar and O. Durgun 2004 investigated “The effect of LPG on spark ignition engine combustion and performance”. The result shows that LPG reduces the engine volumetric efficiency and, thus engine effective power [9]. Moreover, S.Wen, B. Wei, and H. Tong 2018 studied on “Design and Performance Analysis of B15 Engine Intake System”. The result shows that the design of the intake system muffler element is effective and satisfied the target requirement, which greatly saves the development cost, shortens the development cycle and provides guidance for the subsequent design and development [10]. Next, M. Gandyk1, M.Tkaczyk, Lech J. Sitnik, .Trifon uzuntonev 2015 conducted “Combustion Engine Intake Port Design Analysis”. The result shows that the final improvement gives higher power, up to 1.5

hp and about 1 Nm higher torque in wide range of engine speed. The maximum power could be higher but then engine torque would be worst [11]. Moreover, S.Singla, S. Sharma, and D. Gangacharyulu 2015 studied on “Design Improvement of Intake Manifold of Internal Combustion Engine”. The result shows that intake manifold geometry with plenum chamber shows good result where there is an increase of 16% in flow velocity at outlet 1, and velocity in other outlet improved by approximately 5% to 7% [12]. It is obvious from the foregoing analyses; that a lot of work has been done on the performance characteristics of spark ignition engine. However, no researcher has ever examined the impact of different intake manifold length on performance characteristics of the spark ignition engine using GT power software. Therefore, this research focuses on the effect of different intake manifold length on performance characteristics of spark ignition engine using GT power software.

## II. COMBUSTION STRATEGY USED IN SPARK IGNITION ENGINE

Stoichiometric combustion is a process where the fuel is completely burned also called as ideal combustion process. The whole combustion process is a process that burns all the carbon (C) to ($CO_2$), hydrogen (H) to ($H_2O$) and all sulphur (S) to ($SO_2$). The combustion process is uncompleted if unburned gas components like C, $H_2$, CO are present. [13] The overall complete combustion equation is

$$C_8H_{18} + \left(a + \frac{b}{4}\right)(O_2 + 3.773N_2) = aCO_2 + \frac{b}{2}H_2O + 3.773\left(a + \frac{b}{4}\right)N_2$$

**(1.0)**

Equation (1.0) shows the stoichiometric proportions of fuel and air; i.e., there is sufficient oxygen to convert all fuel into fully oxidized products

For stoichiometric combustion $\left(a + \frac{b}{4}\right) = 1$

## III. Experimental Setup And Procedure

There are the selected engine parameters that will be used to control the operation of the engine during the simulation in order to get the best performance characteristic data. It is given in Table 1:

TABLE I
TECHNICAL OPERATING PARAMETER OF THE ENGINE

| | Parameters | Range |
|---|---|---|
| 1 | Speed | 1000rpm-5000rpm |
| 2 | Intake manifold length | 50mm, 55mm, and 60mm |
| 3 | Combustion strategies | Stoichiometric mixture (λ = 1.0) |
| 4 | Throttle valve | Wide open throttle |
| 5 | Spark timing | MBT-Spark timing |

The development process begins with the modeling inside the library of GT-Power software. It begins with the construction of the engine intake system consists of intake runner, inlet port, exhaust port and tail pipe. The parts are created for easier discretion in GEM-3D. By discretizing the GEM-3D part, the 3D model is converted to a GT-Power 1D diagram. The GT-Power also defines intake and exhaust valve geometries. The intake and exhaust valve are crucial and should be defined according to the actual engine.

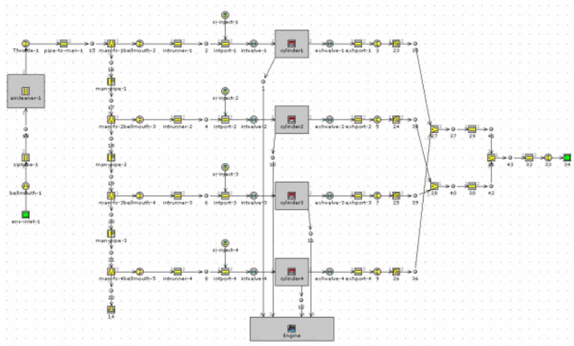


Figure 1: Configuration of the Engine Using GT-Power

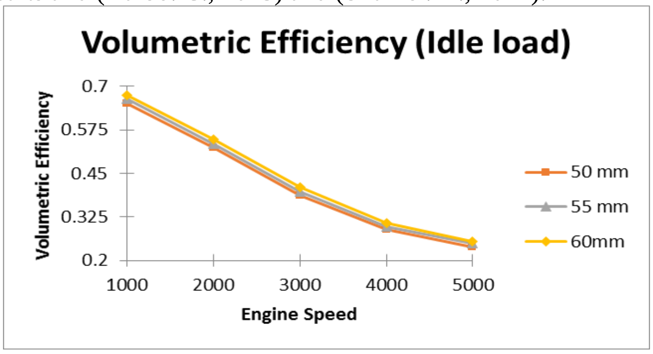
## IV. RESULT AND DISCUSSION

This section focussed on the result obtained from the simulational investigation of the performance characteristics of the Spark Ignition engine using GT-Power software. The simulation was conducted with four (4) stroke four (4) cylinder engine at different intake manifold lengths such as (50mm, 55mm and 60mm) with different load conditions which are idle load ($10^0$ CA), part load ($45^0$ CA) and full load ($90^0$ CA) and $30^0$ BTDC represent the maximum brake torque-spark timing (MBT-Timing) at different engine speed ranging from 1000-5000rpm was utilised. While, stoichiometric mixture was adopted as combustion strategy for this simulation. The results are shown in Figure 4.1- 4.4 and it is fully discussed in the next section. The table of reading is given in appendix A-D.

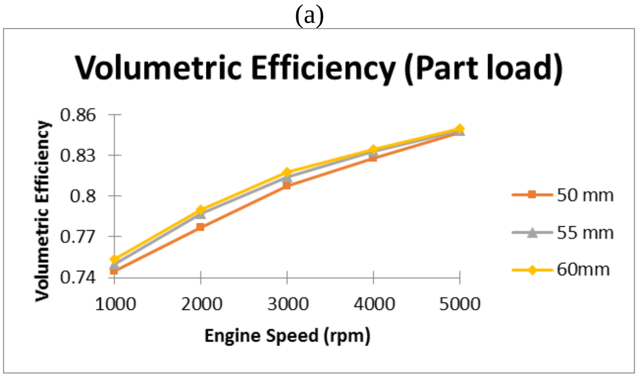
### Performance Characteristics

#### *1) Volumetric efficiency*

Figure 2.1(a) to (c) shows the relationship between volumetric efficiency at different intake manifold lengths against engine speed. From the observation, it is cleared that increasing the engine speed brings about increasing trend in the graph of volumetric efficiency at different engine speeds for all intake manifold lengths under consideration. This can be explained with higher speeds lead to higher volumetric efficiency because the higher speeds give higher vacuum at the intake port and consequence upon this, larger air flow rate will persists. Exception to this observation above occur at idle load where increasing the engine speed, shows the decrease in volumetric efficiency for all intake manifold lengths under consideration. This might due to the cycle-by-cycle combustion occasioned by variation in mixture composition within the engine cylinder. All of these lead to low gas velocities and poor combustion chamber turbulence, which is why the engine is volumetrically inefficient at idle. Furthermore, comparing the volumetric efficiency at different intake manifold length, it is clear that 60mm has the highest volumetric efficiency. This is largely due to the fact the larger the length of the intake manifold; the greater the rate of induction of air and consequence upon this, volumetric efficiency will be highest at this intake manifold as compare to the others. More so, examined the volumetric efficiency for all loads condition under consideration, the highest volumetric efficiency occurs at full load ($90^0$). This might be so, because throttle valve is fully opened at this technical operation condition of the engine which lead to more intake of air into the engine cylinder. Thus, the volumetric efficiency will be highest as compare to other loads.Consider the volumetric efficiency at different intake manifold lengths of 50mm and 60mm under two (2) different engine speeds (1000rpm & 5000rpm) at full load condition [i.e.Figure 2.1(c)]. For 50mm intake manifold length, the volumetric efficiency for the two (2) engine speeds under consideration are 0.744 and 0.8876 respectively. This shows approximately 5% increment in volumetric efficiency at the operating condition of the engine. While, for 60mm intake manifold length with the same technical operating parameter, volumetric efficiency are 0.7456 and 0.8922 respectively. This gives nearly 16% increment in volumetric efficiency. Thus, from the foregoing analyses, it can be concluded that more significant increment was observed with 60mm as compare to 50mm. Good agreement is achieved between these simulation results and (Haibo. C., 2013) and (Shumei. Y., 2017).




(a)

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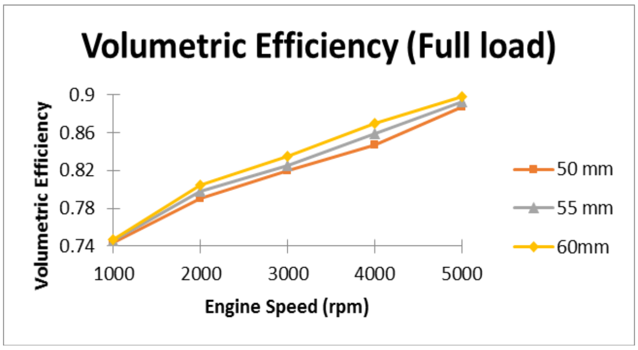
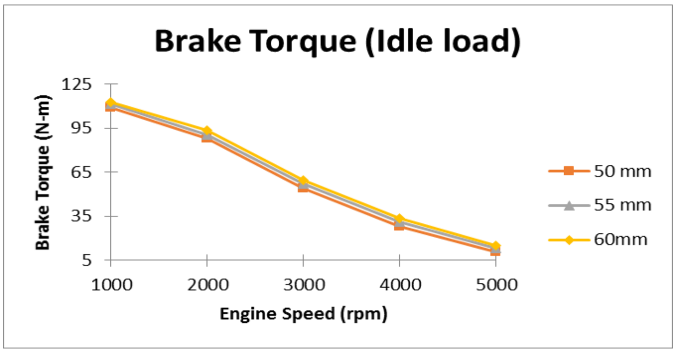



(c)

Figure 2.1: Relationship between Volumetric Efficiency at different intake manifold length against engine speed at different load.

### 2) *Brake Torque*

Figure 2.2(a) to (c) shows the relationship between Brake torques (BT) at different intake manifold lengths against engine speed. From the observation, it is obvious increasing the engine speed lead to increment in Brake torque at different engine speeds for all intake manifold lengths under consideration. This largely due to the fact that increase in engine speed bring about increases in volumetric efficiency of the engine, and this enhance the turbulence within the engine cylinder and consequence upon this brake torque will increase. Exception to the observation above occur at idle load where increasing the engine speed, shows the decrease in Brake torque for all intake manifold lengths under consideration. This might be due to reduction in combustion quality at this operating condition of the engine. Thus, it is reasonable to say that idle load is not suitable for good engine performance. In furtherance, comparing the brake torque at different intake manifold lengths, it is cleared that 60mm has the highest BT. This is so; because increase in engine speed increases the burning velocity and combustion temperature during the combustion process and this lead to increment in BT. More so, examined the Brake Torque for all load conditions under consideration. The highest BT occurs at full load. This might be due to the fact that the throttle valve is fully opened ($90^0$) at this operating condition of the engine which promotes greater induction of air (increase volumetric efficiency) and eventually enhance the turbulence within the engine cylinder and consequence upon this, BT will be highest at this load condition compare to the others load. In addition, consider the BT at different intake manifold length of 50mm and 60mm under two (2) different engine speed (1000rpm & 5000rpm) at full load [i.e. Figure 2.2(c)]. For 50mm intake manifold length, the BT for the two (2) engine speeds under consideration are 127.45 N-m and 154.93 N-m respectively. This shows approximately 18% increment in BT at this operating condition of the engine. While, for 60mm intake manifold length with the same technical operating parameter under consideration, BT are 128.66 N-m and 155.39 N-m respectively. This presents almost 17% increments in BT. Thus, it can be concluded that nearly the same percentage increment in BT for the two intake manifold lengths under consideration was obtained. The results obtained here is coherent with what is obtained by (Jagadish.B. and Nilam.P., 2016) and (Mohd.F., et al, 2014).

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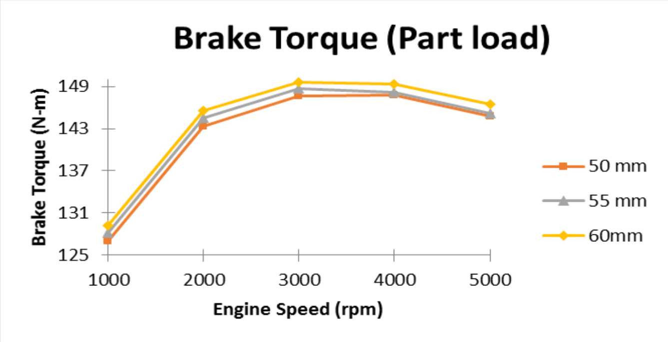


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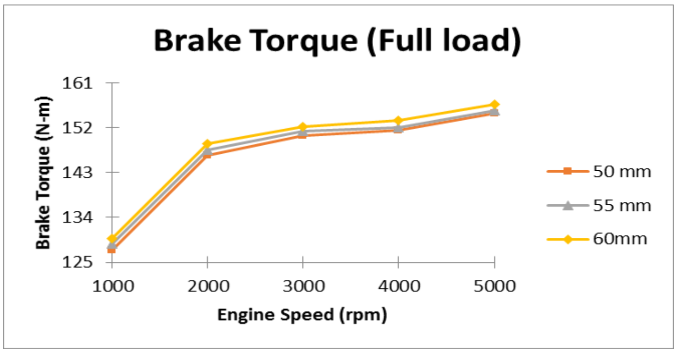
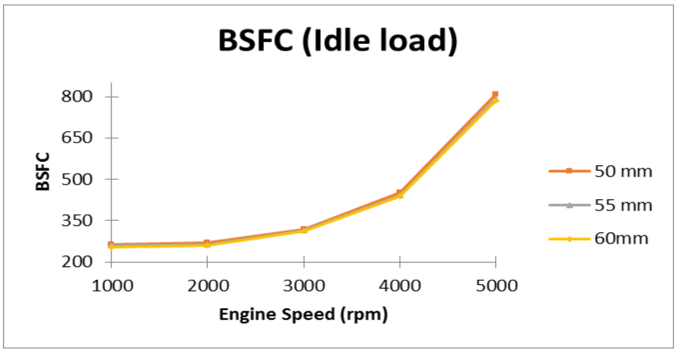



(c)

Figure 2.2: Relationship between Brake Torques at different intake manifold length against engine speed at different load

### 3) *Brake Specific Fuel Consumption*

Figure 2.3(a) to (c) shows the relationship between Brake Specific Fuel Consumption (BSFC) at different intake manifold lengths against engine speed. For part and full load condition [i.e. Figure 2.3(a) and (c)], the BSFC decrease at the early engine speed from 1000 rpm until 2000 rpm. This represents an improvement in fuel consumption at these operating conditions of the engine. This meant that, improved combustion was allowing the same amount of fuel to produce an increase in power, where the combustion efficiency improved, as a result BSFC reduced. Further increases in engine speed from 2000-3000rpm shows constant trend line graph of BSFC. This might due to mechanical efficiency significantly lowered, even for relatively constant friction levels, which lead to nearly insignificant improvements in BSFC. While, increasing the engine speed from 3000rpm to 5000rpm, shows an increasing trend graph of BSFC for all intake manifold lengths under consideration. This is because of the deterioration in combustion quality caused by cycle by cycle combustion variation in the engine. Furthermore, comparing the BSFC at different intake manifold lengths, it is clear that 60mm has the lowest BSFC. This is so because at 60mm intake manifold length, more induction of air (increases volumetric efficiency) is likely to occur and this leads to lesser fuel needed for efficient combustion at this operating condition of the engine; thus BSFC will be lowest at 60mm intake manifold length as compared to other intake manifold length. In addition, examined the Brake Specific Fuel Consumption for all loads under consideration, the lowest BSFC occurs at high load. This might largely due to the fact that at high engine load, the throttle plate is fully opened. More air will be inducted into the engine system and this results in lesser fuel needed for efficient combustion at this operating condition of the engine; hence the reason for lowest BSFC obtained at full load condition as compared to the others. More so, consider the BSFC at different intake manifold length of 50mm and 60mm under two (2) different engine speed (1000rpm & 2000rpm) at full load [i.e. Figure 2.3(c)]. For 50mm intake manifold length, the BSFC for the two (2) engine speed under consideration are 257.21 g/kW-h and 240.17 g/kW-h respectively. This shows approximately 7% decrement in BSFC at this operating condition of the engine. While, for 60mm intake manifold length with the same technical operating parameters under consideration, BSFC are 255.32 g/kW-h and 238.89 g/kW-h respectively. This shows nearly 6% decrement in BSFC. It is technically obvious from the above analysis, that nearly the same percentage decrement was observed with BSFC for the two intake manifold length under consideration. This results obtained here aligned with what is obtained by (Mohd.F., et al, 2014) .

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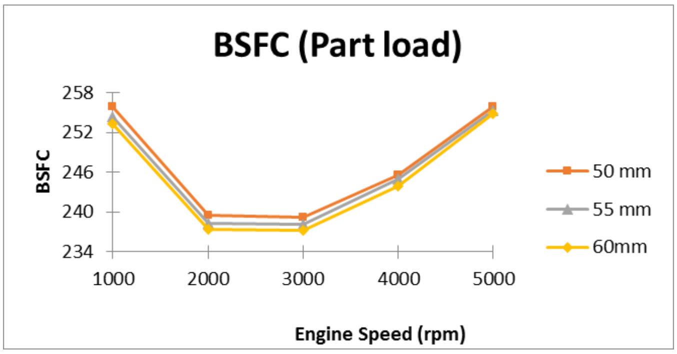


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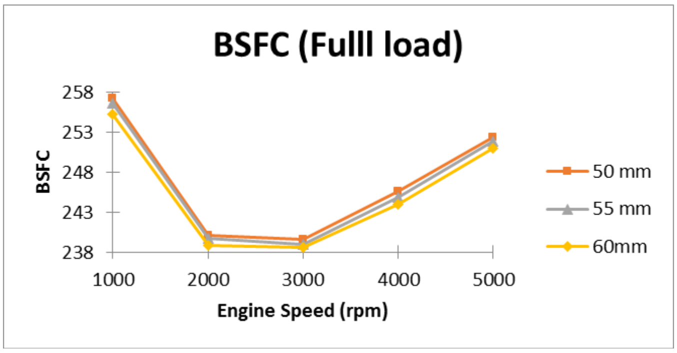


(c)

Figure 2.3: Relationship between Brake Specific Fuel Consumption (BSFC) at different intake manifold length against engine speed at different load.

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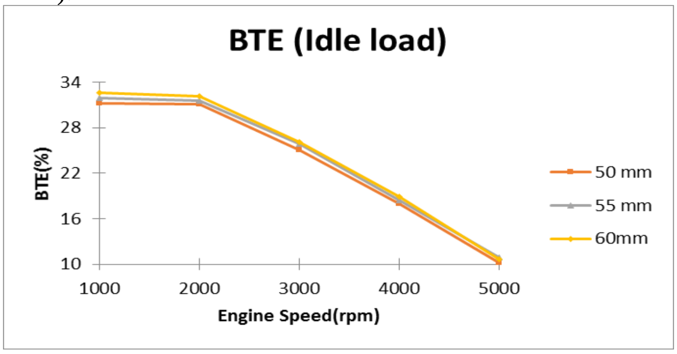
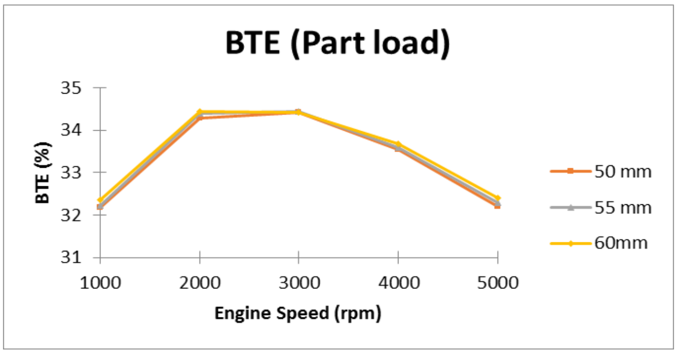
### *4) Brake Thermal Efficiency*

Figure 2.4(a) to (c) shows the relationship between Brake Thermal Efficiency (%) at different intake manifold lengths against engine speed. From the observation on the BTE graphs, it is seen that increasing the engine speed from 1000 to 2000 rpm, brings about increment in BTE for all intake manifold lengths under consideration. This observation can be explained due to the better mixing of air-fuel which increases combustion efficiency and consequence upon this brake thermal efficiency will increase. Exception to the technical observation occurs at idle load [i.e. Figure 2.4(a)] where increase in engine speeds from 1000-2000rpm brings about decrement in BTE. This might be due to reduction in combustion quality observed at this operating condition of the engine. Furthermore, as the engine speed increases up-to 3000 rpm, constant trend line in the BTE graph was observed. This might be due to constant friction levels, which lead to lowest BSFC and consequence upon this, no significant improvements in BTE was obtained. While at higher speed, the BTE of engine decreases. This might be due to cycle-by-cycle combustion variation observed at this operating condition of the engine. In addition, comparing the BTE at different intake manifold lengths, it is clear that 60mm intake manifold length has the highest BTE. This is so because at 60mm intake manifold length, greater induction of air will occur (i.e. increase volumetric efficiency) and this translate to lower fuel consumption by the engine and consequence upon this, BTE will be high at this operating condition of the engine. More so, examined the Brake Thermal Efficiency for all loads condition under consideration, the highest BTE occurs at full load. This is because, at full load conditions, mechanical efficiency can be relatively high in comparison with other load. Furthermore, consider the BTE at different intake manifold lengths of 50mm and 60mm under two (2) different engine speed (1000rpm & 5000rpm) at full load [i.e. Figure 2.4(c)]. For 50mm intake manifold length, the BTE for the two (2) engine speed under consideration are 32.22% and 32.6% respectively. This, shows nearly the same percentage in BTE was obtained at this operating condition of the engine. While, for 60mm intake manifold length with the same technical operation parameters under consideration, BTE are 32.45% and 32.69% respectively. Also no significant change in BTE was obtained at this operating condition of the engine, just as it was obtained under 50 mm intake manifold length. Thus, from the foregoing analyses it can be concluded that no significant change in BTE between these two (2) intake manifold lengths under consideration was observed. Good agreement was achieved between these simulational results and (Naveen. G., 2016).




(a)

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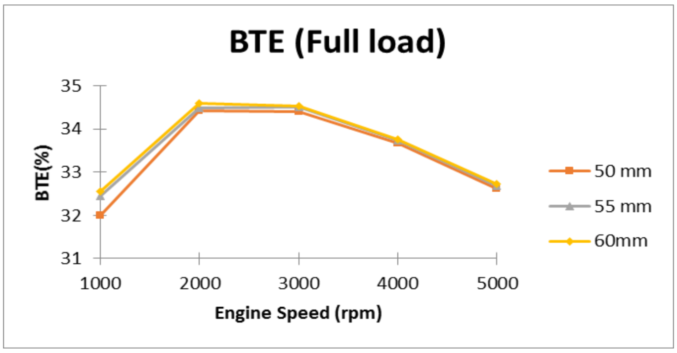


(c)

Figure 2.4: Relationship between Brake Thermal Efficiency (BTE) at different intake manifold length against engine speed at different load.

## V. CONCLUSIONS

A simulational investigation has been conducted to study the effect of different intake manifold lengths (i.e. 50mm, 55mm, and 60mm) on the performance characteristics of four (4) stroke (4) cylinder Spark Ignition engine at various load condition using GT-Power software. The main findings are presented below.

**1)**

- For a specified intake manifold length. Increasing the engine speed bring about increment in volumetric efficiency at part and full load condition. This is due to higher speeds give higher vacuum at the intake port. While, for idle load. Increasing the engine speed reduce the volumetric efficiency due to deterioration in combustion quality.
- For a given intake manifold length. Increasing the engine speed bring about increment in brake torque at part and full load condition. This is so because increases in volumetric efficiency of the engine, enhance the turbulence within the engine cylinder. While for idle load, increasing the engine speed shows the decrement in brake torque. This might due to increase in cycle-by-cycle combustion variation in the engine cylinder
- For a specified intake manifold length. Increasing the engine speed bring about decrement in brake specific fuel consumption at part and full load condition under specific operating parameters of the engine. This lead to improvement in fuel consumption; where combustion efficiency improved. While at idle load.

Increase in engine speed shows the increment in brake specific fuel consumption, this is so because drastic reduction in combustion efficiency.

- For a given intake manifold length. Increasing the engine speed bring about increment in brake thermal efficiency under certain or specific operating condition of the engine (i.e. 1000-2000rpm). The reason is largely due to better air-fuel mixing at this operating condition of the engine.

**2)** It is obvious from the simulational results obtained that intake manifold length (60mm) guaranteed the best (maximum) performance characteristics at full load condition. (i.e. volumetric efficiency= 0.8979 at full load, brake torque= 157N-m at full load, BSFC= 239 g/kW-h at full load, BT= 34% at full load)

Since the focus of this research is to clarify the impact of different intake manifold lengths on the performance characteristics of the ICE (Spark Ignition engine). This research has been able to provide better clarification on the application of intake manifold length at different load condition. It is obvious from the results obtained that the application of different intake manifold length shows a positive results (increment) under part and full load condition; while opposite result (decrement) was obtained under idle load. Hence, the utilization of different intake manifold at idle load condition in ICE (Spark Ignition engine) is greatly discouraged.

## VI. ACKNOWLEDGMENT

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