Research Article

Effects of Intake Blades on Diesel Engine Performance

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Abstract

The idea of using an intake blade is to increase turbulence in the intake manifold which, in turn, increases the higher mixing capability between fuel and air. The aim of research was to investigate the effects of the intake blade on performance of a diesel engine. The computer simulations were performed to analyze the effects of the intake blade's angles and shapes on flow characteristics including velocity, turbulent viscosity, and pressure drop. From the simulations, the blade angle of 60 degree was the best in the term of the turbulent viscosity. The four blades shape was selected to test with a commercial diesel engine. The experimental results showed that using the intake blades with the tested diesel engine did not affect the engine performance included brake power, brake torque, and specific fuel consumption at the significance level of 0.05.

Key Words: Diesel engine; Intake blade; Performance; Turbulent flow

Introduction

Engine performance is defined in terms of brake power, brake torque, and specific fuel consumption (Pulkrabek, 2004); therefore, it can be improved either by increasing the engine power and torque or decreasing fuel consumption (Sprei, Karlsson, & Holmberg, 2008). The performance is affected by many operating parameters such as air-fuel ratio, compression ratio, intake temperature, intake pressure, load and engine speed, ignition timing, injection parameters, and swirling design (Heywood, 1988; R. F. Huang, Yang, & Yeh, n.d.; Taylor, 1985a, 1985b). From the previous research, the engine performance could be improved by various methods such as (1) a flow arrangement of intake and exhaust (Chehroudi & Schuh, 1995; Galindo, Luján, Serrano, Dolz, & Guilain, 2004), (2) a fuel economy improvement by variable valve timing (VVT) (Fontana & Galloni, 2009), (3) a performance improvement by adjusting the control parameter of the common rail system (Goldsworthy, 2012; Li, Deng, Peng, & Wu, 2013; Xu-Guang, Hai-Lang, Tao, Zhi-Qiang, & Wen-Hui, 2012), (4) a using of alternative fuels in the engine such as bio-diesel (Rajesh, Raghavan, Shet, & Sundararajan, 2008; Xue, Grift, & Hansen, 2011), ethanol (Eyidogan, Ozsezen, Canakci, & Turkcan, 2010; Wu, Chen, Pu, & Lin, 2004), and hydrogen (Ji & Wang, 2009; Wang, Ji, Zhang, & Liu, 2012), and (5) emission control (Galindo, Serrano, Guardiola, Blanco-Rodriguez, & Cuadrado, 2011).

For the intake system, it can be classified into two main types, which are normal and boosted intake systems. The normal intake system has negative pressure, while the boosted intake system has positive pressure created by supercharging or turbocharging (Ganesan, 1996; Taylor, 1985a). There were many researches focusing on the intake system such as (1) the effects of intake system components on engine performance (Masi, 2010), (2) the effects of intake temperature and pressure (He et al., 2013; Maurya & Agarwal, 2011), (3) flow simulation at intake and exhaust valves (Jia, Xie, Wang, & Peng, 2011), (4) noise and emission control by modifying the intake system (Davies, 1996; X. Huang, Zhang, & Richards, 2008), and (5) effects of supercharging and turbocharging on emission and performance (C. D. Rakopoulos, n.d.).

This research aimed to investigate the effects of the intake blade installed in the main manifold on the flow characteristics and engine performance. The effects of the intake blade configurations such as angle and shape were also considered.

Methodology

The research procedure was divided into four stages as shown in Figure 1. Since the result of each stage affected the next, the paper presents the details of each stage sequentially. The research started from simulation processes to select to research conditions, investigated the effects of intake blade's angle on flow characteristics, and finally, investigated the effects of intake blade's shape on flow characteristics. Then, the prototypes were tested engine installed with dynamometer for investigating the effects of intake blade on the engine's performance. The engine used in the experiments was TOYOTA in-line four-cylinder diesel engine model 2L. The specifications were as follows: 92 mm bore, 92 mm stroke, a compression ratio of 22.3, maximum brake power of 62 kW at 4200 rpm, and maximum brake torque of 165 N-m at 2400 rpm ("Toyota L engine," 2013). The dynamometer for measuring the power and torque was fluid friction type brand STUSKA model XS-111 water brake dynamometer.

Flow simulation in the intake manifold

First, the flow at the intake manifold was simulated by setting the engine speed at five values: 1500, 2400, 3300, 4200 , and 5100 rpm. The 1500 and 5100 rpm were actual idle speed and actual maximum speed tested from prior project respectively. The 2400 rpm and 4200 rpm were the speed at maximum torque and maximum power from specification. The 3300 rpm was the averaged

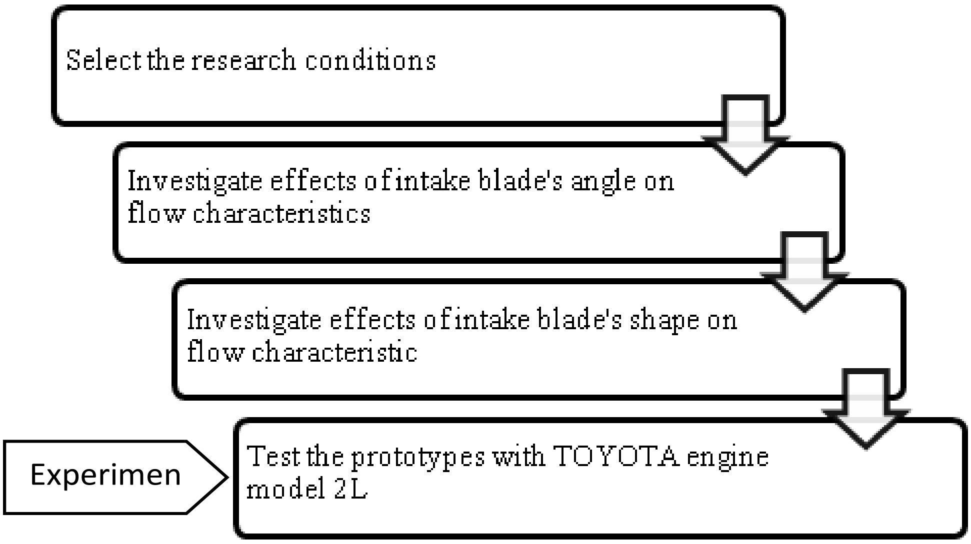


Figure 1 Research procedures

middle point. The computer software used in this research was SolidWorks Flow Simulation version 2010. The confidence level of simulation results were claimed to be higher than 95% (Ivanov, Trebunskikh, & Platonovich, 2013). The velocity at the inlet was calculated from the engine speed, engine specifications, and the cross-sectional area of the intake manifold inlet. Flow characteristics including velocity, turbulent viscosity, and pressure drop in outlets 1 and 2 were simulated instead of all four of them because of the symmetry. As shown in Figure 2(a), outlet 1 connects to first cylinder, and outlet 2 connects to second cylinder. The geometric difference between outlet 1 and 2 should be path and distance. This stage aimed to investigate the difference of flow characteristics between outlet 1 and 2 in order to select only one outlet as a research condition for further stages. The details of simulation setting were shown in Table 1. The results were also shown in Figure 2(b) to (d). The flow characteristics and engine speeds were found to increase with each other (Ganesan, 1996; Taylor, 1985a) and all values of outlet 1 were higher than that of outlet 2 at every speed. The turbulent viscosity and pressure drop of outlet 1 were significantly higher than those of outlet 2 in every speeds due to the longer distance and more complex path. Nevertheless, there was no significant difference between the velocity of outlet 1 and 2. Outlet 1 was selected for the remaining simulations and experiments to be convenient for field measurements.

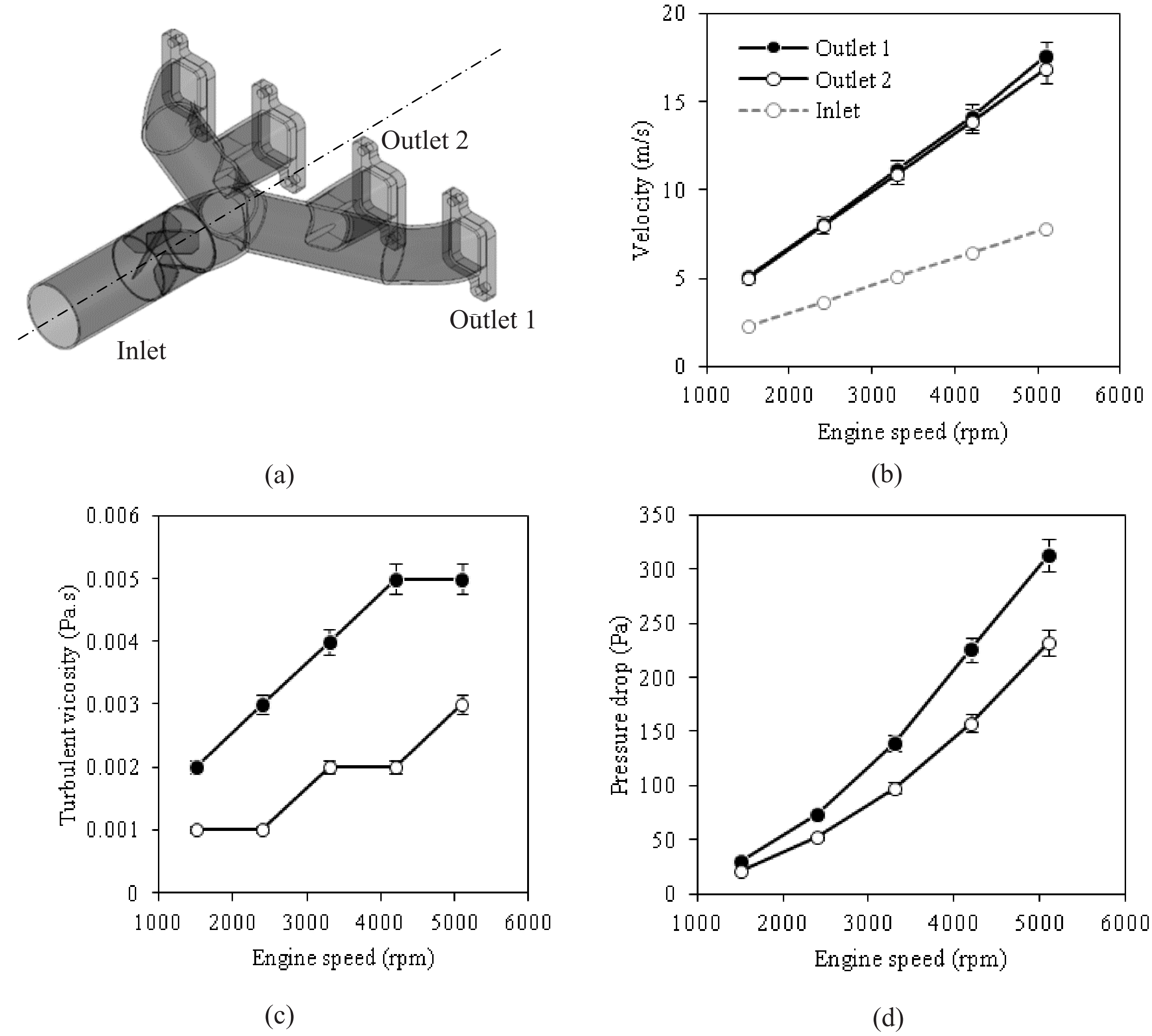


Figure 2 Intake manifold and flow characteristic

Table 1 Details of simulation setting

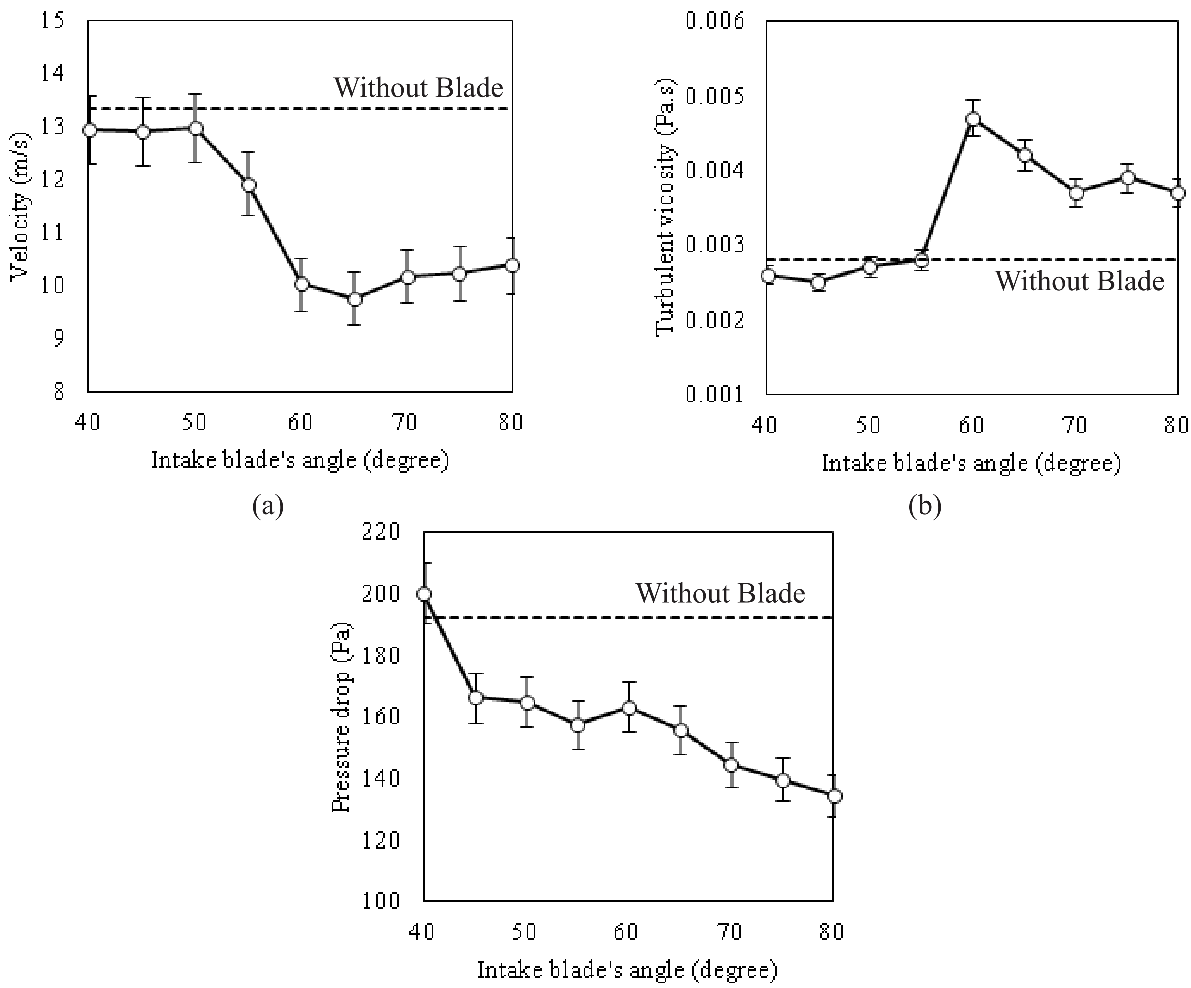
<u>Initial mesh setting</u>	
Automatic initial mesh	On
Result resolution level	3
Advanced narrow channel refinement	Off
Refinement in solid region	Off
<u>Geometry Resolution</u>	
Evaluation of minimum gap size	Automatic
Evaluation of minimum wall thickness	Automatic
<u>Physical Features</u>	
Heat conduction in solids	Off
Time dependent	Off
Gravitational effects	Off
Flow type	Turbulent only
Analysis type	Internal flow
High Mach number flow	Off
Humidity	Off
Default roughness	0 μm
Default wall condition	Adiabatic wall
<u>Material setting</u>	
Fluids	Air
<u>Inlet boundary condition</u>	
Type	Inlet velocity
Coordinate system	Face coordinate system
Flow vectors direction	Normal to face
Fully developed flow	No
<u>Outer boundary condition</u>	
Type	Environment pressure
Coordinate system	Face coordinate system
Environment pressure	101.325 kPa
Temperature	293.20 K

The effect of intake blade angle on flow characteristics

From the previous research done with this engine, it was found that the maximum power occurred at the engine speed of 3500 rpm which was different from the specification. Therefore, next steps of flow simulation were set at the actual maximum power speed point at 3500 rpm. The effects of blade angle on flow characteristics were investigated by changing the angle of the intake blade from 40 to 80 degree referred to the section plane with an interval of 5 degrees. The results were shown in Figure 3. The angle of the intake blade was found to inversely affect the pressure drop since smaller angle tends to obstruct the intake flow. The velocity decreased with the blade angle between 50 to 65 degrees, but seemed to be constant out of this range (see Figure 3(a)). From 60 to 80 degree of blade's angle, the outlet's velocities were not significantly different. By considering the turbulent viscosity in Figure 3(b), the peak value was found to be 0.0047 Pa.s at 60 degree . Since this research focused on the ability of an intake blade to increase the turbulent flow in the manifold, therefore, the angle of the intake blade of 60 degree was chosen for next steps.

The effect of intake blade shape on flow characteristics

Third, the blade shape was modified by trimming to five different shapes as shown in Figure 4(a). The effects of the blade shape on the intake flow parameters were investigated. The simulation was done at the engine speed of 3500 rpm and the blade angle of 60 degree to consider the flow characteristics at the intake manifold outlet 1. The results were also shown in Figure 4(b) - (d). The three highest in turbulent viscosity were the blade model 1, 2, and 5 respectively and they were also the three highest in pressure drop. This was the nature of using the intake blade to increase turbulence flow (Ceviz & Akın, 2010). Consider the velocity, the blade model 1, 2, and 5 were the three highest as well. Therefore, the intake blades model 1, 2, and 5 with the blade angle of 60 degree were chosen for experiment in the next step. The three prototypes were made from 1 mm thickness aluminum sheet by simple methods as shown in Figure 5(a).



(c)

Figure 3 Effect of the intake blade's angle on flow characteristics

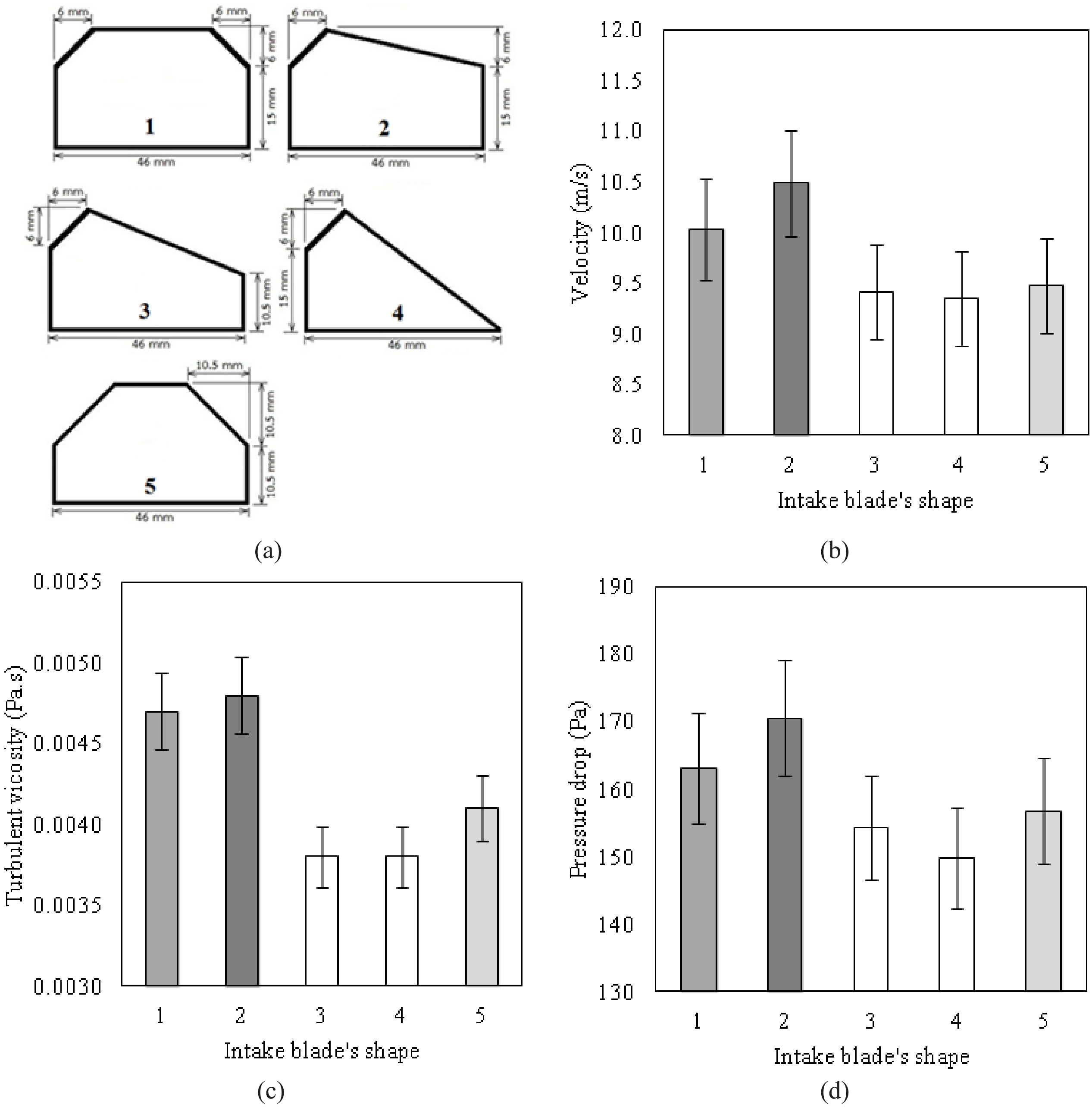


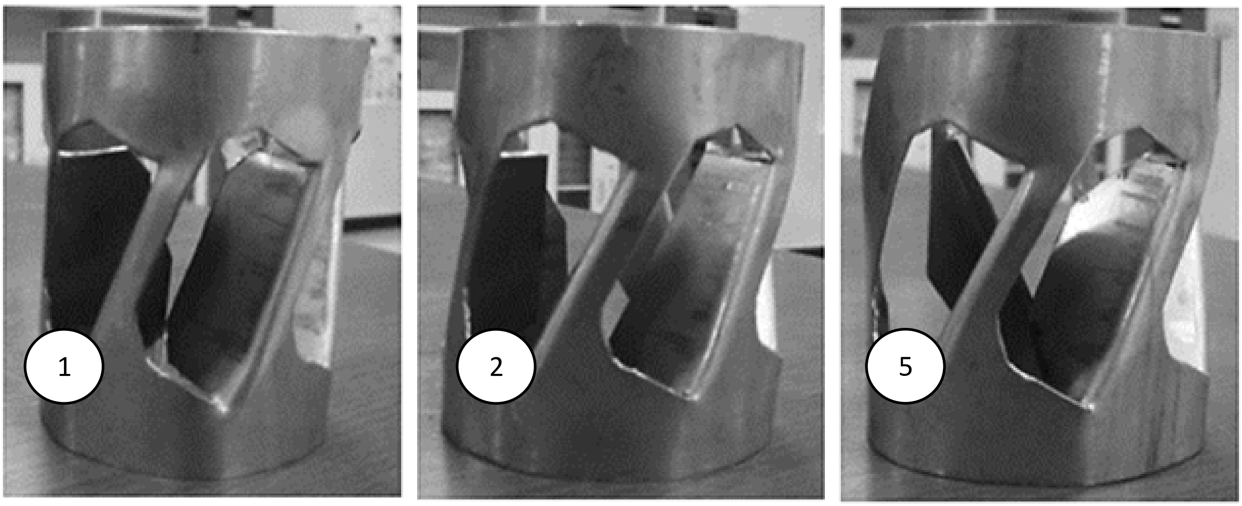
Figure 4 Effect of intake blade's shape on flow characteristics

Testing on engine

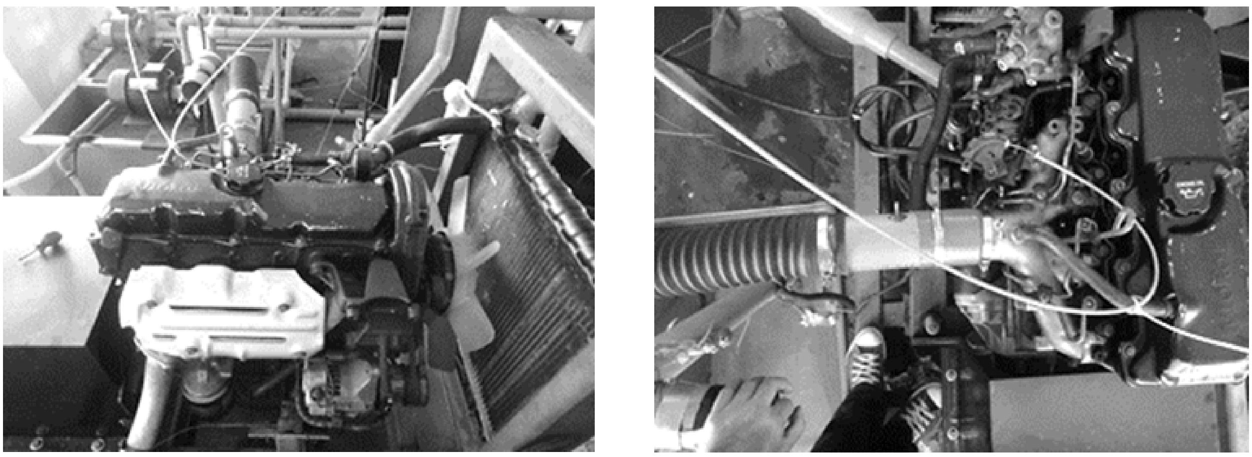
Fourth, the experiments were done to investigate the effect of the intake blade on the engine performance included brake power, brake torque, and specific fuel consumption. The TOYOTA four-cylinder diesel engine: model 2L was attached to the fluid friction dynamometer. The experiment objective was to compare the performance of the engine installed each selected intake blade based on the performance of the engine without the blade. After running with no-load condition until the engine became the steady stage, the engine was run at 2500, 3000, 3500, and 4000 rpm which referred to the previous research done with this dynamometer . The testing started from low speed (2500) rpm to measure all operating parameters. At each speed, the actual engine speed, brake torque, brake power, pressure drop, air flow, and fuel consumption were recorded for five times with one minute interval for averaging. Then the speed was increase d to the next point until 4000 rpm to finish one round test. The experimental processes were repeated three rounds to collect data for statistical analysis (Navidi, 2010). The experimental setup was shown in Figure 5(b).

Results and Discussions

The experimental results were shown in Figure 6. For engine without intake blade, the maximum brake power was found to be 45.30 kW at 3500 rpm. The maximum torque was found to be 133.48 N-m and specific fuel consumption was found to be 76.53 mg/kW-s at 2500 rpm. It could not conclude that this was the maximum toque because the engine could not run at the lower speed (Heywood, 1988; Pulkrabek, 2004; Taylor, 1985a, 1985b). The main topic we focused on this research was to compare the effect of the intake blade on the engine performance. One-way ANOVA method was used to compare the mean of engine performance between cases as shown in Table 2. The results showed that the engine performances of all cases were not different at the significant level of 0.05. Therefore, using the intake blade with the diesel engine did not affect the performance in terms of brake power, torque, and specific fuel consumption.



(a)



(b)

Figure 5 Prototypes and Experimental setup

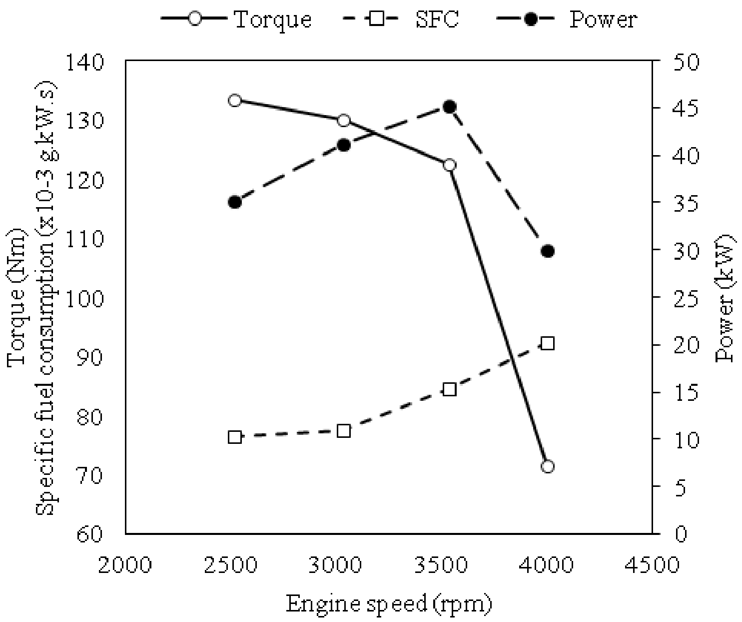


Figure 6 Engine's performance without Intake Blade

Table 2 Experimental results and inferential statistical testing

Rpm	Based case	No. 1	No. 2	No. 5	F-value	p-value
			Torque (Nm)			
2500	133.48 (0.98)	133.73 (2.16)	132.53 (1.72)	133.23 (1.05)	0.10	0.96
3000	130.03 (0.97)	130.69 (2.18)	129.15 (1.35)	130.31 (1.69)	0.12	0.95
3500	122.42 (1.23)	122.25 (4.14)	120.59 (1.68)	122.51 (1.04)	0.14	0.94
4000	71.44 (1.41)	73.70 (3.91)	70.71 (1.33)	70.35 (6.06)	0.15	0.93
			Power (kW)			
2500	35.15 (0.57)	35.09 (0.72)	34.73 (0.62	35.23 (0.51)	0.12	0.95
3000	41.22 (0.53)	41.63 (1.01)	41.09 (0.37)	40.92 (0.68)	0.18	0.91
3500	45.30 (0.37)	45.17 (1.22)	44.37 (0.66)	45.29 (0.51)	0.32	0.81
4000	29.93 (0.52)	31.17 (1.69)	29.74 (0.52)	29.62 (2.62)	0.19	0.91
			Specific fuel consumption (x10-3 g/kW.s)			
2500	76.53 (2.31)	76.63 (1.37)	76.76 (1.97)	77.05 (2.78)	0.01	1.00
3000	77.59 (1.76)	76.88 (3.14)	77.23 (2.23	79.94 (1.60)	0.35	0.79
3500	84.50 (2.26)	85.31 (1.57)	87.36 (1.97)	85.57 (1.35)	0.41	0.75
4000	92.27 (3.44)	94.12 (3.69)	92.10 (3.88)	99.14 (3.35)	0.78	0.51

Conclusion

From simulation, the blade angle of 60 degree was the best case in the term of the turbulent viscosity. The four blades shape were selected to test with a commercial diesel engine. The experimental results showed that using the intake blade with the diesel engine did not affect the engine performance included brake power, brake torque, and specific fuel consumption at the significance level of 0.05.

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