ISSN: 2456 - 4664
International Journal of Advanced Trends in Engineering and Technology
Impact Factor 5.965, Special Issue, January - 2018
1st International Conference on Innovations in Mechanical Engineering (ICIME-2018)
On 5th & 6th January 2018 Organized By
Guru Nanak Institute of Technology & Guru Nanak Institutions Technical Campus, Hyderabad

IMPROVEMENTS OF PERFORMANCE AND EMISSIONS OF A DI DIESEL ENGINE WITH MAMEY SAPOTE BIODIESEL HAVING HELICAL GUIDE VANES

A. Raj Kumar*, Dr. G. Janardhana Raju & Dr. M. Harinatha Reddy***
* Guru Nanak Institution Technical Campus, Hyderabad, Telangana
** Nalla Narsimha Reddy Engineering College, Hyderabad, Telangana

Cite This Article: A. Raj Kumar, Dr. G. Janardhana Raju & Dr. M. Harinatha Reddy, "Improvements of Performance and Emissions of a Di Diesel Engine with Mamey Sapote Biodiesel Having Helical Guide Vanes", International Journal of Advanced Trends in Engineering and Technology, Special Issue, January, Page Number 95-100, 2018.

Abstract:

The physiochemical properties of biodiesel are similar to diesel fuel and it is renewable. It can be used in compression ignition engines with minor modifications. The viscosity and density of biodiesel are more than conventional diesel. These properties make biodiesel less prone to evaporate, diffuse and mix with in-cylinder air resulting in poor combustion and engine performance than diesel fuel. If the in-cylinder air-turbulence inside the combustion chamber can be increased, then this will perhaps improve the higher viscous and slighter volatile biodiesel to evaporate faster and mix with air better resulting in better performance. Therefore, in this research paper, helical guide vanes were inserted into the intake runner to increase the in-cylinder air turbulence especially during the injection period. Four guide vanes with 3, 4, 5 and 6 number of vanes was fabricated in 3D printing machine and tested. The vanes were tested on a DI diesel engine and operate with 100% of Mamey Sapote biodiesel. Based on the experimental results, the five number of vane was found to be optimum as this vane showed the highest reductions of break specific fuel consumption, CO and HC by 7.6%, 14.27% and 15.62%, respectively compared to the run with biodiesel without vanes. The other guide vanes showed lesser improvements. Therefore, this research concludes that the improvement of in-cylinder air turbulence can enhance the engine performance with higher viscous biodiesel.

Key Words: Guide Vane, Diesel Engine, Air Swirl, Turbulence, Emission Control & Intake Runner

1. Introduction:

Although there is huge improvement in the diesel engines in past few decades it is immobile lagging in the performance in the sense of fuel economy and exhaust emissions. This is due to the ineffective utilize of air in the engine which leads to enhance atomization of the air-fuel mixture causes in the poor combustion, which leads to the engine performance characteristics in terms of fuel economy and emissions at part load conditions. Hence to enhance the performance of engine better utilization of intake charge is necessary, different techniques are introduced in form of modification of intake manifold, development of swirl and tumble devices, modification of piston profile for efficient combustion of charge. In this paper different swirl generating devices are analyze and their result is compared with base model without swirl device. Resistance offered by device to flow is prime factor. Since volumetric efficiency of CI engine is always a critical parameter due to numerous component in intake system. Addition of swirl generating device should not develop more resistance to flow. Requirement of swirl is also varying in engine and is not constant at all loading conditions. At cold start conditions and part load conditions engine require slightly rich mixture. Modeling of device is done taken into consideration the fact that it should be able to develop variable swirl while its operation.

2.1 Literature Survey: The major technical benefit of vegetable oil over conventional diesel fuel is that it is renewable and will be formed from domestic feedstock. The other significant advantages of vegetable oil are low toxicity, included lubrication properties, and overall decrease in exhaust emissions [6, 7]. Additionally, it can be straight away used in the diesel engine with slight to no modification [8, 9]. Experiments were conducted by various researchers universally in this area are increasing severely to establish the advantages of working on vegetable oil in a diesel engine. Though, a diesel engine operating on vegetable oil fuel experiences a reduction in engine power, torque and an increase in specific fuel consumption [10-13] compared to conventional diesel fuel due to higher viscosity and density of vegetable oil as compared to the conventional diesel. Various techniques have been implemented to rectify these problems, such as adding additives, preheating the fuel before injection into the cylinder, adjusting the injection timing, increasing injection pressure or even modifying the combustion chamber geometry [3, 6, 12]. Even by incorporating these techniques, vegetable oil operated engine performance is relatively poor compared to diesel operated engines. These problems arise from the inferior physical and chemical properties of vegetable oil compared to conventional diesel fuel such as low volatility, and higher viscosity and boiling points. Thus, vegetable oil operated engines provide lower combustion efficiency and this consequently lowers the engine performance because the fuel molecules are heavier and this reduces the ability of the fuel to move and mix with the air. From combustion theory, it is known that a swirl generated inside the cylinder during the fuel injection period would assist in breaking the fuel molecular chain, and mix the fuel with air better and ultimately improve the combustion and engine efficiency [10], which addresses the problems stated above. In this project, a GVSTD were designed by computer simulation to acquire better in cylinder air flow characteristics. The GVSTD is a set of vanes characterized by four main parameters; vane height, vane angle, vane number and vane length, which are arranged in-front of the intake port to generate an organized turbulent flow so that the swirl is increased. The concept of generating turbulence and swirl in the air flow before it enters the cylinder by using guide vanes has been widely used for petrol engines [11, 14, 15] whereas the baffle type swirl generator is generally used for a CI engine [16]. The main advantages of guide vanes compared to a baffle type swirl generator are that it is simple and provides less resistance to the air flow. Since guide vanes can improve SI engine performance, this research investigates whether it can also provide similar or better effects in a CI engine, especially one which is operating on vegetable oil fuel because the intake system for both of them are relatively similar. Therefore, 3D CI engine simulation models based on a

ISSN: 2456 - 4664
International Journal of Advanced Trends in Engineering and Technology
Impact Factor 5.965, Special Issue, January - 2018
1st International Conference on Innovations in Mechanical Engineering (ICIME-2018)
On 5th & 6th January 2018 Organized By
Guru Nanak Institute of Technology & Guru Nanak Institutions Technical Campus, Hyderabad

HINO W04D generator engine were developed to study the in-cylinder air flow characteristics. The model was then introduced with a GVSTD in front of its intake port to compare the effect on airflow. Furthermore, this project was also interested in discovering the effects of various vane heights. The vane height was divided equally into ten GVSTD models based on the radius of intake runner. Therefore the optimum vane height to the pre-set values of vane angle, vane number and vane length was obtained.

2.2 Objective of the Study: The objective of this study is to investigate the improvements of performance and emissions of a DI diesel engine with mamey sapote biodiesel having helical guide vanes. This research intended to optimize the number of guide vanes to be used in DI Diesel engine.

2.2.1 Guide Vane Swirl Device Model: The parametric optimization technique required the parameter (Number of guide vanes) to be varied and tested one by one on the base model. This research determined that the optimized number of guide vanes between 3 to 6 with equal spacing set between the vanes i.e the size of each space was equal to 360^0 divided by number of vanes. Hence, a total of four guide vane swirl devices were developed. While optimizing the number of vanes, the other parameters (Vane height, Vane angle and Vane length) were set as: R, 35^0 twist angle (TA). Table 2.1 summarizes the specifications of guide vane model. Fig: 2.1 illustrate the Guide vane swirl devices.

Table 2.1: Specifications of Helical Guide Vane Swirl Device

Specifications	Values
Major outer radius (R)	24 mm
Guide vane length (l)	60 mm
Thickness of the vane	2 mm
Pitch	109 mm
Height of the vane	8 mm
Guide vane helical angle(θ)	35^0 Clockwise

The various physical helical guide vane swirl devices produced from 3-D printing photographs are shown in the figure 2.1.

Figure 2.1: Helical guide vane swirl devices produced from 3 D printing

3.1 Experimental Set Up:

The investigation is performed by an experiment on a four-stroke single-cylinder diesel engine test bed with four different types of helical guide vane swirl devices, were installed at the downstream of the air intake manifold as shown in the Fig: 3.1. There by increasing the mixture quality of air & fuel in the combustion chamber before the initialization of ignition. The engine load tests were carried out at different loads with and without air swirl devices. The emissions from the engine were also tested before and after the setup installation to estimate the environmental effects. The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer as shown in fig: 3.1 and the specifications of the test engine are shown in table 3.1.

Figure 3.1: Engine Setup

Table 3.1: Engine Specifications

Make and Model	Research Engine Test setup code 240 PE
Type of Engine	Multi fuel
Number of Cylinders	Single cylinder, Four Stroke
Cooling Media	water cooled,
Rated Capacity	3.5 KW @ 1500 rpm,
Cylinder diameter	87.5 mm
Stroke length	110 mm,
Compression ratio range	12-18
Injection variation	0- 25 ^{o} BTDC
Dynamometer	Eddy current Dynamometer

4. Results and Discussion:

This segment presents the effect of helical guide vanes on DI diesel engine operating with Mamey Sapote biodiesel and finding the optimum number of vanes for the models. For presentation of the test results the standard data for diesel and biodiesel were represented as diesel ,B100 and the guide vanes with biodiesel are named as HG3(3 vanes), HG4 (4 vanes), HG5(5 vanes) and HG 6 (6 vanes) respectively.

4.1 Performance Parameters:

4.1.1 Brake Specific Fuel Consumption: The curves of brake specific fuel consumption verses engine loads for diesel, Mamey Sapote biodiesel and all helical guide vane devices plotted in the Fig: 4.1. From the figure, the brake specific fuel consumption was lowered when the load on engine was increased. The Five vane helical guide swirl device showed the minimum consumption when compared with other devices. This is mainly due to the improved combution of fuel in the combustion chamber. The brake specific fuel consumption is decreased by 7.6 % for HG3.When compared with normal engine at peak load.

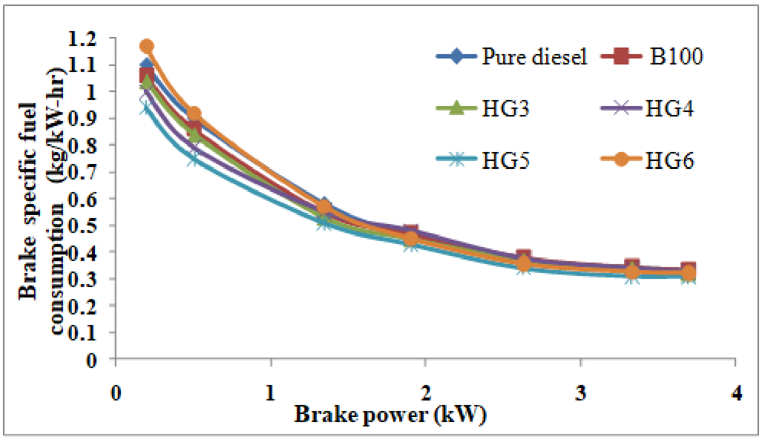

Figure 4.1: Comparision of brake specific fuel consumption with engine load

4.1.2 Brake Thermal Efficiency: The distinction of brake thermal efficiency with engine loads for diesel, Mamey Sapote biodiesel and all helical guide vane devices plotted in the Fig: 4.2. Based on the figure, it is observed that the brake thermal efficiceny 100% Mamey Sapote biodiesel is lower than the diesel. However, with the insertion of helical guide vane in the intake manifold there is better combustion efficiceny due to the proper mixing of air and fuel.The brake thermal efficiency of the engine is observed to be maximum with Five vane helical guide swirl device. Therefore, an ultimate basis of optimized swirl generation in the combustion chamber.This investigation observed that an increase in 8.63% at full load when compared with noraml engine for Five vane helical guide swirl device.

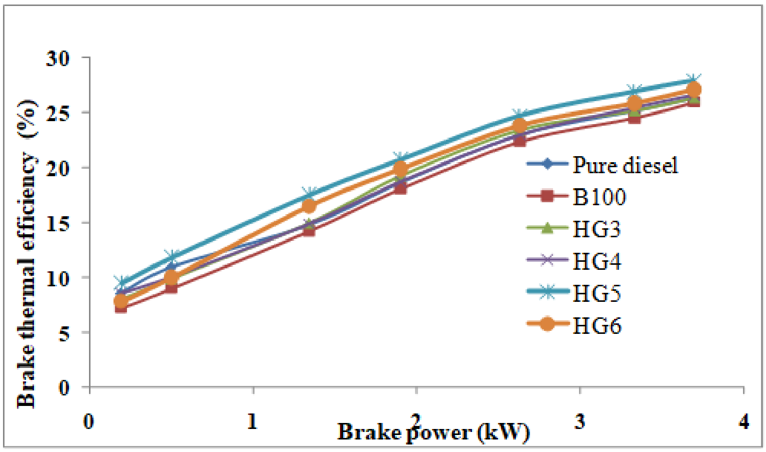

Figure 4.2: Comparision of brake thermal efficiency with engine load

4.1.3 Volumetric Efficiency: The comparison of volumetric efficiency with different brake power for various mamey sapote biodiesel as well as pure diesel is shown in figure 5.4. It is noticed from the figure.4.3 that the volumetric efficiency is decreasing with an increase of applied load under consideration. It is witnessed that the volumetric efficiency for B100 is almost close to diesel. This is due to higher exhaust gas temperature released after the combustion process.

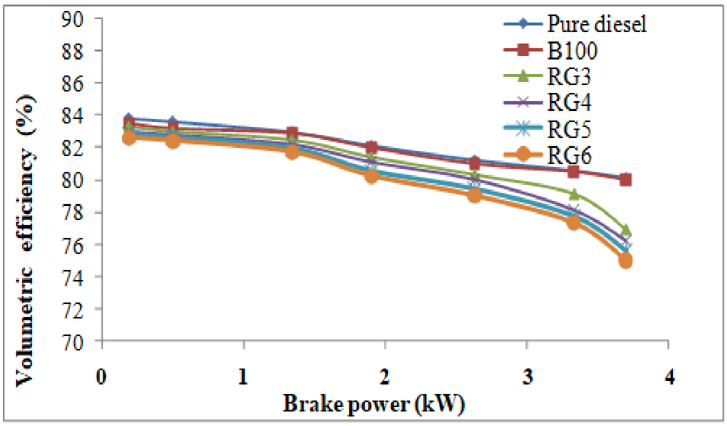

Figure 4.3: Comparision of Volumetric efficiency with engine load

4.2 Emission Parameters:

4.2.1 Unburned Hydro Carbons: The curves of unburned hydro carbons against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.4. Due to the poor air fuel mixing and the smaller combustion period unburnt hydro carbons are emitted from the engine. From the figure, it is observed that hydrocarbon emissions increased when engine load enhanced. In Five vane helical guide swirl device the hydrocarbon emissions are lower when compared with the other devices and found that 15.62% emissions lower than the normal engine at full load.

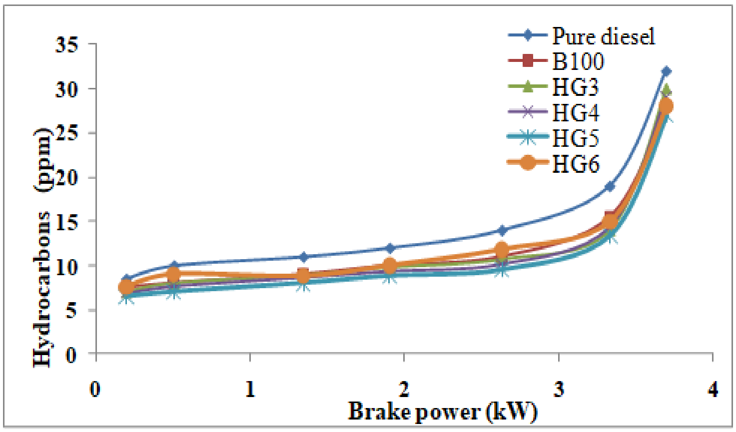

Figure 4.4: Comparision of Hydro Carbons with engine load

4.2.2 Oxides of Nitrogen: The curves of Nitrogen oxides(NOx) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.5. From the figure, it is found that with increase of engine load NOx emissions are also increased. owing to the lower calorific value of Mamey Sapote blend the maximum temperature attained in the cylinder is less when compared with diesel . Due to this reason the formation of Nitrogen oxides are less when compared with the diesel. The five vane swirl device emits low NOx when compared to all other devices, and observed that it emits 3.94% lower than the normal engine at full load.

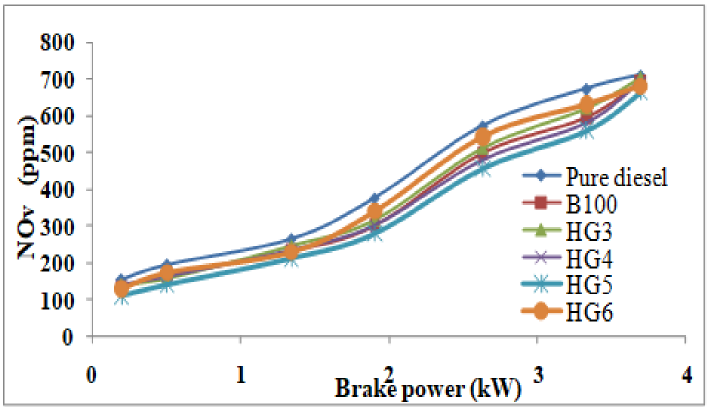

Figure 4.5: Comparision of NOx emissions with engine load

ISSN: 2456 - 4664
International Journal of Advanced Trends in Engineering and Technology
Impact Factor 5.965, Special Issue, January - 2018
1st International Conference on Innovations in Mechanical Engineering (ICIME-2018)
On 5th & 6th January 2018 Organized By
Guru Nanak Institute of Technology & Guru Nanak Institutions Technical Campus, Hyderabad

4.2.3 Carbon monoxide: The curves of Carbon monoxides(CO) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.6. Due to the poor air fuel mixing, poor combustion in the engine cylinder leads to creation of carbon monoxide. It is observed from the figure, when engine load in increased the, accordingly the carbon monoxide emissions were increased. The emissions in the first half load slightly increased and the reamaining load range drastically increased. The same trend was observed on other related research works[13]. In the Five vane helical guide swirl device emits low CO when compared to all other devices, and found that 14.27% lower than normal engine at full load.

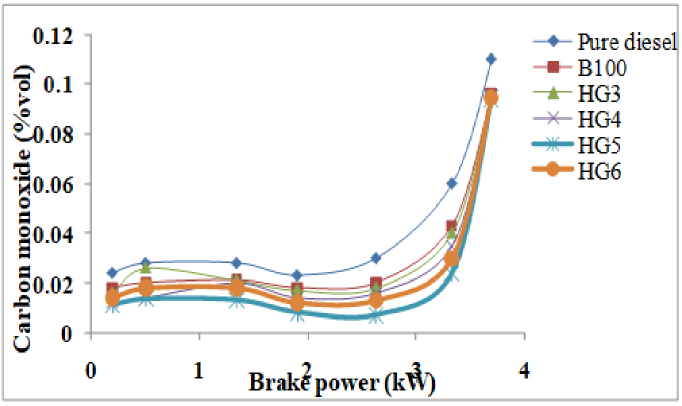

Figure 4.6: Comparision of Carbon monoxide emissions with engine load

4.2.4 Carbon Dioxide: The curves of Carbon dioxides(CO_2) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.7. From the figure, it is observed that the carbon dioxide emissions increses with increases with increase on engine load. Due to the swirl devices better mixing of fuel and air which leads to better combustion efficiency, hence enhanced carbon dioxide emission from all the devices. For Five vane guide swirl device CO_2 emission is very high when compared with other devices, which is 7.24% higher than the normal engine at full load.

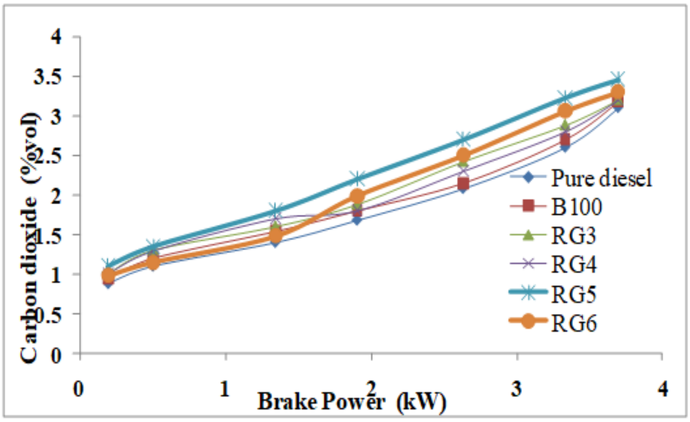

Figure 4.:7 Comparision of Carbon dioxide emissions with engine load

4.2.5 Smoke Density: The curves of smoke density against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.8. Smoke generation mainly depends on air flow circulation into the engine cylinder, From the figure, smoke density increases with increase on engine load. The five vane helical guide vane device emits less smoke when compared with other devices, and found that 9.6% lower than the normal engine at full load.

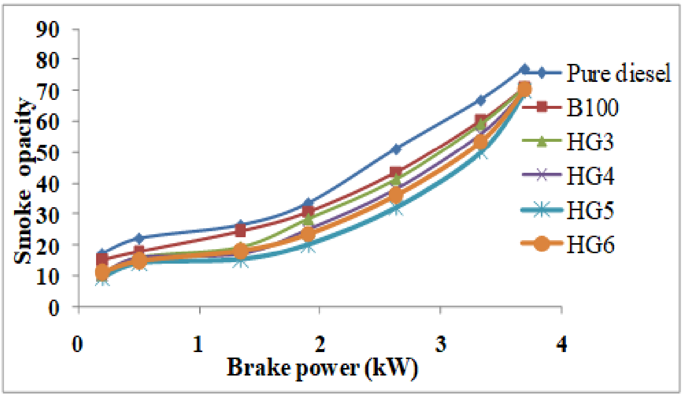

Figure 4.8: Comparision of Smoke denisities with engine load

5. Conclusion:

Experiments for performance & emission characteristics are conducted on a single cylinder, 4-stroke, uniform speed DI diesel engine at a compression ratio of 18. The following conclusions are drawn based on the engine operating on B100 with various number of Helical Guide Vane Swirl devices Viz., HG3,HG4, HG5 and HG6. All parameters are compared at full load with normal diesel engine.

- ✓ The brake thermal efficiency is increased by 8.63 % for HG5
- ✓ The brake specific fuel consumption is decreased by 7.6 % for HG5 The volumetric efficiency decreased by 5.62% for HG5
- ✓ Hydro Carbon emissions are decreased by 15.62% for HG5 Nitrogen Oxide emissions are decreased 4.23% for HG5 Carbon Monoxides are decreased 14.27 % for HG5
- ✓ Carbon Dioxides are increased by 7.4 % for HG5
- ✓ Smoke Densities are decreased by 9.6 % for HG5
- ✓ From the obtained results that out of all configurations tested in the Single Cylinder DI diesel engine the combinations of B100 biodiesel with five vanes Helical guide Swirl Device (HG5) give better remarks in performance as well as in emission aspects.

6. References

1. S. Bari, I. Saad. CFD modelling of the effect of guide vane swirl and tumble device to generate better in-cylinder air flow in a CI engine fuelled by biodiesel. Computers & Fluids. (2013).
2. I. Saad, S. Bari. Optimize Vane Length to Improve In-Cylinder Air Characteristic of CI Engine Using Higher Viscous Fuel. Applied Mechanics and Materials. Vol. 393 (2013) pp. 293-8.
3. X. Zhen, Y. Wang. Study of ignition in a high compression ratio SI (spark ignition) methanol engine using LES (large eddy simulation) with detailed chemical kinetics. Energy. 59 (2013) 549-58.
4. A. Ibrahim, S. Bari. An experimental investigation on the use of EGR in a supercharged natural gas SI engine. Fuel. 89 (2010) 1721-30.
5. S. Bari. Investigation into the deteriorated performance of diesel engine after prolonged use of vegetable oil. ASME Internal Combustion Engine Division 2004 Fall Technical Conference. ASME, Long Beach, California, USA, , 2004. pp. 1-9.
6. B.R. Moser. Influence of Blending Canola, Palm, Soybean, and Sunflower Oil Methyl Esters on Fuel Properties of Biodiesel†. Energy & Fuels. 22 (2008) 4301-6.
7. G. Knothe. Biodiesel: Current Trends and Properties. Topics in Catalysis. 53 (2010) 714-20.
8. I. Saad, S. Bari. Effects of Guide Vane Swirl and Tumble Device (GVSTD) to the Air Flow of Naturally Aspirated CI Engine. International Conference on Mechanical Engineering 2011 (ICME2011). Progressive Printers Pvt. Ltd., Dhaka, Bangladesh, 2011.
9. Saad, S. Bari. Improving Air-Fuel Mixing in Diesel Engine Fuelled by Higher Viscous Fuel using Guide Vane Swirl and Tumble Device (GVSTD). SAE 2013 World Congress & Exhibition. SAE, Detroit, Michigan, USA, 2012.
10. J.B. Heywood. Internal Combustion Engines Fundamentals. McGraw Hill International1988.
11. S.Y. Kim. Air flow system for an internal combustion engine. Google Patents1992.
12. A. Sanjid, H.H. Masjuki, M.A. Kalam, S.M.A. Rahman, M.J. Abedin, S.M. Palash. Production of palm and jatropha based biodiesel and investigation of palm-jatropha combined blend properties, performance, exhaust emission and noise in an unmodified diesel engine. Journal of Cleaner Production.
13. S. Bari, C. Yu, T. Lim. Filter clogging and power loss issues while running a diesel engine with waste cooking oil. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 216 (2002) 993-1001.
14. Shyh-Shyan Lin, J.-C. Yang. Intake Swirl Enhancing Structure for Internal Combustion Engine. United States Patent, USA, 2000.
15. T.Y. Cheng. Gas Swirling Device for Internal Combustion Engine. United States Patent, USA, 2003.
16. S. Fornara, G. Schiavina. Intake manifold with a swirl system for an internal combustion engine. Google Patents2010
17. Idris Saad & Saiful Bari, Improving Air-Fuel Mixing In Diesel Engine Fuelled By Higher Viscous Fuel Using Guide Vane Swirl And Tumble Device (GVSTD), SAE International 2013.
18. A.K.M. Mohiuddin, Investigation of the Swirl Effect on Engine Using Designed Swirl Adapter, IIUM Engineering Journal 2011.
19. Liu Shenghua, Development of New Swirl System and Its Effect on DI Diesel Engine Economy, SAE International 1999-01-288