Effect of Swirl Induction by Internally Threaded Inlet Manifolds on Exhaust Emissions of Single Cylinder (DI) Diesel Engine

Dr. Pankaj N.Shrirao[1], Dr. Rajeshkumar U. Sambhe[2]

[1]Assistant Professor (Mechanical Engineering), Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, India

[2]Associate Professor (Mechanical Engineering), Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, India

Abstract: ***The aim of paper is to design different types of inlet manifolds for direct injection (DI) single cylinder diesel engine in order to create the turbulence by swirl. A good swirl promotes the fast combustion and improves the efficiency. The engine should run at low speeds in order to have low mechanical losses and fast combustion, enabling good combustion efficiency. Therefore to produce high turbulence prior to combustion within the cylinder, swirl induced by the inlet manifold will be helpful. This paper aims at studying the effect of air swirl generated by directing the air flow in intake manifold on engine performance as well as on its exhaust emissions. The turbulence is achieved in the inlet manifold with different types of internal threads of constant pitch. In view this, experimental investigation has been carried out to find the effect of swirl on the performance characteristics of the engine as well as on its exhaust emissions , by inducing swirl in inlet manifolds with three different types of internal threads viz. acme, buttress and knuckle threads of constant pitch. It is inferred that, the inlet manifold with buttress threads gives better performance and yields less exhaust emissions compared to inlet manifolds with acme and knuckle threads. This is because inlet manifold with buttress threads achieved a higher swirl coefficient and swirl ratio compared with inlet manifolds having acme and knuckle threads.***

Keywords: Internal threads, Swirl enhancement, Performance characteristics, Exhaust emissions.

1. Introduction

Diesel engines have an excellent reputation for their low fuel consumption, reliability, and durability characteristics. In-cylinder flow field structure in an internal combustion engine has a major influence on the combustion, emission and performance characteristics. Fluid flows into the combustion chamber of an I.C engine through the intake manifold with high velocity. Then the kinetic energy of the fluid resulting in turbulence causes rapid mixing of fuel and air, if the fuel is injected directly into the cylinder. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion. A good knowledge of the flow field inside the cylinder of an I.C engine is very much essential for optimization of the design of the combustion chamber for better performance [1].

Two general approaches are used to create swirl during the induction process. In first approach, swirl is created by discharging the flow into the cylinder tangentially towards the cylinder wall (helical port) and in the second approach, the swirl is generated in the manifold runner so that the flow rotates about the valve axis before it enters the cylinder. Several research studies related to swirl enhancement in IC engines reported that swirl facilitates the mixing of the air fuel mixture and increases the combustion rate.

To enhance the efficiency of an engine it is important to optimize thermal efficiency, which is obtained at the highest possible compression ratio. However, if the compression ratio is too high, there is a chance to have knock, which should be avoided at all cost. A solution for this problem is to promote rapid combustion, to reduce the available time for the self-ignition to occur [2]. For the promotion of rapid combustion, sufficient large-scale turbulence (kinetic energy) is needed at the end of the compression stroke because it will result in a better mixing process of air and fuel and it will also enhance flame development. However, high turbulence leads to excessive heat transfer from the gases to the cylinder walls, and may create problems of flame propagation [3] [4] [5]. The key to efficient combustion is to have sufficient swirl in the combustion chamber prior to ignition. The Swirl can be generated in the diesel engine by modifying three parameters in the engine, they are the cylinder head, the piston i.e. modification of combustion chamber and the inlet manifold [6] [7]. The experimental work of Sihun Lee *et al.*, [8] showed that both swirl and tumbling motions enhanced the fuel vaporization and fuel-air mixing and results in better cold start performance. Another advantage that was reported was ability to retard ignition timing as it has faster burning, which gives enough time for fuel vaporization and fuel-air mixing before being ignited.

Taehoon Kim *et al.*, [9] improved the lean misfire limit by the introduction of swirl and tumble motion. Three types of ports with an IACV (Intake Air Control Valve) have been developed to obtain sufficient swirl and tumble motion to improve combustion and still keep high volumetric efficiency. Tests showed that the combustion duration was shortened and consequently lean misfire limit and EGR tolerance were improved with considerable reduction in the level of NOx.

Abdul Rahim Ismail *et al.*, [10] in their experiment investigated air flow and coefficient of discharge desirable for inflow (reverse flow) through the exhaust port using super flow bench. The experimental results show that the air flow and coefficient of discharge in the intake port and exhaust port of the four stroke diesel engine provided the best at 0.25 L / D and in highest test pressure. Increasing the valve lift and test pressure can increase the air flow, valve air flow and coefficient of discharge in intake manifold system or in exhaust manifold system, but after the maximum valve lift per diameter 0.25L / D, the air flow, valve air flow and coefficient of discharge is stable and did not increase.

From the review of literature, it can be analyzed the design of inlet manifold configuration is very important in an IC engine. In general, the presence of a swirl in the cylinder of an internal combustion engine improves the homogenization of the air - fuel mixture, and consequently, enhances fuel combustion. The aim of this work is to analyse the effect of the swirl on the performance characteristics of the engine as well as on its exhaust emissions, by inducing swirl in inlet manifolds with three different types of internal threads viz. acme, buttress and knuckle threads of constant pitch.

2. Experimental Work

In the present work the effects of swirl on the performance characteristics of the engine, by inducing swirl in inlet manifolds with three different types of internal threads viz. acme, buttress and knuckle threads of constant pitch of 2 mm. The experiments are conducted on a single cylinder Kirloskar make direct injection four stroke cycle diesel engine. The general specifications of the engine are given in Table-1. Water cooled eddy current dynamometer is used for the tests. The engine is equipped with electro-magnetic pick up, piezo-type cylinder pressure sensor, thermocouples to measure the temperature of water, air and gas, rotameter to measure the water flow rate and manometer to measure air flow and fuel flow rates.

Table 1: Specifications of Engine used for Experimentation

Sr. No.	*Engine Parameters*	*Specifications*
1	Engine Type	TV1. Kirloskar, Vertical, Four stroke diesel engine
2	Software used	ICEngineSoft version 8.0
3	Number of cylinders	Single cylinder
4	Bore Diameter	80mm
5	Stroke Length	110mm
6	Rated Power	3.68 kW (5 HP)
7	Rated Speed	1500 RPM
8	Compression Ratio	17.5:1

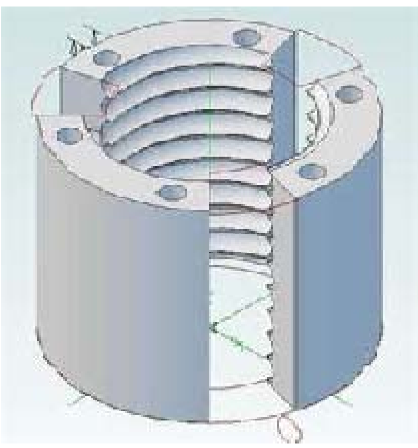

Figure 1: Internally Threaded Inlet Manifold

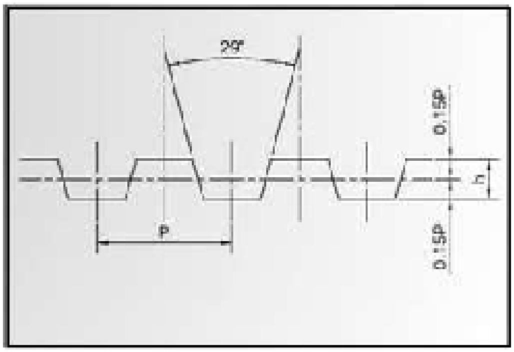

Figure 2: Acme threads

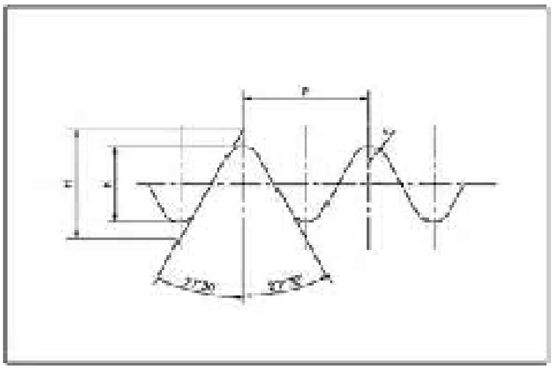

Figure 3: Knuckle threads

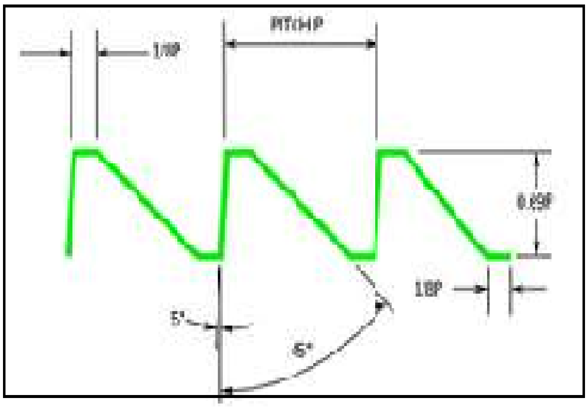

Figure 4: Buttress threads

If, p = pitch of the thread; d = depth of the thread; then, [d = 0.54127* p].

3. Results And Discussion

3.1 Brake Specific Fuel Consumption (BSFC)

The BSFC is a measure of engine efficiency. In fact, BSFC and engine efficiency are inversely related, so that the lower the bsfc the better the engine. Engineers use the bsfc rather than thermal efficiency because a more are less universally accepted definition of thermal efficiency does not exist. The Brake Specific Fuel Consumption Vs load for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads is compared with the engine with normal inlet manifold and is shown in fig.5. From Fig, it is inferred that the brake specific fuel consumption is decreasing with an increase in load for all the configurations that are under consideration. The brake specific fuel consumption of engine with normal inlet manifold at 3/4 of rated load is 0.48. It can be observed that the engine with inlet manifolds having acme and buttress internal threads give brake specific fuel consumption of 0.44 and 0.43, respectively, at 3/4 of rated load. It is significant to note that 11.62% of reduction in BSFC is observed at 2.5kW load for inlet manifold having buttress internal threads compared to engine with normal inlet manifold. The decrease in BSFC may be due to higher swirl produced in inlet manifold having buttress internal threads compared to engine with normal inlet manifold.

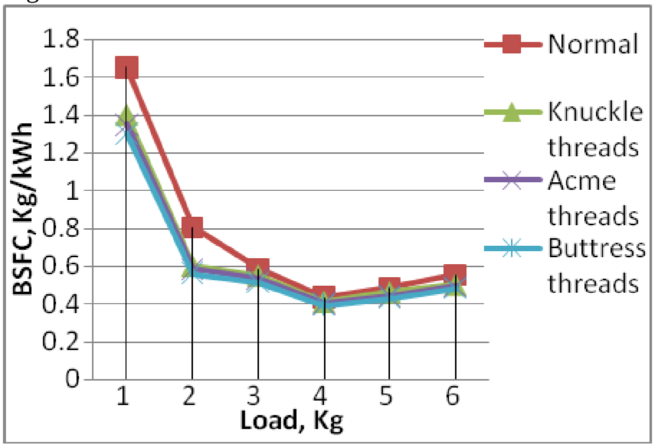

Figure 5: Brake Specific Fuel Consumption Vs Load

3.2 Exhaust Gas Temperature

Figure.6 depicts the variation of exhaust gas temperature for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads is compared with the engine with normal inlet manifold. Exhaust gas temperature is indication for conversion of heat into work that takes place in the cylinder. The exhaust gas temperature is higher for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads than engine with normal inlet manifold. At various load conditions it is observed that the exhaust gas temperature increases with load because more fuel is burnt to meet the power requirement. It can be seen that in the case of the engine with normal inlet manifold exhaust gas temperature is 223^{0}C at 2.5kW load. For diesel engine with inlet manifolds having knuckle and acme internal threads are exhaust gas temperature marginally increases to 232 and 238^{0}C respectively. The exhaust gas temperature is more for diesel engine with inlet manifolds having buttress internal threads is 247 ^{0}C at 2.5kW load.

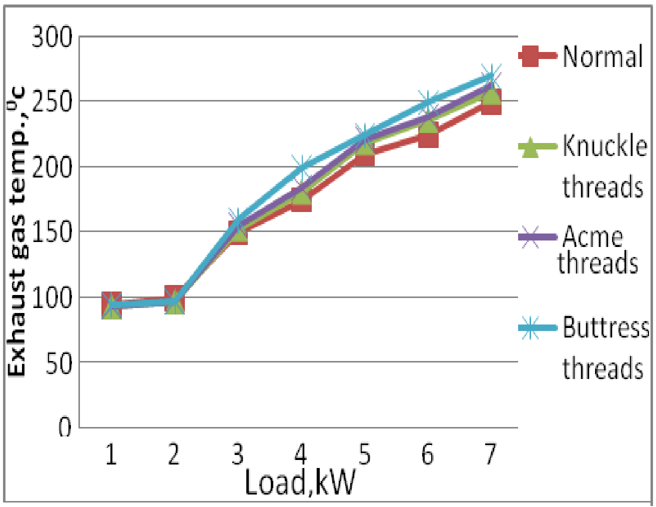

Figure 6: Exhaust gas temperature Vs Load

3.3 HC Emission

The comparison of Hydrocarbon emission in the exhaust is shown in Figure 7. Unburnt hydrocarbon emission is the direct result of incomplete combustion. It is apparent that the hydrocarbon emission is decreasing with the increase in the turbulence which results in complete combustion. The lowest hydrocarbon emission is for engine with inlet manifold having buttress internal threads when compared to engine with normal inlet manifold is about 18.88 % by volume at 3/4 of rated load. It is also observed that for diesel engine with inlet manifolds having acme and knuckle internal threads reduction in HC levels is about 12.32 % and 9.33% by volume at 3/4 of rated load when compared to engine with normal inlet manifold.

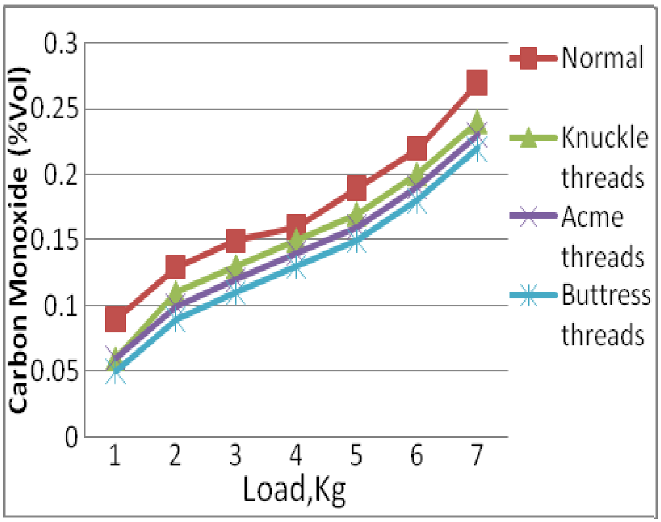

Figure 7: Load Vs Hydro carbons

3.4 CO Emission

Fig. 8 shows the comparison of Carbon monoxide emission with Load for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads is compared with the engine with normal inlet manifold. Generally, C.I engines operate with lean mixtures and hence the CO emission would be low. With the higher air turbulence in the inlet manifolds with internal threads, the oxidation of carbon monoxide in the engine is improved and which reduces the CO emissions. The lowest carbon monoxide emission is for engine with inlet manifold having buttress internal threads when compared to engine with normal inlet manifold is about 26.66 % by volume at 3/4 of rated load. It is also observed that for diesel engine with inlet manifolds having acme and knuckle internal threads reduction in CO levels is about 21.7% and 19.53% by volume at 3/4 of rated load when compared to engine with normal inlet manifold.

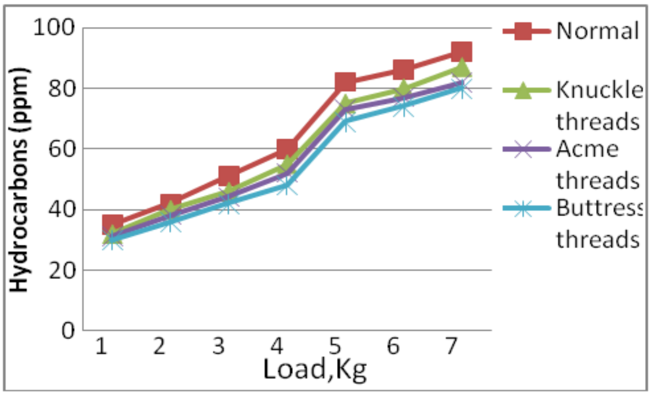

Figure 8: Load Vs Carbon monoxide

3.5 NOx Emission

Fig.9 shows the comparison of NOx emission with Load for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads is compared with the engine with normal inlet manifold. The NOx emissions for diesel engine with inlet manifolds having buttress internal threads is 499 ppm and whereas for engine with normal inlet manifold is 516 ppm. NOx emissions are lower for diesel engine with inlet manifold having buttress internal threads when compared to engine with normal inlet manifold at 3/4 of rated load. This is due decrease in the operating temperature in the cylinder by the air swirl inside the cylinder and leads to less NOx formation. Therefore, the NOx formation is lower with inlet manifold having buttress internal threads and is about 3.6% than normal inlet manifold at 3/4 of rated load. The decrease in NOx emissions for the engine with inlet manifolds having acme and knuckle internal threads are 2.9 % and 1.8 % at 3/4 of rated load respectively.

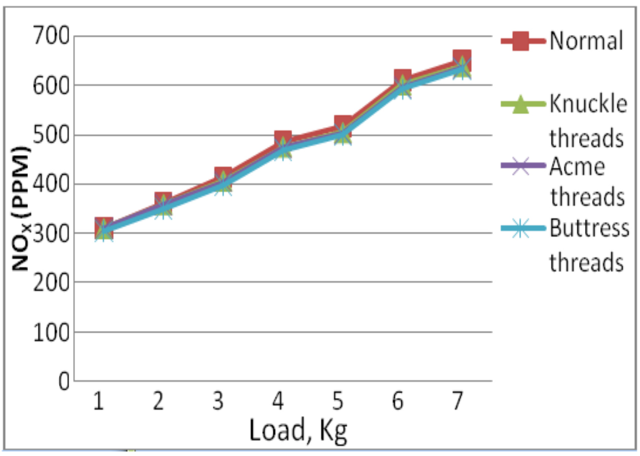

Figure 9: Load Vs NO_X Emissions

4. Conclusion

The Configuration inlet manifold with buttress internal threads enhances the turbulence and hence results in better air-fuel mixing process among all the configurations of inlet manifolds. As a result, the thermal efficiency is increased and BSFC and exhaust emissions are reduced. It can be concluded that inlet manifold with buttress internal threads is the best trade-off between performance and emissions.

1. It is observed that 11.62% of reduction in BSFC at 2.5kW load for engine with inlet manifold having buttress internal threads compared to engine with normal inlet manifold.
2. The exhaust gas temperature is higher for diesel engine with inlet manifolds having three different types of internal threads viz. acme, buttress and knuckle threads than engine with normal inlet manifold.
3. It is observed that 12.32%, 26.66% and 3.6% of reduction in HC, CO and NOx emissions respectively at 2.5kW load for engine with inlet manifold having buttress internal threads compared to engine with normal inlet manifold.
4. The results indicate that inlet manifold with buttress threads is identified as optimum configuration based on performance as well as exhaust emissions of diesel engine.

References

[1] Murali Krishna B, Bijucherian A, and Mallikarjuna J.M (2010). Effect of Intake Manifold Inclination on Intake Valve Flow Characteristics of a Single Cylinder Engine using Particle Image Velocimetry. *International Journal of Engineering and Applied Sciences* **6**(2) pp.119-125.

[2] Jorge martins, Senhorinhateixeira, Stijncoene, “Design of an inlet track of a Small I. C. engine for swirl enhancement”, Proceedings of COBEM 2009, 20th International Congress of Mechanical Engineering November 15-20, 2009.

[3] Blair, G. P, “Design and Simulation of Four-Stroke Engines”, Warrendale (U.S.A), SAE, 1999.

[4] Lumley, J. L., “Early work on fluid mechanics in the IC engine”, Annual Reviews, Annual Review of Fluid Mechanics Volume 33, Issue:1.2001.

[5] Stone, R., “Motor Vehicle Fuel Economy”, Middlesex (England), Macmillan education Ltd. 1989.

[6] Payri ,J.V.Benajes and M.lapuerta ,The Effect of Air Swirl on The Combustion Process on D.I Diesel Engine, International Symposium COMODIA 1990 PP:545-550.

[7] S.L.V. Prasad, Prof. V.Pandurangadu “Experimental study of the effect of air swirl in intake manifold on diesel engine performance”-International Journal of Multi displ. Research& Advances. In Engg (IJMRAE), Vol. 3, No. I (January 2011), pp. 179-186.

[8] Sihun Lee, Kun Tong, Bryan D. Quay, James V. Zello and Domenice A. 2001. Santavicca Effects of Swirl and Tumble on Mixture Preparation during Cold Start of a Gasoline Direct-Injection Engine. SAE paper. 01-1900.

[9] Taehoon Kim, Seokhong Noh, Chulho Yu and Insik Kang. 1994. Optimization of Swirl and Tumble in KMC 2.4L Lean Burn Engine. SAE paper. 940307, Warren dale PA.

[10] Abdul Rahim Ismail and Rosli Abu Bakar Semin.2008. An Investigation of Valve Lift Effect on Air Flow and

Coefficient of Discharge of Four Stroke Engines Based on Experiment. American Journal of Applied Sciences. 5(8): 963-971.

Author Profile

Dr. Pankaj N. Shrirao is Assistant Professor (Mechanical Engineering) in Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, India. He has completed his Doctoral research work from Government College of Engineering Amravati and awarded Ph.D. from Sant Gadge Baba Amravati University, Amravati. He holds his Bachelor Degree in Mechanical Engineering and Master Degree in Thermal Power with total 09 years of experience. He has published 09 papers in international journals and conferences. His areas of interest are heat transfer and IC Engine.

Dr. Rajeshkumar U. Sambhe is Associate Professor (Mechanical Engineering) in Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, India. He is completed his Doctoral studies from Government College of Engineering Amravati and awarded Ph.D. from Sant Gadge Baba Amravati University, Amravati. He holds his Bachelor Degree in Mechanical Engineering with University Merit and Master Degree in Production Technology with total 16 years experience. He has published 15 papers in international journals and conferences including paper International Journal of Productivity and Quality Management and International Journal of Business Excellence.