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# EFFECT OF MULTIPLE INJECTION STRATEGIES TO REDUCE OXIDES OF NITROGEN AND CONTROL OF POLLUTANT EMISSIONS OF AN AUTOMOBILE

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**ABSTRACT**
Simultaneously reducing smoke and oxides of nitrogen to meet the stringent emission standards received considerable attention in diesel combustion chemistry. The Zeldovich kinetics depends on the temperature during the combustion, to reduce the NOx formation in the combustion duration. Modifications of the combustion system designs are used to control NOx emissions in the compression ignition engines. In the present investigation improvement in performance, combustion and emission characteristics of a direct injection diesel engine by achieving better fuel air mixing by turbulence inducement through internal jet arrangement. The experimental results of modified combustion chambers having the two, three and four internal jets are compared with that of the base engine performance. These results show that, decrease in peak pressure and smoke and a marginal increase in the oxides of nitrogen at part load conditions.
**Keywords:** Combustion Chemistry, Zeldovich Mechanism, Oxides of Nitrogen, Turbulence Technique, Diesel Engine.


## INTRODUCTION

There has been increasing attention on the use of diesel engines because diesel engines pollute the atmosphere even though its efficiency and better fuel efficiency compared to spark ignition engines[1]. The major concern is on the reduction on the emissions, oxides of nitrogen (NOx), and smoke to meet the environmental regulations[2]. In a diesel engine, air-fuel mixture is mixed in the inlet port and burns stoichiometrically during the combustion process. During combustion the rich fuel region is a source for soot which is formed due to the insufficiency oxygen and in turn increases the temperature. High temperature increases the oxides of nitrogen formation. Oxygen is sufficiently available during the combustion process the smoke is oxidized due to the higher temperature[3]. In a compression ignition engine reducing both NOx and smoke simultaneously is a huge task; researcher used different methods, when attempts make to reduce smoke inside the cylinder results to increase in NOx[4]. Smoke can be reduced effectively by advancing the injection time. Another way to smoke is increasing the ignition delay, but these two methods increases NOx emissions. Nitric oxide is concentration is more when the oxides of nitrogen produced during combustion[5].

Bae et al (2002) conducted experiment to analyze the effect of injector nozzle holes and developed a model for the spray of diesel. He concluded that five holes nozzle reduced the emission of hydrocarbon effectively[6,14]. Li conducted experiments on multi-hole injector nozzle and concluded that the cavitation and turbulence in a diesel injector nozzle has desirable effect on the characteristics of nozzle spray[7,15]. The zeldovich explained the thermal route which exhibits the temperature active over approximately 1800 K. Retaining the combustion product in the cylinder has also influence the increase in nitrous oxide[7]. In the combustion gas, which contains nitrogen also facilitate the formation of nitrous oxide[8].

Chen *et al.* revealed that multiple fuel injection methods reduce the engine emission and reported that NOx emissions decrease[9,19]. It is considered impossible to reduce both NOx and Smoke because one usually increases if the other one degreases. Multiple injections are effective methods report by the Yehliu et al in his experiment with the use of different diameter orifice to split the fuel spray, which reduces the particulate matter significantly[10,20]. This is basic idea is injecting a fraction of fuel at the end of the combustion period, oxidation reaction improved and due to the oxidation the particulate emission decreased in the cycle[11-14]. Multiple injections are more effective at low loads. In the present work, multiple injections through three types of internal jets used to introduce fuel in the cavity for inducing turbulence in combustion chamber. The results concerning the performance, emission and combustion aspects of the engine in different methods are compared with the experimental data of the base engine test.

## EXPERIMENITAL

To provide complete combustion at a constant rate, there is common design objective of bringing sufficient air in contact with the injected fuel particles. For this purpose, the piston crown and the cylinder head were shaped to induce a swirling motion to air, while during compression piston is moving towards TDC. The production of turbulence by different means, however, is considered necessary for better fuel-air mixing. For the present investigation, an experimental set up is installed with the necessary instrumentation to measure performance, combustion and emissions from the direct injection compression ignition engine at different operating conditions. This set up involves an engine with dynamometer and provisions for measurement of engine speed, fuel and air flow rates, cylinder pressure history and exhaust emissions such as smoke and oxides of nitrogen. The experimental results were obtained for various arrangements arising out of the proposed three methods two, three and four internal jets of 3 mm diameter positioned 180, 120 and 90 respectively degrees to each other in cavity for inducing turbulence in combustion chamber. The experimental results of modified combustion chambers having the two, three and four holes' internal jets are compared with that of the base engine performance, combustion and emission characteristics.

## RESULTS AND DISCUSSION

For different internal jets, Figure-1 shows the variation of the peak pressure with load. There is a decrease in peak pressures in all these cases compared to the base engine value with very limited difference in the magnitude of the peak pressures with different internal jets[15-17].

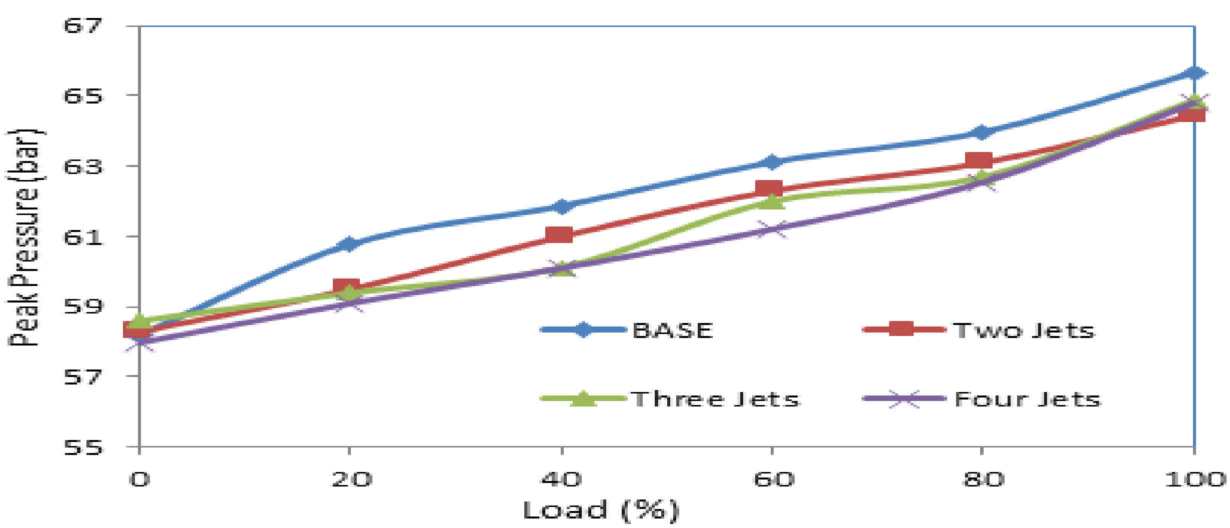


Fig.-1: Variation of Peak Pressure with Load

Figure-2 shows the variation of the maximum rate of pressure rise with load. The maximum rate of pressure rise is significantly reduced in the presence of internal jets, suggesting smoother operation of the engine in

comparison to the base engine. It is observed that under the combined effect modifications in fuel-air mixing, the peak pressure and the maximum rate of pressure rise values decreased over base engine values. These results reveal a smoother combustion is attained in the engine with the modifications in place.
Figure-3 shows the variation of the ignition delay which is found to increase in all the cases. These facts relate with each other to corroborate the reduction in peak pressure and the possible change in mixing level during that phase of combustion. Generally, a marginal increase of 1°CA is observed in the ignition delay over base line engine conditions[18-19]. While the effect on the ignition delay is not considered too significant, the combustion duration under the fuel air mixing modifications seems to have shortened considerably. This would imply that a better mixture formation due to well-timed jet induced turbulence in conjunction with better combustion chemistry.

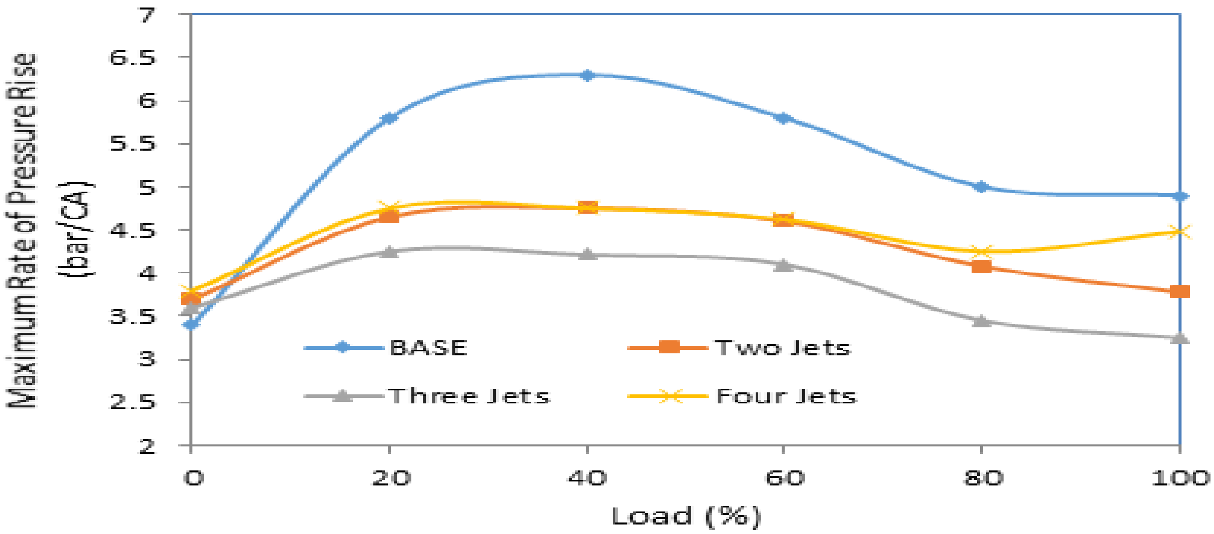


Fig.-2: Variation of Maximum Rate of Pressure Rise with Load

Figure-4 shows the variation of the smoke value with load for base, two jets, three jets and four jets. There is a significant reduction in smoke level with the internal jets vis-à-vis base engine smoke values. The reduced combustion period observed in the case of internal jets are possibly the cause of decrease in smoke and a marginal increase at part load conditions in the concentration of NOx[20-22]. It appears that the changes in engine combustion have resulted in significant influence on the exhaust smoke values[23-24]. About nitric oxide emissions are concerned, a marginal increase of about 5% is observed at full load as shown Figure-5.

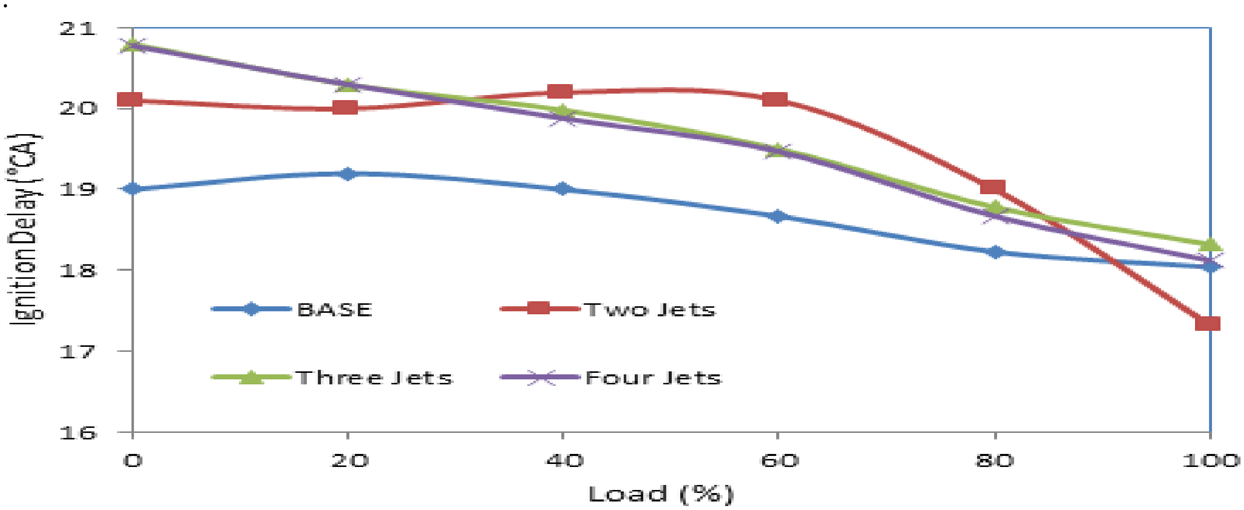


Fig.-3: Variation of Ignition Delay with Load

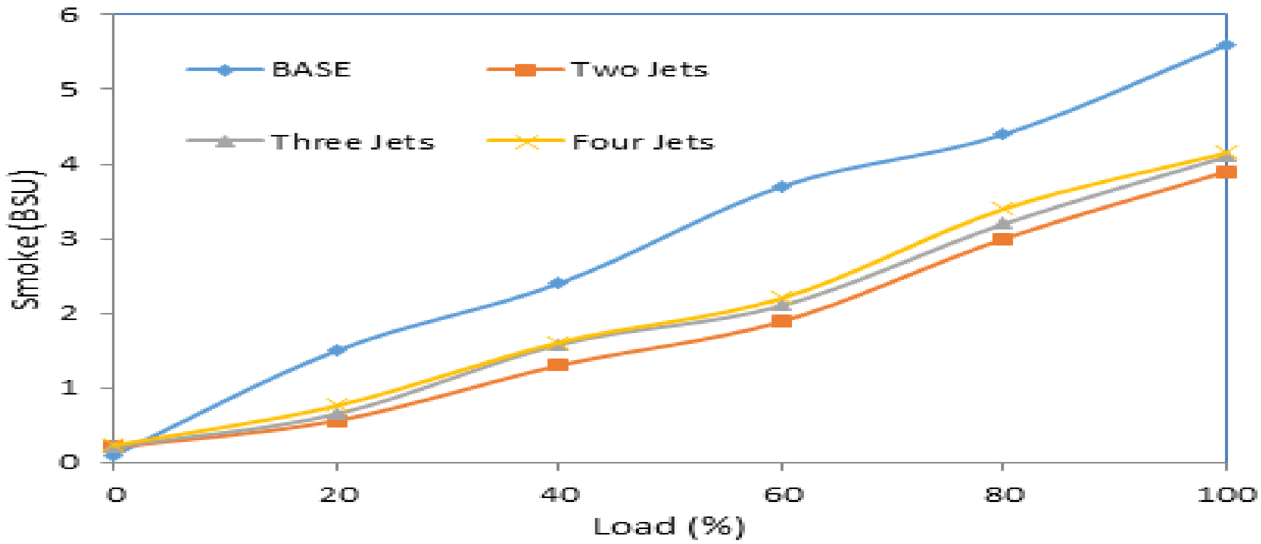


Fig.-4: Variation of Smoke with Load

At part load condition the quantity of the injected fuel is less, which indicates that a lean combustion occurs at part load condition which resulted in higher NOx emissions, whereas at full load the fuel quantity injected is more for the same quantity of air where the air fuel mixture tends towards stochiometric condition which has resulted in less NOx at full load condition. Thus, it can be inferred that internal jets could produce more favorable conditions of in-cylinder turbulence than the basic engine configuration. In case of three and four jets, there may be interference of internal jets to result in unfavorable mixing due to level of turbulence produced.

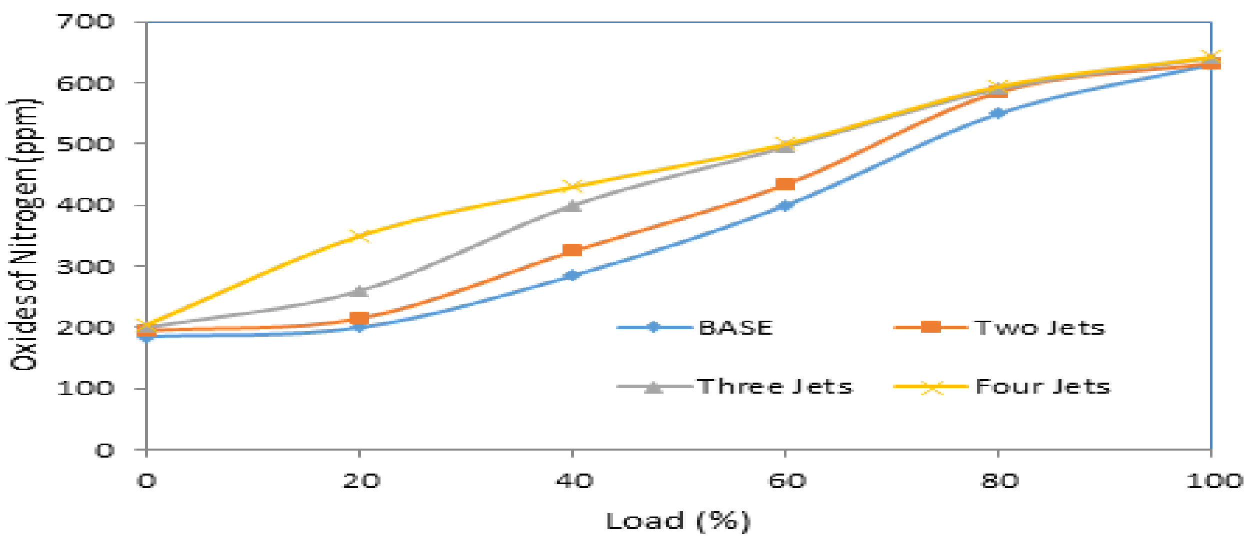


Fig.-5: Variation of Oxides of Nitrogen with Load

## CONCLUSION

The effect of three internal jets spray combustion was investigated. The extended Zeldovich Mechanism through the internal jet with different angle show better combustion chemistry inside the cylinder. The two internal jets configuration shows evidence in helping reduce smoke as well as comparable NOx emissions with base engine values, possibly due to better combustion chemistry. The peak pressure is reduced and ignition delay increased compared with base line engine. The reduced combustion period observed in the case of internal jets are possibly the cause of decrease in smoke and a marginal increase at part load conditions in the concentration of oxides of nitrogen.

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