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Experimental investigation of diesel engine with water injection system on emission parameters

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Abstract : *The concept of water addition to the IC engine has been around for over 50 years. Diesel engines are nominated for highly emission producer like NOx, CO, CO_2 and HC. These emissions are highly depending upon the combustion chamber temperature which is exceeding up to 750 K. Therefore by controlling peak combustion chamber temperature NOx formation can be controlled effectively. The latent heat of evaporation of water is 2256 kJ/kg. In the study, water injection method is applied to a Single cylinder diesel engine to control NOx emissions. Water injected in intake manifold of diesel engine is by using calibrated burette. For Constant compression ratio, 9, 16, 38ml/min water mass supply to engine. Results are observed for 1 to 8 load condition. The obtained results are compared with conventional diesel engine in terms of NOx, CO, CO_2, HC emissions. In the experimental results, it is determined that the engine NOx,decreased and CO, CO_2, HC increased.*

Keywords: *Diesel engine, Water injection, Engine Emission, NO_x, Fumigation.*

I. Introduction

Among most two type internal combustion engine diesel engine generate more undesirable emission during combustion process. The pollutants are directly affecting atmosphere and cause problems such as global warming, acid rain, smog, respiratory hazards etc. These emissions are mostly due to dissociation of nitrogen, nonstoichometric combustion, major emissions include oxides of nitrogen (NO_X), unburnt hydrocarbons (HC), oxides of carbon (CO,CO_2). There are various way to control theses pollutants. Two major ways are: control process in to the combustion cylinder and after treatment outside cylinder. In this experiment water is placed with intake air supplied to engine and emission parameters are studied.

The reduction in NOx, CO and CO_2 is more then 80% by water scrubbing and air dilution system compare to without system.[1] Fuel consumption also remains constant at no load to high load condition. It was invention of his study that no fuel penalty observed. The change in torque and power at 1200 r.p.m with rate of 20% steam injection, result also showed minimum SFC and maximum effective efficiency highest NO formation reduce at 1200 rpm with 20% steam injection and also no inverse effects on HC,CO,CO_2 are observed [2]. The reduction in the level of both NO_X and particulate matters (PM), NOx is reduced almost 30% and 60% in PM by 15% water in diesel emulsion. It has only limited effect on CO_2 [3]. Water diesel emulsion effects due to the reducing peak temperature of combustion chamber and micro explosion phenomenon. The performed experiment on heavy duty diesel engine with real time water injection (RTWI), RTWI system delivered metered quantity of water to injectors [4]. At tip of injector the initial portion of injection contained mostly diesel fuel. RTWI system has BSFC cost for 1% NOx reduction is 0.05% and for other like EGR it is 0.13%, Retarded injection timing 0.4%. It clears that RTWI is cheaper than other techniques.

Based on previous literature reviews Experiment is carried out on single cylinder diesel engine to investigate study of water injection at atmospheric temperature and pressure condition.

II. Experimental Setup And Technical Method

Experiments were carried out with single cylinder, four strokes and water cooled, multi fuel research engine. Table and fig-1 shows engine specification and engine setup respectively. To measure brake torque the engine is connected to eddy current type dynamometer for loading. Before start experiments load cell is calibrated accurately.

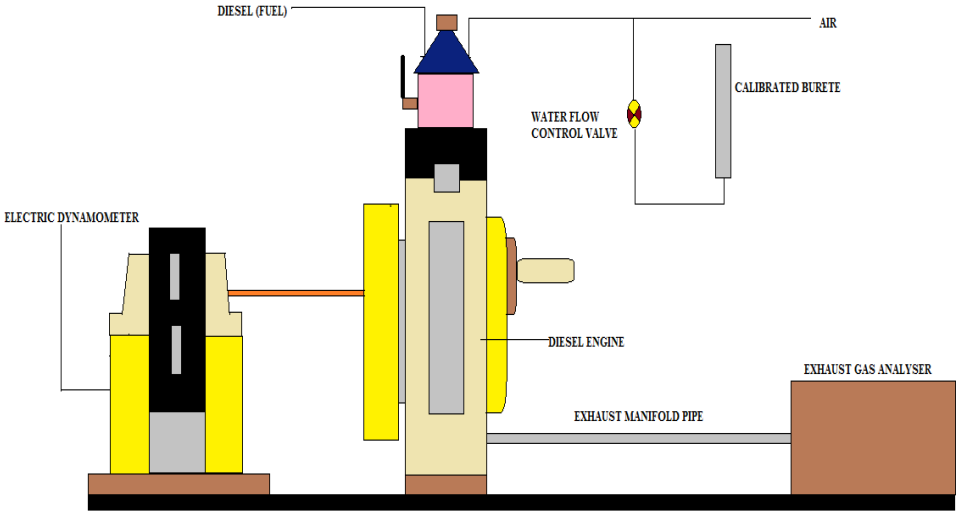

Fig.1 Experimental Setup

Technical Specifications

Model	TV1
Make	Kirlosker Oil Engines
Type	Four stroke, Water cooled, Diesel
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Combustion principle	Compression ignition
Cubic capacity	0.661 liters
Compression ratio 3 port	17.5:1
Lubrication system	Forced feed system

In this study QUATTRO PRO, GA4040 type gas analyser was used so as to measure exhausts emission before It use in experiments, device were calibrated. In order to inject water into engine manually controlled water injection system was developed. Water injection system is shown in fig.2.

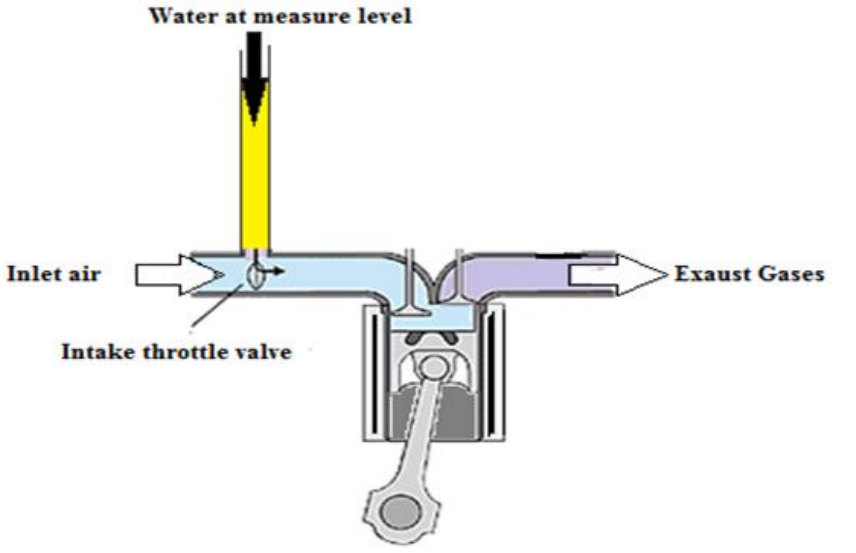

Fig.2 Double burette arrangement for intake manifold water injection system

Experiments were done in variable load 1to 8 kg and constant speed condition. In order to compare firstly standard diesel tests were carried out. Then water at atmospheric pressure and temperature was injected with nozzle in intake manifold via water nozzle. Water flow rates 9ml/min,16ml/min,38ml/min were used. Experiments were repeated for each flow rate and obtained emission values compared with these of standard diesel values.

III. Result And Discussion

	Diesel				9 ml/min				16 ml/min				38 ml/min			
Load (Kg)	**CO (%)**	**CO_2 (%)**	**HC (ppm)**	**NO_X (ppm)**	**CO (%)**	**CO_2 (%)**	**HC (ppm)**	**NO_X (ppm)**	**CO (%)**	**CO_2 (%)**	**HC (ppm**	**NO_X (ppm)**	**CO (%)**	**CO_2 (%)**	**HC (ppm)**	**NO_X (ppm**
1	0.12	1.21	28	340	0.13	1.25	30	270	0.14	1.31	32	145	0.15	1.4	35	45
2	0.09	1.32	31	892	0.11	1.37	33	480	0.13	1.42	35	325	0.14	1.53	38	99
3	0.08	1.4	36	1500	0.1	1.52	38	590	0.11	1.68	40	422	0.13	1.74	43	275
4	0.07	1.61	42	2089	0.09	1.71	43	1010	0.1	1.85	46	712	0.12	1.9	49	347
5	0.06	1.85	43	2856	0.07	1.92	45	1332	0.08	2.17	49	1214	0.1	2.26	51	658
6	0.05	1.95	44	3893	0.06	2.17	46	1845	0.07	2.29	49	1586	0.08	2.34	53	905
7	0.04	2.11	47	4532	0.05	2.23	48	2232	0.06	2.34	52	1841	0.07	2.46	54	1245
8	0.03	2.19	50	5608	0.04	2.31	51	3206	0.05	2.39	55	2927	0.06	2.47	58	1409

No_x Formation

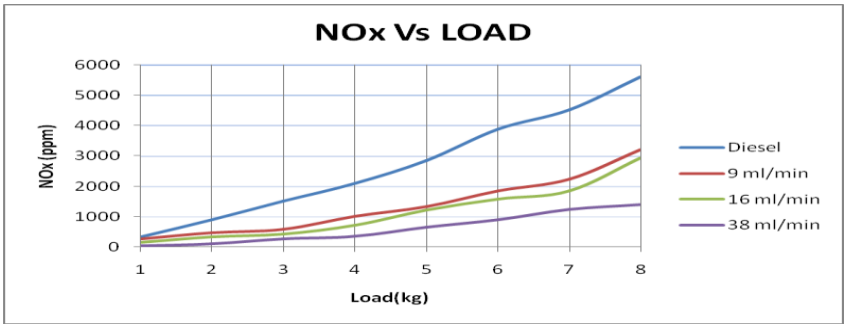

Fig.3 Comparison of NO_X level

The comparison of NO_X formation in cylinder at 1 to 8 kg load conditions for different water flow rates 9 ml/min, 16 ml/min and 38 ml/min, tested is given in fig-3. As can be seen from the fig water injected caused to decrease NO_X emissions. The NO_X emission decrease at all engine loads with increase in water flow rate. The minimum NO_X is 45 ppm at 1 kg load with 38 ml/min. According to observed NO_X emission value change is 4199 ppm at 8 kg load for 38 ml/min water flow rate, lowest change is 45 ppm at 1 kg load 38 ml/min.

It is clear from above result that water in the form of fine spray droplets exerts positive effects on exhaust emission particular to NO_X. The finely atomized water droplets vaporize after injected into combustion chamber. Combined effect of absorbing heat developed by fuel and increased partial pressure of oxygen puts down the combustion temperature and thus it help to decrease formation of NO_X. As can be seen from above fig increase water flow rate give more NO_X reduction at all load conditions.

CO and CO_2

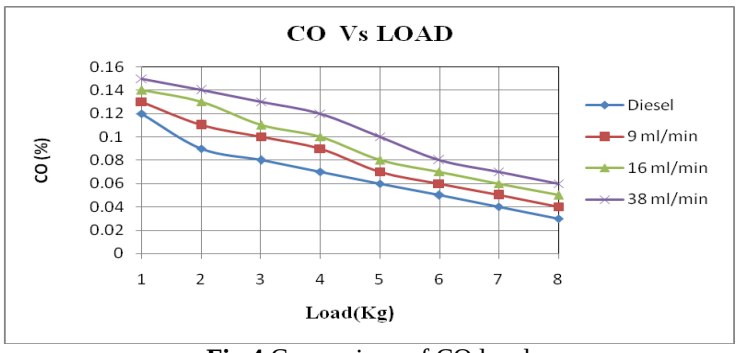

Fig.4 Comparison of CO level

Fig-4 compares CO emission of water injected diesel engine with standard one. The CO emission enhance with different water injection rate at all engine loads. Higher water percentage load to incomplete combustion which leads to higher formation of CO and CO_2. The minimum CO is 0.04% at 8 kg load with 9 ml/min, which is almost near to 0.03% at standard diesel fuel.

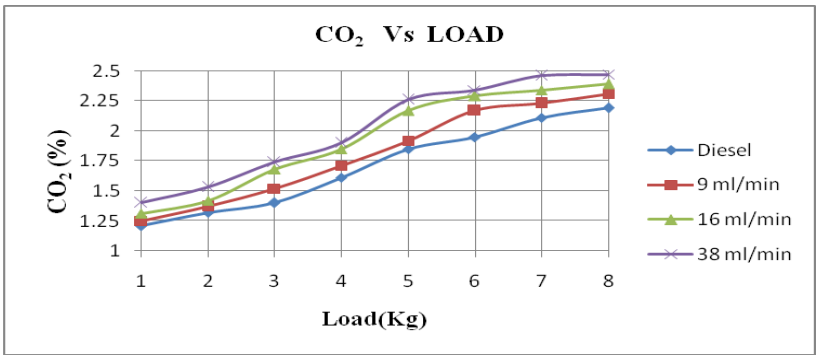

Fig.5 Comparison of CO_2 level

The comparison of CO_2 emission of different water flow rates and standard diesel engine is shown in fig-5. CO_2 emission increase with water injection at all engine loads. The minimum CO_2 emission is 1.25% at 1 kg at water injection conditions. Maximum increasement in CO_2 emission is 0.28 % at 8 kg load.

HC

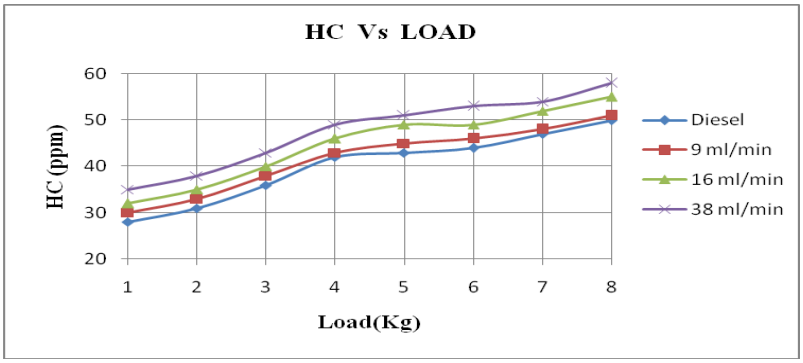

Fig.6 Comparison of HC level

Fig-6 illustrates the comparison of HC emission of different water flow rate and standard diesel. The - HC emission increase with water injection of 38ml/min at 1 to 8 load. Minimum HC emission is 30 ppm at 8 kg load of 9 ml/min water injection.

IV. Conclusion

In this study the effects of manually controlled water injection system on emission have been investigated. There is an significantly decrease in formation of NO_X at higher water flow rates, it also give negative effect on CO,CO_2,HC at all engine loads. Based on the experimental results the main effects of water injection are summarized as follows:

1) Water injection at intake manifold does not significantly affect cylinder pressure and heat release rate of CI engine operating with diesel. The results shows that water injection at the intake manifold affects the premixed combustion chamber which is mainly cause of NO_X formation.

2) The water injection in to intake manifold reduces the NO_X emission up to 46 % over the entire load range but noticeable increase in HC and CO_2. However CO emission increased by about 0.02% to 0.08%.

3) Based on above it is conclude that water injection into the intake manifold has capability of reduce NO_X emission with loss of power and has negative effect on specific fuel consumption.

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