# IMPACT OF WATER-IN-DIESEL EMULSION PREPARED USING HIGH PRESSURE HOMOGENIZER ON ENGINE PERFORMANCE AND EMISSION

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**Abstract**

**Exhaust emissions are main problem faced by people due to use of engines and industry. Diesel engine is responsible for NOx emissions due to high combustion temperature. Water-in-diesel emulsion has strong influence in reduction of NOx emissions without any engine modifications. In this study, 10% water is added to 88% diesel and 2% surfactant namely Tween80 and Span 80 for emulsion preparation and experimentation was done on Variable Compression Ratio (VCR) engine at two compression ratios 16 and 19. Water-in-diesel emulsion is prepared first time ever by using High Pressure Homogenizer and used in diesel engine. Simultaneous reduction of CO, HC and NOx was found using emulsified fuel at both compression ratios which is result of microexplosion phenomenon. NOx is reduced by approximately 25-50%.**

**Index Terms: Diesel engine, emulsion, surfactant, micro-explosion, emission**

## I. INTRODUCTION

As diesel engine concern, NOx, particulate matter, soot particles are main emission components. To control these emissions some engine modifications and after-treatment processes are required. But the initial as well as maintenance cost of after-treatment processes is more. In that case it is necessary to develop an alternative fuel which can control emissions as well as saves the fuel in some extent. Water-in-diesel emulsion has advantage of emission control and it saves the fuel as some fuel is replaced by water by some percentage. An additional advantage of using water/diesel emulsion is that no engine modifications are required.Water can be injected into combustion chamber using separate injector but this is again costly and injector requires the maintenance regularly. So, to use water in engine with diesel, emulsion is best method. Many surfactants can be used to prepare emulsion such as Tween, Span, Triton-X, Gemini, Glycol etc. Tween and Span are generally used to stabilize the water and diesel phases. Water-in-diesel (w/d) emulsion has advantage to remove the use of selective catalytic reduction or catalytic converter from diesel engine. Like other alternative fuels like compressed natural gas, there is no extra cost on engine modifications as there is no need of engine modifications by using w/d emulsion.

The effect of water-in-diesel emulsion on emission and performance is given in Table. I

Table. I Effect of water-in-diesel emulsion on performance of diesel engine

| *Reference →* | *[1]* | *[2]* | *[3]* |
|---|---|---|---|
| Engine type and Loading conditions | 1.5 l water-cooled HSDI 4-cylinders diesel engine, with 2 valve/cylinder and which conforms to Euro III standards. | 0.406 L single cylinder, four stroke, air-cooled, direct injection diesel engine. | 8 hp 1 c, direct injection, 1850 rpm |
| % of water | 20% | 5, 10, | 10 |

| | | | |
|---|---|---|---|
| | | 15, 20% | -30% |
| Surfactant used | Span and tween | Span 80 | Tween 80 and Span 80 |
| Amount of surfactant used | 2% | 2% | 4% |
| % increase in specific fuel Consumption | Increased | Decreased by 14% | Increased |
| % increase of Torque | NA | NA | Increased by 1.72 % |
| % increase of Brake thermal efficiency | NA | NA | 5% |
| % reduction NO*x* | 30-50% | 41% | 78% |
| % reduction of PM | 94% maximum | 35% | 35% |
| % reduction of HC and CO | NA | CO increased by 40% | NA |

| *Reference →* | *[4]* | *[5]* | *[6]* |
|---|---|---|---|
| Engine type and loading conditions | 1 c, direct injection, 12 hp, 2000 rpm | 1 c, 4s engine | 4-c, 4-s, turbocharged intercooled diesel engine connected to a dynamometer. 2000 rpm |
| % of water | 10% | 15% | 0, 10, 20, 30 |
| Surfactant used | sodium hydroxide, calcium hydroxide and chlorine | Span 80 and Tween 80 | Span 80 and Tween 80 |
| Amount of surfactant used | 1% | NA | 1% |
| % increase in specific fuel Consumption | 45% | Decrease by 15.54% | NA |
| % increase of Torque | NA | NA | NA |
| % increase of Brake thermal efficiency | NA | Increased | 38% |
| % reduction NO*x* | 17.64% | 30.95% | 45% |
| % reduction of PM | NA | NA | CO Increase by 33% |
| % reduction of HC and CO | CO- 5 % | 9% CO 3.73 HC | |

## II. PREPARATION OF EMULSIFIED FUEL

For the preparation of emulsion fuel 10% distilled water, 88% diesel and 2% surfactant is used. Mixture of two surfactants gives better stability of emulsion. So, Tween 80 and Span 80 are used in this work.

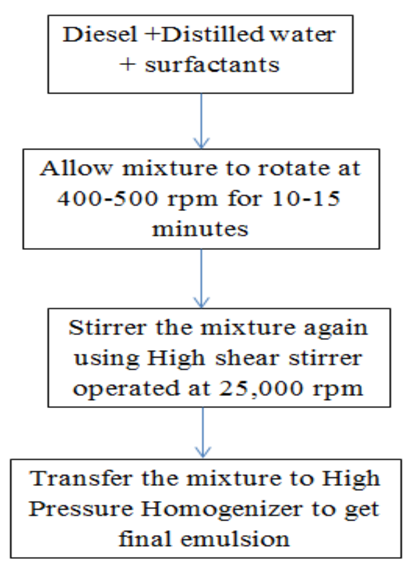


Fig. 1 Methodology involved in emulsion preparation

In the previous research study, ultrasonic homogenizer, high speed stirrer etc. are used for the preparation of emulsified fuel. But this is first time to prepare w/d emulsion using high pressure homogenizer. The emulsion is prepared first time by using high shear stirrer and High Pressure Homogenizer simultaneously for better stability and micro emulsion. To find out the amount of surfactant required following formula is used.

$$HLB_{comb} = HLB_T . W_T + HLB_S . W_S \qquad (1)$$

Where, $HLB_T = 15$

$HLB_S = 4.3$

Put the above values in (1)

$$5 = 15 . x + 4.3 . (1 - x)$$

x= 0.07 ml

Where, T and S subscript stands for Tween and Span respectively and W stands for mass ration of corresponding surfactant. From the above formula the required amount of surfactants got are Tween 80= 0.07 ml and Span 80= 0.93 ml for 1 % of total surfactant mixture. Emulsion is prepared using methodology as shown in Fig. 1.After the preparation of fuel the properties were measured in the laboratory shown in Table. II

Table. II Measured properties of w/d emulsion

| Fuel → Properties ↓ | Water | Diesel (Indian Oil) | Water-in-diesel (10% water) |
|---|---|---|---|
| Density (kg/m$^3$) | 1000 | 832 | 839 |
| Viscosity (cSt) | 0.99 | 2.35 | 5.73 |
| Gross Calorific Value MJ/kg | 0.0042 | 45.5 | 39.062 |
| Cetane Number | 0 | 45 | 40 |

From the measured properties, it was found that density and viscosity are increased for w/d emulsion whereas cetane number and calorific value are decreased due to presence of water. But whether these values increased or decreased, they are within limit so that can be used in diesel engines without any engine modifications.

## III. RESULT AND DISCUSSION

### A. *Specification of Engine*

Specifications of the selected engine are given in Table. III which is a variable compression ratio, four stroke, single cylinder diesel engine. Tests are executed on lower and higher compression ratios i.e. 16 and 19 for both diesel and water-in-diesel emulsion.

Table. III Specifications of Engine test setup

| | |
|---|---|
| Make | Legion Brothers, Bangalore |
| Engine Type | Single Cylinder 4S Diesel/Petrol/CNG |
| Compression Ratio | 5:1to 20:1 |
| Bore | 80 mm |
| Stroke Length | 110 mm |
| BHP | 3 to 5 HP |
| Speed | 1450 to 1600 rpm |
| Power | 3 to 5 HP |
| Cooling | Water |
| Lubrication | Forced |
| Starting | Manual Crank Start |

### B. *Load v/s Brake Power*

Fig. 2 shows load v/s brake power results. Brake power is found to be same for neat diesel and w/d emulsion. There was not much change in brake power with 10% water emulsion. Brake power varies linearly with load. BP is found to be improved with compression ratio. BP is more at CR19 for both neat diesel and emulsion.

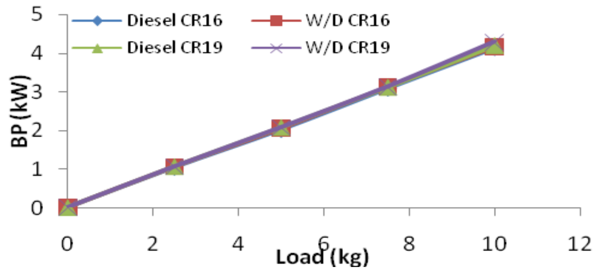


Fig.2 Load v/s brake power

### *C. Load v/s Brake Thermal Efficiency (BTE)*

Brake thermal efficiency v/s load is shown in Fig. 3. From the figure it is found that BTE is low for w/d emulsion. This is due to presence of water in emulsion which reduces the combustion temperature and lowers BTE slightly.
Though there is decrease in BTE, but it is within limit and there is very slight difference at both compression ratios i.e. 16 and 19. BTE varies linearly with load due to increase in temperature. At higher loads, there is improvement in BTE.

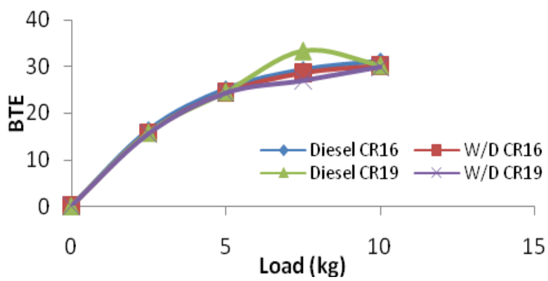


Fig.3 Load v/s BTE

### *D. Load v/s Specific Fuel Consumption (SFC)*

Fig. 4 shows load v/s SFC. It is found that, SFC is more for w/d emulsion at both compression ratios than neat diesel. This is due to lower calorific value of w/d emulsion which consumes more fuel for energy fulfillment. For w/d emulsion SFC is found to be improved with compression ratio. For w/d emulsion, at CR19 SFC is less than that at CR16.

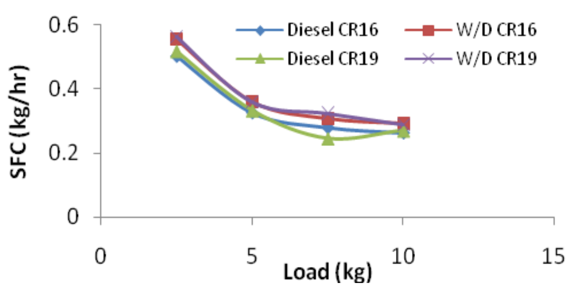


Fig.4 Load v/s SFC

### *E. Load v/s CO Emissions*

Fig. 5 shows load v/s CO emissions. There is decrease in CO emissions at both compression ratios for w/d emulsion. The reason behind the reduction in CO emissions is due to the presence of oxygen which increases the CO oxygenating rate. For w/d emulsion, CO emissions are improved with CR. This is due to as CR increases, temperature increases which enhance the oxidation process to convert it into $CO_2$. For lower CO emissions higher compression ratio is better operating condition. At higher loads CO emissions are low because of increase in temperature which enhances the oxidation process.

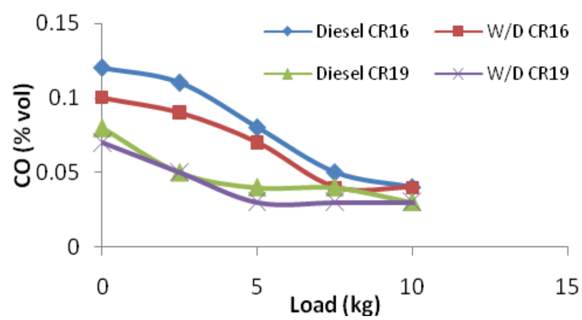


Fig.5 Load v/s CO

### *F. Load v/s HCEmissions*

Fig. 6 shows load v/s HC emissions. From the figure, it is found that HC emissions are less for w/d emulsion compared to neat diesel at both compression ratios. This might be due to the occurrence of micro-explosion phenomena which occurred only in w/d emulsion due to the evaporation temperature difference between water and diesel.

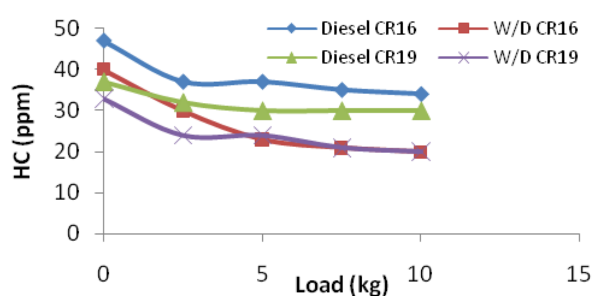


Fig.6 Load v/s HC

Micro-explosion phenomenon is responsible for primary as well as secondary breakup which breaks fuel into fine droplets. The fine atomization makes homogeneous mixture and gives complete combustion. HC emissions are caused by incomplete combustion in diesel engines. At higher loads HC emissions are low because at higher loads micro-explosion phenomenon might be become more explosive which gives complete combustion.

### G. *Load v/s NOx Emissions*

Fig. 7 shows load v/s NOx emissions. From the graph, it is found that NOx emissions are low for w/d emulsion at both compression ratios. For w/d emulsion, it is found that NOx emissions are increases with compression ratio due to increase in combustion temperature at higher loads but are less always than neat diesel. Reduction in NOx is due to decrease in combustion temperature due to presence of water droplets and evaporation of water inside combustion temperature.

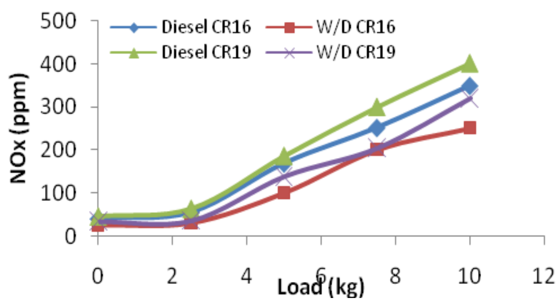


Fig.7 Load v/s NOx

## IV. CONCLUSION

From the above discussion it has been concluded that w/d emulsion has strong influence on reducing HC, CO and NOx emissions if prepared stable. Water-in-diesel emulsion can be used as alternative green fuel as it reduces emissions as well as replaces diesel by water by some extent. W/d emulsion is prepared first time by using high pressure homogenizer and it shows better results of emission. NOx, HC and CO are reduced in the range 30-50% compared to neat diesel. For the preparation of stable emulsified fuel, selection of surfactant, HLB plays vital role. As compression ratio increases, NOx emissions increases while HC and CO emissions decreased with compression ratio. Performance of w/d emulsion is not much affected by compression ratio compared to diesel. Lower compression ratio (i.e. 16) should be better working condition by keep in mind NOx emissions for diesel emulsion with 10% water.

The work can further extend by study the effect of injection timing and pressure on performance of engine using w/d emulsion. Also onboard fabrication emulsion process can be developed to control the amount of water.

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