# Spray Characteristics of Diesel and Ethanol Blends At Ambient Condition by Schlieren Photography Technique

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***Abstract - Environmental concerns and limited amount of petroleum fuels have caused interest in the development of alternate fuels for internal combustion engines. This paper presents a report on the performance of a diesel engine using blends of ethanol with diesel at various blending ratios. The purpose of this is to find the optimum percentage of ethanol that gives simultaneously better performance and lower emissions. The experiments were conducted on a Direct Injection diesel engine using 0% Ethanol (neat diesel fuel), 5% Ethanol (95% diesel), 10% Ethanol (90% diesel), 15% Ethanol (85% diesel), and 20% Ethanol (80% diesel) ethanol–diesel blended. Experimental tests were carried out to study the performance and spray characters of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that the smoke emissions from the engine fuelled by the blends were lower than that fuelled by diesel. Schlieren photography is a technique to capture the image of fuel spray. The present research attempted to characterize fuel spray pattern, such as spray angle, spray penetration and their mixture formation by recourse to images analysis. In this experimental study, the spray characteristics of diesel and ethanol fuel were comparatively evaluated. Images of fuel spray were captured at different injection pressures and at varying injector angles $0^0$ to $90^0$. The series of images were captured by high speed mono chrome video camera with resolution of 6,000 frames per second for Schlieren photography and shutter speed of 1/10,000 sec. From the results, we can conclude that the optimum injector angle for better performance and lower emissions.***

***Keywords:*** ***spray characteristics, injector angle, Schlieren photography technique.***

## I. INTRODUCTION

With rising concern on fossil fuel shortage and environmental issues from continuously increasing global energy demand, the development of alternate fuel engines have attracted more attention. Absolute alcohol, familiarly known as ethanol, drew immense attention as alternate fuel because it can be produced from many sources of biomass; it is a renewable resource that can also reduce emissions in compression engines. Although diesel cannot entirely replace petroleum- based fuels, biofuel and diesel fuel blends can replace the petroleum based fuels. Since the properties of ethanol vary from the conventional diesel, different spray characteristics may affect engine performance and efficiency. These factors include blend properties such as stability, viscosity and lubricity, safety and materials compatibility. A high octane number of ethanol allows higher compression ratio; thus, an engine fuelled with ethanol can have higher power output and better thermal efficiency.

The chemical characteristics of ethanol are: it melts at –114.1°C, boils at 78.5°C, and has a density of 0.789 g/mL at 20°C. Its low freezing point has made it useful as the fluid in thermometers for temperatures below -40°C, the freezing point of mercury, and for other low-temperature purposes, such as for antifreeze in automobile radiators. Despite the lower heating value of alcohols compared to that of diesel, alcohols release a little more heating value than diesel under the same equivalence ratio.

The experiments were conducted on a Direct Injection diesel engine using ethanol–diesel blends 0% ethanol (neat diesel fuel), 5% ethanol (95% diesel), 10% ethanol (90% diesel), 15% ethanol (85% diesel), and 20% ethanol (80% diesel). The Schlieren photograph techniques was selected to capture image of spray characteristics. Furthermore, these works are helpful to understand and offer comprehensive database of ethanol and diesel spray characteristics.

## II. EXPERIMENTAL SETUP

To simulate the spray characteristics in a stratified charge engine, a high pressure chamber was designed. The high pressure multiport injector was selected from BOSCH EFEP

60H model. Schematic diagram of experimental apparatus in Fig.2.1consists of five major components.

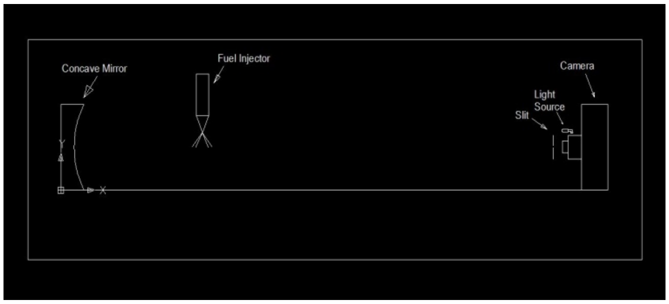


Fig.2.1 Schematic diagram

First, **Fuel injector test rig** in Fig. 2.2 consists of pressure gauge, handle, seamless tubes, and the Fuel tank. Pressure gauge is used to measure the pressure that is to be applying on the injector. Handle is used to pump the fuel. Fuel tank is to store the Diesel. Seamless tubes are used to inject the fuel into the fuel injector.

Fig.2.2 Fuel Injector Testing Equipment

Second, concave mirror, in Fig. 2.3 of specific Diameter: 150mm; Focal Length: 750mm. Third, base length of the basement is 2000mm, where the distance between mirror and light source must be 2 times (2X) the focal length of concave mirror. Fourth, **LED light source** of diameter 8mm. is used to get the point light focus on the mirror. Fifth is **Dark Room** where all the equipment is placed in their required locations and experiments are carried out. Its dimension is nearly (3×3×5) meter cube. Apart from these five components, external to the set-up is the SLR camera to capture the spray characteristics. Spray characteristics process is visualized by high speed mono chrome video camera at 6,000 fps and 1/10,000 sec of shutter speed. It can zoom up to 300mm

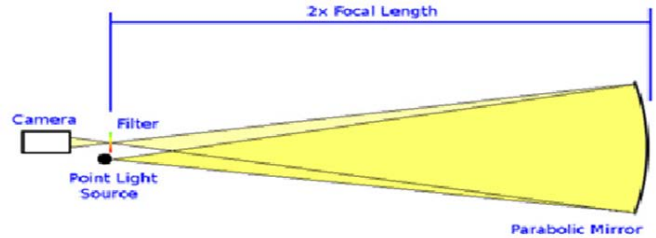


Fig.2.3 Concave mirror and Camera setup

For a clearly defined spray position, Schlieren photography technique is used in this experimental study. The results of spray characteristic visualization images were analysed with as a function of time after injection. Fig.2.4 shows the arrangement of Schlieren system for spray characteristic visualization.

Fig.2.4 Spray Characteristic Visualization model

## III. PREVIOUS WORK

A lot of research has been focused on the effect of fuel injection pressure on performance of diesel engine. A work by M.L.S.Deva Kumar, S.Drakhaya, K.Vijaya Kumar Reddy [1] presents a relative comprehensive study of various factors that influence the performance of engine such as compression ratio, atomization of fuel, fuel injection pressure and quality of fuel, combustion rate, air fuel ratio, pressure etc. to find efficient performance and less pollution. Jain Gao, Deming Jiang, and Zuohua Huang [3] these authors examined the effect of "Spray properties of alternative fuels: A comparative analysis of Ethanol-gasoline blends and gasoline." A comparative analysis of blended fuels and gasoline spray is also presented along with spray tip penetration decreases and the spray angle increase with increase of ethanol fraction. Another area of interest for researchers by [4] Ivan Filipovi, Boran Pikula, DZevad Bibi approached the role for the quality of air/fuel mixture by representing the characteristics of jet length, cone jet angle, physical and chemical structure of jet on different cross sections. Characterization of very high pressure diesel sprays using digital imaging techniques-the work done by E.Delacaut, B.Desmeta, B.Bessaon [6] investigate on the macroscopic spray characteristics and measurement techniques were also referred for information.

## IV. PROPOSED METHODOLOGY

The entire photo technique is set-up in a darkroom so that there would be no dispersion of light with the environment and in order to obtain a perfect Schlieren photography image of the spray. The concave mirror is placed parallel to the light source. The camera is placed against the light source. The colour filter is placed in front of the light source so that light from the light source gets filtered. This technique is based on a white light source and is kept at a constant distance so that the image of same size of injector spray is obtained on the concave mirror. The fuel injector is placed in between the concave mirror and light source so that the image of the fuel spray can be seen in the concave mirror and during each fuel spray the camera captures the imagery of the spray. The knife edge is placed in between so that all light get deviated and only filtered light gets reflected to focus the camera and Schlieren image of fuel spray is observed.

The simplex injector is taken and mounted into a cylindrical fuel tank. The fuel tank is fitted with a pressure gauge to monitor the pressure across the nozzle (this entire arrangement can be replaced by a nozzle injector tester).The fuel(diesel) is supplied to the injector through a hose connected to the fuel tank of the nozzle injector test rig. The injector is vertically positioned, injecting the liquid downward. The spray is discharged into an open quiescent environment. The cloud of droplets is collected by an extraction system placed under the injector. The spray characteristics are then determined by the image taken and are inspected visually at various operating conditions.

Finding cone angle and dispersion angles of spray:

The spray angle is defined as the angle between the lines drawn on the edge of different contrasts. All data from experiments were measured by Photoshop and Auto CAD 2014 software. Spray cone angle, dispersion angle and penetration length of diesel and ethanol blends at various injector angle images respectively were shown below.

Fig.4.1 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 1000ml Diesel at various Injector Angles

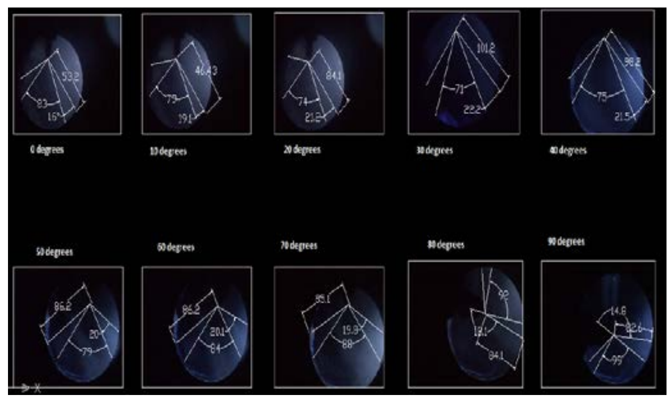

Fig.4.2 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 950ml Diesel and 50ml Ethanol at various Injector Angles

Fig.4.3 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 900ml Diesel and 100ml Ethanol at various Injector Angles

Fig.4.4 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 850ml Diesel and 150ml Ethanol at various Injector Angles

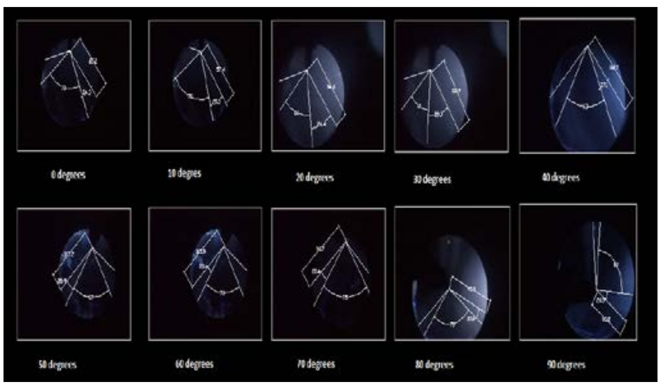

Fig.4.5 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 800ml Diesel and 200ml Ethanol at various Injector Angles

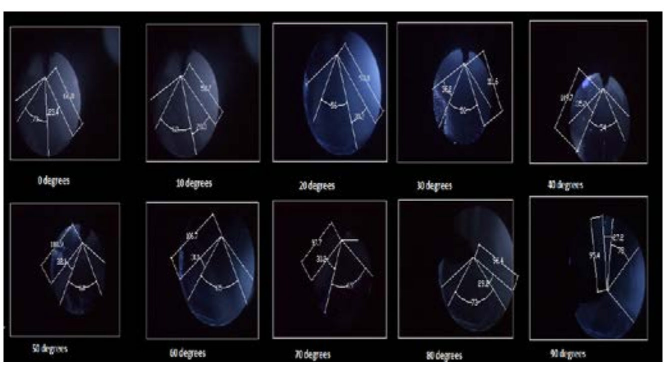

Fig.4.6 Spray Cone Angle, Dispersion Angle and Penetration Lengths Of 750ml Diesel and 250ml Ethanol at various Injector Angles.

## V. EXPERIMENTAL RESULTS

It is concluded in experimental trails that blending of diesel with ethanol at different compositions and with increase of injection pressure will increase penetration. From Fig.5.1 Results show that for injection angles $30^0$-$40^0$ leads to increment in penetration length from 111.6 - 109.7 cms at 750 ml of diesel and 250 ml of ethanol. It is not whether the increase of injection pressure increases the penetration because the pressure increase is accompanied simultaneously by decrease in droplet size due to increase in air resistance. So the assistance of local velocity leads to penetration of the spray with increase of injection pressure.

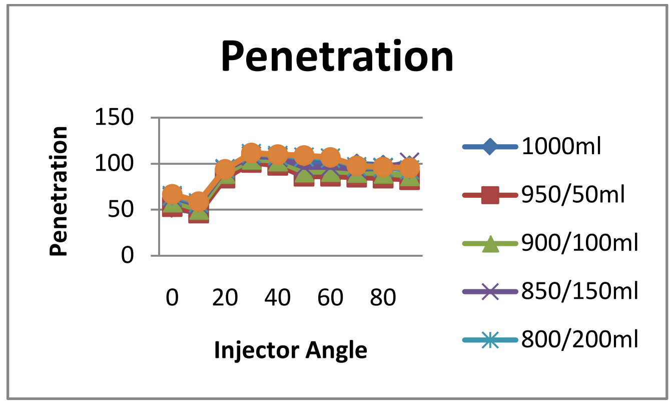


Fig.5.1 Penetration us Injector angle

It is observed that the cone angle is narrow at injection angle $30^0$ and at 750 ml of diesel and 250ml of ethanol resulting in $36.2^0$ maintain satisfactory penetration length. From Fig.5.2, Based on fluid mechanics fundamentals, we can conclude that as the orifice diameter increases there is an increase in spray penetration at the same discharge velocity. This increases ratio of spray momentum to the air resistance.

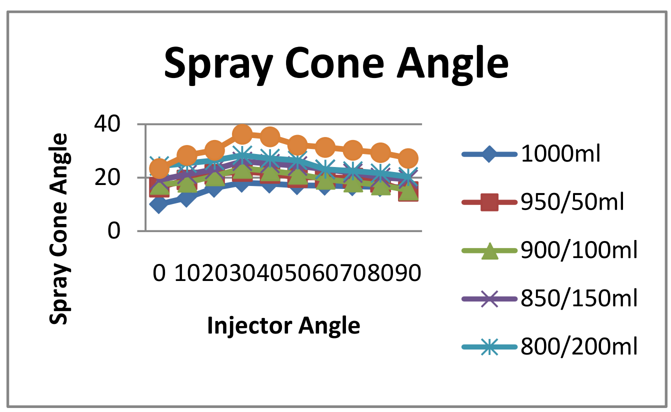


Fig.5.2 Spray cone angle us Injector angle

It is observed from an atomizer with plain orifice, narrow cone angle and wide diversion angle and spray at injection pressure of 150bar. The convergent shape of spray is due to radial component of velocity of the fuel flowing from the orifice as soon as fuel jet leaves.

The experimental observations in relation to spray dispersion using Schlieren photography method for estimating intensity of the spray i.e. max volume per unit area at tangent is slightly high at $30^0$-$40^0$ and also the dispersion of spray is improved with increases of distance from atomizer. From Fig. 5.3 it is clear that Maximum dispersion angle is $91^0$ obtained at $90^0$ injector angle blend of 950 ml of diesel and 50 ml of ethanol.

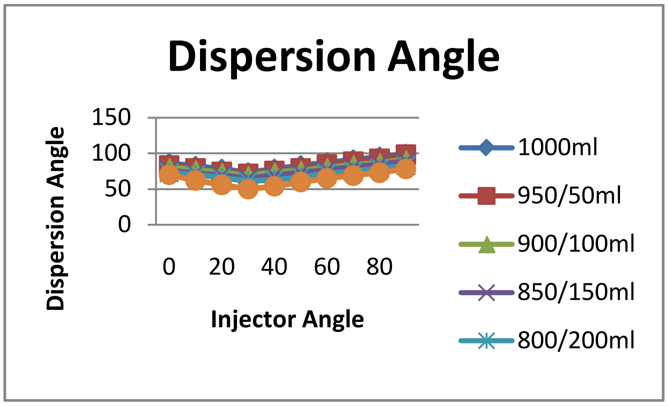


Fig.5.3 Dispersion angle us Injector angle

With reference to above experimental observations and results, the cone angle and penetration length, is satisfying within the range between 30°-40° of injector angle and penetration length increases from 50°–90°. This means that as the fuel injector penetration length increases, the turbulence increases leading to better atomization in the combustion chamber

## VI. CONCLUSION

Test results show that the smoke emissions from the engine fuelled with the blends were lower than that fuelled by diesel. Fuel spray at different injection pressures and at varying injector angles from $0^o$ to $90^o$ were analyzed and it is observed that a better performance and lower emissions were found at $30^o$ injector angle.

## VII. FUTURE SCOPES

Current research is conducted with a constant pressure of 150 bar at ambient conditions without swirl injector and with a single orifice. It can be extended by varying induction pressure and velocity at different ambient conditions under controlled volume and swirl injector with multiple orifices can be used for an increase in the fuel efficiency.

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