EXPERIMENTAL STUDY TO ANALYSE THE IMPACT OF ETHANOL-BLENDED FUEL ON FUEL INJECTOR PERFORMANCE

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Abstract*- Over the course of the last several years, many governments have made decreasing fuel emissions a priority as part of their overall goal. Every manufacturer of automobiles has been searching for an alternative fuel for its internal combustion engines in order to lessen the amount of carbon that is released from the exhaust. Ethanol fuel is quickly becoming the most viable alternative to either completely replace gasoline or be used in conjunction with gasoline as a fuel additive. Corn, sugarcane, grain, and other plants may all be used to quickly and efficiently produce ethanol, often known as ethyl alcohol. It's possible that ethanol is utilized in our daily lives more often than we realize. After all, ethanol is a component of every alcoholic beverage that we consume. It may be purchased under a variety of names, including ethyl alcohol, pure alcohol, and grain alcohol, and it can have varying percentages of water content. It is considered an alternative fuel and has seen a significant rise in popularity for a number of different reasons. When used as ethanol combined with gasoline, it has a lower impact on the environment than other types of fuel due to the lower emissions it produces. It does this by raising the octane rating of the gasoline, which in turn improves the condition of the engine. People, governments, and companies that make automobiles all recognize its numerous advantages and have come to terms with accepting it. In addition to promoting the use of ethanol-blended fuel in India, the government of India has begun blending 20% ethanol into gasoline in Bengaluru. In the not too distant future, this policy will be expanded to include the all of India. In order to utilize ethanol as fuel, the components of the fuel system must be evaluated to determine whether they are ready to run as is or whether they need some change to handle the ethanol. For the purposes of this investigation, a target component of the fuel system is the fuel injector. Because it regulates and supplies the metered and atomized fuel, a fuel injector is a very important component that bears a significant amount of responsibility for regulating emissions. In order to carry out this research, important performance criteria were determined, and fuel injectors were put through rigorous testing in a laboratory setting using E10, E20, and E30 (anhydrous).

***Keywords*: Fuel Injector, Ethanol Blended Fuel (anhydrous), Injector Driver, Pre-Performance, Post-Performance**

INTRODUCTION

A fuel injector is a solenoid-operated mechatronic component of an internal combustion engine. Injectors accept fuel that has been pressured from the fuel pump in order to perform their primary job, which is to give atomized fuel to the engine. The air-fuel mixture, the combustion process, and ultimately the thermal efficiency of the engine are all directly influenced by the macroscopic and microscopic spray characteristics, such as spray tip penetration, spray cone angle, droplet size distribution, and Sauter Mean Diameter (SMD). Other important parameters include the Sauter Mean Diameter (SMD). A significant range of elements, including fuel pressure, fuel temperature, ambient pressure, ambient temperature, fuel qualities, and injector geometry, amongst others, all have an effect on the spray characteristics. There are a few critical performance parameters of injectors that are mandatorily required to perform the engine in defined conditions and to have a designed output. In this experimental analysis impact of ethanol fuel blends studied, these critical parameters are considered for the study. Before starting the study initial performance of the injector was tested at all critical parameters, like-

[1] Dynamic Flow

Dynamic flow is the flow rate calculated in dynamic conditions at different pulse rates.

[2] Static Flow

Static flow rate is calculated at injector full open condition i.e. injector is continuously open, similar to this condition happens in the vehicle during WOT.

[3] Static Leakage

In injector off condition, it is expected no leakage through the injector orifice to the engine,

[4] Cone Angle

Cone angle or spray targeting is another critical parameter that ensures maximum valve wetting during injection and avoids fuel puddling.

After initial performance measurement, Injectors were subjected to durability testing for 500 hrs with 5ms ON and 5ms OFF. Fuel pressure was 3.0 bar and fuel temperature was 60 degrees. This test was done with E10, E20, and E30 at different samples.

All the injectors were tested post-performance and prepared the test results. And then subjected to a validation test.

LITERATURE REVIEW

A lot of data is created for ethanol blended fuel usage and its benefits for the betterment of society and the environment. Published in the Journal of Scientific & Industrial Research, In the Brazilian market, this fuel is already commercialized and available on E93 case-to-case basis. In India, the automotive industry is moving towards ethanol usage for IC engines. The government is also promoting the usage of Ethanol mix fuel. Ethanol that is made from renewable resources is now being investigated on a worldwide scale with the intention of replacing fossil fuels in the most visible and effective way possible. The fermentation of raw materials that are collected from a variety of renewable resources like as sugarcane, corn, and sweet sorghum is the process that is used to create it anywhere in the globe. Gasohol is mostly produced by blending ethanol with gasoline in a variety of proportions and is recognized by its popular name. Because of this one particular usage, the amount of ethanol that was produced on a worldwide scale increased by 85 percent between the years 2002 and 2006. Because of the oil crisis that occurred in 1973, Brazil was compelled to commence and execute the use of bioethanol as a mandated component of vehicular fuel up to a maximum of 100%. In order for this to be possible, flexi-fuel cars that are capable of running on both gasoline and E100 (bioethanol) were made available for purchase. This productive model was copied by other nations such as the United States, Europe, and India in order to accomplish their goals of fuel self-sufficiency. The current percentage of ethanol that is mixed into gasoline in India is 5%. The usage of MTBE and ETBE has been phased out and replaced by the addition of ethanol to gasoline, which also raises the oxygen content of the fuel.

METHODOLOGY

Considering the reactiveness of ethanol at higher temperatures and its corrosive property, it is very important to check the fuel injector in durability i.e. in continuous operation and corrosion testing. Based on the above aspects, there are two test items that are mandatorily required to check the impact of ethanol-blended fuel on injector performance.

1. Fuel Injector Durability @ 50°C for 300 Million Cycle

[1 cycle = 5 sec ON and 5 Sec OFF]

2. Internal corrosion Testing @ 60°C for 480 hrs

[Injectors filled with test fuel and kept in Thermal Chamber]

Validation Test Set-up for Fuel Injector Durability Test

Test set-up was designed to ensure a continuous fuel supply of hot fuel, 50°C at 3.0 bar, and PWM signal to Injectors with a defined ON/OFF Cycle. Set-up consists of

1. Two Power Supplies, one for Injectors and another to operate fuel pumps.
2. Injector Drivers to operate 24 injectors at a time.
3. Oscilloscope to give PWM signal to Injector drivers.
4. Closed Fuel Container
5. Water thermal chamber to heat the fuel container,
6. Injector Mounting Fixtures
7. Piping Arrangement.

Refer to the below images for the test setup.

Validation Test Set-up for internal corrosion testing

The reactivity of ethanol-blended fuel with the internal child parts of the fuel injectors was verified by internal corrosion testing. In this Test, Injector were filled with test fuel and kept at 60°C for 480 Hrs. After 480 Hrs post-performance was measured and the sample tore down for an internal child parts

survey and inspection. Samples moved through SEM EDX analysis for detailed analysis. Refer to Figure 3 for the test setup. Set-up consists of

1. Thermal Chamber to maintain the temperature at 60°C
2. Injector mounting fixtures.

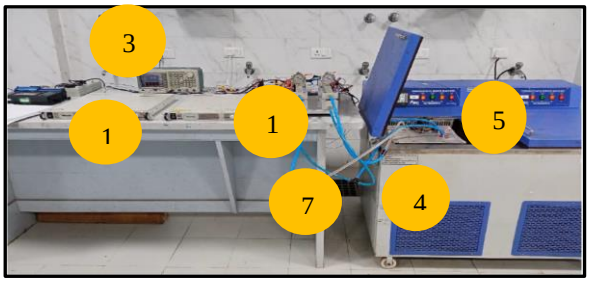


Figure 1-Durability Test Bench

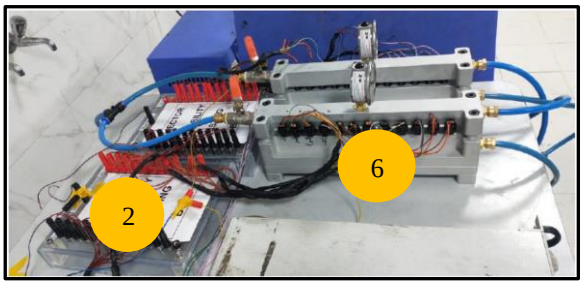


Figure 2- Durability Fixtures and Drivers

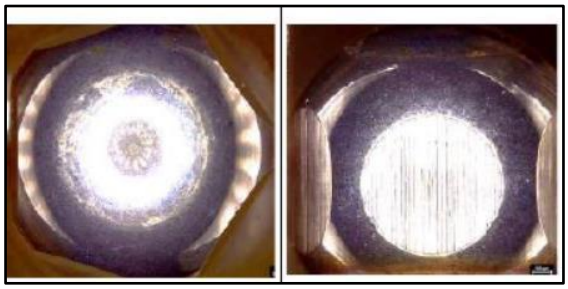
RESULTS AND DISCUSSIONS

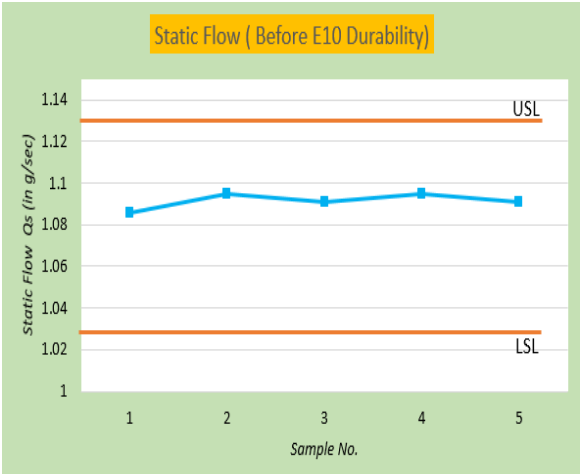
Fuel Injector Durability @ 50°C for 300 Million Cycle

[1 Cycle = 5 sec ON and 5 Sec OFF]

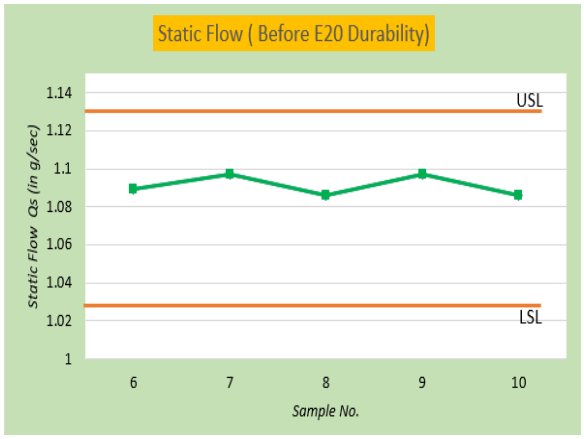
Fuel injectors were actuated for 300M cycles in all three test fuels E10, E20, and E30 at a fuel pressure of 3.0 bar with a cycle of 5 sec ON and OFF. After the 300M cycle, the performance of all samples was taken and plotted against initial performance respectively. It was clearly seen that the injector performance parameters are well within defined limits given USL-Upper Specification limit and LSL-lower Specifications limit. Static flow is within ±4% from the nominal value, 0.5cc/minute before and after the validation with all three test fuels.

After Internal corrosion test, Static flow, Dynamic flow and static leakage also well within limits and didn't show any deviation from the designed spec of the injector. Further Teardown and material analysis showed that injector selected for teardown had trace organic contamination on the seat or ball or external contamination identified as trace oil film residue on the ball. Below images show teardown photos and material analysis of an injector that passed all functional requirements post E85 internal corrosion testing. Teardown report did not show any signs of excessive or significant corrosion which was specifically asked for during teardown analysis

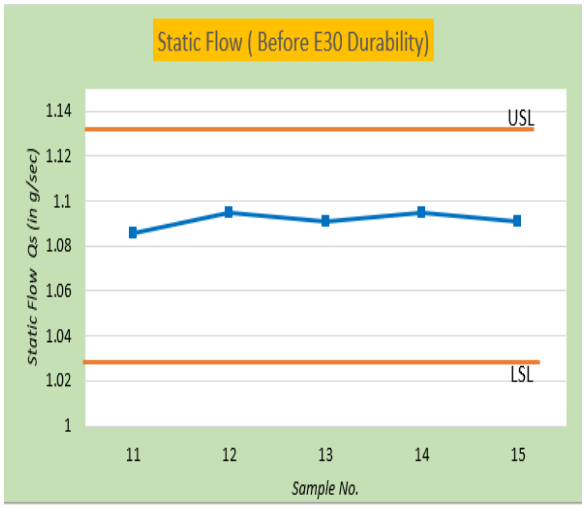




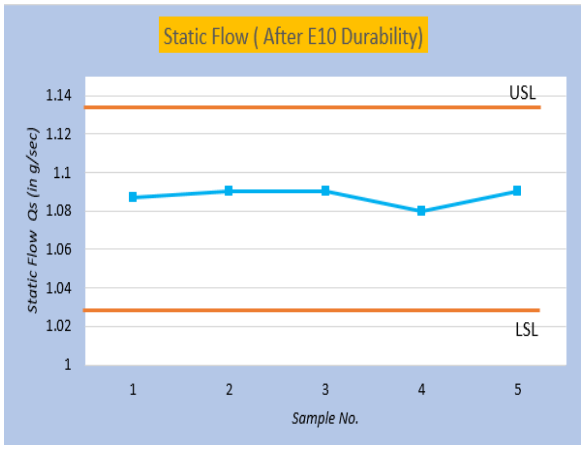
Graph-1 Static Flow (Before Durability Test with E10)



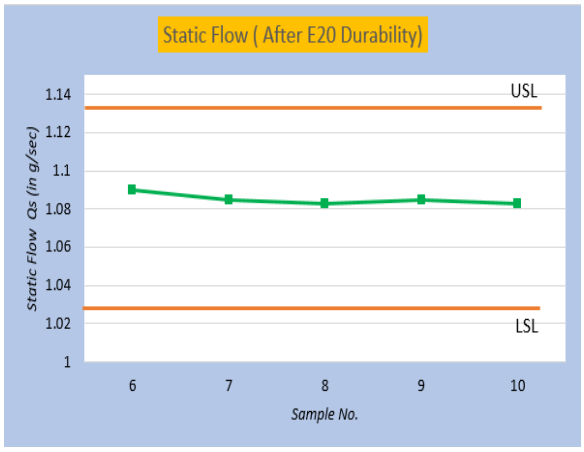
Graph-2 Static Flow (Before Durability Test with E20)



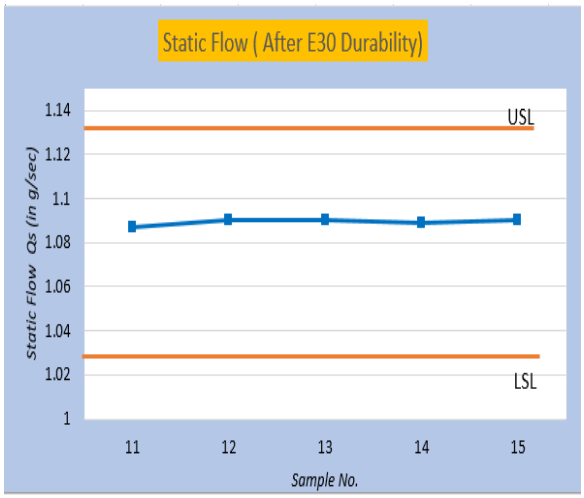
Graph-3 Static Flow (Before Durability Test with E30)



Graph-4 Static Flow (After Durability Test with E10



Graph-5 Static Flow (After Durability Test with E20)



Graph-6 Static Flow (After Durability Test with E30)

CONCLUSION

A comparative analysis between the pre and post-performance data in all three test fuels viz. E10, E20, and E30 show that the critical parameters of the fuel injectors were well within the working limits after the defined test conditions. It indicates that these injectors can be used in the above-mentioned ethanol-blended fuel without any changes in any component designs or material changes.

The injector has endured the harshness of the above ethanol fuel blended in a laboratory. However, the following needs to be noted:

• The test fuel used was of high grade and utmost care was taken to ensure quality/purity. It may not represent actual field fuel.

• Fuel adulteration is a general concern for the market and its effects are currently untested.

• Fuel handling – storage, transportation, and environmental conditions affect changes to ethanol fuel, sometimes causing the change in pH, water separation, etc., leading to fuel degradation.

• Conducted durability tests should be considered as a singular data point and only laboratory validation of injector performance. It should not be used as a qualifier to predict the product's long-term performance in a fuel that is not commercially available in the market.

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