

A Representative Testing Methodology for System Influence on Automotive Fuel Filtration

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ABSTRACT

Filtration of diesel and gasoline fuel in automotive applications is affected by many external and internal parameters, e.g. vibration, temperature, pressure, flow pulsation, and engine start-stop. Current test procedures for automotive fuel filters, proposed by most of the researchers and organizations including Society for Automotive Engineers (SAE) and International Organization for Standardization (ISO), do not apply the previously mentioned real-world-conditions. These operating conditions, which are typical for an automotive fueling system, have a significant effect on fuel filtration and need to be considered for the accurate assessment of the filter. This requires the development of improved testing procedures that will simulate the operating conditions in a fuel system as encountered in the real world. Although researchers have studied this topic in the past, they did not address the analysis of individual and combined effects of all the relevant fuel system parameters, which influence the filter performance. In this paper the effects of these parameters on the performance of diesel fuel filter for passenger cars will be studied using state-of-the-art testing facilities with the capability of simulating several of these system parameters in a laboratory set up.

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INTRODUCTION

The purpose of an automotive fuel filter is to remove hazardous contaminants from the fuel in order to protect the engine components and ensure efficient combustion of the fuel.

To meet stringent emission regulations and performance requirements higher operating pressures in engine is required. Lower tolerances between moving parts in fuel injectors and high pressure fuel pumps are critical for achieving such high pressures making these parts more vulnerable to contaminants.

A. von Stockhausen et al in their work [1] have described in detail the procedures for determining the allowable particle contamination for diesel Fuel Injection Equipment (FIE). Figure 1 shows a cross section of Bosch CRI2 injector, which is used for diesel application. Dotted circles in the figure highlight injector components which are most vulnerable to contaminant particles.

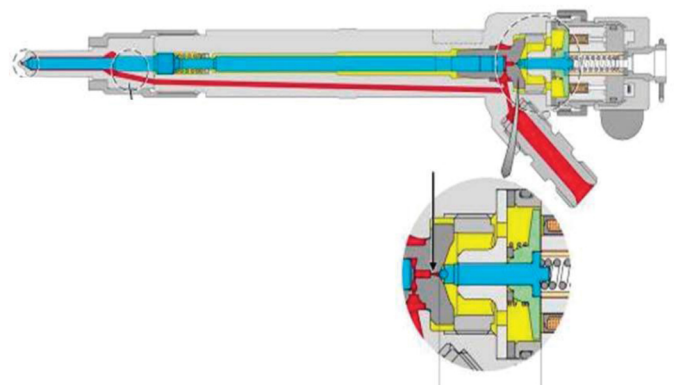


Figure 1. BOSCH CRI2 injector with magnified view of control valve [1]

Figure 2 shows how the ball-seated type control valve used in this injector (magnified view in Figure 1) can be damaged by contaminant particles. This control valve is used to separate the high pressure and low pressure sides of the injector. The valve wear or erosion, caused by contaminants,

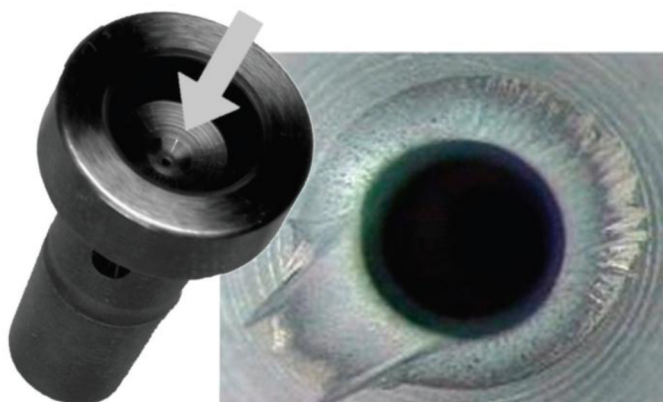


Figure 2. Impact of fuel contaminants on ball valve seat of CRI2 injector [1]

result in higher backflow on the low pressure side of the injector that causes the system to fail in achieving the required pressure in the rail. This leads to shutting down the system by the engine control unit.

Standard Performance Tests for Automotive Fuel Filter

Standardized performance test is used to determine the efficiency of a filter. Organizations like SAE and ISO have proposed and often revised standard methods to test performance of automotive fuel filters for years [11, 12, 13, 14]. These tests are repeatable and can be used for comparing fuel filters from different manufacturers.

These performance tests are designed to ideally assess the performance of the filter under extreme operating conditions and under real-life conditions. Standard SAE and ISO test procedures do not address these criteria, of combined influences of such conditions on filter performance. These conditions that are typical for an automotive fuel system are:

1. Pressure pulses created at suction side due to high pressure fuel pumps
2. Filter performance at different fuel viscosities, changes in fuel flow rate through the filter and system vibrations.

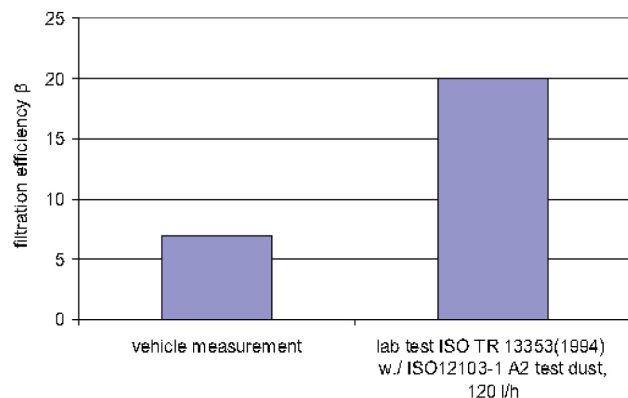


Figure 3. Comparison of filtration efficiency in the vehicle and in the ISO standard test [1]

Figure 3 shows comparison between filter performance under standard performance test and in an actual vehicle [1]. It can be observed from the picture that β value drastically drops in real world as compared to the standard test.

Motivation and Methodology

The first step in evaluating a representative filter performance is to develop an effective test method, which tests the filter performance under extreme operating conditions. Hence it is necessary to study the system parameters leading to the degradation in the performance of the filter.

Researchers have studied this topic as shown in [1, 2, 3, 4, 5, 6, 7, 8] although this body of work has not addressed the analysis of individual and combined effects of all the relevant fuel system parameters, which influence the filter performance. The work presented in this paper covers the progress in the previously mentioned field of study. The details of the research are covered in the following sections.

FILTER PERFORMANCE SYSTEM PARAMETERS

In order to realistically test automotive fuel filters performance, it is necessary to characterize the system parameters with the most significant influence. Work covered in [2, 3, 4, 5, 6, 7] show that the viscosity of the operating fluid/fluid temperature, system vibrations and rapid changes in fluid flow rate can show strong influence on filter performance.

Cyclic flow with 0.1Hz frequency and 75% flow reduction is one of the most widely accepted when studying the effect of rapid changes in flow rate on filter performance [16]. In addition, the changes in fluid flow rate for engine start/stop condition newly developed by Bosch, have to be considered. Moreover, high pressure CR pumps are observed to produce pressure pulses on suction side of the pump that might have impact on the filter performance.

Also, the next generation of fuel pumps is designed to provide fuel to the high pressure pump at more than one flow

rates. Since the fuel passes through the primary filter before reaching the high pressure pump the effect of variable flow rates was considered. The parameters influencing the filter performance were summarized as follows:

viscosity/fuel temperature, fuel flow rate, system vibrations, pressure pulses generated by CR pump, cyclic flow and Start-Stop technique.

Figure 4 shows a typical layout of an automotive fuel system. In this figure, fuel filter is shown on the pressure side of the fuel feed pump. In some fuel system designs, fuel feed pump is not present and filter works under comparatively low system pressures. Figure 4 helps in visualizing the different parameters that influence fuel filter performance.

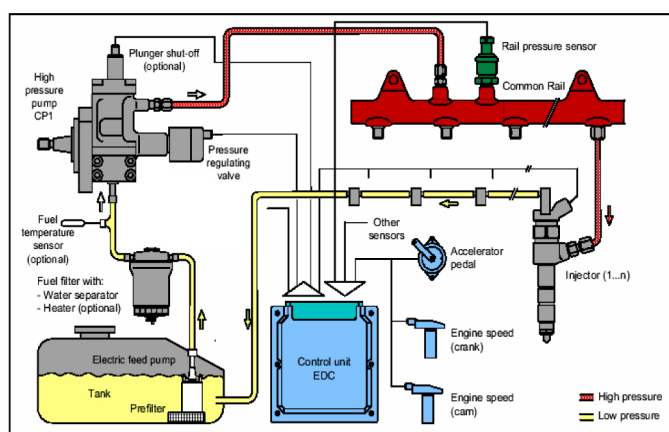


Figure 4. Schematic diagram of a typical automotive fuel system

EXPERIMENTAL SET-UP AND TEST PROCEDURES

Experimental Set-Up

Figure 5 shows schematic diagram of filter performance test circuit. It consists of two reservoirs for both clean fuel and fuel with high concentration of contaminants. Contaminant reservoir is provided with a stirrer which diffuses contaminant particles in fuel. A contaminant insensitive pump which provides steady flow at variable flow rate, system pressure and temperature ranges is used as contaminant dosing pump. Two particle counters are placed upstream and downstream of the test filter. Heat exchanger is used to maintain system temperature.

Component specifications and validation of the test circuit is confirming to ISO19438 [11] and ISO11171 [10].

A special feature of this test circuit is the integration of CR pump with the ability to operate at different speeds. It provides a great advantage in simulating real-life fuel system conditions during the test. Also, the fuel pump is capable of producing cyclic flow at the desired specifications; hence no additional mechanism is integrated for this purpose. A

pneumatic vibration generator capable of producing three distinct levels of vibration intensities was connected to the test filter when desired.

Use of test fluid confirming to ISO 4113 and contaminant particles confirming to ISO 12103-A2 fine test dust [12] was made for the tests.

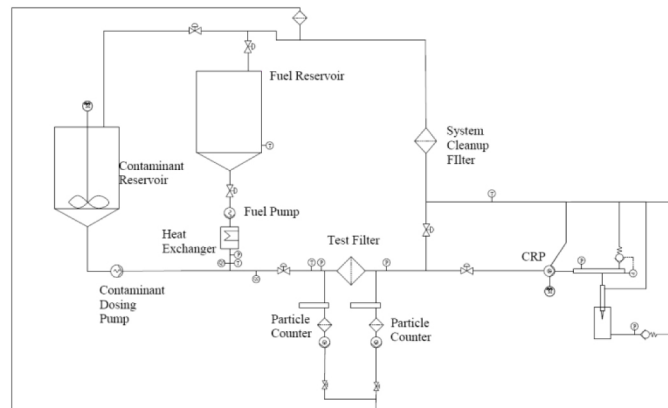


Figure 5. Filter performance test circuit



Figure 6. Filter Test set-up

Test Procedures

Sensitivity tests for CR pump and vibrations are performed at 40°C fuel temperature and 180 l/hr flow rate. Sensitivity tests for temperature are performed at 180 l/hr flow rate while tests for flow rate sensitivity are performed at 40°C temperature.

In the case of tests on pre-loaded filter, filter was first pre-conditioned to eliminate air bubbles inside the filter housing. Desired quantity of contaminant particles is then loaded on the filter every time in the same manner.

Filter efficiency tests were carried out as per single-pass method. The filter was pre-conditioned for bubble elimination