

Research on Clogging Mechanism of Multilayered Fuel Filters and Extension of Filter Life Span in Ethanol Blended Fuel

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ABSTRACT

Recently, the use of ethanol blended fuel is growing worldwide. Therefore, there is increasing needs for addressing issues relating to ethanol blended fuel use in gasoline engine fuel supply systems. In this paper, we focused on one of such issues, which is the reduced life of a multi-layered fuel filter used at inlet side of a fuel pump when it is used with ethanol blended fuel. In this study, we clarified that ethanol blended fuel tends to disperse dust particles contained in fuel to a greater extent than gasoline, and that it has a mechanism to accelerate clogging by concentrating the clogging only on the finest layer of the multi-layered filter. Also, in the process of clarifying this principle, we confirmed that dust particles dispersed by ethanol are coagulated when passing through the filter layers. Based on this, we developed a filter structure that increases dust particle capturing capability by combining dust particles into larger size before reaching the filter, thereby doubling the effective life of the filter for ethanol blended fuel.

INTRODUCTION

Recently, ethanol blended gasoline for automobiles sells increasingly due to concerns on global environmental issues, soaring prices of crude oil, and the social needs to get out of the dependence on fossil fuels. In Brazil, gasoline containing 20% ethanol (hereinafter indicated as E20%) and hydrated ethanol 100% fuel have been already widely used. In the US, application of E85% has been started. In the Thai market, E20% is widely used, and E85% has been introduced on a trial basis. In India, the use of E10% has started and is getting popular. In future, ethanol blended gasoline will be widely used as a main fuel in many more regions. Under these situations, it is required to consider the durability of fuel supply components used with ethanol blended fuels.

In this study, we clarified the fact that ethanol blended fuel causes the reduction of life of multi-layered fuel filters and explained the mechanism. Furthermore, based on the mechanism, we designed a structure of fuel filter with extended life when it is used with ethanol blended fuel as well.

FUNCTION OF FUEL SUCTION FILTER

A fuel filter is installed so as to capture the dust particles contained in fuel sucked by a fuel pump. The purpose of capturing dust particles is to protect components, such as a fuel pump, a fuel injector, and a pressure regulator. In the conventional fuel supply systems on motorcycles, fuel filters used to be installed on both of inlet side and outlet side of the fuel pump. However, in recent years, most of the motorcycles have a filter only on the inlet side eliminating the one on the outlet side. Removing the outlet-side filter gives the advantage in cost reduction but filter life of the inlet filter becomes a concern. In Fig. 1, the structure of the fuel supply system for small motorcycles is shown.

The growth of clogging on the inlet-side filter as it capture the dust particles in the fuel results in the pressure loss of sucking of the fuel pump. The increased loss of suction power of the fuel pump leads to insufficient fuel supply and may possibly hinder the driving performances. Therefore, the fuel filter needs have the characteristics of hardly clogging in early stage, together with the ability of capturing as many dust particles as possible. As shown in Fig. 2, nonwoven fabrics with different mesh size are layered in the fuel filter for each layer to capture different size of dust particles. Hereinafter, the expression “the fuel filter” in this paper represents the fuel filter with this multi-layered structure.

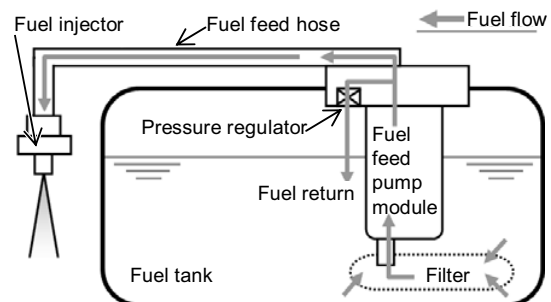


Fig. 1 System structure of fuel supply on small motorcycles

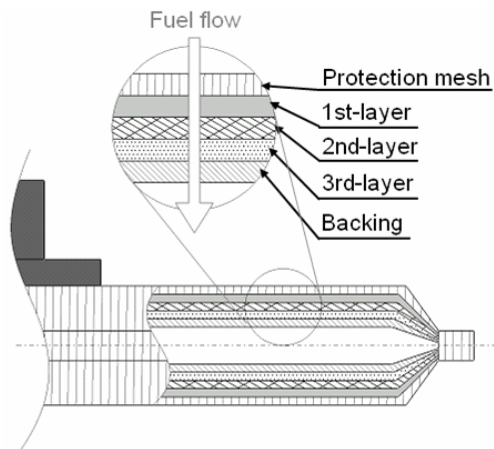


Fig. 2 Typical structure of the multi-layered nonwoven fabric filter

CLOGGING PHENOMENA OF FUEL FILTER BY ETHANOL BLENDED FUEL AND OBJECTIVES OF THE STUDY

It is a confirmed fact that there is a tendency for ethanol blended gasoline to reduce filter life. In this study, the mechanism has been investigated using the measurement method in which the pressure loss between the fuel filter and the pump is measured while the pump, installed with the inlet side filter, is operated within the test fuels of neat gasoline or E25%, with dust particles mixed in them. A schematic view of the test method is shown in Fig. 3. Standardized test powder of JIS Z 8901 class 8 was mixed with the fuel substituting the dust particles. Regarding JIS Z 8901 class 8 powder, 90% of the constituent is made up of SiO_2 , Fe_2O_3 and Al_2O_3 and its median diameter is about 7.2 μm .

The change in pressure loss of fuel filter, relative to the dust amount mixed in the fuel, is shown in Fig. 4. The pressure loss at the fuel filter operated with ethanol blended fuel increases twice as faster as the filter operated with neat gasoline. When we observed the filter clogged in early stage, of which the enlarged photos are shown (Fig. 5), it was noticed that the dust particles were concentratedly captured by the 3rd layer of the filter, which is made of the finest mesh.

We have also noticed that there's a differences in dispersion conditions of dust particles. The photos in Fig. 6 show the situations of ethanol and gasoline when they are added with

dust particles. It is perceived visually as well that the dust particles coagulate easily when they are in neat gasoline but rather hardly coagulate in ethanol.

Based on these observations, we have assumed that dust particles in ethanol blended fuel are easily dispersed and captured mostly by one layer of the fuel filter resulting in early clogging. Then the following 3 items were defined as research subjects.

- (1) Quantitative evaluations of dispersed status of dust particles in fuel, and the relationship between the concentration of ethanol and the dispersion of dust particles.
- (2) Influence of dispersion status of dust particles in fuel on the filter clogging, and its mechanism.
- (3) Proposal of the design for a long-life fuel filter that copes with ethanol blended fuel.

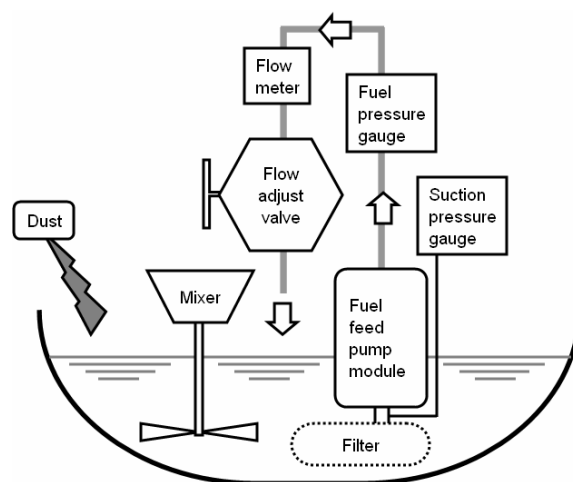


Fig. 3 Schematic view of filter test

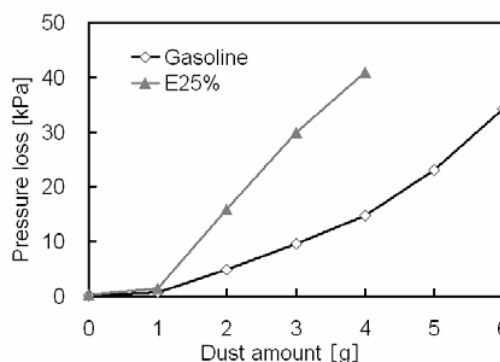


Fig. 4 Relationship between input dust particle amount and pressure loss

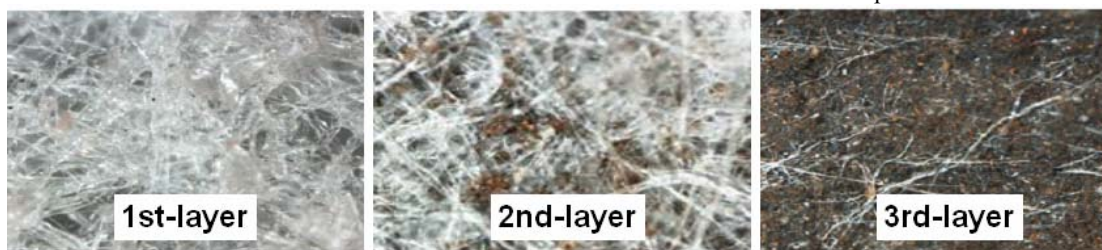


Fig. 5 Clogged filter condition when using E25%

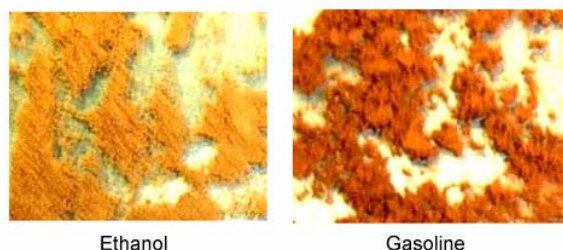


Fig. 6 Comparison of dust particles dispersion condition in fuel

PROPERTY OF DUST PARTICLES IN FUEL

DUST PARTICLES IN FUEL

Automobile fuel contains a substantial amount of micro dust particles. Although the number of the dust particles differs depending on the regions, 40,000 to 300,000 particles per 1 ml, which are 1 μm or larger in size, are contained. The typical cumulative particle size distribution (based on the particle count) is shown in Fig. 7 for in-fuel dust of major countries. Most of dust particles in fuel range from 2 μm to 30 μm in size and 99% of them are 5 μm or less. The minute dust particles contained in fuel, which are 10 μm or less in size, are classified in the particle system called colloidal dispersion system. 50 to 80% of these micro dust particles are made up of SiO_2 , Fe_2O_3 , and Al_2O_3 . These are the common components of soil, and it is presumed that soil contents are carried, e.g. by wind, in the process of the distribution or fueling to vehicles. The particles in the status of colloidal dispersion system are hardly influenced by the gravity or the buoyancy and rather stay still in the liquid phase. Therefore, most of the dust particles remain adrift without causing precipitation and sucked with fuel by a fuel pump.

QUANTITATIVE UNDERSTANDING OF DISPERSION STATUS OF DUST PARTICLES IN FUEL

Dispersion status of dust particles in fuels can be measured by an analyzer using laser diffraction technology. Measurement samples are prepared by mixing the same standardized dust with the same concentration. The median diameter, which is one of the measured values, is used to identify the dispersion status, and the way of judgment has been decided as the smaller the median diameter is, the larger the degree of dispersion is. Results of the measured median diameter to the ethanol mixture ratio are shown in Fig. 8. We have analyzed each fuel sample which contains the equivalent amount of dust as marketed fuels by using laser diffraction analyzer. We have confirmed that the particle size distribution of the dust in 100% ethanol is characterized with the median size of 1/4 compared to that size for neat gasoline. Accordingly, it can be concluded that the degree of dispersion of the dust goes up when the concentration of ethanol increases.

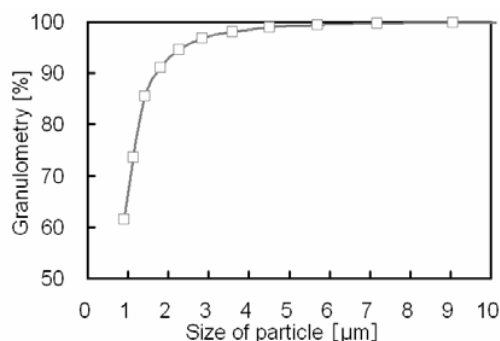


Fig. 7 Cumulative particle size distribution of average dust particles in fuel in major countries (Particle Count Basis)

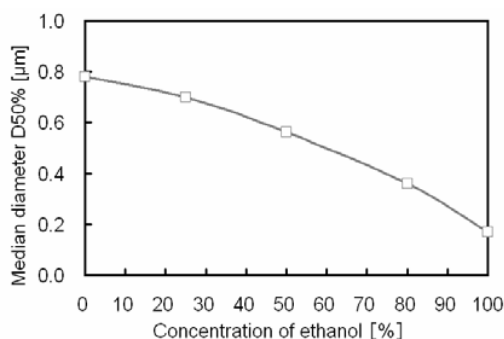


Fig. 8 Ethanol concentration in gasoline and median diameter of dust particles contained in gasoline

COMPARISON OF DUST CONDITIONS USING SEDIMENTATION SPEED

Another method to measure the dust dispersion status is to measure the sedimentation speed of the dust drifting in a liquid phase. The dust in the status of colloidal dispersion system gets only a little influence from the gravity and, the more dispersed it is, the longer time it takes for its sedimentation. Using this characteristic, it is possible to utilize this sedimentation time as a criteria for scaling the degree of dispersion of dust. We put the same amount of dust particles in fuel samples containing gasoline and ethanol with a variety of ratios, and have compared settling times. Sedimentation time has been defined as the time required until the liquid reaches a constant transparency. As shown in Fig. 9, the higher the alcohol concentration is, the longer the settling time, i.e. the more dispersed the dust is.

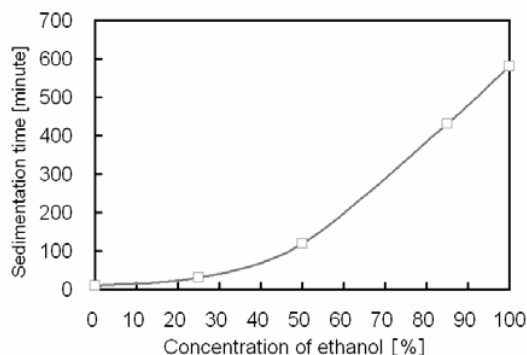


Fig. 9 Ethanol concentration in gasoline and settling time