

Analysis of impact parameters on the water/diesel separation process with filter elements

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The separation of dispersed water droplets from diesel fuel is an important process in fuel conditioning to protect the sensitive parts of modern diesel injection systems from damaging results of the water. Water leads to corrosion, wear due to reduced lubrication in fuel-lubricated system components and it facilitates microbiological growth. The water content in the diesel as well as the base diesel quality varies over season and region of the world. This makes it necessary to describe the worldwide fuel qualities with respect to the properties of water separation. This basic information is also necessary for an optimized design and an effective testing of diesel/water separators.

The water removal is usually integrated in the inline diesel filter systems that are used for the particle filtration in passenger cars, light-duty and heavy-duty trucks, stationary engines, and other off-road vehicles. The polarity of water (extremely polar) and diesel (almost non-polar) is completely different due to the different molecular structures of water and diesel. This property is used as the basis for the separation of the water droplets. The basic design idea of almost all filter elements for water/diesel separation comprises the serial combination of hydrophilic (oleophobic) and hydrophobic (oleophilic) media in various sequences. Using the hydrophobic filter medium as the first layer upstream it serves as a barrier and the few remaining water droplets will coalesce and separate in the subsequent hydrophilic filter medium. Applying the reverse combination the droplets coalesce first in the hydrophilic filter layer and they are retained at the second, hydrophobic filter medium. The separated water is removed from the filter elements by a drainage system.

In practice both concepts show an unpredictable operating behavior or often fail completely dependent on the fluid properties of the real diesel fuel. This is due to the almost unknown concentration of undefined fuel additives to improve the lubricity, the cold temperature stability, and the combustion properties. These additives can act as surfactants and then stabilize the water/diesel emulsion. Due to the flow conditions and the forces acting on the water/diesel emulsion, especially caused by the fuel

pumps, the water droplets are disrupted and often sized down to below 5 microns which also increases the emulsion stability. Finally legislative constraints require or allow the addition of biodiesel to mineral diesel in varying concentrations. During the processing of biodiesel by-products of low molecular weight arise which act as surfactants as well, and lower the interfacial tension between water and diesel to values down to 2 mN/m in extreme cases.

The design of coalescer filter elements for the water/diesel separation is difficult due to the amount of unknown or varying influence factors. The most important parameters regarded in this context are

- interfacial tension in the water/diesel system and its variation with time
- surface adhesion behavior of water droplets on different filter fibers
- pH-value and conductivity
- water droplet size distribution and volumetric water content and the variation with time
- time-dependent behavior of coalescer filter elements in single and multi pass experiments
- surface velocity on the filter elements and filter media
- sequence and structure of hydrophilic and hydrophobic filter media layers
- thickness of the filter medium

The separation behaviour of filter media is another difficulty. While many filter media experiments show a good coalescence behavior for new elements, a change to a bad separation behavior after some filtration time and dust loading is possible. It is supposed that the surface properties of the filter fibers are altered due to the adhesion of surfactant molecules from the diesel fuel.

The first part of the presentation gives an overview on the state-of-the-art of the known phenomena in water/diesel separation processes with filter elements with respect to the aforementioned influencing factors.

The second part describes the setup and the results of experiments in water/diesel separation performed by the authors. Two test rigs are used. The first test rig is an automated setup for filter elements which are investigated under single or multi pass conditions. The second test rig is a laboratory setup where the production of the emulsion and the filter media can be varied quickly and which allows an arbitrary probe sampling on the clean side. Water/diesel systems are generated by orifices, fuel pumps and dispersion stirrers. The droplet size distribution is comparable to the range of droplet sizes found in real applications with fuel from gas stations. Pleated filter elements as well as unpleated individual filter layers are used for the separation processes. The water content before and after separation is measured with the Karl-Fischer-titration method. A laser spectroscopy is applied to determine the droplet size distribution on the raw and clean side and to characterize the stability of water/diesel emulsions from different emulsification processes and raw materials. The material

characterization, especially the interfacial properties, are measured by the ring method and the droplet volume method for the interfacial tension and with a macro video system to capture the contact angle of water droplets on different filter media surfaces.

The goal of all investigations is the identification and the correlation of the relevant operational and material parameters and the fluid properties on the water/diesel separation process. This knowledge allows for carrying out comparable experiments and a suitable design of coalescer filter systems and coalescing filter media.