Automotive

Comprehensive system for diesel fuel cleaning

The removal of emulsified water from diesel fuels often encounters serious problems, which lead to operation failure and breakthrough of water into the fuel injection equipment. This can cause a severe damage of common rail systems. Here, a novel design of diesel filter shows significant improvements in terms of dirt holding capacity, water separation and thus the life-time of the engine.

Filters applied for removal of emulsified water from diesel fuels encounter serious problems in recent 10-15 years, which often leads to operation failure and breakthrough of water into the fuel injection equipment. This can cause a severe damage of common rail systems, which are vulnerable to contamination with solids as well as the presence of emulsified water droplets can cause a very fast wear and damage of the injection nozzles.

The problem of water penetration though filtration units is brought about by changes in the composition of diesel supplied to the market. These changes were imposed by legislation due to environmental concerns, and refer to ultra-low sulphur diesel and biodiesel blends[1]. The experimentally observed foam-like structure of the water droplets collected on hydrophobic filter media show that their coalescence is hindered[2].

This leads to an increase of the pressure drop and breakthrough of small droplets before they merge and drain upstream the hydrophobic barrier. The increased stability of the emulsion, lower surface tension, smaller size of water droplets created at the same hydrodynamic conditions and additional repulsive interactions between droplets are the main reasons responsible for more difficult separation conditions.

Various additives or biodiesel blended with petrodiesel (or used in its pure form, i.e. B100) contain compounds which adsorb on the interface like surfactants and stabilize the W/O emulsion. Very often they also increase the water solubility. In such dispersions commonly used one-stage hydrophobic filters are not efficient in removing small water droplets, and to meet water concentration limits (200 mg/dm^3 of total water according to EN 590:2013) a coalescence step must be applied prior to the separation.

Filter assembly

The operation concept is based on a two-stage process, which is a standard for jet fuels filtration as well as in large separation for diesel, gasoil and other liquid hydrocarbons of similar viscosity. In such system the separation rate (i.e. settling velocity) is slow, and this would require a non-realistic size of separator housing to reach required efficiency. Therefore, a hydrophobic screen with uniform pores are applied to stop and collect the water droplets on the surface, while the hydrocarbons pass through the separation barrier.

The criterion for successful operation is that the size of droplets needs to be larger than openings in the hydrophobic screen to enable the contact of droplet with hydrophobic surface. Hence, if the dispersion consists of very small droplets, they must be merged in the coalescence element and grow to a reasonable size. In addition, the surface area of the separation element should be sufficiently large such that the pressure drop across the separator is less than the capillary pressure.

The concept of two-stage process has been studied by Krasinski and Wierzba[3], where the elements were stacked, i.e. coalescer with in-to-out flow orientation was mounted onto the separator made of pleated cellulose with the flow direction

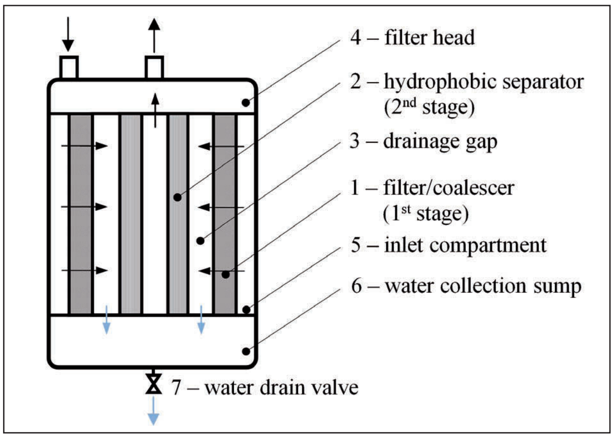

Figure 1. A cross-section scheme of the compact two-stage diesel filter. The contaminated fuel enters the housing through a head (4), which uniformly distributes the dispersion in the inlet compartment (5). Then the emulsion flows across filter/coalescer (1), and the enlarged droplets which disengage from the drain layer of element (1) settle down in the drainage gap (2) into the water collection sump (6). Droplets which are too small to settle down in the drainage gap reach the surface of the separation element (2) and they are collected on the hydrophobic surface, while the purified fuels passed the barrier and leave the filter through the top outlet. The presented design requires separate vents for the inlet compartment (5) and drainage gap (3).

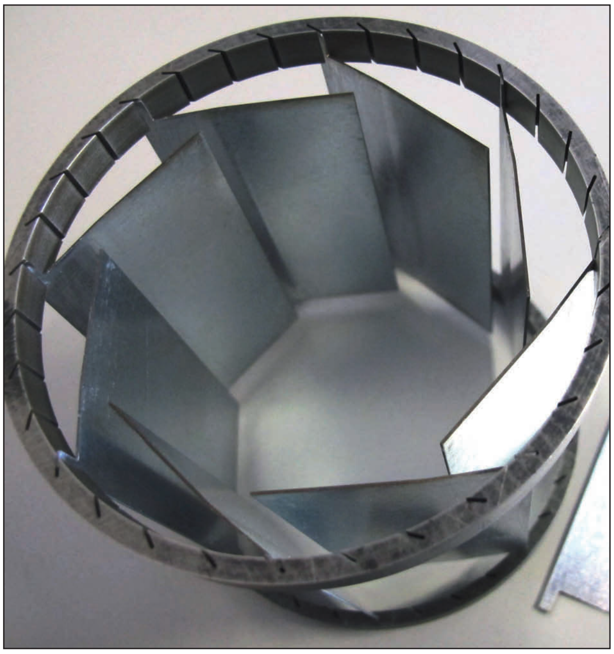

Figure 2. Flow guiding vanes used in prototype.

radially inwards. Good results in terms of separation efficiency were an incentive to devise a compact diesel filter for direct use in vehicles. In presented design two elements are fitted uniaxially as presented in Figure 1.

Filter media

The filtration/coalescence element was made of PBT (polybutylene terephthalate) using the melt-blown technique. The fully automated machinery enables programming the production for maximum reproducibility of multilayer structures. At the inlet to the element (i.e. on the outer side of a cartridge) the filtration depth structure characterized with decreasing porosity and fibre size along flow direction is located. Next the primary coalescence, intermediate and drain layers are placed, which form a complete coalescence structure. The melt-blown structure was made as a coreless element, and the support was provided by the element with guiding vanes (Figure 2). The separator was made of a commercial grade of hydrophobic cellulose.

Vane elements

To minimize the collection of water on the surface of separation element the flow guiding vanes are fitted in the drainage gap (Figure 2).

The presence of vanes supports the separation by changing the local hydrodynamics in two ways. The reasonable geometry provides an orifice between adjacent elements so that the fuel accelerates – the local velocity can be up to 30 times larger than on the outlet of element, depending on the design. Multiple liquid jets tangential to the contour of element are entering the volume surrounding it. Hence, larger water droplets are separated from the element due to their inertia and action

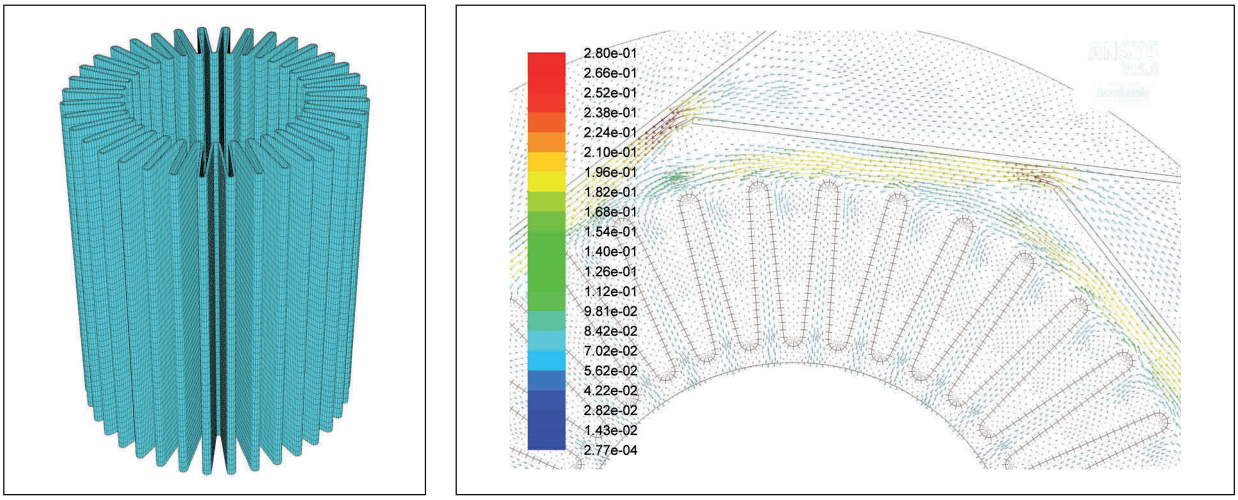

Figure 3. The mesh representing pleated element (on the left) and velocity vectors in the cross section near the vanes (on the right); velocity on the outlet from coalescer 0.01 m/s.