Visualisation of diesel injector with neutron imaging

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Abstract. The injection process of diesel engines influences the pollutant emissions. The spray formation is significantly influenced by the internal flow of the injector. One of the key parameters here is the generation of cavitation caused by the geometry and the needle lift.

In modern diesel engines the injection pressure is established up to 3000 bar. The details of the flow and phase change processes inside the injector are of increasing importance for such injectors. With these experimental measurements the validation of multiphase and cavitation models is possible for the high pressure range. Here, for instance, cavitation effects can occur. Cavitation effects in the injection port area destabilize the emergent fuel jet and improve the jet break-up.

The design of the injection system in direct-injection diesel engines is an important challenge, as the jet breakup, the atomization and the mixture formation in the combustion chamber are closely linked. These factors have a direct impact on emissions, fuel consumption and performance of an engine. The shape of the spray at the outlet is determined by the internal flow of the nozzle. Here, geometrical parameters, the injection pressure, the injection duration and the cavitation phenomena play a major role.

In this work, the flow dependency in the nozzles are analysed with the Neutron-Imaging. The great advantage of this method is the penetrability of the steel structure while a high contrast to the fuel is given due to the interaction of the neutrons with the hydrogen amount. Compared to other methods (optical with glass structures) we can apply real components under highest pressure conditions. During the steady state phase of the injection various cavitation phenomena are visible in the injector, being influenced by the nozzle geometry and the fuel pressure. Different characteristics of cavitation in the sac and spray hole can be detected, and the spray formation in the primary breakup zone is influenced.

1. Introduction
The relationship of the internal nozzle flow and the primary break up is important for combustion process. These processes of injection are very complex. There have to many physical processes, such as the momentum exchange between liquid phase and gas phase turbulence in the liquid phase and in the gas phase, transient heat transfer, boiling behaviour, surface tension effects, cavitation etc. are included (Figure 1) [1].

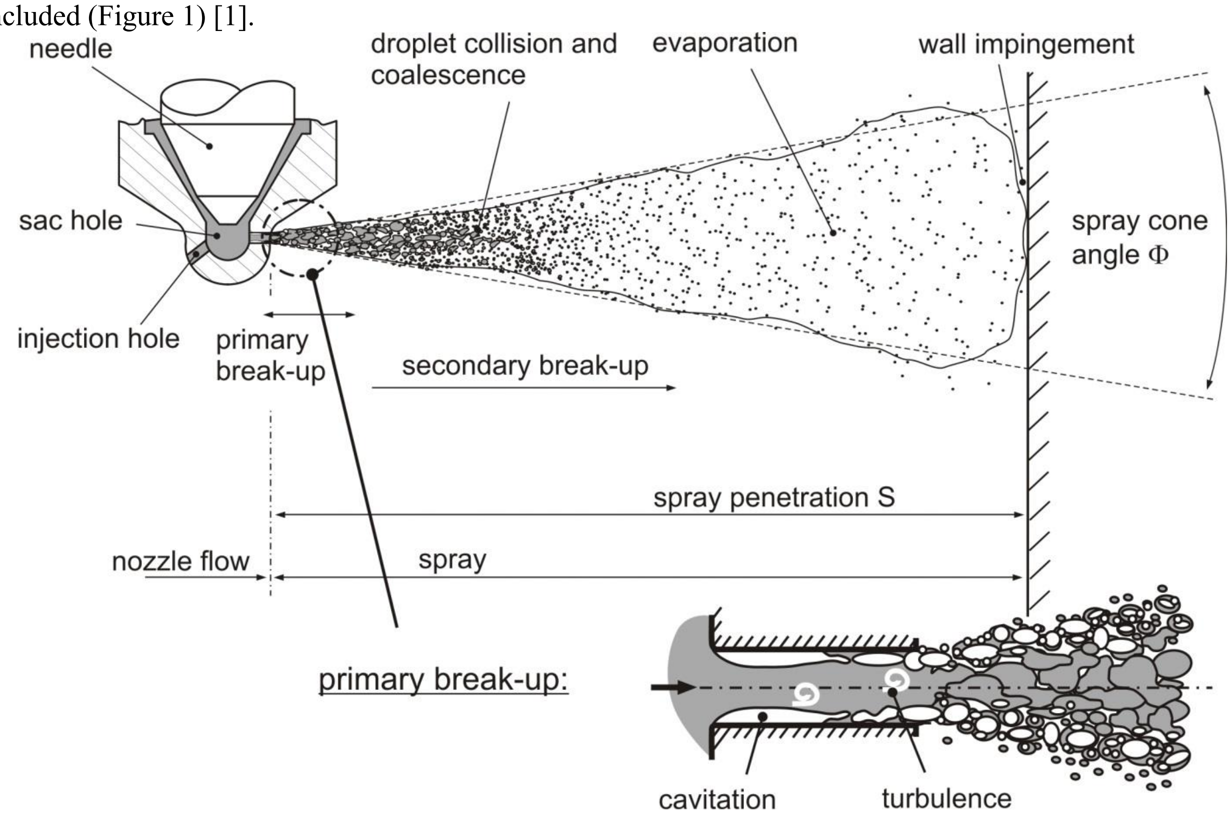

Figure 1. Features during the spray formation in the Diesel injection nozzle [1]

In the nozzle flow injection pressures are used up to 3000 bar. The liquid fuel is through the injection ports with speeds exceeding 500 m / s is injected into the combustion chamber. In the spray holes the cavitation zones and prevailing turbulence are the main departure mechanisms of the jet break-up at spray hole outlet [2]. Immediately after leaving the spray hole breaks the liquid jet into drops and ligaments, which form a dense spray in the vicinity of the nozzle. This first section of the spray break-up is called primary break-up. During the subsequent disintegration process, the so-called secondary break-up, existing droplets fall into more smaller droplets. In this areas, drops are collides and associates. The secondary break-up is caused due to aerodynamic forces. The relative speed between droplets and gas phase decelerated the droplets. Droplets on the spray holes are delayed through the strong resistance forces than the droplets which follow these drops. Thus, the jet is always replaced by new droplets and thus reflects the spray spread. The fuel jet is characterized in this case by the penetration depth and the spray cone angle. Also found in the area the spray cone a massive evaporation instead of the liquid fuel [3],[4],[5].

2. Neutron Imaging approach
As shown in Figure 2, the Diesel injection nozzles are relatively transparent for thermal neutrons while the small amounts of Diesel fuel gives considerable contrast. This advantage of the method can be used favorably for dedicated studies. On the one hand, the spray formation close to the nozzle outlet in

near filed until the density limit is reached can be observed in stationary mode or in pulsed operation where the neutron imaging detector is triggered via the injection signal [6].

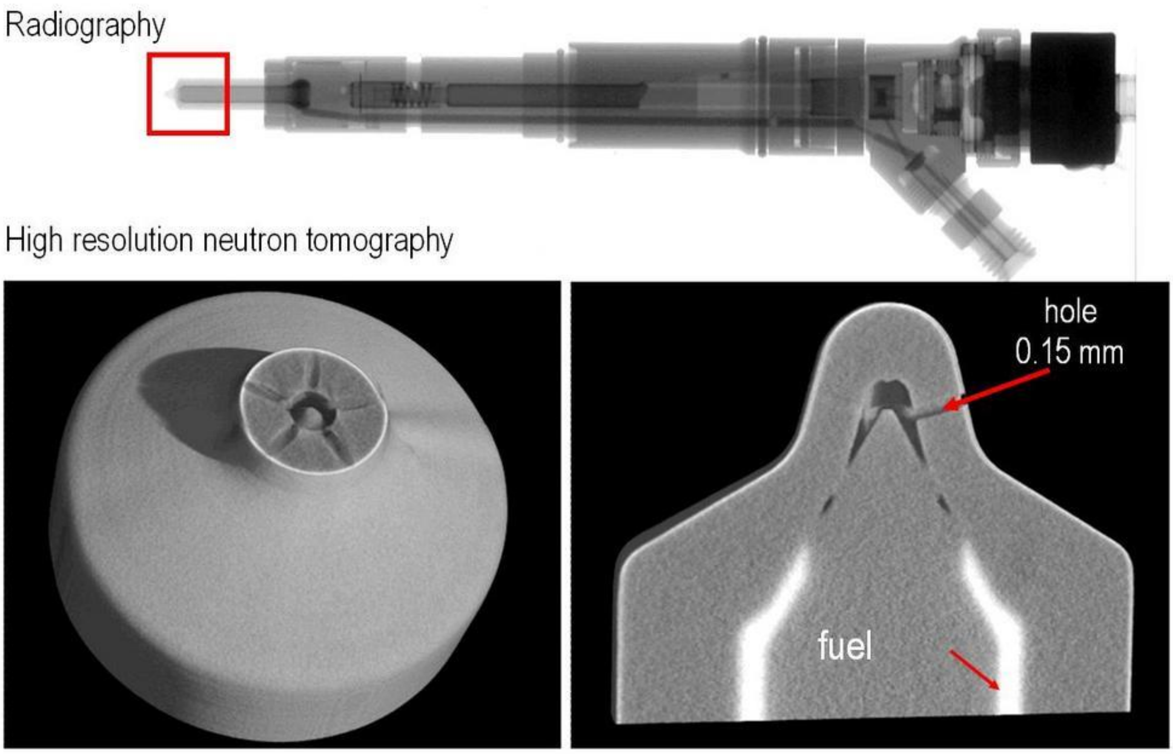

Figure 2. Neutron transmission image of a Diesel injection nozzle (top) showing the fuel distribution (dark lines) inside the steel structure with high transparency. The lower part is the neutron tomography of the nozzle outlet: horizontal slice through the holes (left), vertical slice through the middle (right), where remaining fuel is indicated in white contrast

Further, the structure of the nozzle outlet holes and their alterations can be investigated non-destructively by means of neutron tomography, as it is shown in Figure 2. The spatial resolution is on the order of 10 um and will be improved to about 5 um soon.

We have in mind, to investigate the running injection process with the highest possible spatial resolution and in dynamic mode in order to see the processes like cavitation and gas formation in the fuel directly. We will use a gated and intensified CCD detection system with high sensitivity for neutrons. This technique will be tried at first in a stationary process for averaged values.

Neutron imaging is a well-established technique at PSI, based on the operation of more than two facilities with high-end performance [7].

3. Appraoch

It is the intention to combine in this project the already established knowledge and experience (simulation and optical tests) with the new approach of neutron imaging in the best manner.

4. Results and Discussion

For the moment, we can only show independently achieved results: studies with optically transparent "dummy" cells and the related process simulations and neutron imaging data with static components. In addition, we can give results of dynamic processes of the spray formation near the nozzle exit, obtained with coarse spatial resolution for optical measurements. For the neutron imaging the combination of the high resolution option with the high contrast for the fuel will enable to see the stationary averaged processes in the nozzle outlet in the best possible way.

5. Conclusions

We described a new approach for the investigation of cavitation effects in the fuel exits of Diesel injection nozzles by means of neutron imaging. Using the high penetration power through steel, the high contrast for small amounts of fuel and the high spatial resolution of the newly developed neutron imaging detectors it will be possible to perform dedicated studies of the cavitation effects under realistic conditions.

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