Effect of degassing phenomenon of the aviation fuel cavitation dynamics in a case of a three-bladed inducer

Théodore Magne, Richard Paridaens, Florent Ravelet, Sofiane Khelladi, Farid Bakir, Petar Tomov, Loïc Pora

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Théodore MAGNE, Richard PARIDAENS, Florent Ravelet,
Sofiane KHELLADI, Farid BAKIR
DynFluid Laboratory
ENSAM ParisTech
151 Blvd de l'Hopital
75013 Paris, FRANCE

Petar TOMOV, Loïc PORA
Fuel Equipment Design Office
SAFRAN Aircraft Engines
77550 Rond-Point René Ravaud, FRANCE

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Corresponding author: theodore.magne@safrangroup.com

Cavitation phenomenon is vastly present in different technical devices such as hydrofoils, pumps and convergent-divergent nozzles observed in various fields of engineering. One particular field of interest is the cavitation in the low pressure stage of a fuel pump, located at the interface between the aircraft and its engine. Cavitation phenomenon can generate vibrations, noise, and instabilities in the flow, which can reduce the main fuel pump hydraulic performance. Moreover, a degassing phenomenon from the aircraft fuel can take place during aircraft climbing. As a result, both phenomena can be coupled, which can lead to the emergence of a complex multiphase flow, which needs a thorough research and exploration.

An experimental work is conducted on two 3-bladed axial inducers of a low pressure stage fuel pump at partial flow rates in cavitating and non-cavitating regimes for two different working fluid. The two different fluid are: water with added dissolved CO_2 and a jet fuel. Futhermore, two different procedures will be tested, for the first procedure, the depressure is achieved with a vacuum pump, for the second procedure it is done by closing an upstream valve. Typical Net Positive Suction Head (NPSH) curves and characteristic curves are obtained for numerous rotational rate and flow coefficient. The resulting cavitation inception and dynamics are different for each case study. The cavitation dynamics is observed by means of a high-speed camera.

The experiments were conducted in a closed water loop at Dynfluid's facility. The latter consists of a 1000 L fuel tank and a test section, where the three-bladed inducer is located in a 80 mm diameter circular duct. The test section is transparent in order to perform visualization with the high-speed camera at a sampling rate of 1 kHz. Additionally, the outer casing of the test section has a rectangular shape to minimize the effect of a light refraction. The high-speed camera is not fixed on the loop, so that any vibrations from the rotating machinery can be omitted. The water temperature is equal to 18°C $\pm$ 1°C and it is constantly monitored during the tests. The inducer rotating speed ranges from 0 rpm to 8000 $rpm \pm 10$ rpm. One of the water tank is partially filled with liquid so that a free surface is created inside. A vacuum pump is connected to the free surface in order to decrease the pressure in the system and to simulate the aircraft climbing in altitude. Moreover, a specific device is placed in one of the tanks in order to inject a controlled quantity of CO_2 and to dissolve it in water. The valve needed for the ARP procedure is mounted at almost 26 D_H upstream the test section. The fluid motion can be achieved by the inducer only or by a coupling with a centrifugal pump present in the loop. The flow rate ranges from 0 $m^3 \cdot h^{-1}$ to 40 $m^3 \cdot h^{-1}$. In the present study, the centrifugal pump is used for fluid flows higher than 10 $m^3 \cdot h^{-1}$. It has been verified that there is no impact on the inducer hydraulic performances when the centrifugal pump is activated. The fluid flow is controlled by multiple manual valves. The pressure measurements are taken on multiple locations: 20 D_H in upstream the inducer and 11.25 D_H downstream. There are also two average pressure tap locations, which are located 1 D_H upstream the tip leading edge of the inducer, the one at the outlet is at 0.75 D_H downstream.

The NPSH curves and ARP curves are plotted for various inducer operating points. The similarity of these curves is dependent on the properties of the working fluid. In fact, for the case with gassed water the procedure does not change the performance of the inducer at a given running condition. While for the jet fuel case, differences in the cavitation inception can be found .

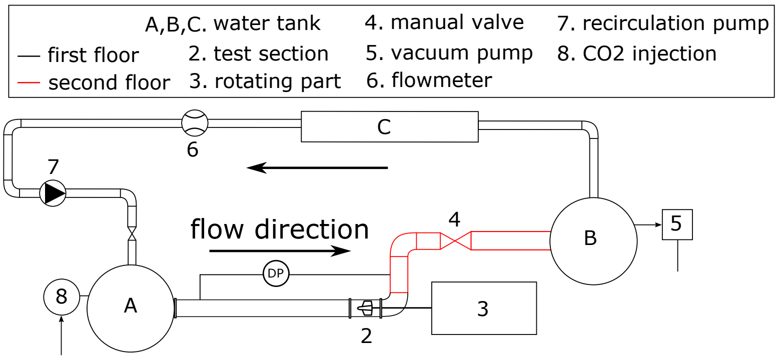

Figure 1: Schematic view of the Dynfluid test facility. The flow direction is indicated with the flesh. The injection of CO_2 takes place on the bottom of tank A. The circuit pressure is driven by the vacuum pump. The test section is fully transparent between tank A and tank B.

Figure 2: Different views of the inducer U1