Experimental and numerical investigation of dense gas fluid dynamics and BZT fluids exploitation for energy conversion applications

Project Aim

The main objectives of the project are, i) the experimental verification of the existence of nonclassical gasdynamic phenomena, and particularly of rarefaction shockwaves in the dense vapor of high-molecular weight fluids, ii) the development of CFD tools capable of handling dense-gas flows and, iii) The study of possible applications of nonclassical gasdynamic and dense-gas effects in turbomachinery.

Progress

The Flexible Asymmetric Shock Tube (FAST) has been built in the Process & Energy Lab of the TU Delft and a picture of the facility is shown in Fig. 1. The setup is made for tests with organic silicon oils at moderate pressures and at high temperature, namely of the order of 360 oC. The setup is somewhat like a Ludwieg tube wind tunnel whereby here, the aim is to generate and measure the speed of propagation of an unsteady downstream sonic rarefaction shock wave created in a 9-meter charge tube. The wave speed is measured using a time of flight technique employing 4 dynamic pressure instruments positioned at accurately known mutual distances. Currently, the operation of the facility is tested using air. The FAST is to be equipped in the near future with a fast-opening valve (refer to Figs. 2 and 3) which can open in < 4 ms. The valve incorporates a nozzle with adjustable throat area. The valve is designed by Hyperschall- und Strömungstechnik GmbH (HST GmbH) and at the moment, successful tests are being conducted in Germany regarding the operation of this crucial device. Achievements:

1. Building and commissioning of the FAST facility;
2. Successful testing of the data-acquisition and temperature control system;
3. First tests using the fast-opening valve showed that the measured signals were reproducible. Some sealing problems need to be solved.

Achievements from a theoretical viewpoint are the identification of a region of negative nonlinearity in the vapor-liquid critical region of a single-component fluid (under validity of, among other things, the thermodynamic equilibrium hypothesis) and the possibility of creating expansion-shock waves featuring phase transition in the abovementioned critical region, without the necessity of the fluid exhibiting retrograde behavior.

Dissertations

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Scientific Publications

1. C. Zamfirescu, A. Guardone, and P. Colonna, "Admissibility region for rarefaction shock waves in dense gases," J. Fluid Mech., vol. 599, pp. 363-381, March 2008.
2. P. Colonna, N. R. Nannan, and A. Guardone, "Multiparameter Equations of State for Siloxanes: [(CH3)3-Si-O1/2]2-[O-Si-(CH3)2]i = 1...3, and [O-Si-(CH3)2]6," Fluid Phase Equilib., vol. 263, pp. 115-130, 2008.
3. P. Colonna, A. Guardone, N. R. Nannan, and C. Zamfirescu, "Design of the Dense Gas Flexible Asymmetric Shock Tube," J. Fluid Eng.-T. ASME, vol. 130, March 2008.

Project leaders

P Colonna

Research theme

Complex dynamics of fluids

Participants

RN Nannan (PhD student),
A Guardone (visiting professor),
C Zamfirescu (research associate),
TP van der Stelt (research associate)

Cooperations

Politecnico di Milano; Università degli Study di Brescia; Process Equipment Section (3mE, Process and Energy Department, TU Delft), Turboden; Tri-O-gen B.V.; Carrier Corp. (UTCPower); FeyeCon B.V.

Funded

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1st 100% 2nd - 3rd -

Start of the project

2004

Information

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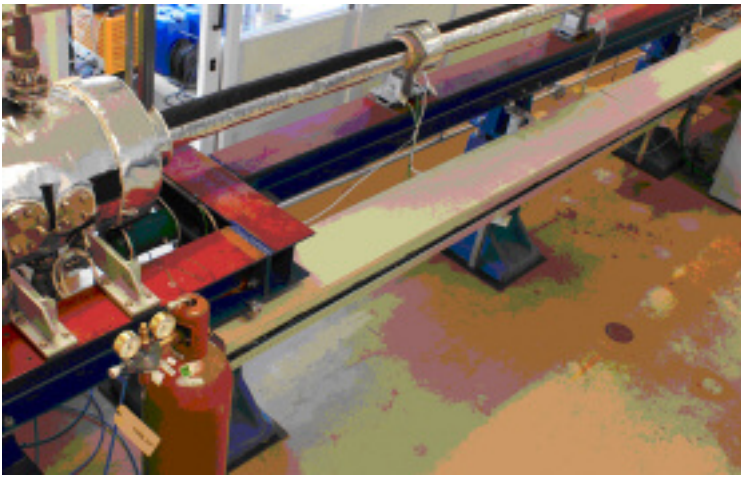
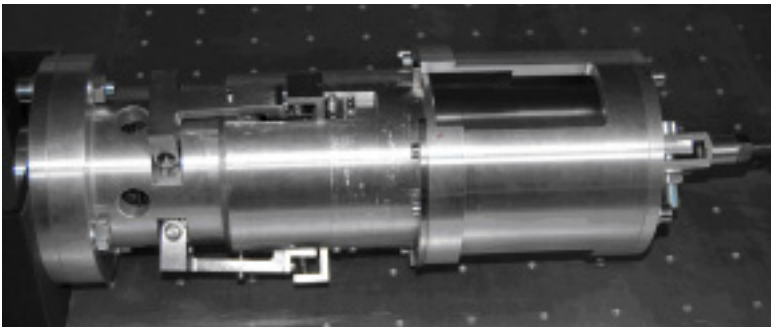
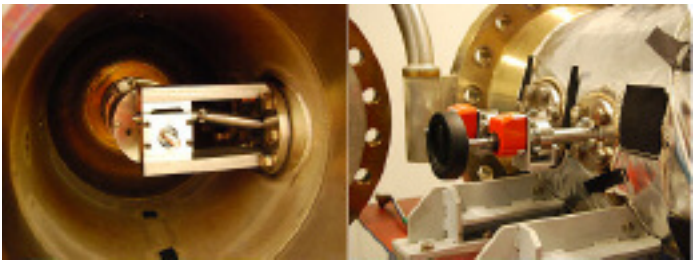


The FAST setup: on the left, the dump-tank can be seen which is connected to a 9 meter charge tube. Not visible are the vapor generator and the condenser. Note that the facility is a closed system.



The fast-opening valve at HST GmbH. On the left, two locking pins can be seen, as well as the holes through which the fluid exits radially after passing the nozzle.



The fast-opening mounted in the dump-tank of the FAST. Notice in the picture on the right that there is a gauge to tune the flow area though the nozzle which is built-in the valve. Short opening times are achieved using pre-acceleration with inconelTM springs.