Simulation and Experimental Validation of a Looped Thermoacoustic Generator with Stub

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Introduction and Concept

Thermoacoustic travelling-wave engines combine a simple design with high efficiency and relatively low operating temperatures which makes them a promising alternative to conventional heat engines. Starting from the one-wavelength loop design proposed by Ceperley in 1979 [1] and set up from Yazaki in 1998 [2], a breakthrough in power and efficiency has been made with the TASHE from Backhaus and Swift in 1999 [3]. They introduced a more complex acoustic network, including a quarter-wavelength resonator, inertance tube, and compliance. This layout sets optimal travelling-wave phasing and impedance in the regenerator, resulting in great thermal to acoustic conversion efficiency. However, a rather large amount of acoustic power is lost in the resonator.
Another option to influence phasing and impedance in the regenerator is by means of an acoustic matching stub and an increase of the cross-sectional area of the regenerator section [4], [5]. At TU Dresden, numerical simulations have shown that position and length of the stub are essential parameters for achieving high performance. They are also greatly influenced by the position of the acoustic load. Therefore, an experimental apparatus is designed to validate the simulation data.

Modelling and Simulation

The researched engine is a one-wavelength loop type with matching stub (see Figure 1). It has a loop length of 4 m and is operated with argon at a pressure of 20 bar, resulting in a resonance frequency of 77 Hz. The regenerator section has a nominal diameter of DN150 that is connected to the DN80 feedback tube via reducing cones.

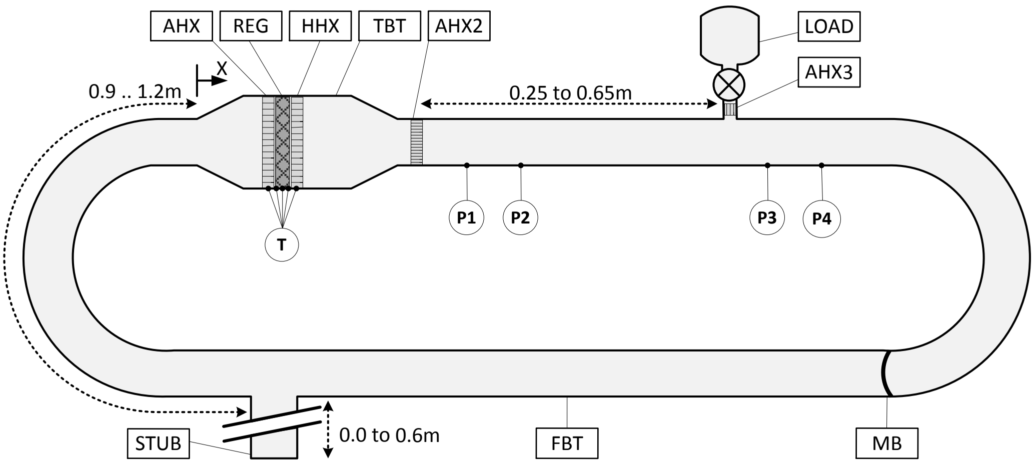

Figure 1: *Schematic view of the test rig (AHX..ambient heat exchanger, REG..regenerator, HHX..hot heat exchanger, TBT..thermal buffer tube, AHX2..secondary ambient heat exchanger, LOAD..acoustic RC load, AHX3..tertiary ambient heat exchanger, STUB..acoustic matching stub, FBT..feedback tube, MB..membrane)*

Acoustic power is removed from the system by use of an adjustable acoustic RC load. The geometrical parameters "load position", "stub position", and "stub length" are variable in the range shown in Figure 1.
Numerical simulation and design is done with DeltaEC [6]. The computer code integrates the one dimensional wave equation in dependence of chosen gas and geometry. Figure 2 presents preliminary simulation results. The left side shows the distribution of pressure amplitude and volumetric velocity along the generator when heat input in the hot heat exchanger is 2000W. The positions of regenerator, acoustic load and stub are indicated by sharp amplitude changes. The right side of Figure 2 illustrates the impact of load position on the temperature difference across the regenerator and load power consumption. Cold side temperature was kept steady at 350K.

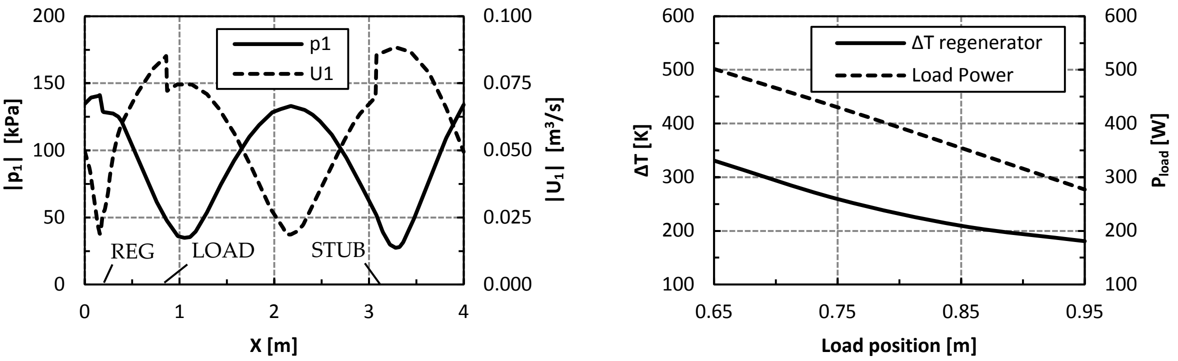

Figure 2: *Pressure amplitude and volumetric velocity along the generator (left), temperature difference between hot and cold side of the regenerator and consumed load power dependent on load position (right)*

Experimental apparatus

The test rig is planned to be made of stainless steel tubing. Stainless steel screens will be used for the regenerator. Heat exchangers will be made of copper blocks drilled with holes. Ambient heat exchangers are water cooled and the hot heat exchanger will be electrically heated. The acoustic load consists of a control valve and a cavity. A flexible membrane will prevent Gedeon streaming. Thermocouples will measure the temperature distribution inside heat exchangers and regenerator. Moreover, four pressure sensors will be used to determine acoustic power gain, consumed power, and feedback power. The gained data will enable a detailed analysis on the acoustical impact of the geometrical parameters.

Acknowledgements

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