Acoustic Resonance Excited Heat Exchanger

Interim Report

Project Summary

The project deals with enhancing the performance of a typical roughened heat exchanger (HE). The research is based on the preliminary findings, which proved that application of a standing wave over separating and reattaching flow greatly improves the heat transfer between the fluid and the wetted surface. Based on laboratory testing, the heat transfer was augmented by up to 25% without imposing an additional pressure drop penalty to the flow, Figure 1. The results of the basic science research were published in leading academic journals. In following, a PCT patent has been filed.

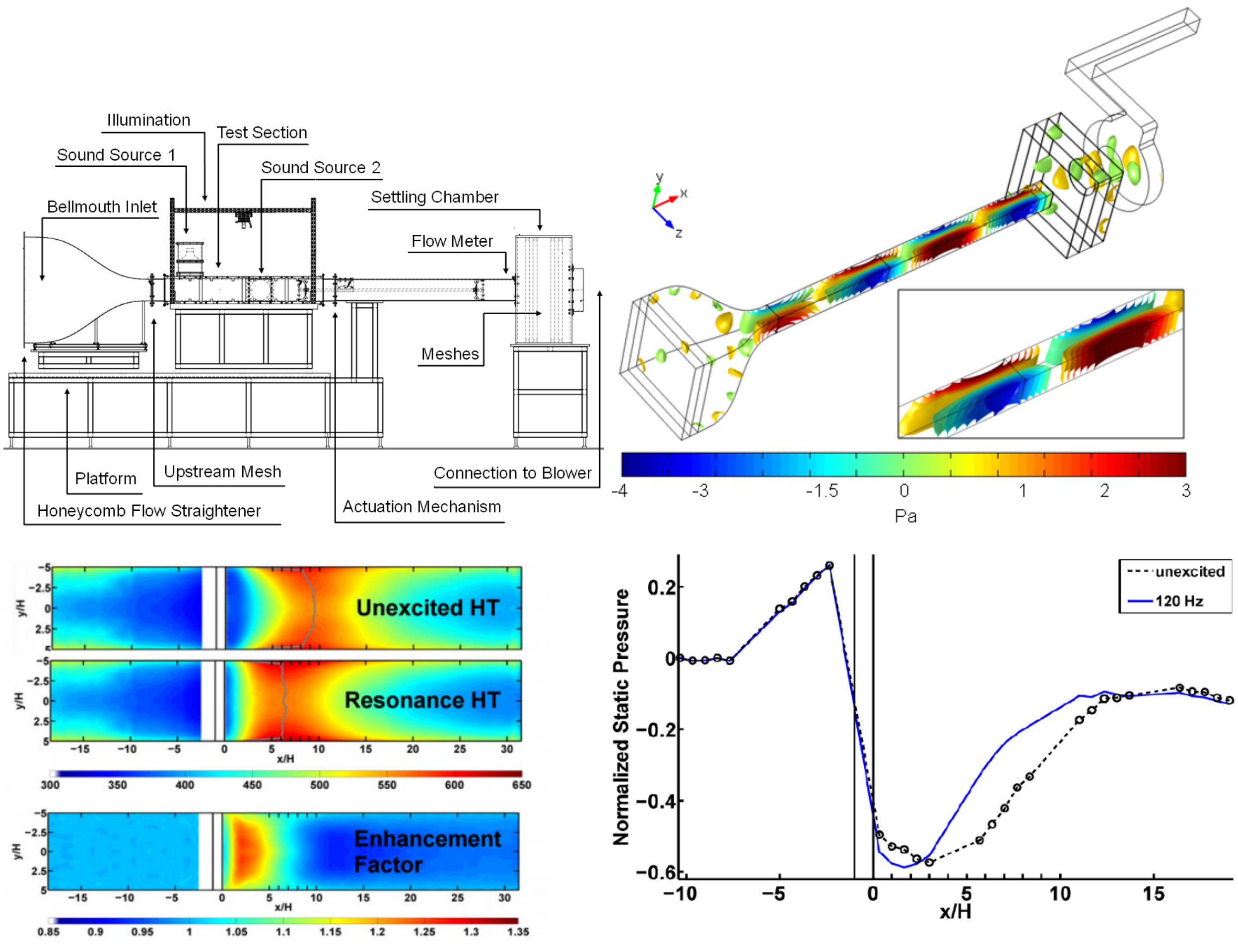

Figure 1 – a) Wind Tunnel Facility Simulating Internal Channels of a Heat Exchanger b) Acoustic Resonance Analysis of Test Section c) Local Nusselt Numbers for Unexcited Flow, Resonance Excited Flow and Local Enhancement Factor, d) Local Normalized Static Pressure for Unexcited and Excited Flow

While the preliminary research studied the physical phenomenon, the project aims to adapt the technology for general industrial use. Its feasibility is to be evaluated in a relevant application by adapting an existing HE unit to accommodate the appropriate changes. The prototype unit will integrate a tuned acoustic excitation source (active or passive) to impose standing wave inside the heat exchange passageways. The goal of the study is to augment the technology readiness level from 3 (analytical and experimental critical function and/or characteristic proof-of-concept) to reach 5 (system/subsystem/component validation in relevant environment) within the timeframe of the project. In this scope, the main technological gaps to be bridged are the determination of inherent acoustic resonance frequencies in heat exchange passageways and the selection of appropriate acoustic excitation source that will induce pressure waves at frequencies conducive to enhanced heat transfer.

During the first part of the project, the research group established valuable connections with the local and the international heat exchanger industry to further secure their support and interest. In this light, the team contacted over 10 companies, including:

- Kanthal
- Lordan
- Sondex
- Swep
- Tranter
- Thermacore
- Gold-Bar Engineering
- TAT Technologies
- Krashin-Shalev
- GF Engineering
- Yaad Thermal Innovations
- Oran Heating
- Feltec Cooling
- Berlin Technologies
- Techenergy

In following, considering both the Israeli and the global markets, the gasketed plate type heat exchanger was selected to be most suitable in the scope of the study. The decision was supported by the following reasons:

- Due to the extreme flexibility of plate size, corrugation patterns and cooling passage arrangements, the heat transfer surface area can be readily changed or rearranged for different tasks and anticipated changes in operating loads.
- The flow inside the heat exchanger features detaching and reattaching of boundary layers, swirl and vortex flow generation. These patterns yield high turbulence levels that allow to achieve higher heat transfer coefficients.
- The surface area required for a plate type heat exchanger is typically one-half to two-thirds smaller than that of a shell-and-tube heat exchanger for the same heat duty. Thus, overall cost, volume and space requirements are reduced. Furthermore, the gross weight of a plate heat exchanger is about one sixth from that of an equivalent shell-and-tube heat exchanger.
- Leakage from one fluid volume to the other cannot take place unless a hole develops on one of the plates.
- The flow-induced vibrations, noise, thermal stresses and entry impingement problems of shell-and-tube heat exchangers do not exist in plate type heat exchangers.
- The units can be easily taken apart into their individual components for cleaning, inspection and maintenance.
- The plate type heat exchangers represent the largest share of the global compact heat exchangers market and thus, any potential improvement can be of significant interest for the Israeli industry.

After identifying the most suitable application, we have obtained several typical heat exchanger plate samples, Figure 2a. The samples are currently subjected to a thorough study by:

- Advanced testing under fully representative conditions in our existing wind tunnel facility
- Conversion into exact CAD model, Figure 2b, and subsequent acoustic simulations using COMSOL Multiphysics software.

In parallel, a dedicated heat exchanger test facility is being designed for demonstration in relevant aero-thermal environments. The facility schematic is presented in Figure 3. The facility will include an industrial in-line heater to create hot flow conditions, two mass flow controllers for the cold and the hot flow paths, honeycomb flow straighteners, inlet / outlet temperature and pressure sensors and data acquisition system. The test rig components are to be integrated during the upcoming stages of the project.

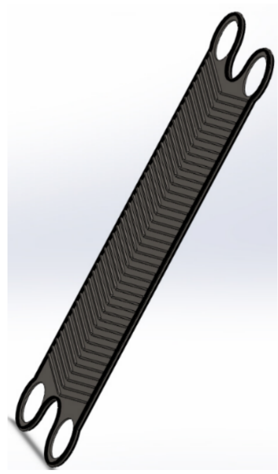

Figure 2 - a) Heat Exchanger Plate Samples, b) Heat Exchanger Plate CAD Model

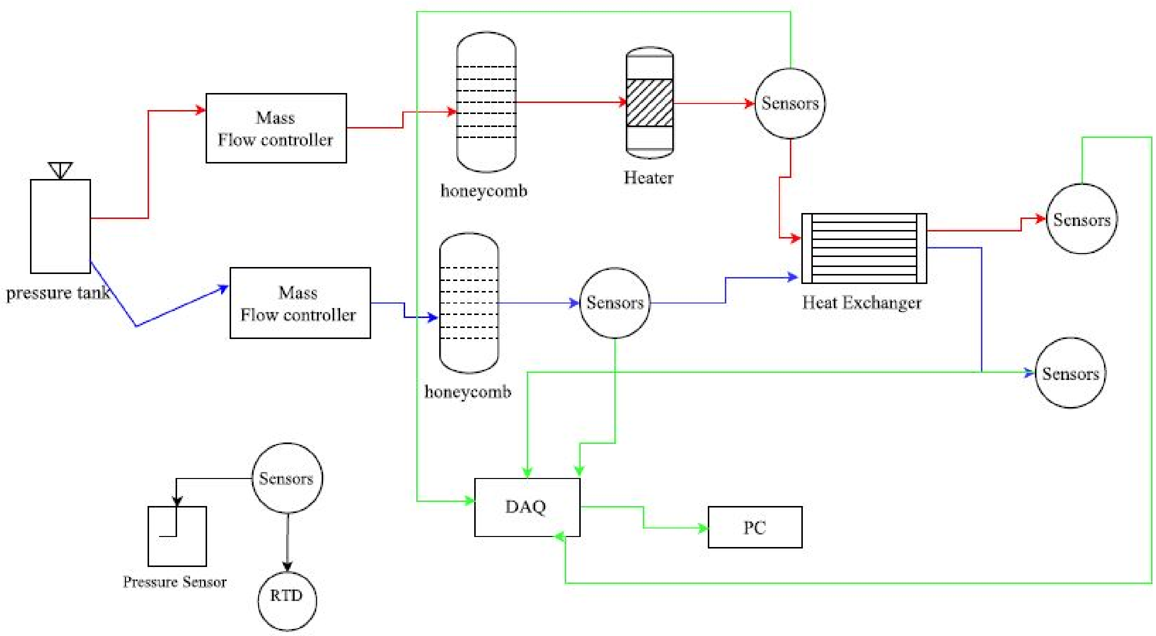

Figure 3 - Heat Exchanger Test Facility Schematic