Heat transfer in high subsonic velocity environments behind the fan of a gas turbine.

Abstract:

Main objective of this thesis is to propose a methodology to investigate the heat transfer processes occurring between an extended surface and a relatively cold flow characterized by Reynolds numbers typically encountered in turbomachines for aircraft propulsion.

The methodology aims reducing the difficulties linked to the high speeds involved and to the measurement capability in complicated configuration.

To achieve this goal a method to predict surface temperature at high subsonic speed from low subsonic speed experiments is considered. The proposed approach exploits the similarity analogy to reproduce conditions similar to aircraft engine reference cases.

The methodology allows the determination of the local heat convection coefficient proposing a solution for the Inverse Heat Conduction Problem. The so computed heat convection coefficient is then exploited, coupled with the experimental analysis of the flow field surrounding the heat conducting body, to predict the surface temperature at high speed.

The thermal part of the experimental analysis consists therefore in surface temperature measurements. Indeed the boundary condition to be imposed to solve the IHCP problem is the surface temperature of the heat conducting body and is obtained by means of Quantitative Infra-red Thermography measurements.

The "ill-posed" nature of the IHCP translates into a high sensibility to measurement errors, possibly leading to non-unique solutions. To reduce this sensibility a regularization procedure based on a ridge regression is implemented.

The proposed IHCP solving methodology is first tested numerically and, subsequently, experimentally on a heated flat plate in a low subsonic speed wind tunnel. The actual heat exchanger is reproduced by means of a central fin, made of high thermal conductivity material and acting as heating resistance. The prototype symmetry is exploited in order to simplify its testing model.

Near-wall and free flow boundary conditions are imposed using different experimental techniques like Constant Temperature Anemometry and Particle Image Velocimetry. The CTA technique is the most used for both high and low speed test cases. The measurements are performed by means of hot-wire and hot-film probes and to increase the measures capability a rake specifically designed for a wide range of velocities is conceived, manufactured and tested.

The proposed regularization procedure applied to the experimental analysis is shown to enhance the accuracy of the results obtained by solving the IHCP.

The design of the experimental models, which aims to reduce complexity, allows to easily obtain information on the coefficient of convective heat exchange also for the case of a single fin heat exchanger.
The proposed methodology is proven to allow accurate prediction, within the IR camera accuracy, of the heat conducting bodies surface temperature submerged in high subsonic speed flows by means of low subsonic speed analysis.

Keywords: Heat Exchange, Inverse Heat Conduction Problem, Quantitative Infrared Thermography, Constant Temperature Anemometry, Similarity Analogy