Intrusive Probe Measurement in Turbomachinery

Labreport

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Abstract

In this experiment the flow of a one-stage turbomachine is examined. As a measuring tool a five-pinhole-probe is introduced to analyze the pressure and velocity of the flow in different positions behind the stator. All data is stored in LabView, the program that controls the entire measurement process. Finally the information obtained is post processed and visualized in Matlab.

The flow after the stator is higly unsteady. Even though the measured steady data is expressive. By averaging over the massflow some unsteady influences were removed. The effect of the boundary layer around the blade was visible on most of the plots and also the radial pressure difference due to the rotating fluid.

The performed experiment shows clearly that with this setup it is possible to improve the efficiency of blades by analyzing the pressure and velocity distribution.

Introduction

Turbomachines are devices that transfer energy either to or from a continuously fluid by dynamic action of moving blades. While a turbine transfers energy from a fluid to a rotor, a compressor transfers energy from a rotor to a fluid. Due to a change of pressure and velocity provoked by rotating blades the enthalpy of the fluid changes, which implies a positive or negative amount of work. In a fan (W<0) the fluid pressure is increased and therefore work is needed. In contrary turbines are expanding the fluid (delta p<0) and result in a power-producing machine. Turbomachines are widely used and of extraordinary importance for most energy conversion processes.

Experimental Setup

In the experiment performed at ETH Oct. 11th, 2012 an axial fan LTG is used, powered by a 7kW electrical engine providing up to 5000 rpm. The experimental setup consists of a 3m long inlet tunnel and a diffuser behind the probe device. The actual fan comprises a rotor (upstream) and a stator behind. The probe is located downstream of the stator and can be moved in radial, circumferential (THETA) and yaw (GAMMA) direction. The cobra shaped five-hole probe (2mm diameter per hole) measures the individual pressures of the holes. With this data yaw angle, pitch angle, total pressure, static pressure and Mach number are computed. Now absolute velocity and its components can be derived.

Method of attack

After turning on the engine the fan is set to approximately 5000 rpm, which results in a mean velocity of 20.66 m/s in the test section. A LabView program controls the pressure measurements. The actuator moves automatically in radial direction. The distance between two measuring points is 5.5mm. After measuring the individual pressure of each hole at one circumferential angle (THETA) the probe needs to be moved manually to the next angle where the measurement starts all over again. The evaluated range is 22.5◦ with a step size of approximately 1.125◦. The data has been saved in a text file and is analyzed in MATLAB. Finally velocity components can be derived from the definition of mach number and geometrical concepts.

(4.11-4.14)

Results

Conclusion

This experiment illustrates the general structure of a flow inside of a turbomachine. Furthermore it elaborates how to compute various angles, pressures and velocity components from a single five-hole measurement. The importance of the flows shape to improve the blades is obvious. Even though the flow is highly unsteady this measurement method provides expressive results without having as much data as in an unsteady technique.