Measuring Techniques for Transonic and Supersonic Flow in Cascades and Turbomachines

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HETERODYNE LASER INTERFEROMETRY FOR CASCADE FLOW INVESTIGATIONS

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ABSTRACT

Currently, in two ongoing projects funded by the Austrian Science Foundation experiments are performed in the institute's transonic cascade. For these experimental tests different laser techniques - Laser Doppler Anemometry, Holographic Interferometry and Differential Interferometry - have been used together with various kinds of standard diagnostic techniques (For flow investigations the Institute for Thermal Turbomachinery and Machine Dynamics is equipped with a 3MW compressor station located in the two basements of the institute). Here we present our results obtained with digitally evaluated interferometric techniques. Whereas holographic interferometry was used for subsonic flow diagnostics, differential interferometry provided quantitative data on density gradients in transonic flows.

1.Introduction:

From 1994 to 1999 six institutes from the two Austrian Technical Universities Graz and Vienna participate in the Research Program S68 "Thermal Energy Production-Efficiency Improvement and Emission Reduction of Thermal Power Plants" led by H.Jericha. This Research Program tackles the problem of efficiency improvement on several fronts. Some of the projects deal with materials for high temperature steam plants, gas turbines for particle loaded gases, efficiency improvement by cycle optimisation and flow optimisation in turbomachinery. Many of the results obtained during the first two years have been published at ASME Cogen Turbo Conference 1995 in Vienna.

For the enhancement of the accuracy of computational fluid dynamics methods, the projects are supported by data acquisition in a transonic test rig at the institute and will be supported by data from a continuously operating test turbine currently under construction. For this purpose the laboratory at the Institute for Thermal Turbomachinery and Machine Dynamics is equipped with a 3MW compressor station located in the two basement of the institute. This compressor station consists of one screw and two turbo compressors and can operate in 13 different configurations with pressure ratios between 3 up to 10 and mass flows from 2.5 up to 15 kg/s [1]. One of the test rigs currently used for the research program is the transonic cascade - a linear arrangement of seven blades (each with a height of 10cm) with a window section on both sides to enable the use of non-intrusive optical methods. Among those are colour Schlieren visualisation, Laser-Doppler-Velocimetry for velocity measurements along grid coordinates provided by the numerical flow calculations and interferometric methods. Since large amounts of numerical data are needed for numerical code improvement there is a need for a digital evaluation of interferograms to obtain density information from subsonic or transonic flows. This is of special importance since in turbulent flows interferograms recorded with a pulsed laser system give only momentary density information, but density maps of flow fields should represent mean values. Different techniques for fringe evaluation had been developed since more than 10 years by several authors [2,3,4,5,6,7]. In the following we will present and discuss techniques for heterodyne holographic and heterodyne differential interferometry we use in our test rigs.

2. Holographic Interferometry
Temporal Heterodyning (Phase Stepping)

Fig. 1 shows a typical holographic interferogram of a transonic flows through our linear blade cascade recorded with a pulsed ruby laser (LUMONICS HLS2). The optical setup was mounted on a table equipped with vibration insulation and was shielded with a cover against the acoustic noise from the continuously operated test rig. Since the interferogram was recorded with and without flow the interference lines represent isolines of flow density. The interferogram was digitised using a Hitachi KP-110 CCD camera and a PC Vision Plus frame grabber

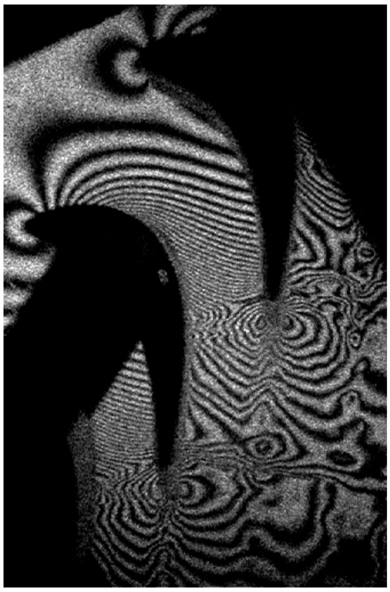

Fig.1 pulsed holographic interferogram of transonic flow at isentropic exit Mach number M= 1. The blade chord length was 58 mm.