Experimental investigation of supersonic inflow of a compressor cascade by the laser-2-focus-method

by
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1. INTRODUCTION

The experimental determination of the inlet values of supersonic cascades is very problematic and the technical solution is unsatisfactory, till now.

In most cases, semi-empirical methods [1] are used leading very often to inaccurate values, especially in the region of transonic inlet velocities. (The reasons are well-known: Blockage effects by probes, which disturb the whole flow field).

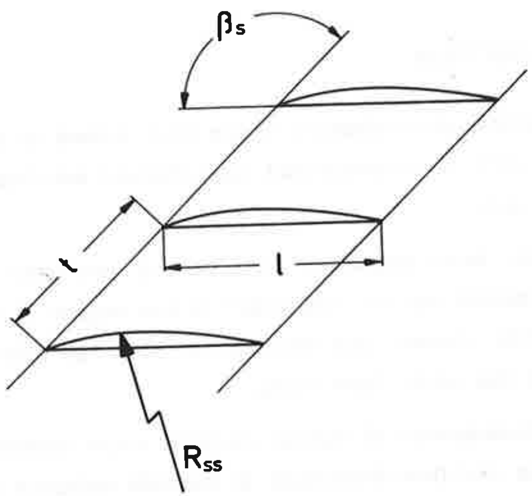
The recent development of optical methods allow measurements of flow velocities and flow directions in cascade entrance planes. After evaluating these measured distributions one gets the inlet flow conditions far upstream.

In this paper a description of measurements is given, which have been performed with the laser-2-focus method (L2F) [2] in a transonic inlet flow field of a compressor cascade.

2. TEST SET - UP

The present investigation of the transonic inflow of a compressor cascade has been done in the supersonic cascade wind tunnel of the DFVLR in Köln-Porz [3] .

This cascade consists of blades with flat pressure surfaces, constant cambered suction surfaces, sharp leading and trailing edges. The cascade geometry is shown in Fig. 1.



chord	:	$l = 76.2$ mm
space/chord ratio	:	$t/l = 0.7$
suction side radius/chord ratio	:	$R_{ss}/l = 2.525$
stagger angle	:	$\beta_s = 152°$

Figure 1 Cascade geometry

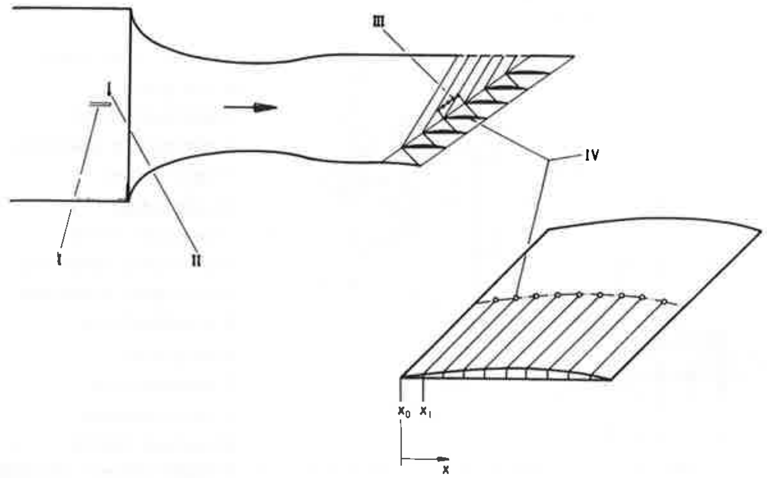


Fig. 2 Location of the measuring planes

In Fig. 2 the locations of the measuring planes are presented:

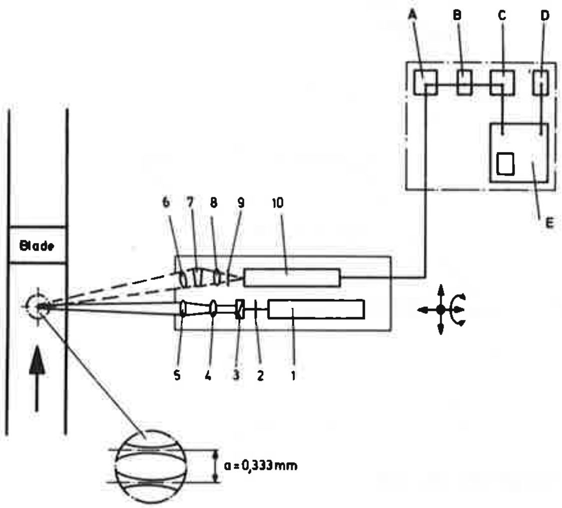
I. Total pressure p_{1tot}, measured in the settling chamber.

II. Total temperature T_{1tot}, measured in the settling chamber.

III. Wall static pressure distribution p_1, located = 0.5 spacing axially upstream of the cascade front.

IV. Blade static pressure distribution p_s on the suction surface at midspan.

Besides this conventional inlet flow measuring method the L2F-method was used. The schematic drawing of this set-up is shown in Fig. 3. The laser, the photomultiplier and all the other optical parts are fixed in a box. This unit is mounted such, that the measuring volume can be rotated and moved in 3 directions.



1 He-Ne-Laser (5 mW)
2 λ/4-plate
3 Wollaston prism
4 microscope objectives
5 lens system
6 lens system
7 deviation prism
8 microskope objectives
9 two-holes diaphram
10 photomultiplier
A amplifier
B discriminator
C time-analyzer
D nuclear counter
E multi-channel-analyzer

Fig. 3 Schematic drawing of the L2F system

3. TEST PERFORMANCE

The principle shock configuration of the inflow is presented in Fig. 4: It is a typical unstarted flow case with detached shock waves.

The periodicity of the cascade flow was controled by the wall static pressure distributions in the cascade inlet and outlet planes. The location of the shock waves was observed by shadowgraphs.

The velocities and directions were measured in two planes, A and B (Fig. 4), at mid span. The tests have been performed at different inlet Mach numbers.

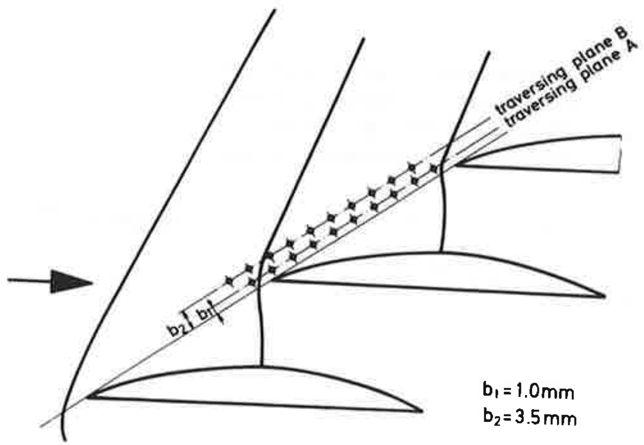


Fig. 4 Principle shock location and traversing planes

4. TEST EVALUATION

The measured distribution have been recalculated by the conservation laws (two-dimensional momentum method [4]). By this procedure one gets the inlet flow conditions far upstream of the cascade front. Besides this a conventional method was used to get the inflow values by wall static and suction surface pressure distribution [1,4].

5. TEST RESULTS

In Fig. 5 the inlet flow angle β_{∞} is plotted against the inlet Mach number M_{∞}. The dash-dotted curve is derived by the theoretical "unique incidence" method [5] for this cascade configuration. The other curve is the theoretical two-dimensional momentum solution [4], which includes entropy gradients in the inlet flow field.

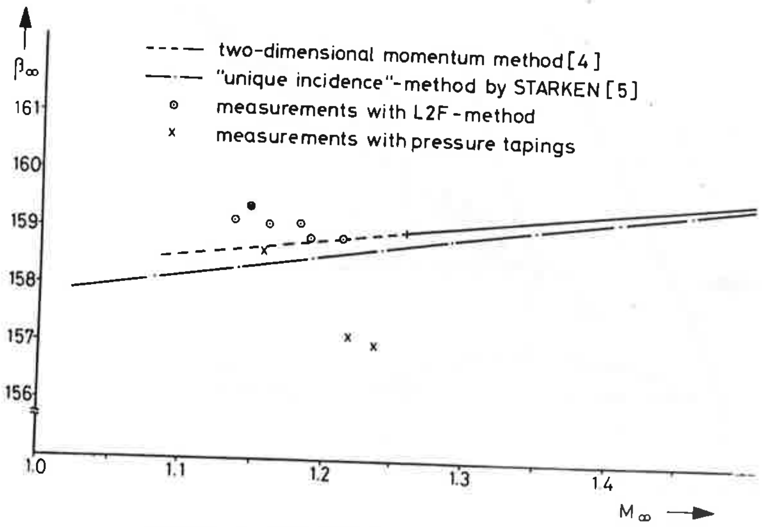


Fig. 5 Test results and comparison with theoretical methods

The circular symbols represent the test results obtained by the L2F method and the cross symbols show the results evaluated by the conventional method.

In the transonic flow cases the theoretical curves are boundaries for minimum flow angles. All these unstarted cases lead to reduced mass flow, that means increasing flow angles (circular symbols).

Figures 6 and 7 show the results obtained in the measuring plane A (Fig. 4) for $M_\infty = 1.15$ and $\beta_\infty = 159.3^o$.

The Mach number and flow angle distribution is plotted against the coordinate η in the plane A.

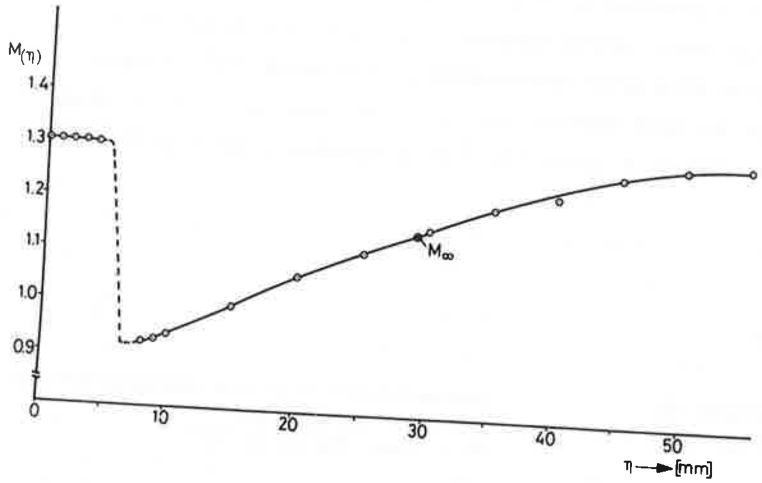


Fig. 6 Mach number distribution in the measurement plane A (Fig. 4)

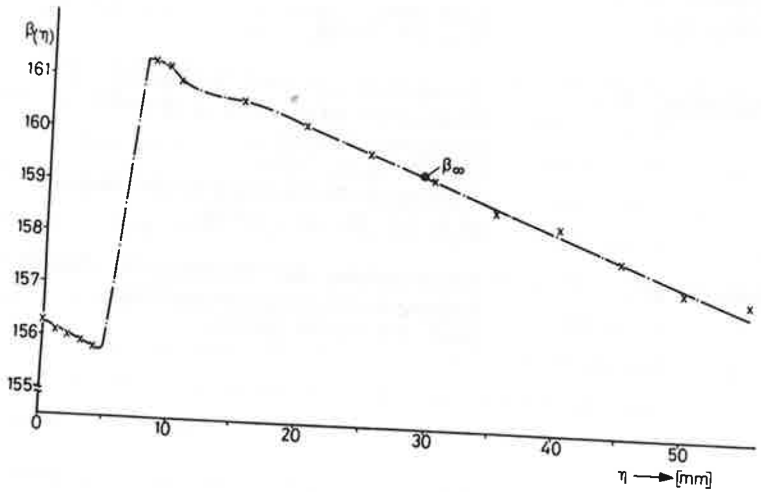


Fig. 7 Flow angle distribution in the measurement plane A (Fig. 4)

6. CONCLUSIONS

Nowadays, it is possible to make cascade tests at transonic Mach number range using optical methods. Till now, the accuracy of transonic inlet flow angle measurements was about $\pm 2^{o}$ or much worse. With the L2F system, we used, one can resolve 0.2^{o}, that means an accuracy of about $\pm 0.1^{o}$ (low turbulence level in the inflow).

References

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[5] Starken, H.: Untersuchung der Strömung in ebenen Ueberschallverzögerungsgittern. DLR-FB 71-99 (1971).

Unsteady flow measurements in straight cascades

by

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1. INTRODUCTION

The cascade tunnel as experimental check for theoretical blade calculation schemes on one side and blade performance data producing instrument on the other side plays still an important role in the turbomachinery world. Contrary to the flow in rotating machinery, the cascade flow is looked at as being basically 2-dimensional and steady. However, contrary to the "two-dimensionality" which has often been the subject of long discussions, the "steadiness" of the flow has hardly been put into question until recently. Nowadays, however, it is recognised that two basically different kinds of instable flow phenomena occur in cascade tunnels: the first one is linked to the cascade tunnel itself, the second one to the blade wake flow.

2. UNSTEADY FLOW PHENOMENA IN CASCADE TUNNELS

Everybody who has had the occasion to watch the transonic or supersonic outlet flow behind a turbine cascade with a continuous schlieren optical system, has probably noticed that the shocks appear rarely as sharp defined density gradients but look in general rather blurred indicating a light oscillating motion of the shock system. High speed movies taken at VKI and the AVA-Göttingen have shown that these instabilities can be much more dramatic as one might expect from simple schlieren observation. The shock oscillations are in fact associated with drastic changes of the wake flow direction. The flow variations reach their maximum in the transonic range.

The reason for the above described instabilities can be found by comparing the two schlieren pictures in Fig. 1 which shows the supersonic flow field of a transonic turbine cascade. Both photographs are taken at