Computerized Balancing of a Wedge Shaped Probe

O. Johanßen
Universität der Bundeswehr Hamburg, Germany

1.Introduction

The wedge shaped probe is a useful instrument in order to measure total pressure and static pressure in the flow as well as fluid velocity regarding amount and direction. Therefore it is well fitted for measurements in the downflow of cascades. By these measurements the profile losses can be computed. By means of the laser L2F – measure equipment, which is installed at our labaratory, measuring nondisturbing is possible. However, in contrast to measuring with the wedge shaped probe there is no pressure information available, only the velocity vector is measured. So it seems to be worthwhile, optimizing measuring practice with the wedge shaped probe.
In this report it is to be shown, how the balanced position of a wedge shaped probe can be found very quickly by computation in contrast to experimentation.
First the principle of measuring with a wedge shaped probe is to be illustrated, then the modelling, which yields the formula to compute is presented and finally some comparison between measurement and computation is shown.

2. Principle of measuring

Figure 1 shows the construction of the wedge shaped probe. There are three pressure bore holes. The middle one gets the total pressure, the holes on the left and right side are static pressure holes. The probe is balanced, if the pressure difference on the static bore holes comes to zero. Then the pressures given by the right and left bore hole are the same and approximatly equal to the static pressure in the flow. In this case the probe faces fluid direction, the total pressure is given by the top hole.

In order to find the balanced position the probe is turned by a step motor. As trial and error is not a satisfying procedure an algorithm has been developed between the turned position of the probe in relation to the balanced and the measurable pressure difference of the static bore holes.

3. Modelling

In figure 2 the model is shown, which the algorithm is based on. γ means the wedge angle of the probe, β is the turning angle of the probe referring to the balanced position.
Regarded is a two – dimensional flow w. It is preconditioned, that the flowfield is isentropic and homogenius. p and p_t represent static and total pressure.
The basic idea of the model is, that the pressure measured on the sidewise boreholes is not only of static nature, but is also built by a dynamic part. Therefore the flowvector is splitted into a component w_t tangential to the probe flank and a component w_v rectangular to w_t. If there was only the tangential part of the velocity, starting with the total temperature conservation of energy leads to the ficticiuos static temperature

$$T_s = T_t - \frac{w_t^2}{2c_p} \qquad (1)$$

and additionally by banking up of the part w_v at the bore hole a temperature called
T_{ts} is given

$$T_{ts} = T_t - \frac{w_t^2}{2c_p} + \frac{w_v^2}{2c_p} \quad . \qquad (2).$$

According to figure 2 the velocity components are given by

$$w_t = w \cdot \cos(\gamma/2 \pm \beta) \qquad (3)$$

$$w_v = w \cdot \sin(\gamma/2 \pm \beta) \qquad (4).$$

The minus sign is valid for the left side of the probe. The temperature ratio T_{ts}/T_t can be computed by the isentropic relation into a pressure ratio. So the pressure ratio can be expressed by

$$\left[\frac{p_{ts}}{p_t}\right]_{r,l} = \left\{1 + \frac{w^2}{2T_t\, c_p}\left[\sin^2(\gamma/2 \pm \beta) - \right.\right.$$
$$\left.\left. - \cos^2(\gamma/2 \pm \beta)\right]\right\}^{\frac{\kappa}{\kappa-1}} \qquad (5),$$

yielding the pressure difference between right and left flank by

$$\Delta p = p_{tsr} - p_{tsl} \qquad (6).$$

The enthalpy — entropy — diagram, figure 3, shows the corresponding energy levels. The static pressure level p_s is located between the total pressure p_t and the static pressure p of the undisturbed flow. With the velocity component w_v banked up at the bore hole p_s amounts to the actual pressure p_{ts}.

4. Comparison with measurement

Figure 4 shows the relationship between difference pressure and turning angle of the probe referring to the balanced position. Measurements have been taken for machnumbers reaching from .597 to .967, symboled by dots. The values computed by the described formula are connected by solid lines. The graphs show, that for small angles the computed values well coincedences with the measurements, even up to the higher machnumbers. The curves gradient increases with machnumber, as it is expected. The variations of the measured difference pressure along the computed curves might be caused by probe fluttering. For a cascade a first estimation of the outlet angle can be done with the sine rule. After the probe is orientated in this direction, the necessary turning angle for the balanced position lies in the range of a few degrees, for that the computation fits well.
For the measurements presented the probe has been turned according to the computed value in order to check the balance and to get the static and total pressure. The exact static pressure then was found by the measured one using a calibration between the static pressure aberration and machnumber.

Literature

Strömungsmechanisches Verhalten einer Keilsonde
Dreesch,H.
Institut für Strömungsmaschinen, Universität der Bundeswehr Hamburg, 1992

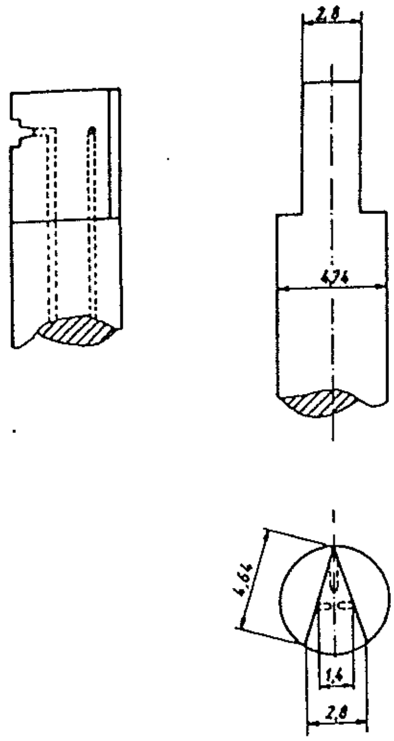

Fig.1: Wedge shaped probe

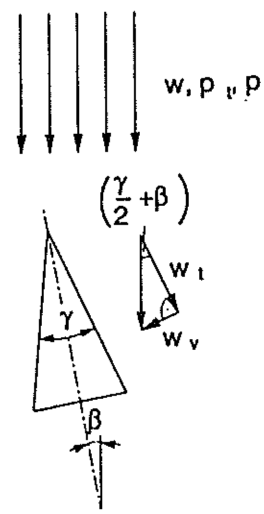

Fig.2: Mathematical Model

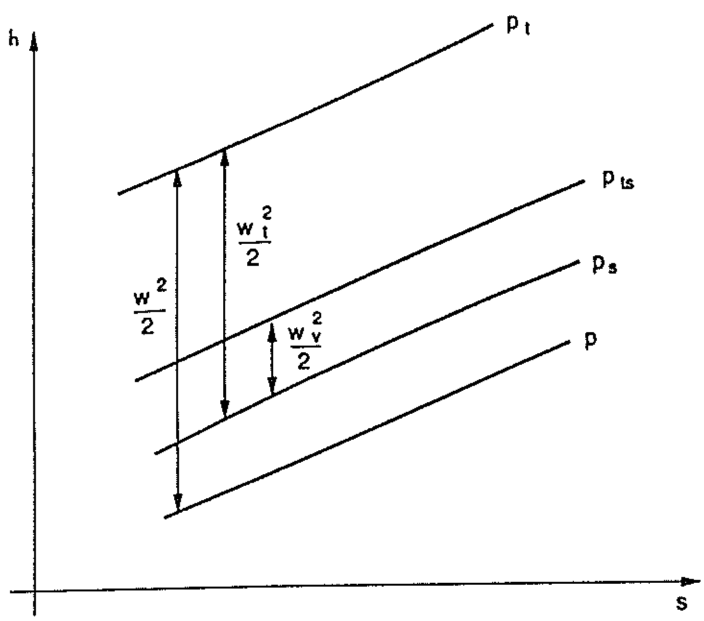

Fig.3: Energylevels in the h--s--diagram

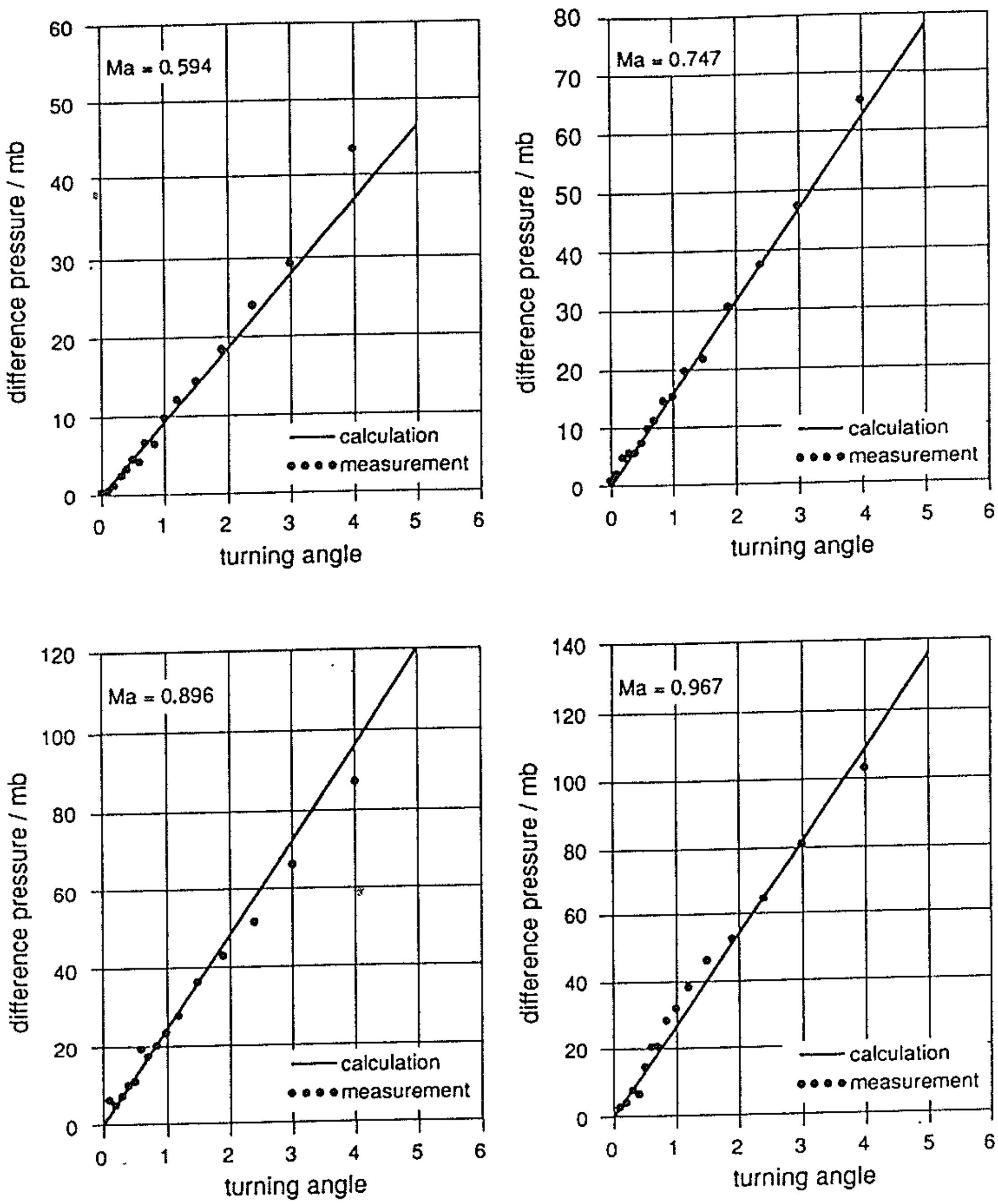

Fig.4: Comparison between measurement and computation