

ESTIMATION OF THE DOWNSTREAM FLOW OF VALVES

J.Prost, K.Käfer

Institute for Waterpower and Pumps
Vienna University of Technology
1040 Wien, Austria

Abstract: At the Institute for Waterpower and Pumps we use hot wire anemometry to investigate the downstream flow of valves in an air channel. The velocity distribution is determined point-by-point. Due to our experience and corresponding to the developments in data acquisition our measuring system has been adapted continually. Today the calibration of the probes, the velocity measurement and the data analysis is done computer aided. The paper reports on our system and the software developed by ourselves. The practical application of the system is demonstrated on the investigation of the downstream of a slide plate gate valve.

Keywords: flow measurement ,hot wire anemometry, slide plate gate valve

1 INTRODUCTION

Although laser-using systems are more and more used in flow measurement there are a lot of applications where the hot wire anemometry is still favorable. It is a low-priced, widely accepted tool for fluid dynamic investigations in gases and liquids and has been used as such for more than 50 years.

At the Institute for Waterpower and Pumps we use this system to investigate the downstream flow of valves in an air channel. Testing valves in an air channel it is not possible to analyze several phenomena of liquid flow passing valves (e.g. cavitation). The measuring conditions however are much more easier.

Our first investigations using this system started more than 15 years ago (e.g. [1] and [2]). The main components of the measuring equipment date from this time and are still in use. The acquisition and evaluation of the data however has remarkable changed. The use of an A/D-converter makes possible the handling of the analogue output of the CTA-bridge by a PC. So the calibration of the probes, the velocity measurement and the data analysis is done computer aided. The current state of the system will be presented.

2 TEST ARRANGEMENT

The valve to be tested is installed between two Plexiglas-pipes of 150 mm diameter. On the downstream pipe a self-developed holding and positioning device is mounted, see figure 1. The special feature of the system is that only a small aperture in the pipe - just enough to insert the probe support -

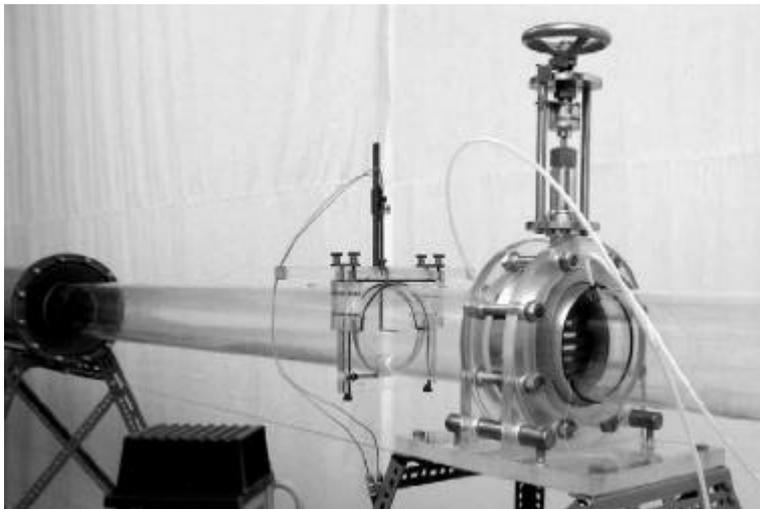


Figure 1. Air channel with valve to be tested and positioning device

is required. Turning the pipe and adjusting the positioning device makes it possible to position the probe at any point of the measuring section. The velocity distribution is determined point-by-point corresponding to a pre-defined grid.

The CTA-system at our laboratory is a two-channel system and makes it possible to use X-probes. Thus we are able to measure the local velocity and the vertical flow angle. This is sufficient as the downstream flow usually is symmetric in the horizontal plane.

3 DATA

ACQUISITION AND ANALYSIS

Due to our experience and corresponding to the developments in data acquisition our measuring system has been adapted continually. Today the calibration of the probes, the velocity measurement and the data analysis is done computer aided. The software required has been developed by ourselves and thus is highly adapted to our special needs. Prerequisite for the system was the use of standard PC's and standard software tools. The PC used for data acquisition is equipped with a 12 bit A/D converter. The programs for the calibration of the probes and the velocity measurement are based on the system TestPoint®.

3.1 Calibration of the probes

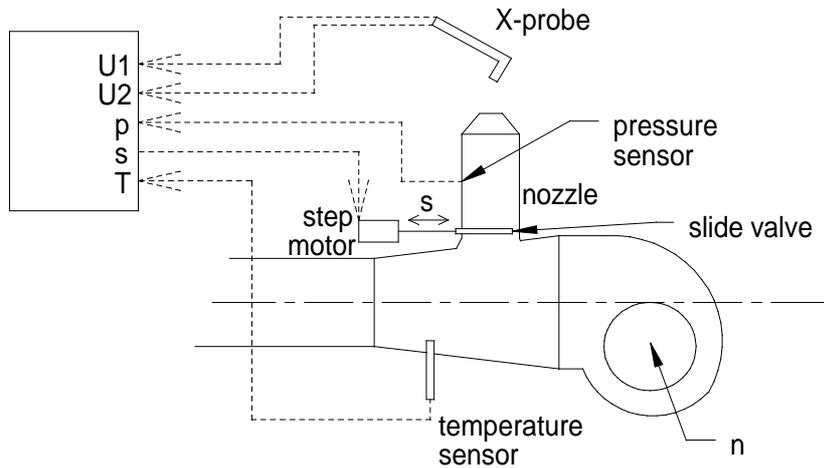


Figure 2. System for the calibration of X-probes

The calibration unit for the X-probes is coupled with the test rig. The nozzle is situated directly behind the speed regulated fan, figure 2. Adjusting the position of the slide valve and the speed of the fan the bypass flow can be regulated. The calibration is done as follows:

Starting the calibration program on the PC the following initial values have to be fixed:

- the velocity range for the probe, represented by the minimum velocity v_{min} and the maximum velocity v_{max} for the calibration procedure
- the lift of the slide valve between two measurements, represented by the number of steps of the step motor (different values for opening s_o and closing s_c)
- the length of time for the measurement of the voltages t_m
- the nozzle factor f_n

When the calibration procedure of the program is started the slide valve is closed until v_{min} is reached. The velocity is calculated using the pressure p in the nozzle (measured value), the nozzle factor f_n and the density ρ of the air. The density of the air is calculated from the temperature T (measured value). The angle α at which the probe is fixed on the calibration unit is entered as a numerical value.

The real calibration of the probe is done during the opening of the slide valve. After the slide valve

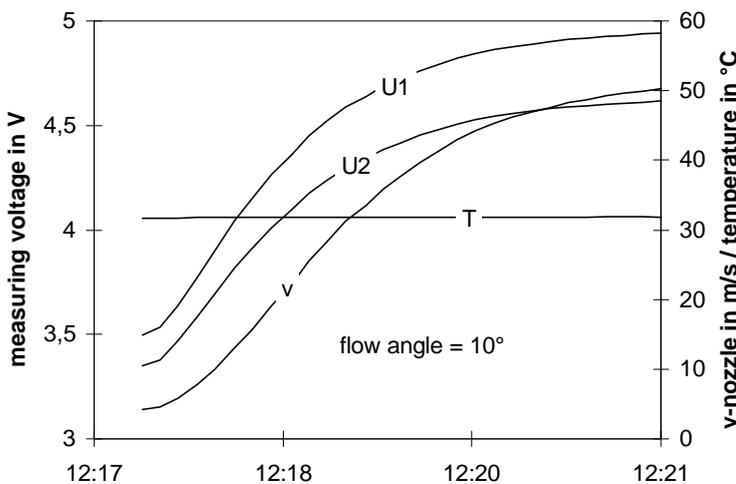


Figure 3. Gradients of U1, U2, v and T during the calibration

has moved the preset lift s_o it is stopped. Then the voltages of the two CTA-bridges for the two wires of the probe are recorded over the period t_m and the mean values of each channel are calculated. The two voltages U1 and U2 are stored in an array together with the corresponding velocity. For a later documentation all measured values (p , T , U1, U2) and the calculated values (density ρ and velocity v) as well as time of measurement and flow angle α are stored in a file. Then the slide valves is moved again and the voltages for the next velocity are recorded, figure 3. This procedure is repeated until

the maximum velocity v_{max} is reached. Then the closing movement of the slide valve follows until v_{min} is

reached. The actual velocity respectively the pressure in the nozzle is controlled after each lift s_c of the slide valve.

For the actual flow angle now the relationship between voltage of each wire of the probe and velocity is calculated out of the recorded data. This is done by least error squares approximation using polynomials as well of second and fourth degree. After a positive valuation the polynomials are stored in files and the calibration is repeated with a new angle α for the probe. The polynomials are stored again.

After finishing the calibration procedure with a adequate number of flow angles we get two calibration files for the probe, one with polynomials of second degree, one with a polynomials of fourth degree. The user later may chose which will fits better. Figure 4 shows some of the polynomials of fourth degree obtained for one probe.

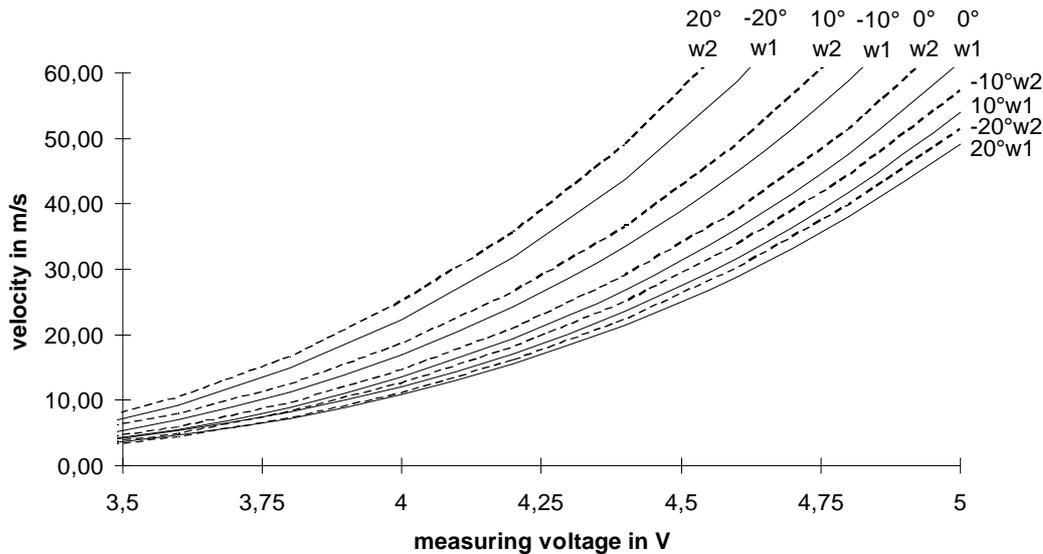


Figure 4. Velocity in dependence of the measuring voltage for a probe

3.2 Measurement of the velocities at the test rig

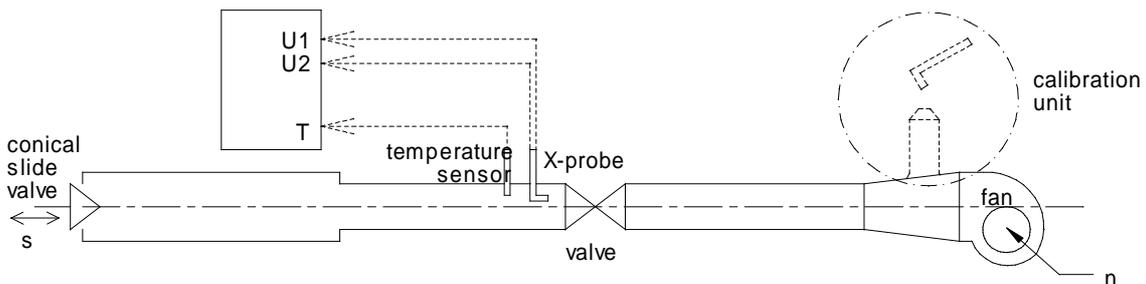


Figure 5. Schematic drawing of the test rig

Figure 5 shows a schematic drawing of the air channel. As mentioned above the valve to be tested is installed between two Plexiglas-pipes. There are two possibilities to vary the flow conditions for the valve: by changing the speed of the fan or the position of the conical slide valve. As those adjustments only have to be changed once ore twice during a test program they are done manual. The adjustment of the position of the X-probe has to be done manual too.

For the estimation of the local velocity the voltages for the two channels of the X-probe have to be measured. So these two values are transferred from the CTA-bridges via A/D-converter to the measuring software. In addition the temperature of the air in the system is recorded. Starting the measuring software the calibration file for the X-probe has to be opened. So the velocity and the flow angle for one point can be calculated and displayed immediately after the measurement. The final values again are mean values of the measurement which is done for a adjustable length of time. The variation of the measuring signals in time can be plotted in a window for verification.

After a positive valuation of the data and a manual input of the position of the probe the values are stored in a measuring file. Previous data are listed in a window of the measuring software and assist the valuation by the operator.

3.3 Data analysis

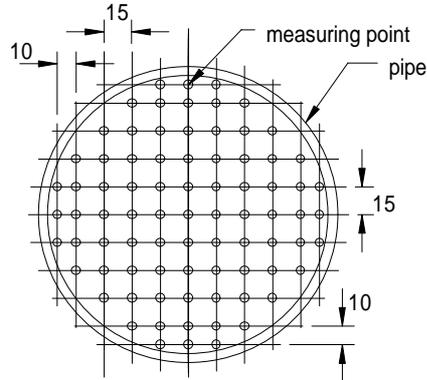


Figure 6. Arrangement of the measuring points in one measuring section

In principle the existing positioning device makes possible to determine the local velocity in every point of a measuring section. In practice an arrangement of the measuring points like that presented in figure 6 has proved to be sufficient for the analysis of the downstream flow. The measured values are stored in a text-file and thus can be imported in every standard software package for further analysis. Figure 7 shows the velocities obtained for the upper half of a measuring section using the arrangement of figure 6.

In some cases however a more graphic presentation of the results is wanted. Some features to do this are included in every standard software of good quality. The results however are not satisfactory as the algorithms for the calculation of the surface graphs do not fit well velocity profiles.

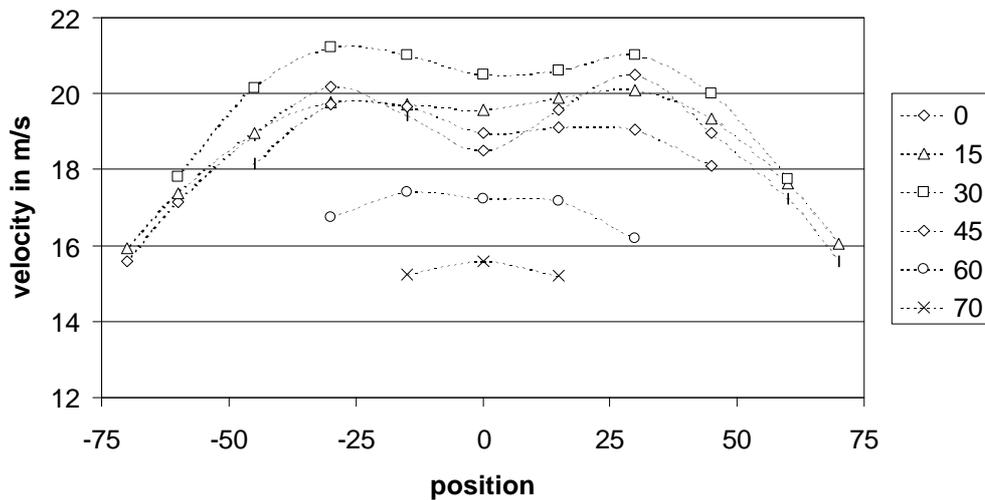


Figure 7. Velocities in horizontal planes (upper half of a measuring section)

In order to avoid this we create a very dense grid of velocities by calculating interstitial velocity points. For the calculation of these interstitial velocities we make use of the algorithm published by Spielbauer et al [3]. The algorithm has proved its worth calculating the flow in pipes or open channels out from current-meter-measurements. The velocity gradient between two measured values is calculated using cubic parabola. For the area next to the wall Prandtl's universal law for peripheral zones extended by a linear term is used. Condition of compatibility for two adjoining gradients is the same value and tangent of the function at a measuring point.

4 PRACTIAL APPLICATION

The practical application of the system is demonstrated on the investigation of the downstream of a slide plate gate valve. This type of valve has a plate with horizontal slits fixed in the casing. A second plate with slits of the same arrangement is moved vertical and thus increases respectively decreases the cross section for the flow, figure 8.

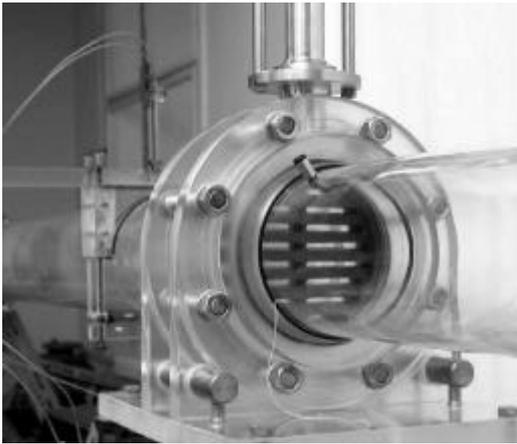


Figure 8. Slide plate gate valve at the test rig

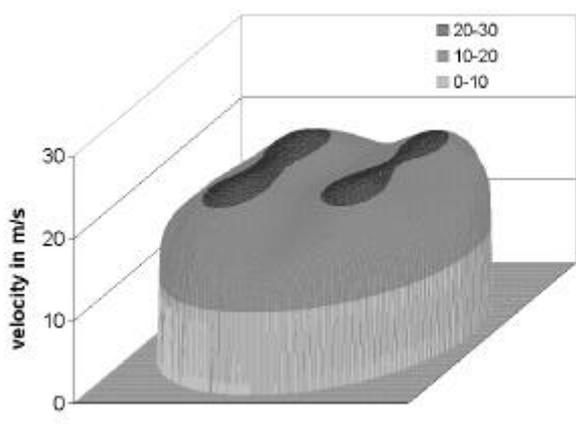


Figure 10. 3-dimensional plot of the velocity profile downstream a slide plate gate valve

The figures 9 and 10 demonstrate the results obtained for a measuring section downstream this valve. The arrangement of the measuring points corresponds to figure 6. Using the algorithm described above a velocity grid with an interspace of 1 mm is calculated. Using the standard graphic tools of Microsoft Excel the figures 9 and 10 are produced.

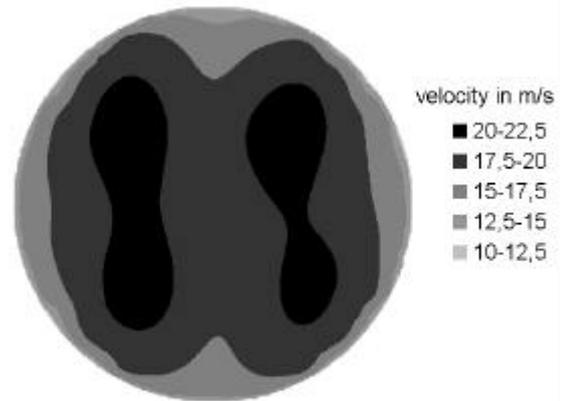


Figure 9 Contour plot of the velocity profile downstream a slide plate gate valve

REFERENCES

- [1] H.-B.Matthias, J.Prost, Strömungsverhältnisse hinter Drosselklappen, *3R international* **24** (1/2) (1985) 71-75.
- [2] H.-B.Matthias, J.Prost, in B.Velensek, M.Bajd (ed.), *Proceedings of the Conference on Hydraulic Machinery* (Ljubljana, 13-15. September 1988), Slovenia, 1988, p.135-143.
- [3] M.Spielbauer, W.Faiß O.Müller, Numerisches Integrationsverfahren zur Auswertung von Flügelmessungen, *Die Wasserwirtschaft* **11**, (1969) 313-320

AUTHOR(S): Ass.Prof.Dr.Josef PROST, Ass.Prof.Dr.Klaus KÄFER, Institute for Waterpower and Pumps, Vienna University of Technology, 1040 Wien, Austria,
Phone: +43 1 58801 30513, Fax: +43 1 58801 30599, e-mail: jprost@pop.tuwien.ac.at