Cascade Testing
Paper 3

WINPANDA - AN ENHANCED PC-BASED DATA ACQUISITION SYSTEM FOR WAKE AND PROFILE PRESSURE DISTRIBUTION MEASUREMENTS AT THE HIGH-SPEED CASCADE WIND TUNNEL

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ABSTRACT

At the High-Speed Cascade Wind Tunnel of the University of the Federal Armed Forces Munich PC-based measuring and controlling techniques have been established for the investigation of design concepts for bladings of axial turbomachines. For easy use and short training periods a graphical user and an online help system has been set up. The computer system is integrated into an existing network in order to achieve high data throughput and common use of the measurement results with different postprocessing tools. A three axis traversing system for the supported wedge probes and five hole probes, combined with thermo-resistors and different pressure measurement devices permit full automatic independent measuring capability. The calibration of the pressure transducers can be performed without any manual set-up. A monitoring system of the reference dimensions for the check of the steady state conditions of the wind tunnel is included. Automatic online-evaluation of the measured data is performed and graphically displayed in windows with automatic range and scale adjustment and stored in spreadsheet files. Offline evaluations with corrective parameters can be subsequently added. Many tests proved the realiability and accuracy of the system. Comparisons between the new and the former system show very good agreement.

NOMENCLATURE

<u>**Symbols:**</u>

c_p	[-]	static profile pressure coefficient
e_M/l	[-]	position of measurement plane
l	[m]	chord length
Ma	[-]	Mach number
p	[Pa]	static pressure
q	[Pa]	dynamic pressure
R	[J/(kgK)]	gas constant
Re	[-]	Reynolds number
S	[K]	Sutherland constant
t	[m]	pitch
T	[K]	temperature
u	[m]	circumferential coordinate
U	[V]	Voltage
w	[m/s]	flow velocity
x	[m]	axial coordinate
z	[m]	coordinate in spanwise direction
α	[°]	flow angle in spanwise direction
β	[°]	flow angle in circumferential direction
β_S	[°]	stagger angle
β_S	[kg/(msK$^{1/2}$)]	Sutherland constant, see gas dynamic equations
κ	[-]	isentropic exponent
ξ	[-]	total pressure loss
Ω	[-]	axial velocity density ratio
ρ	[kg/m^3]	density

<u>**Subscripts and Superscripts:**</u>

1	upstream condition
2	downstream condition
ax	<u>ax</u>ial
bez	reference (<u>Bez</u>ugs~)
Env	<u>Env</u>ironmental~
is	<u>is</u>entropic
k	related to the pressure tank of the wind tunnel (<u>K</u>ammer~)
krit	critical (<u>krit</u>isch)
m	<u>m</u>ean
ref	<u>ref</u>erence
t	<u>t</u>otal
th	<u>th</u>eoretical
u, U	within the wake traverse plane
Umg	barometric condition (<u>Umg</u>ebung~)
V	loss (<u>V</u>erlust~)

Vk	related to settling chamber (Vorkammer~)
x/l	local profile surface quantity

Abbreviations:

GPIB	General Purpose Interface Bus
GUI	Graphical User Interface
HGK	High-Speed Cascade Wind Tunnel (Hochgeschwindigkeits-Gitterwindkanal
MOD	Magneto-Optical Drive
MS	Microsoft
PANDA	Automatic wake and profile pressure distribution measurement program (Programm zur automatischen Nachlauf- und Druckverteilungsmessung inklusive Auswertung)
PC	Personal Computer
ROM	Read Only Memory
WINPANDA	Automatic wake and profile pressure distribution measurement Windows program (Windows-Programm zur automatischen Nachlauf- und Druckverteilungsmessung inklusive Auswertung)

INTRODUCTION

The enhancement of the overall effectiveness of modern gas turbines can be achieved through the improvement of the component efficiencies. An increase in the efficiency of turbo components requires detailed information about the aerodynamics. Besides the analytical investigation of the flow field and measurements in real engines one method of profile flow investigation is the measurement in cascade wind tunnels. Since the real flow in axial turbomachines is highly three-dimensional, compressible, viscous and unsteady some simplifications have to be performed to gather information on the different influence parameters. A very customary simplification is the plane cascade model, applied to cascade wind tunnels.

For the determination of the plane cascade aerodynamics several programs for the automatic measurement were developed at the institute. In case of the pneumatic measurements these are PANDA (*Wilfert et al*, 1990) and FELD (*Weiß*, 1991). The first one is intended for the wake and profile pressure distribution measurements. Due to the fact that this software was written in FORTRAN using old hardware components and operating systems some restrictions occurred. The number of supported wake traversing points and the maximum amount of attached static profile pressure tappings were limited. Also the integration of the hardware in modern postprocessing chains, i.e. computer network and supplementary devices, was not possible. State of the art user interfaces on the software side could not be implemented. Therefore a new system had to be developed for the automatic measurement and evaluation.

test section data:

- Mach number : $0.2 \leq Ma \leq 1.05$
- Reynolds number : $10^6 \leq Re/l \leq 1.5 \cdot 10^7$
- degree of turbulence : $0.3\% \leq Tu_1 \leq 6\%$
- upstream flow angle : $25° \leq \beta_1 \leq 155°$
- blade height : 300 mm

wind-tunnel data:

- a.c. electric motor : P = 1300 kW
- axial compressor (six stages):
  - air flow rate : $\dot{V} = 30\ m^3/s$ (max.)
  - total pressure ratio : $\Pi = 2.14$ (max.)
  - rotational speed : n = 6200 rpm (max.)
- tank pressure : $0.05\ bar \leq p_k \leq 1.2\ bar$

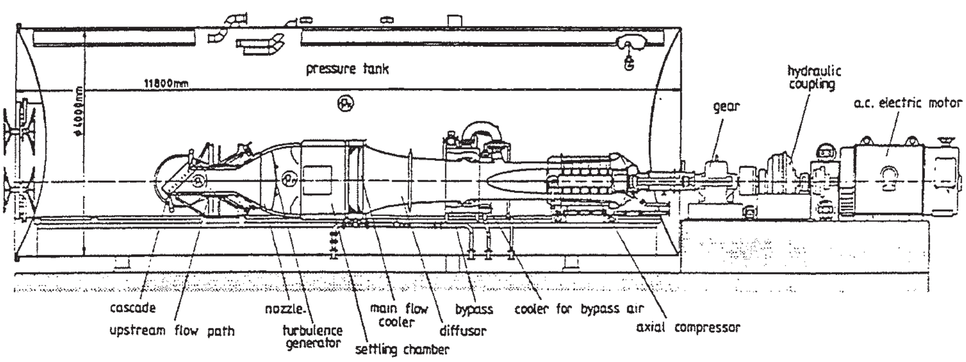

Fig. 1: The High-Speed Cascade Wind Tunnel

TEST FACILITY

For the detailed cascade measurements matching the real turbomachinery conditions the Mach number and Reynolds number analogy must be fulfilled. The High-Speed Cascade Wind Tunnel of the University of the Armed Forces Munich complies with these requirements. It allows the independent variation of the Mach number and Reynolds number in typical gas turbine ranges.

The wind tunnel is installed in a pressurised tank (Fig. 1). By the regulation of the static pressure in the tank, the outlet pressure of the air delivering compressor and the total temperature in the settling chamber the Mach number and the Reynolds number are defined. The Mach number is given by the equation

$$Ma = \left\{ \frac{2}{\kappa - 1} \cdot \left[\left(1 + \frac{q}{p}\right)^{\frac{\kappa - 1}{\kappa}} - 1 \right] \right\}^{\frac{1}{2}} \qquad (1).$$

The Reynolds number is a function of the static pressure, the total temperature, the chord length and several constants (see *Ammecke*, 1967)

$$Re = \left[\frac{\kappa}{R}\right]^{\frac{1}{2}} \cdot \left[\frac{l}{\beta_S}\right] \cdot \frac{Ma \cdot p \cdot \left[T_t \cdot \frac{1}{1 + \left(\frac{\kappa - 1}{2}\right) \cdot Ma^2} + S \right]}{\left[T_t \cdot \frac{1}{1 + \left(\frac{\kappa - 1}{2}\right) \cdot Ma^2} \right]^2} \qquad (2).$$

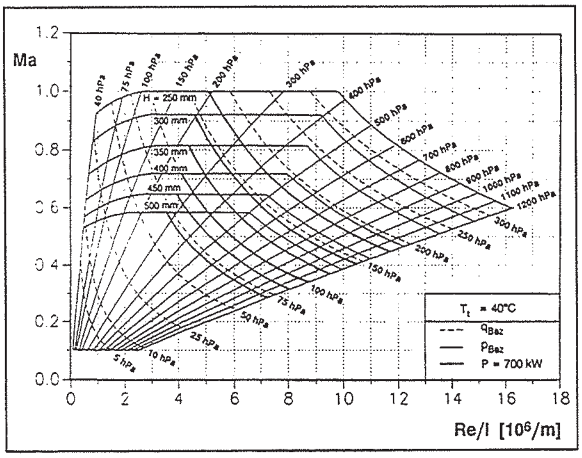

Fig. 2: Performance map of the High-Speed Cascade Wind Tunnel (*Sturm et al*, 1985)

By altering the turbulence generator upstream of the cascade the inlet turbulence intensity can be adjusted. Depending on the number of blades and the upstream flow angle and the upstream channel height different ranges of the similarity parameters can be obtained. Fig. 2 shows the performance map of the wind tunnel. Detailed information on the test facility can be found in *Sturm*, 1988.

PRINCIPLES OF PROFILE PRESSURE DISTRIBUTION AND THE WAKE MEASUREMENTS

The purpose of profile pressure distribution measurements is the determination of local flow parameters on the profile surface. For a quantification the static profile pressure coefficient is calculated using the local static pressure, the reference pressure and the dynamic pressure:

$$c_{p,bez}(x/l) = \frac{p_{x/l} - p_{bez}}{q_{bez}} \qquad (4)$$

With the static profile pressure coefficient the isentropic Mach number distribution and the relative contour velocity along the profile surface can be derived as:

$$Ma_{is,x/l} = \left[\frac{2}{\kappa - 1} \cdot \left[\left(\frac{p_{t1}}{p_{x/l}}\right)^{\frac{\kappa - 1}{\kappa}} - 1 \right] \right]^{\frac{1}{2}} \qquad (5)$$

and

$$\frac{w_{is,x/l}}{w_{bez}} = \frac{Ma_{is,x/l}}{Ma_{bez}} \cdot \left(\frac{1 + \frac{\kappa - 1}{2} \cdot Ma_{bez}^2}{1 + \frac{\kappa - 1}{2} \cdot Ma_{is,x/l}^2} \right)^{\frac{1}{2}} \qquad (6)$$

The calculated parameters are acquired using the upstream flow conditions for compressor cascades and using the isentropic downstream flow conditions for turbine cascades. The critical profile pressure coefficient is defined as

$$c_{p,krit} = \frac{\left[\frac{2}{\kappa + 1}\right]^{\frac{\kappa}{\kappa - 1}} - \frac{p_{bez}}{p_{t1}}}{\frac{q_{bez}}{p_{t1}}} \qquad (7)$$

and the critical relative contour velocity as

$$\frac{w_{krit}}{w_{bez}} = \left[\frac{1 + \frac{\kappa - 1}{2} \cdot Ma_{bez}^2}{\frac{\kappa + 1}{2} \cdot Ma_{bez}^2} \right]^{\frac{1}{2}} . \qquad (8)$$

The aim of wake measurements is the determination of local and integral cascade parameters i.e. total pressure loss coefficient, static pressure rise coefficient and flow deviation. Adiabatic conditions are assumed. The desired parameters are obtained with homogeneous upstream and downstream conditions. Since the flow through the cascade is periodical in circumferential direction, it is sufficient to investigate only one blade passage of the cascade.

Due to the fact that the upstream conditions are homogeneous its values can be measured in one point (Fig. 3) of a plane parallel to the inlet plane of the cascade. The total pressure p_{t1} is measured with a Pitot probe at a distance of 50 mm from one sidewall and about one chord length in front of the cascade.

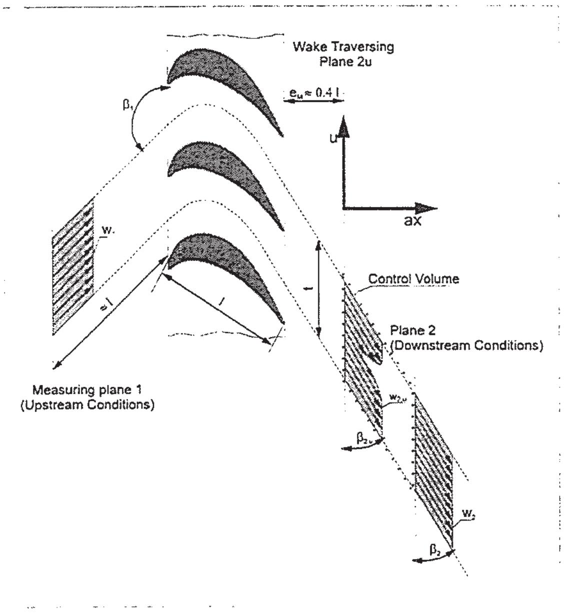

Fig. 3: Principles of wake measurement

At the same distance from the cascade the static pressure p_1 is determined with static wall tappings. Assuming adiabatic conditions the total inlet temperature can be measured as a mean value of four thermo-resistors in the settling chamber upstream of the cascade behind the main flow cooler.

The downstream flow field is inhomogeneous and a function of the axial and circumferential position. The measurements are performed at 40 % chord length (e_M/l=0.40) downstream of the trailing edge plane at midspan position by traversing a probe through the wake. At every probe position the local total pressure $p_{t2,u}$, the local static pressure $p_{2,u}$ and the reference pressure p_{bez} are recorded. The flow angle in circumferential direction (wedge probe and five hole probe) is measured using the pressure differences between two symmetrically to the probe axis arranged holes in a plane through the probe axis and perpendicular to the spanwise direction. The flow angle in spanwise direction is established using another pair of holes perpendicular to the former mentioned (*Wilfert et al*, 1990). Supposing the size of the probe is small enough, the local pressure gradient can be approached with the differential quotient using the pressure differences between the two pairs of holes. The evaluation leads to the desired local parameters (*Amecke* 1967):

- total pressure loss coefficient

$$\zeta_{V,bez} = \frac{\Delta p_{t,u}}{p_{t1,u} - p_{bez,u}} = \frac{p_{t1,u} - p_{t2,u}}{q_{bez,u}} \tag{7}$$

- static pressure rise coefficient

$$\frac{\Delta p_u}{q_{bez,u}} = \frac{|p_1 - p_2|_u}{q_{bez,u}} \tag{8}$$

- exit flow angle $\beta_{2,u}$ in circumferential direction
- exit flow angle $\alpha_{2,u}$ in spanwise direction (only five hole probe)
- local exit Mach number $Ma_{2,u}$.

The reference quantities in the equations (7) to (9) depend on the cascade type:

	Compressor	Turbine
p_{bez}	p_1	p_K
q_{bez}	$q_1 = p_{t1} - p_1$	$q_{2th} = p_{t1} - p_K$
T_{tbez}	$T_{t1} = T_{t,Vk}$	$T_{t1} = T_{t,Vk}$

Wake Measurements	Profile Pressure Measurements
z-, u- und β′-Coordinate of the probe wake	
$q_{1,u} = (p_{t1} - p_1)_u$ $\Delta p_u = \lvert (p_1 - p_2) \rvert_u$ $\Delta p_{t,u} = (p_{t1} - p_{t2})_u$	$\Delta p_{x/l} = (p_{x/l} - p_{bez})$
$T_{t,Vk,u}$ $p_{Umg,u}$ $(p_{Umg} - p_{bez})_u$ $q_{bez} = (p_{t1} - p_{bez})_u$	

Using the laws of conservation of mass

$$\frac{1}{t} \cdot \int_0^t \rho_{2,u} \cdot w_{2,u} \cdot \sin\beta_{2,u} du = \rho_2 \cdot w_2 \cdot \sin\beta_2 \tag{9}$$

and momentum parallel and normal to the inlet and exit plane on the control volume shown in Fig. 3

$$\frac{1}{t}\cdot\int_0^t\left(\rho_{2,u}\cdot w_{2,u}{}^2\cdot\sin^2\beta_{2,u}+p_{2,u}\right)\cdot du =$$

$$=\rho_2\cdot w_2{}^2\cdot\sin^2\beta_2+p_2 \qquad (10)$$

$$\frac{1}{t}\cdot\int_0^t\rho_{2,u}\cdot w_{2,u}{}^2\cdot\sin\beta_{2,u}\cdot\cos\beta_{2,u}\cdot du =$$

$$=\rho_2\cdot w_2{}^2\cdot\sin\beta_2\cdot\cos\beta_2 \qquad (11)$$

the measured quantities of the inhomogeneous flow can be converted into homogeneous flow conditions.

The solution of the equation system yields the integral cascade parameters:

- total pressure loss coefficient
- static pressure rise coefficient
- exit flow angle β_2
- exit Mach number Ma_2
- axial velocity density ratio

$$\Omega=\frac{\rho_2}{\rho_1}\cdot\frac{w_2}{w_1}\cdot\frac{\sin\beta_2}{\sin\beta_1} \qquad (12).$$

The assumption of two-dimensional flow is indicated by a value Ω=1.0 and the value should not differ more then 5%.

Detailed information on the evaluation of all parameters can be found in *Amecke* (1967) and *Wilfert et al* (1990).

DESCRIPTION OF WINPANDA

Considering the limitations of the former measurement system PANDA 6.0 a new system had to be set up overcoming the limits posed by the obsolete hardware, the operating system and the programming language.

The selection of the hardware and the chosen operating system based on the following terms:

- use of existing bus controlled digital measurement devices
- integration in present computer network
- easy data exchange for postprocessing and presentation
- comfortable user interface for short training periods and short measurement time
- low purchase costs

This leads to a PC-based data acquisition system with DOS and Microsoft Windows 3.11 as the graphical user interface (GUI). For the data acquisition and the protocol with the measurement devices a IEEE-488 bus-management plug-in card is installed in the PC. The specifications of this bus support a maximum number of fifteen attached measurement devices at a maximum cable length of twenty meters. These limits can be extended with an optional bus extender and a bus expander.

The special features of Windows also enabled the implementation of large memory use during the measurement. Furthermore the GUI supports all different kinds of graphical devices without the need of specific driver programming.

The software package WINPANDA has a modular structure consisting of two main parts (Fig. 4) and several controlling files. One main module is the executable file WINPANDA.EXE. It contains all parts dealing with program user interface, the experimental setup, the evaluation of the measurement and the graphical output of the data. The second main module, PANDAMES.DLL, includes all routines for the control of the measurement devices and the IEEE-488 bus management. This module is loaded into the memory when a measurement is performed and afterwards unloaded. Therefore everything which does not need any contact with the measurement system can be carried out on an ordinary PC without special equipment.

WINPANDA.EXE	PANDAMES.DLL
Included Routines:	Included Routines:
• Initialisations • Menus, Dialogues, Windows • Printer Control • Input, Output • Memory Management • Graphics • Calculations	• IEEE-488 Management • Control of Measurement Devices • Conversions: Voltage → Pressures, Temperatures

Fig. 4: Modular Design of WINPANDA

The two modules are subdivided in several source codes for easier program maintenance and portability for other purposes. The programming language is C. This implies the chance making use of dynamic memory allocation. This enables the user to measure large amounts of wake and profile pressure distribution data. Tab. 1 shows the current supported number of measurement locations of WINPANDA in the version 1.0 in comparison to the former minicomputer based system PANDA release 6.0. Together with the new system some improvements concerning measurement time reduction and graphical output capability were achieved.

	Maximum Number	
	PANDA 6.0	WINPANDA 1.0
Wake traversing locations	99	unlimited
Downstream flow angle	99	unlimited
Static profile pressure taps	99	188 (*)

(*) due to hardware limitations

Tab. 1: Limitations of PANDA 6.0 and WINPANDA 1.0

The supported probe types for direct evaluation of the wake measurements are:

- wedge probes
- five hole probes.

The measurement system WINPANDA is integrated in the existing hardware installations at the High Speed Cascade Wind Tunnel. Fig. 5 contains a block-diagram of the current measurement system and the supported apparatus. The accuracies of the devices are described in detail by *Wilfert et al* (1990). The system uses differential pressures based on only one absolute pressure p_{Env} being measured with a barometer. The reference pressure p_{ref} is obtained with the environmental pressure p_{Env} and a highly accurate single channel pressure transducer DDM 15. All other differential pressures as the wake pressures and the inlet pressures use the multichannel transducer PSI DPT-6400. This device has twenty-four channels with six different ranges. Depending on the anticipated pressure the most appropriate channel should be selected. The DPT-6400 pressure transducer must be calibrated. This is accomplished by two pressure regulation devices DPI-500 and EPR-2 with different pressure ranges.

The static profile pressure tappings are connected to a Scanivalve Measurement System. All pressures are measured against the reference pressure. A calibration of the Scanivalve system is not necessary. Assuming a linear behaviour of the transducer between the output voltage and the supplied pressure the profile pressure coefficient can be written as

$$c_p = \frac{p_{x/l} - p_{ref}}{p_{t1} - p_{ref}} = \frac{\Delta p}{q} = \frac{k_1 + k_2 \cdot U_{\Delta p}}{k_1 + k_2 \cdot U_q} \qquad (13).$$

If the reference pressure is connected to one channel on the measuring side of the transducer, the offset voltage U_0 for zero differential pressure can be detected. This offset value can be subtracted and the resulting equation for the profile pressure coefficient yields

$$c_p = \frac{k_2 \cdot (U_{\Delta p} - U_0)}{k_2 \cdot (U_q - U_0)} = \frac{U_{\Delta p} - U_0}{U_q - U_0} \qquad (14).$$

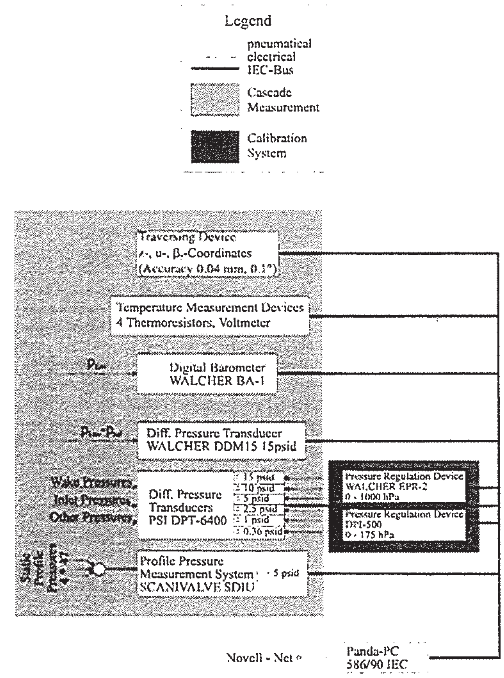

Fig. 5: Blockdiagram of the Measurement System

The software package WINPANDA is built upon the graphical user interface of Microsoft Windows 3.11. This assures easy use and short training periods. Fig. 6 and Fig. 7 show the graphical design and the user interface of WINPANDA.

The graphical evaluation of the measured data is displayed in two different windows, one for the wake data and the second for the profile pressure distribution data. The axis of the viewgraphs have automatic range and scale adjustment. For the surveillance of the wind tunnel an online monitoring window with the main experimental data is included. This window located in the upper right part of the main window is updated every second for the control of the steady state of the flow conditions. The main set-up data are displayed in the window at the bottom. (Fig. 6)

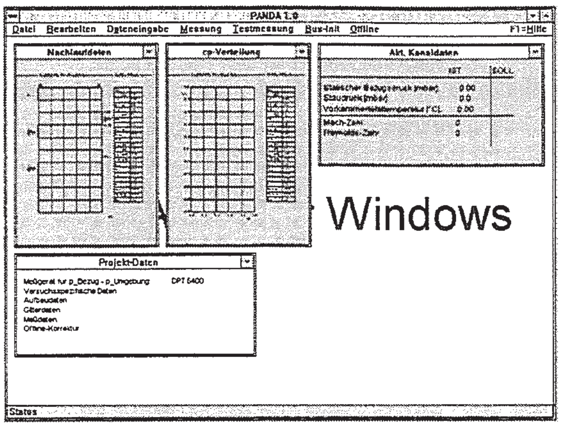

Fig. 6: Main Window of WINPANDA

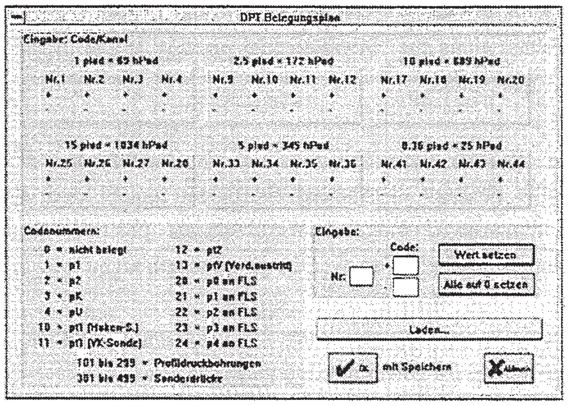

Fig. 7: Example of Dialogue Driven Program Control

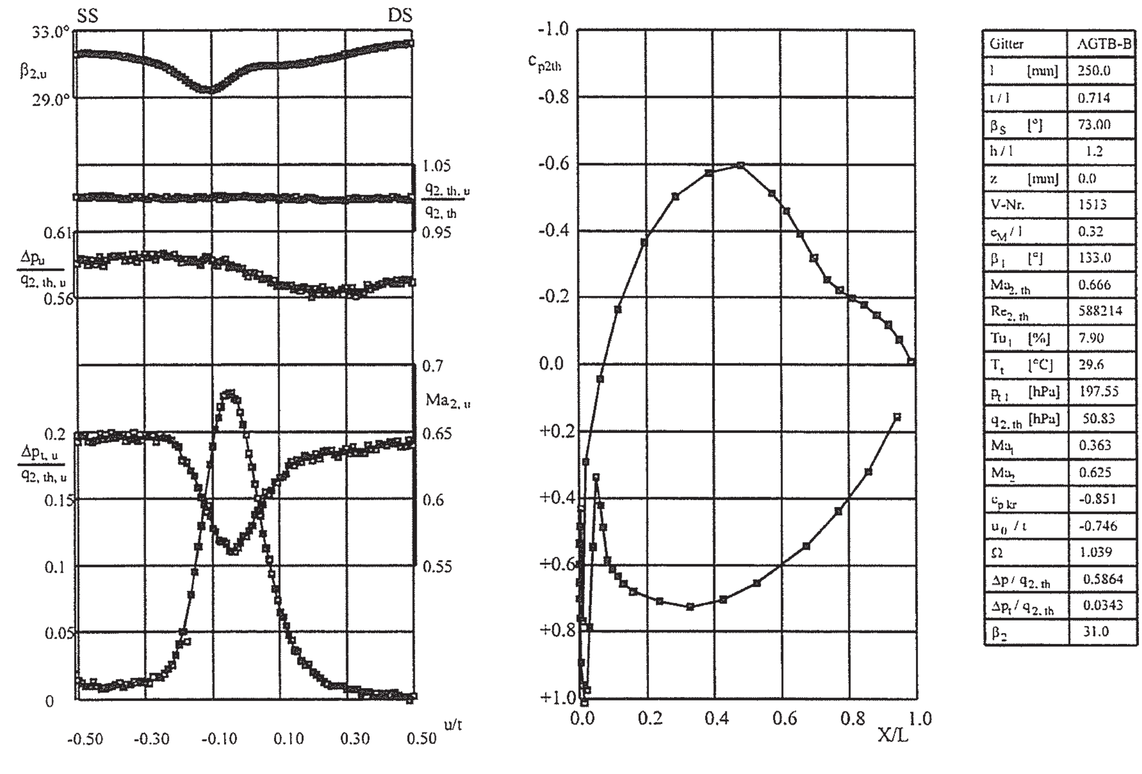

Fig. 8: Standard Output of Wake and Profile Pressure Distribution Measurements

All input is performed using dialogue boxes (Fig. 7). The input data are stored in spreadsheet files and can be combined to form the complete test configuration. An online help with an index and a keyword data base for rapid user assistance is also included in the package. The GUI allows the dynamic data exchange with common postprocessing tools like presentation software.

After the measurement and the evaluation the results are obtained in graphical form and in spreadsheet files. The output of the former described windows can be printed on high resolution printers also making use of the autorange and autoscale performance of the program (Fig. 8).

A legend containing the main profile data and integral cascade parameters is implemented. The output consists of two coordinate systems. One viewgraph shows the main wake data plotted over the nondimensional circumferential position u/t. These are in particular:

- downstream flow angle in circumferential direction
- nondimensional dynamic reference pressure development
- nondimensional static pressure rise
- exit Mach number distribution
- total pressure loss coefficient.

Assuming adiabatic conditions the total temperature is constant along the circumferential position and is therefore not plotted.

The second viewgraph contains the nondimensional profile pressure distribution coefficient plotted over a nondimensional longitudinal dowstream position, for example axial position over the chord length x/l.

The data output in spreadsheet form is stored in files and can be used for postprocessing purposes.

WINPANDA - MEASUREMENT CYCLE

Fig. 9 describes a measurement cycle with the data acquisition and evaluation system WINPANDA.

Prior to a measurement with WINPANDA the test case definition must be carried out. This is the definition of several data by changing old similar data or by new input of:

- Cascade data (chord length, blade height, stagger angle, etc.)
- Experimental set-up data (inlet flow angle, pressure transducer connections to the desired channels, etc.)
- Test specific data (Mach number, Reynolds number, total temperature, number of measuring locations, etc.)

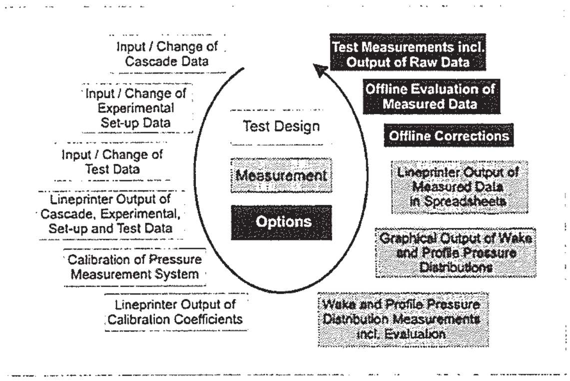

Fig. 9: Flow-Chart of WINPANDA Measurements

This input data can be printed in spreadsheet form. Then the pressure transducers must be calibrated with the automatic calibration routine. After the execution of an automatic measurement the obtained results can undergo an offline correction and a new offline evaluation. The corrective parameters are:

- Total inlet pressure
- Geometrical wake probe setup (i.e. circumferential probe position, probe angle in circumferential and spanwise direction)

For simple test cases without automatic evaluation a possibility of test measurements with output of raw data (i.e. output voltage of pressure transducers) can be performed. In this case the entire test case definition is not necessary.

VALIDATION MEASUREMENTS

The validation of the enhanced data acquisition system WINPANDA 1.0 was performed on many different types of cascades. A bare cascade used for the simulation of rotor-rotor and stator-stator interaction was included in the validation program. The AGTB-B1 profile is a leading edge filmcooled high pressure turbine cascade. The model T106-100 is a low pressure turbine cascade. Tab. 2 contains the main cascade data in their design points and the current test cases.

	Reference Reynolds number	
	Design point	Test case
T106-100	500000	300000
AGTB-B1	580000	580000
	Reference Ma-number	
	Design point	Test case
T106-100	0.59	0.59
AGTB-B1	0.65	0.65
	Inlet angle in circ. direction	
	Design point	Test case
T106-100	127.7°	127.7°
AGTB-B1	133.0°	133.0°
	Stagger angle	
T106-100	59.3°	
AGTB-B1	73.0°	
	Chord length	
T106-100	100 mm	
AGTB-B1	250 mm	
	Pitch ratio	
T106-100	0.799	
AGTB-B1	0.714	
	Number of Blades	
T106-100	6	
AGTB-B1	3	

Tab. 2: Main Data of the Validation Cascades

Fig. 10 shows an online evaluation without any use of corrective parameters of the profile pressure coefficient plotted over the nondimensional axial position.

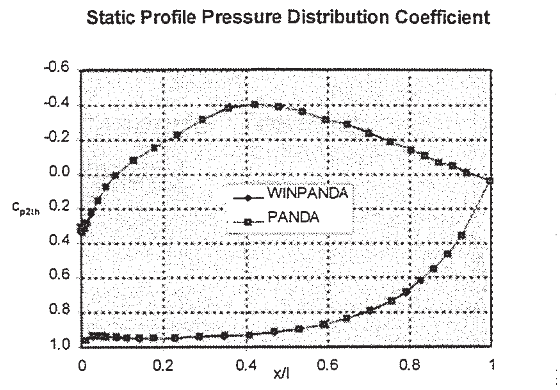

Fig. 10: Validation Measurements - Profile Pressure Distribution on the Turbine Cascade T106-100

Fig. 11 contains the comparison of two evaluations with the former system PANDA 6.0 and the new enhanced system WINPANDA 1.0 on a bare cascade. The maximum local difference of the total pressure loss coefficient is smaller then 0.8 % between WINPANDA and PANDA, whereas two subsequent measurements with one system showed differences of the same magnitude. This also proves the reproducibility of the measurements.

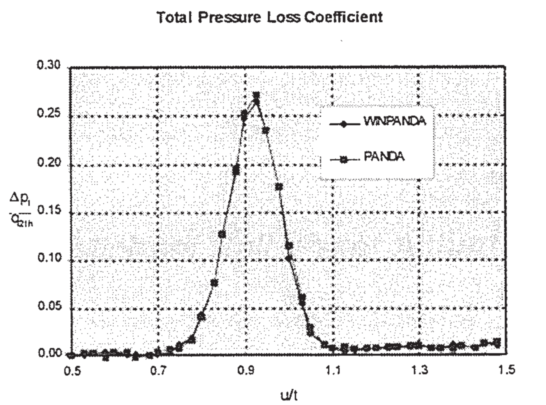

Fig. 11: Validation Measurements - Total Pressure Loss Coefficient on a Bare Cascade $Ma_{2th} = 0.277$, $Re_{2th} = 264000$

Tab. 3 displays the evaluated integral cascade parameters of two validation measurements performed with the turbine cascade AGTB-B1. The differences between the values are very small relative to the values themselves.

All measurements carried out proved the high accuracy of the new system and the good agreement compared with the former system.

Integral Parameter	WINPANDA 1.0	PANDA 6.0
p_{t1}	197.2 hPa	196.7 hPa
p_{t2}	195.8 hPa	195.1 hPa
p_1	180.3 hPa	179.5 hPa
p_2	150.5 hPa	149.9 hPa
$(p_{t1}-p_{t2})/q_{2th}$	0.034385	0.033138
$(p_1-p_2)/q_{2th}$	0.586082	0.587189
β_2	31.0°	31.0°
$\beta_1-\beta_2$	102.0°	102.0°
q_1/q_{2th}	0.338152	0.339707
ρ_2/ρ_1	0.876600	0.876746
w_1/w_{2th}	0.547683	0.562642
w_2/w_1	1.679859	1.676844
w_2/w_{2th}	0.943463	0.942942
Ω	1.036778	1.038195
w_{krit}/w_{2th}	1.430223	1.429811
Ma_1	0.362966	0.363949
Ma_2	0.624915	0.625482
$Ma_2\ (p_{t2}/p_k)$	0.655737	0.656123
$cp_{2th,\ krit}$	-0.833338	-0.832391
$cp_{2th,\ krit,\ \zeta}$	-0.851152	-0.849897

Tab. 3: Integral Cascade Parameters of the Validation Measurements of the Cascade AGTB-B1

CONCLUSIONS AND OUTLOOK

A PC-based data acquisition system for wake and profile pressure distribution measurements was set up. The limitations posed by the former system were overcome due to the new hardware and the new programming system. A comfortable program control based on the graphical user interface Microsoft Windows 3.11 is included. The software package contains automatic evaluation routines and graphical output functions. The validating measurements and comparisons with the former system showed the high accuracy and reproducibility of the experimental results.

The structure of the system permits the portability of modules for other measurement purposes.

For the determination of secondary flow phenomena this system will be extended for area traversing in the cascade exit plane.

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