

Measurement equipment on a standards test-rig for radial fans

by Fred Schäfer, Volker Klupsch, Ingo Thurn and Rudolf Ahrens

To assess radial fans and to compare their performance, measurements are taken on standards test-rigs and from these the fan characteristics can be calculated. The article describes a pipe-type test facility for standards testing incorporating an on-line measurement system on the downstream side based on the MGC Digital Measuring Amplifier System. The driving torque, speed and power are measured and differential pressure transducers monitor the static pressure. An orifice meter is used to obtain the volume flow, an inductive displacement transducer measures the position of the conical throttle and thermocouples monitor the temperature. The fan performance characteristics derived from a number of test series are produced as an example of the results.

Introduction

In the Laboratory for Turbomachines at the Märkischen Fachhochschule Iserlohn a standards test-rig to DIN 24163 has been designed and constructed for recording the performance characteristics of radial fans. The performance characteristics illustrate in the form of graphs the relationship between the volume flow and the increase in pressure and they enable conclusions to be drawn about the performance capabilities of fans. Details of the test-rig used are also included with the performance characteristics so that the comparability with other sets of characteristics can be assessed. For this reason that it was decided to use a standards test-rig.

With the test-rig, measurements are taken from which the fan parameters can be calculated and represented in tabular and graphical form. The processing of the analog measurement signals takes place in an on-line measurement system using the computer-controllable MGC Measuring Amplifier System which passes its output signals to a PC. The software package DIA/ DAGO[®] was run on the PC.

Test-rig

Performance measurements on fans using standardized test-rigs are carried out, for example, to find the characteristic curves required for a performance specification, to predict the performance capabilities of large fans from model tests or to assess the individual stages in the development of new fans.

Ort the international scale there are a large number various guidelines for the construction and operation of fan test-rigs. Here, the American AMCA standard deviates significantly from the European standards. This restricts the comparability of test results obtained from different test-rigs.

Since the operating characteristics, and therefore the characteristic curves for a fan, depend to a large extent on the intake and connection conditions on the intake side, these must be defined by standards to ensure the reproducibility of the test results. DIN 24163 permits

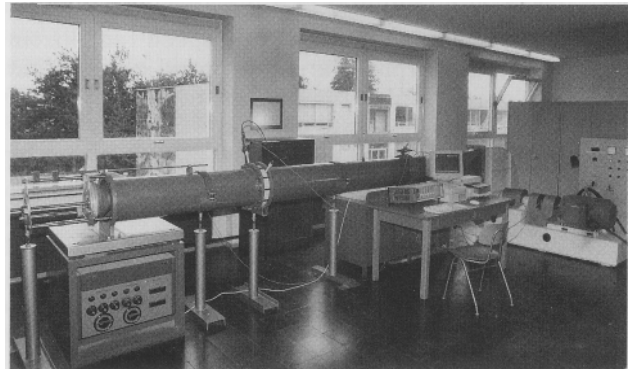


Fig. 1: Overall view of the radial-fan test-rig.

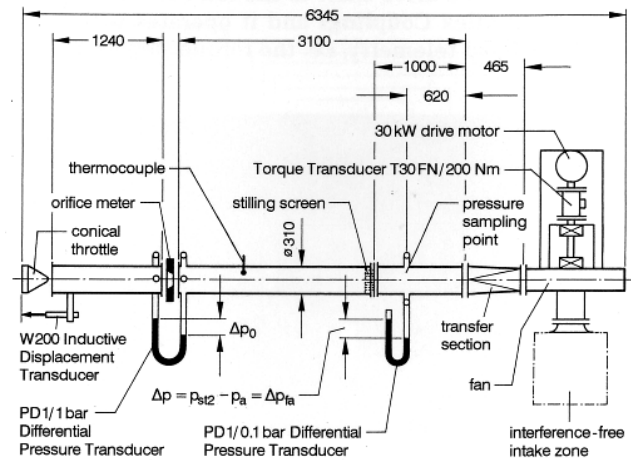


Fig. 2: Diagram of the test-rig.

the use of different test-rig designs based on pipe or chamber test-rigs with intake or downstream measurement arrangements. After considering the advantages and disadvantages of the different designs, it was decided to build a pipe-type test-rig with the measurement arrangement on the downstream side. **Figure 1** shows an overall view of the radial-fan test-rig.

The basic structure of the test-rig and its main dimensions are shown in **Fig. 2**. To the right can be seen the fan which is driven by a motor coupled via a torque transducer. The outlet section is joined by a transfer pipe to the pressure sampling point and the corner-tapped orifice meter for the volume flow measurement. A conical throttle is situated at the end of the pipe.

The downstream side of the pipe test-rig enables an easy calculation of the overall pressure increase to be carried out using one differential pressure measurement and a simple, economical measurement of the volume flow through an orifice meter. A conical throttle is used as the throttle device. The minimum measurement lengths at the inlet and outlet of the orifice plate as described in the standard DIN 1952 however demand a facility with a longer overall length. The static pressure which is measured after the fan depends on the turbulence. The influence of this dependence on turbulence is minimized by allowing an adequate distance between the outlet of the fan and the pressure measuring point.

The drive to the impeller of the fan is provided by a 30 kW asynchronous motor in the speed range from 300 rpm to 3,000 rpm. The AEG control cabinet that was employed enabled the continuous adjustment of the motor speed. Separate parameters such as run-up time, braking period or the maximum current can be programmed using a keypad.

Measurement acquisition

A T30FN Torque Transducer from HBM with a nominal torque of 200 Nm (148 ft lbf) was used for the measurement of the torque and speed. The torque transducer is mounted in the drive shaft to the fan between OF250 Desch-Ferroflex Couplings and it operates with non-contact signal telemetry, i.e. the torque signals are in-

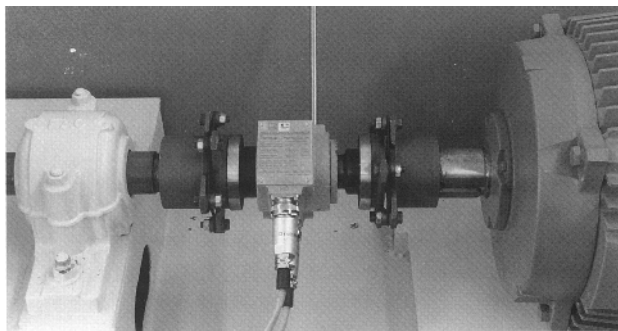


Fig. 3: The T30FN Torque Transducer mounted in the fan drive between couplings.

ductively transmitted from the transducer rotor to the stator. The transducer housing (stator) is secured against rotation by a mechanical retaining device. The chosen mounting arrangement as shown in **Fig. 3** enables the torque transducer with the connected halves of the couplings to be easily removed without having to disturb the motor and later re-align it. PVC pipe with an internal diameter $d_2 = 310$ mm (12.2 in) is used over the complete pipe measurement section.

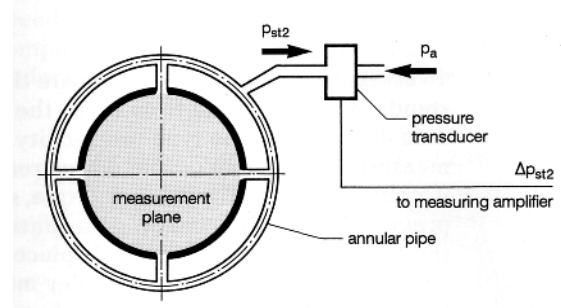


Fig. 4: Diagram showing the measurement of the static pressure.

Important parameters which must be measured on the pressure side of the fan are the static pressure in the pipe and the volume flow. The static pressure can be directly measured with the aid of a PD1 Differential Pressure Transducer which is situated at a distance equal to double the pipe internal diameter from the transfer section on the fan outlet. The pressure measurement is taken via four holes uniformly distributed around the circumference of the pipe. The holes are in turn connected together by an annular pipe. The PD1/0.1bar Differential Pressure Transducer is connected at one side to this annular ring through a T-piece and the other pressure input to the transducer is left open to the atmosphere. **Figure 4** illustrates this arrangement in a diagram.

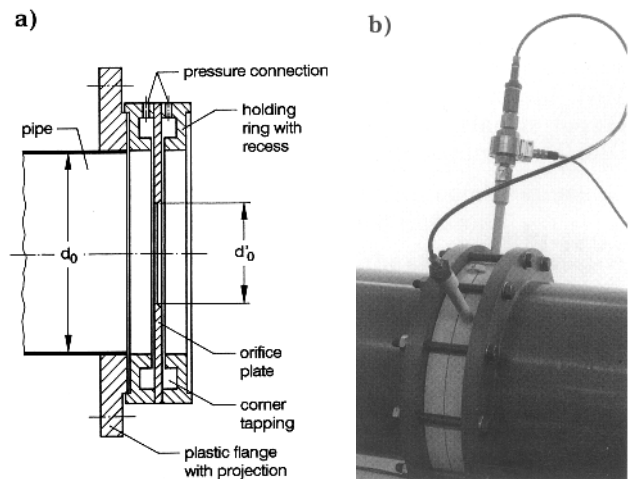


Fig. 5: Corner-tapped orifice meter conforming to DIN 1952 for the measurement of the volume flow:

a) diagram,
b) photograph of the orifice meter with the mounted PD1 Differential Pressure Transducer.

The measurement of the volume flow is carried out with the aid of a differential pressure measurement on a corner-tapped orifice meter conforming to DIN 1952. The main parts are two holding rings each with a corner tapping machined in them and an orifice plate which gives an exactly defined restriction in the cross-section at the measuring point. At each side between the orifice plate and the holding ring, a circumferential slot makes sure that the pressure arising on the orifice plate is passed to the corner tapping. The orifice plate is clamped between both the holding rings. **Figure 5** shows the orifice meter as a sketch (a) and as a photograph (b) with the mounted PD1/1bar Differential Pressure Transducer.

According to Bernoulli, the total energy in a flow, which is composed of the kinetic energy (dynamic pressure) and the pressure energy (static pressure), is constant. The increase in the velocity of flow causes a reduction in the static pressure. The drop in static pressure that results is termed the effective pressure Δp_0 and is a measure of the flow per unit time. Both pressure connections on the orifice meter are connected to the PD1/1bar Differential Pressure Transducer from HBM which supplies an electrical measurement signal corresponding to the differential pressure.

An interference-free, straight section of pipe must be provided in front of the orifice meter, the length of which depends on the preceding source of the interference and the diameter ratio β on the orifice. From experimental experience ten times the pipe internal diameter is selected for the entry length, i.e. in this case 3100 mm (122 in). A honeycomb stilling screen of 100 mm (3.9 in) length and a cell diameter of 8 mm (0.32 in) is mounted in the first third of the pipe section.

With regard to the differential pressure transducers, which operate on the inductive measurement principle, it should be noted that they are not to be located in regions of strong magnetic interference fields. Also, they should be mounted such that any accelerations that occur (vibrations) should not act in the direction of the transducer axis.

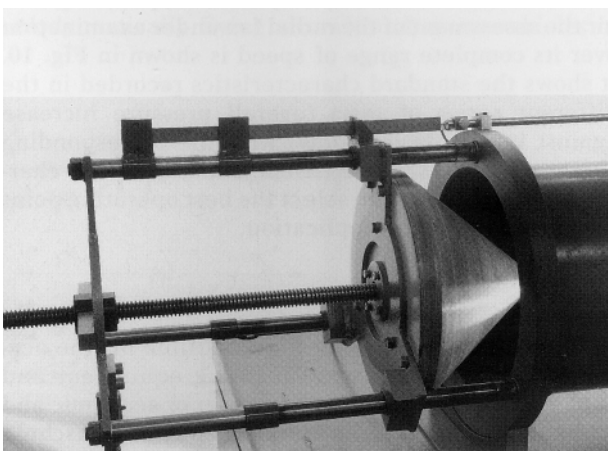


Fig. 6: Conical throttle with a scale device and inductive displacement transducer.

A temperature measurement is required in the pipe in front of the orifice meter in order to be able to determine the density of the gas flowing through it. This is carried out with the aid of a NiCr/Ni thermocouple.

At the end of the downstream pipe section there is a movable throttle cone, the form of which is aerodynamically selected such that it presents only a slight resistance when fully opened. The exact axial position of the cone can be set by a crank-operated trapezoidal spindle. A measurement scale fitted over the throttle cone enables accurate and reproducible positioning. A W200 Inductive Displacement Transducer is used to relate the measurements found on the test-rig to a certain throttle setting. **Figure 6** shows the conical throttle with the scale device and the displacement transducer.

Processing the measurement data

The measurement signals are conditioned in an MGC Measuring Amplifier System from HBM. All the transducers are connected to this amplifier. Suitable amplifier plug-in modules are available for the various transducers, the amplifier parameters being set via the AB12 Display/Operating Panel on the MGC System. Here, for example, calibration values can be set and zero balances carried out. The amplifier contains six plug-in modules: Two of the type MC60 for torque and speed, three of the type MC55 for both differential pressure transducers and the displacement transducer and one of type MC01 for the thermocouple. **Figure 7** shows the relevant block diagram.

The MGC amplifier system can be fully controlled by computer. A CPU with the RS-232-C and RS 485 serial interfaces is built into the amplifier. In addition an IEEE 488 bus interface is implemented in the PI12 plug-in module. The digitized signals (measurements) can be transferred via the CPU to a computer where they can be processed by suitable software.

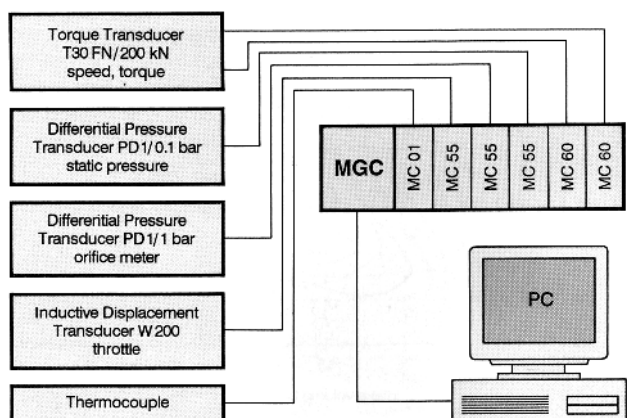


Fig. 7: Block diagram of the complete measurement arrangement.

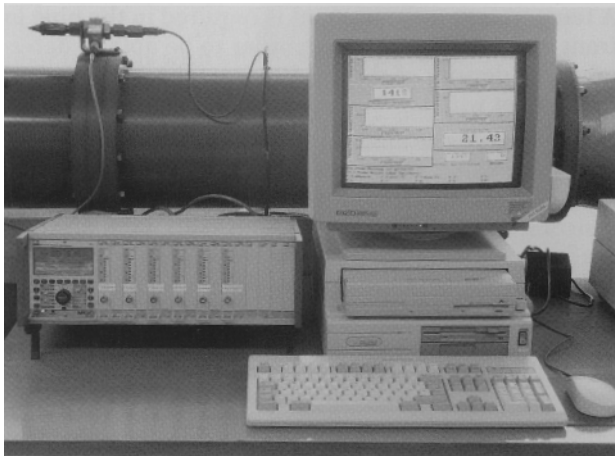


Fig. 8: Photograph of the MGC Measuring Amplifier and on-line display of results on the monitor; to the left in the background can be seen the measuring point for the static pressure.

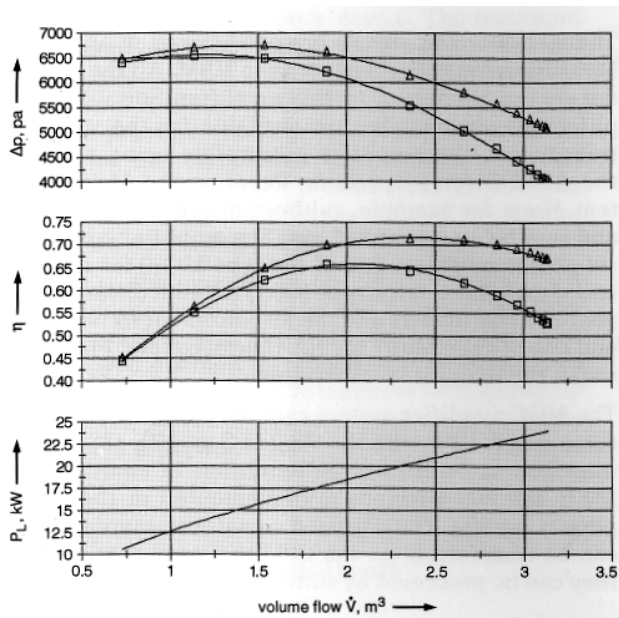


Fig. 9: Printout of a set of characteristics (speed 2,950 rpm, density 1.2 kg/m³).

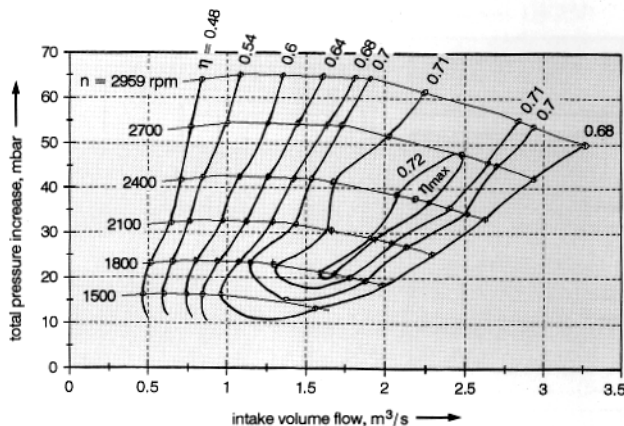


Fig. 10: Set of characteristics in the form of a shell-shaped family of graphs: Total pressure as a function of the intake volume flow.

MGC amplifiers combine the advantages of both analog and digital techniques. The patented analog/digital converter digitizes without loss of information so that the measurement signal is processed almost error-free. An interesting feature is that an EEPROM on each amplifier module stores all the channel data. This means that all the settings including the balance values and the signal flow are saved secure against line and battery failure.

The measurement acquisition and evaluation is carried out on-line in a PC using the DIA/DAGO[®] program package. The measurement trace can be followed on the monitor in previously defined on-line graphics. The measurements are saved as required and stored afterwards as a complete set of data. Once a full data set has been stored, it can be analyzed, evaluated and printed out in the DIA part of the program. The analysis offers the application of mathematical correction functions, statistics, cursor and zoom functions and classification methods according to DIN. Figure 8 shows a photograph of the equipment used for the signal processing and evaluation. The pressure pipe on the test-rig can be seen in the background.

Results

As an example a total of six series of tests were carried out during the determination of fan parameters with speeds from 1500 rpm to 2950 rpm. In each set of tests 14 throttle settings were used and the corresponding measurements recorded. In the evaluation the graphs can be arranged as desired and data from separate channels displayed. In addition there are various text fonts available and macros can be created to simplify continuously repetitive sequences. In the application described here a macro was created for the determination of the fan parameters which are derived from the recorded measurement data. Finally, the graphs that have been created with their corresponding curves can be output either to the monitor or to the printer. Figure 9 illustrates sample graphs for the increase in pressure Δp , the efficiency η and the drive power P_L in relation to the volume flow V .

The set of characteristics, here shell-shaped, required for the assessment of the radial fan under examination over its complete range of speed is shown in Fig. 10. It shows the standard characteristics recorded in the different series of tests (overall pressure increase against intake volume flow) with the corresponding curves for the same efficiency. Using these characteristics, the user can select the best operating point for the fan to suit his application.

Prof. Dr.-Ing. Fred Schäfer is responsible for the academic field of power and operating equipment and Dipl.-Ing. Rudolf Ahrens is a member of academic and research staff, both at the Märkischen Fachhochschule Iserlohn. Dipl.-Ing. Volker Klupsch and Dipl.-Ing. Ingo Thurn carried out their diploma projects in the Laboratory for Turbomachines at the same establishment.