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TEST RIG FOR THE DEMONSTRATION OF THE FLOW IN A RADIAL PUMP

Bernhard List, *Josef Prost*

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

Abstract – The paper gives information about a new PIV test rig for the education and training of students in the field of hydraulic machinery.

Keywords: PIV measurement, hydraulic machinery, education

1. INTRODUCTION

In order to update the education of the students in the field of hydraulic machinery at the Institute for Waterpower and Pumps a new test rig had to be designed and constructed [1]. One aim was to form a link between calculation and final product. The second was to acquaint students with up-to-date methods in flow measurement. Therefore the main objective of this pump has not been the highest possible efficiency, but a good optical observability and a design easy to manufacture.

Furthermore the use of different runners should be possible in the future, in order to demonstrate the influences of various runner geometries. A modular, easily dismountable runner/casing setup was another demand for the construction of this test rig

To meet these requirements a test rig for the study of the flow inside the impeller of a radial centrifugal pump was built. The runner and the casing of the radial centrifugal pump were made of acryl. In this way it is possible to investigate the flow inside the runner using Particle Image Velocimetry.

2. BASIC CONDITIONS

Using the PIV system available [2] some limitations result to the dimensions of the pump runner. In order to get a good resolution of the flow in the runner the maximum runner diameter is decided to 200 mm. This value is based on a image area of 60x60 mm and the resolution of the camera. The flow field in the runner area shall be almost two-dimensional in order to get a flow area easy to observe. Thus a runner with a low specific speed has preference. The pump housing shall have no curved outer surface to get no problems due to refraction of light. The necessary non transparent parts (e.g. screws and seals) have to be positioned outside any possible observation area.

The test rig is planed to be movable. So the design flow of the pump has to be less in order to limit the water capacity of the test rig and the necessary power supply.

3. THE TEST PUMP

Based on the requirements mentioned above the following design data are fixed:

- Flow: 20 m³/h (0.005 m³/s)
- Head: 10 m
- Speed: 1450 min^{-1}

These data yield to a radial runner (specific speed 19.2 rpm) with single curved blades and parallel cover disks, fig.1. All components are glued together, fig.2.

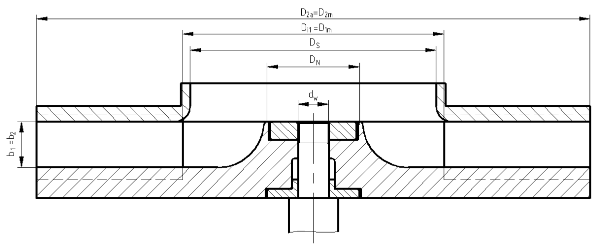

Fig. 1 Sectional drawing of the runner

Fig. 2 Runner of the test pump

The cross sections of the volute areas are rectangular. Thus the volute casing can be glued using plates, fig. 3. The inner contour of the central plate is designed corresponding to a constant spin flow. The screws fixing the pump cover are situated outside the runner, fig. 4. The observation of the runner flow thus can be done from both sides of the casing.

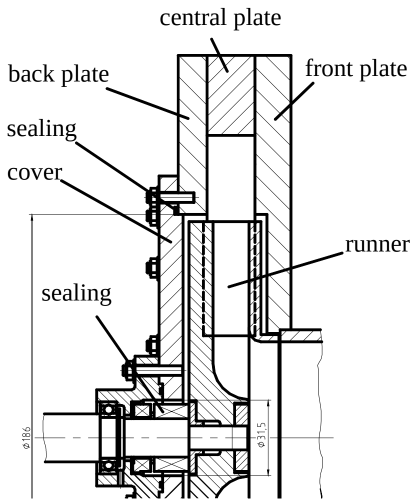

Fig. 3 Sectional drawing of the volute casing

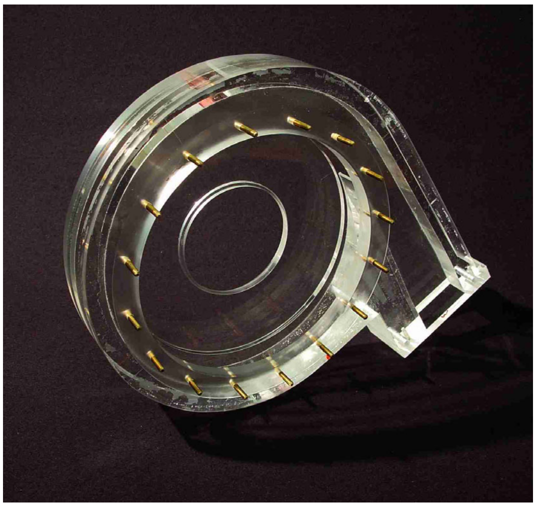

Fig 4 Volute casing of the test pump

4. THE TEST RIG

Fig. 5 shows the test rig completely instrumented with CCD-camera (3), ND YAG laser (2) and evaluation system (6). The camera is mounted on a support that can be moved. So it is possible to modify the position of the camera and the distance between camera and pump. Thus the observation area can be altered. The camera is synchronised using an inductive transmitter which is mounted on the shaft of the runner.

All components of the test rig are made of plastic or other corrosion resistant materials. The pump (1) is driven using a frequency converter (5). The water tank (4) has a capacity of 50 l, polyamides (ρ=1,016g/cm³, d_{50}=45µm) are used as seeding. A diaphragm. valve (7) makes possible to vary the back pressure of the pump. Pressure transducers and an ultrasonic flow meter (8) are installed for the determination of the pump characteristics.

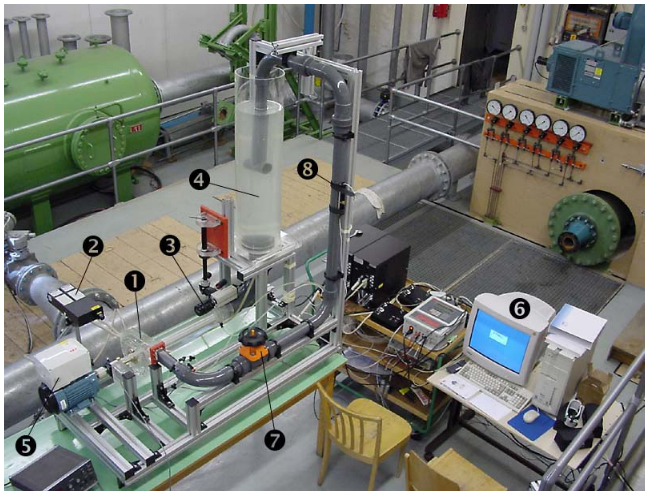

Fig. 5 Test rig

The test rig is very compact and mounted on a frame. Thus transportation is rather simple.

5. MEASURING RESULTS

5.1. Pump characteristics

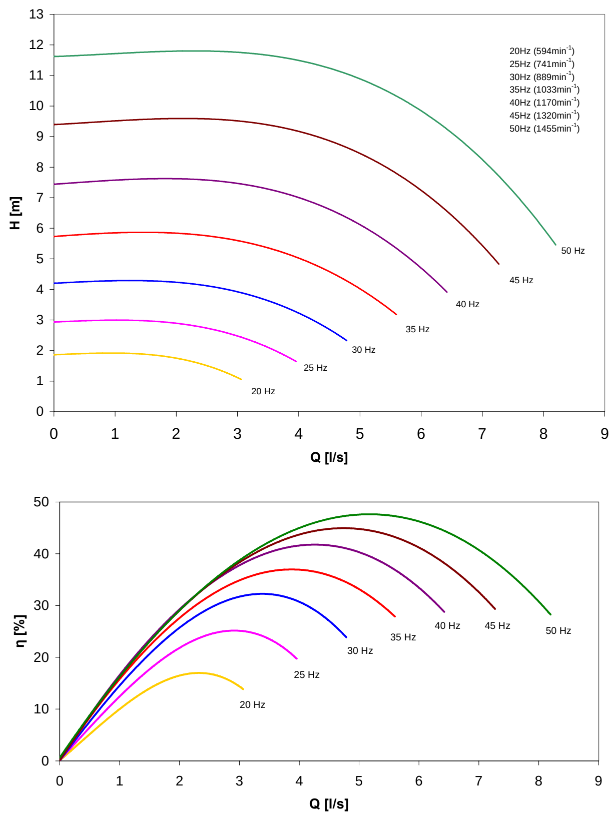

Fig. 6 Pump characteristic and overall efficiency

The pump characteristic (fig 6) is determined from the pressures at the suction and the back side of the pump and from the flow. The inductive transmitter is used to get the speed of the rotor. The temperature of the water is controlled to guarantee stable test conditions.

Measuring the power input of the motor the total efficiency of the unit can be calculated. As the friction losses of the bearings and the electrical losses of the motor and the frequency converter are not determined this measured total efficiency delivers no exact information on the hydraulic quality of the runner. An estimation of the operating point (overload, partial load) however is possible. This gives information on the flow pattern that has to be expected doing the PIV-measurements.

The characteristic and the efficiency curves are determined for different rotational speeds. This is done by adjusting the frequency converter to a selected value f_{motor} . The operation point of the pump is varied by adjusting the diaphragm valve.

5.2 Flow inside the runner

For the determination of the flow inside the runner PIV is used. The instrumental set-up is as follows:

- Dantec PIV2100 Real-Time Processor
- New Wave Research Minilase III /15 Hz (Nd:YAG Laser, Wavelength: 532nm, Pulse energy: 50 mJ)
- Kodak Megaplus ES-1.0 CCD camera (1008 x 1018, max frame rate: 15 Hz)

Fig. 7 shows a typical test arrangement.

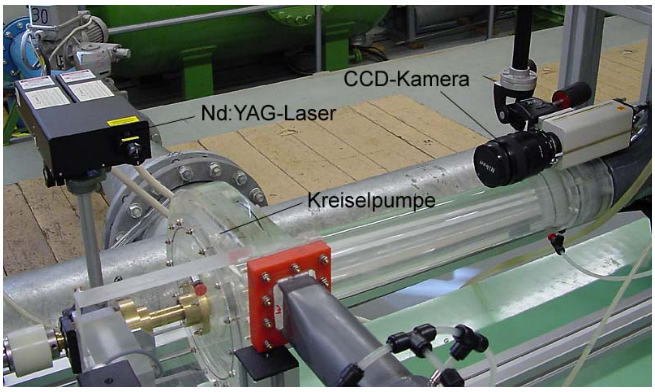

Fig. 7 Test arrangement

Positioning the CCD-Camera and the ND YAG laser as shown an runner area like that in fig 8 can be analysed.

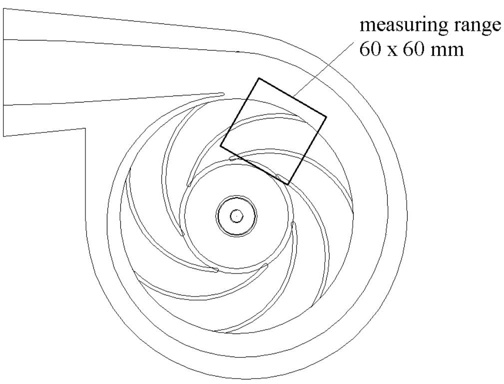

Fig. 8 Measuring area at the runner outlet

One of the double images used for PIV-evaluation is presented in fig. 9. It represents the flow at the optimum operation point of the pump.

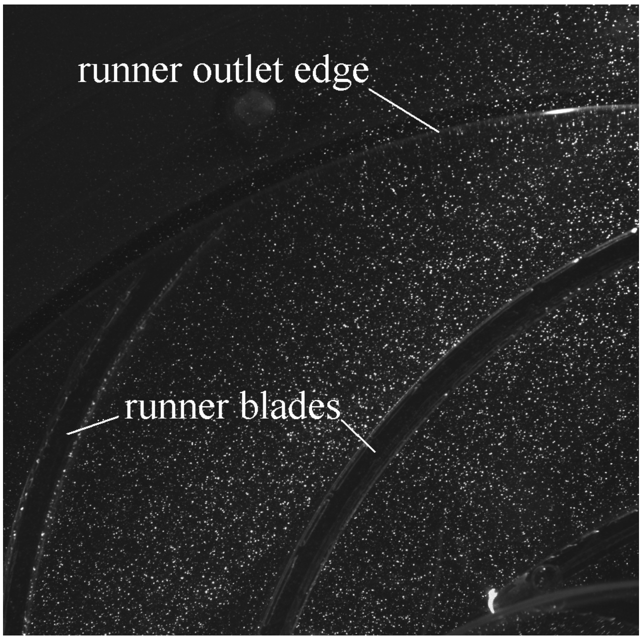

Fig. 9 Flow at the outlet edge of the runner

Using the „FlowManager" software by Dantec the absolute velocities can be determined. Using a „Moving Average Filter" on an interrogation area of 32x32 pixel with no overlap we get a vector field as shown in fig. 10.

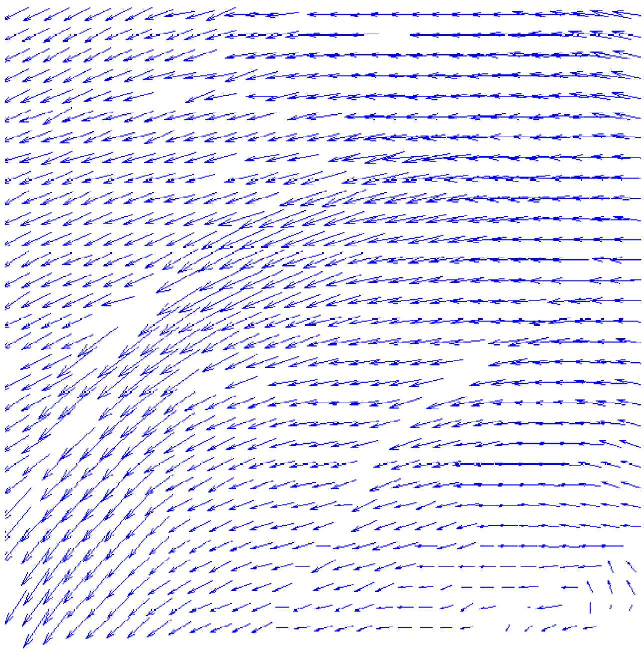

Fig. 10 Vector field (Q/Q_{opt} = 1.0)

The absolute velocities obtained from this measurement are presented in fig. 11. The maximum velocities are approximately 12 m/s and correspond good to a calculated value of 11.42 m/s.

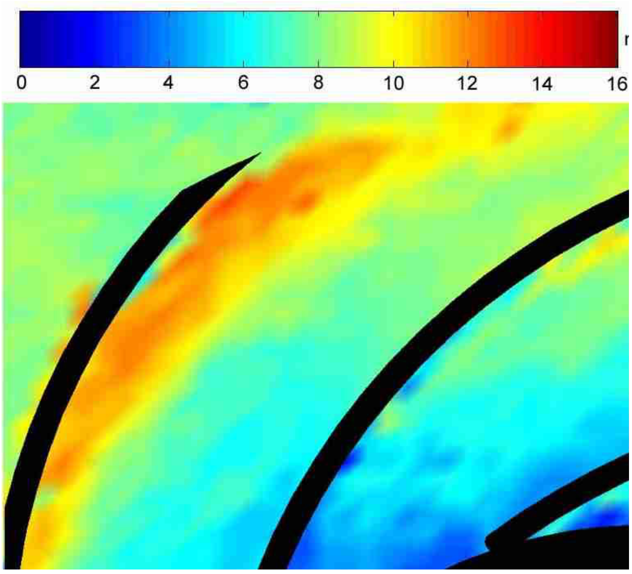

Fig. 11 Absolute velocities at Q/Q_{opt} = 1 and f_{motor}.= 30 Hz

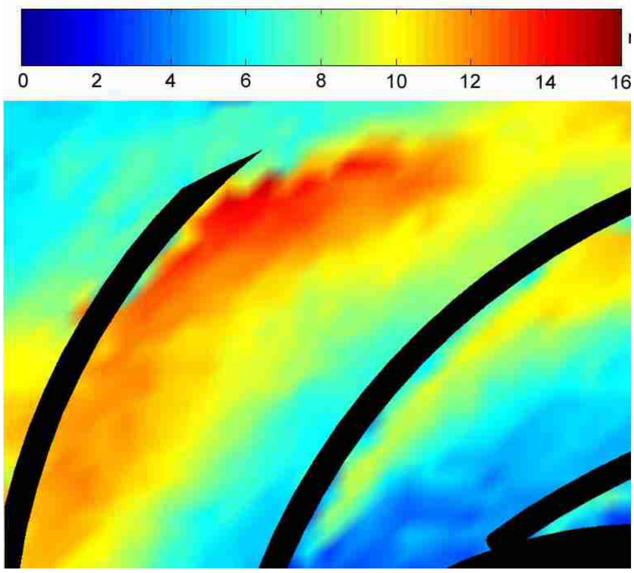

Fig. 12 Absolute velocities at Q/Q_{opt} = 0.6 and f_{motor}.= 30 Hz

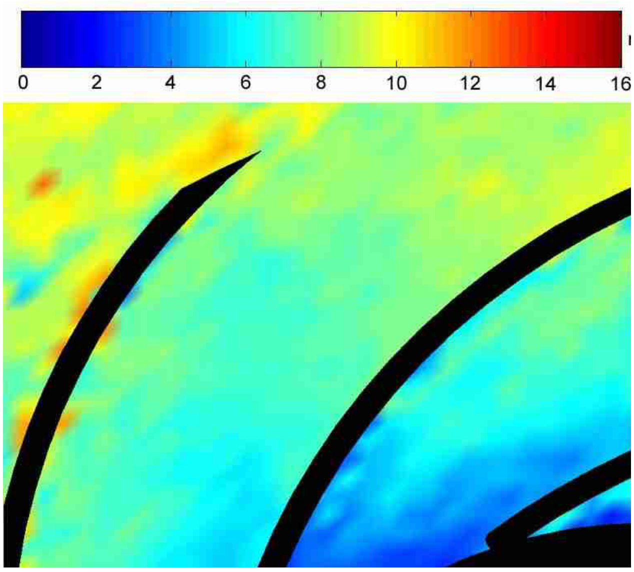

Fig. 13 absolute velocities at Q/Q_{opt} = 1.4 and f_{motor}.= 30 Hz

Comparing fig. 11, 12 and 13 the decrease of the velocities at the backside of the buckers from partial load to overload become obvious.

6. CONCLUSION

First measurement have demonstrated that the intention for this new test rig have proved to be right.

On the test rig it is possible to demonstrate the use of PIV in the field of hydraulic machinery. The flow in the runner at different operation points can be demonstrated. Thus the students will get a better impression on the flow phenomena in radial pump impellers.

The design of a rather simple radial runner enables the students to calculate the flow for this runner using CFD and to compare their results with measurements. They realise the possibilities of numerical calculation and flow measurement.

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Authors:
Dipl.-Ing Bernhard List, Vienna University of Technology, Institute for Waterpower and Pumps, Karlsplatz 13, 1040 Wien, Austria, phone: +43 1 58801 30514, fax: +43 1 58801 30599, e-mail: bernhard.list@tuwien.ac.at
Dr.Josef Prost, Vienna University of Technology, Institute for Waterpower and Pumps, Karlsplatz 13, 1040 Wien, Austria, phone: +43 1 58801 30513, fax: +43 1 58801 30599, e-mail:: jprost@pop.tuwien.ac.at