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EFFICIENCY MEASUREMENT, CONTROL AND EVALUATION

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Abstract: At the Institute for Waterpower and Pumps we use PC-aided measurement and controlling on a test rig for pelton turbines. The results of the measuring are the efficiency hill (a 3D-surface over the operation range for the turbine). A new method for evaluation this efficiency characteristic from the measuring data was developed. The paper reports on the test rig and the software developed for control, measurement and evaluation.

Keywords: efficiency measurement ,PC-aided control and measurement, pelton turbine

1 INTRODUCTION

At the test rig for Pelton turbines at the Institute for Waterpower and Pumps all kinds of operating conditions can be researched. The best way to evaluate a lot of measuring data is to represent it graphically. Therefore we have developed a new method to present the efficiency hill for turbines in a 3D-Surface.

2 TEST RIG, CONTROL AND DATA ACQUISITION

2.1 Pelton turbine test rig

At our test rig horizontal Pelton turbines with a pitch diameter up to 450 mm by heads up to 150 m is can be tested. The head for the turbine is produced by two pumps (parallel and/or serial operation). They are powered by speed regulated DC-motors. The DC-motor-generator for the Pelton turbine has a maximum power of 87 kW an a speed range of 0-3000 min^{-1}. The speed of the pump (head for the turbine) and the speed of the turbine can be controlled manually or automatically by PC. The followed picture shows our test rig. For more details of the test rig see [1 or 2].

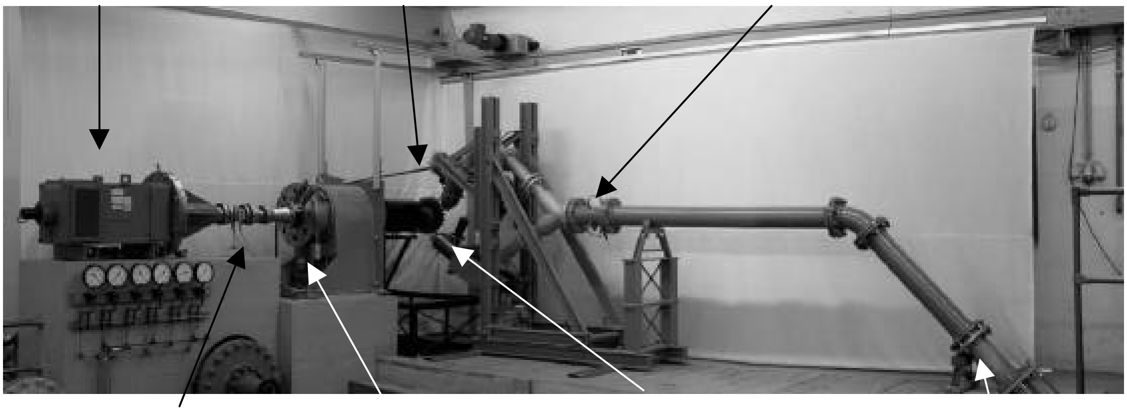

Figure 1. Pelton test rig with point of measurement

The main measured value for the efficiency evaluation are the hydraulic input- and mechanical output power. Pressure p_1 and flow Q represents the input power, torque M_D, speed n and reaction force F_R of the bearings represent the output power.

2.2 Control and data acquisition

Prerequisite for control and data-acquisition on the test rig is the use of standard PC and standard software tools to limit the costs. Therefore the system has been realized with two independent PC's, one for control the other for measurement. The followed figure shows the principal scheme.

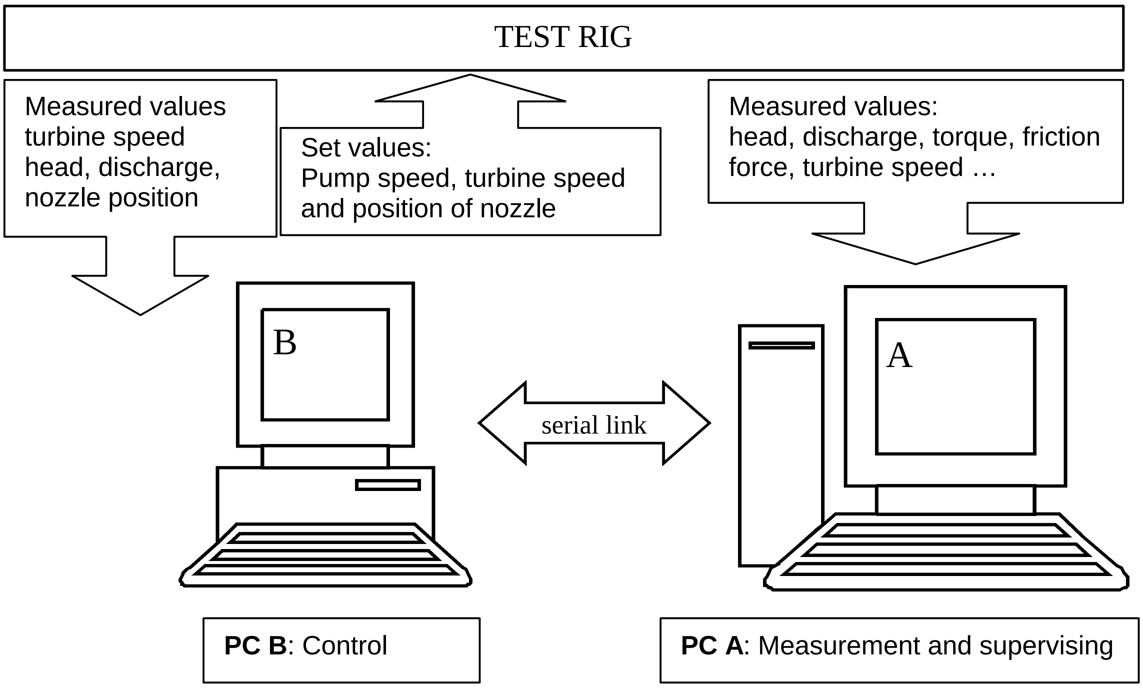

Figure 2. PC-scheme for control and measurement

All measured physical values are converted by transducers and amplifiers to voltage values. Therefore all values can be taken by the PC's, which are equipped with multifunctional I/O Boards with A/D Input, D/A Output and DIO. The use of this configuration gives us the opportunity for an automatic measurement over the whole range of operation of a turbine. The programs needed for both PC are developed by the use of TestPoint™, a Software tool for data acquisition from CEC. The jobs are shared to the two PC as follows.

All points of operation must be feed by an user to the PC A (measurement and supervising). Then the whole measurement will be done automatically. First step is the calculation of the discharge, head and speed of the turbine according to the desired point of operation. This values are the input for PC B (control) over the serial link (RS232). From these values the control software calculate the set points needed for the nozzle, the DC-motors of the feeding pump and DC-motor-generator of the turbine. This values are the input for the test rig, the response are measured. The developed control software can be switched between a PID like or step by step algorithm. If the test rig is stabile, PC A is informed by PC B over the serial link and PC A continues his job with the next step. There is acquire of all values from the test rig, calculate and display of desired values (e.g. efficiency…) record the measured and calculated data. Then the program continues with the next point of operation and the procedure, described above, will be repeated.

The PC B regulate the stability of the desired values until the next preset value are reached over the serial link.

3 EVALUATION

When the measure of the whole range is done we got a file with the representative values for the turbine (head, discharge, speed, torque and efficiency). Standardization of this data gives us an array of specific speed (n_{11}) ,specific flow (q_{11}) and efficiency (η). The efficiency then is a function of the independent variable n_{11} and q_{11}.

$$h = f\left(n_{11}, q_{11}\right) \tag{1}$$

The traditional way to get the efficiency hill is to interpolate the formula above in two steps with linear interpolation in the direction of one variable with constant of the other variable.

The new method get a surface in three-dimensional space, which must be found by interpolating discrete data points that scattered in plane of variables.

$$w(x) = \sum_{j=1}^{N} a_j G_2\left(x - x_j\right) \qquad (2)$$

The basic function are a linear combination of green functions of the biharmonic operator. These basic function are of rotational symmetry and are centered on each data point. The coefficient a is calculated by solving a system of linear equations. This basic functions results in a surface that passes through all data points.

Because the data contains a random error the interpolation method has to be modified to get a smoothed surface that pass not exactly all data point. Therefore the function G get a constant value added.

$$G_c = c + G_{2(x)} \qquad (3)$$

With this estimate we get a minimizations from the sum of the squared deviations which corresponds with the known statistical variance of the measured data.

The calculation of the coefficient depends on the distances of the data points to each other $(x\text{-}x_j)$ The magnitude of the variable n_{11} and q_{11} differs usually. Therefore it is necessary to scale the data by a certain factor, otherwise the method would add artificial ripples to the surface. The optimal scaling factor can be found by iterative minimization of the ripple functional. For detailed theory see [3]. The program is developed by use of MATLAB™ , a program system for numerical calculation.

4 PRACTICAL APPLICATION

The next figures shows some examples of the results from the developed method. The program consists essentially of two parts. The first part calculates the specific data as well as the actual interpolation. The result is a vector of coefficients describing the three-dimensional surface which the measured values represent. The second part contains the different display possibilities of the interpolation function. These are three-dimensional surface, efficiency hill diagram and q-η curve without a new calculation. Figure 3 shows a perspective representation of the three-dimensional surface. The black dots on the surface represent the measured values. The model is lightened with an arranged source of light to emphasize the roughness. The user has the oportunity to rotate the model.

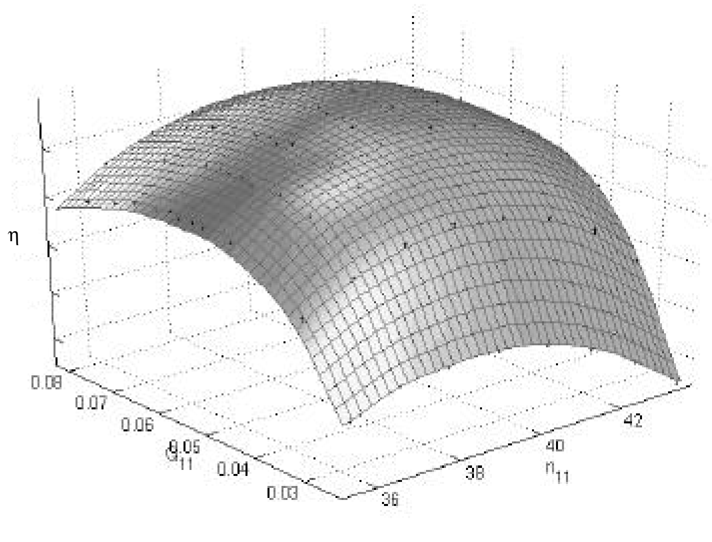

Figure 3. Perspective view of efficiency over n_{11} and Q_{11}

The followed figure shows the efficiency hill diagram, a standard mode of displaying for the efficiency of a turbine for the whole range of operation. The distance between the lines (equal efficiency) is userdefinable. The efficiency can be plotted in absolut or relivative values.

Figure 5 shows the η q diagramm, a diagram which corresponds to the operation range of a real turbine with nearly constant head. The curve is calculated as a cut through the interpolation surface.

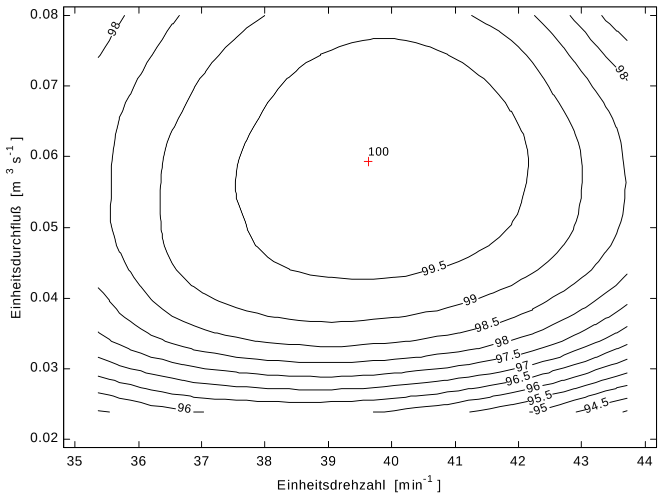

Figure 4. Efficiency hill diagram

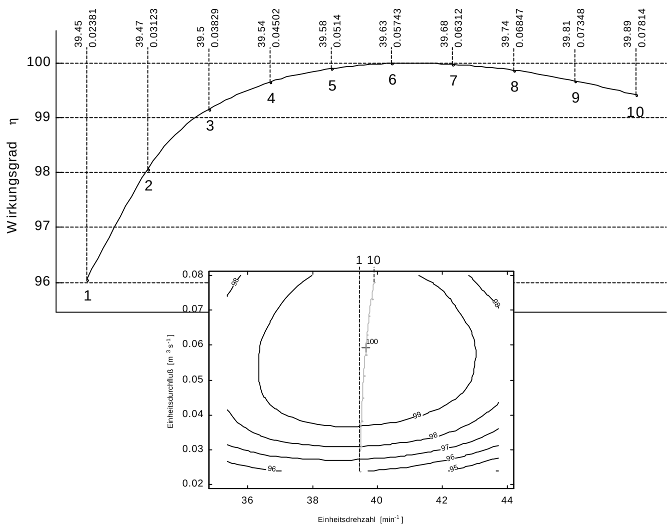

Figure 5. η-q diagram

5 CONCLUSION

With this new developed software and the test rig we can do a good job in education of students or researching

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