PRESSURE DISTRIBUTION IN WATER SPRAY

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ABSTRACT

This article describes the system for measuring the pressure distribution in water spray. The system is used as a test bench for cooling water nozzles. It consists of two-axis support with mounted piezoelectric pressure sensor, support engine drive unit, charge amplifier and PC with data acquisition. The article contains a short description of the test bench and an overview of the software created in LabVIEW 7.0.

1 INTRODUCTION

The Lechler Company, a great German nozzle manufacturer, asked for developing a test bench for their products. In the Laboratory of Heat Transfer and Fluid Flow, Faculty of Mechanical Engineering, BUT, this test bench was constructed. My job was to create a control program for controlling the nozzle measurement with the test bench.

The creation of this system is the first step on the way to find a correlation between pressure distribution in the spray and heat transfer coefficient distribution. In current state, the heat transfer coefficients must be obtained using “hot measurement” – tested nozzle must be used to cool hot metal plate while measuring the temperatures in several points under the plate surface. From the data acquired by such measurement, the values of heat transfer can be calculated using inverse analysis. This method was created by Dr. Horský from Laboratory of Heat Transfer and Fluid Flow and is described in his habilitation work [1].

But such measurement is very time and energy consuming. A great amount of energy is used to warm the metal plate up and a great amount of water is required to cool the plate down again. The cooling process must be precisely controlled to keep the cooling curve inside specific limits. It is also necessary to change the metal plate from time to time, because the periodic heating and cooling changes the internal structure of the plate and so influences the heat transfer coefficients.

It would be much easier to perform a static spray measurement without heating anything. But first, the correlation must be found. This test bench should help in this task.

The function of the system is to measure the pressure distribution in selected height of the water spray. The measurement is automated – the user must only select the pressure sensor sensitivity and measurement trajectory and then start the process.

2 SYSTEM DESCRIPTION

The test bench consists of two-axes (*xy* plane) support powered by two 3phase stepping engines with incremental encoders, engine control unit controlled from PC by serial cable (both from BERGER-LAHR), piezoelectric pressure sensor mounted on the end of the shorter axis, charge amplifier for the sensor - also controlled from PC by serial cable (both from KISTLER), and PC with two PCI data acquisition cards (from National Instruments - NI) - analog input NI PCI-6034E card for acquiring the voltage output from Kistler charge amplifier and counter-timer NI PCI-6601 card for measuring the support position indicated by incremental encoders.

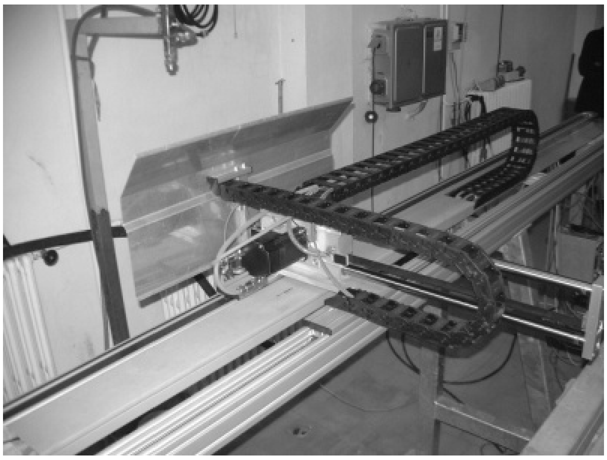


Fig. 1: *Two-axes support and tested nozzle (upper left corner)*

Fig. 2: *Pressure sensor mounted on the shorter axis and the tested nozzle*

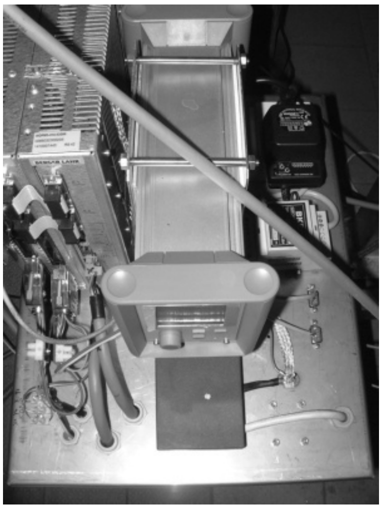


Fig. 3: *Engine control unit (left) and charge amplifier (center) in opened device box*

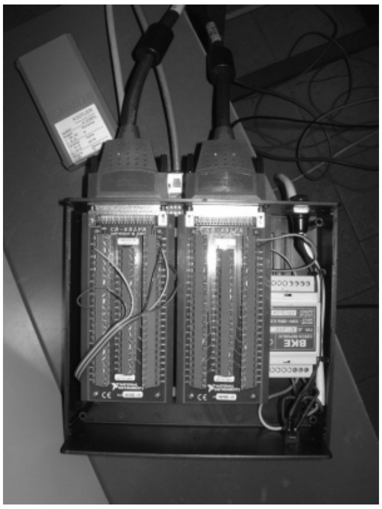


Fig. 4: *Data acquisition cards I/O connector blocks*

3 SOFTWARE

The control software for the test bench is completely created in LabVIEW 7.0 [2], a graphic programming environment from National Instruments. The block scheme of the program is on the figure 5.

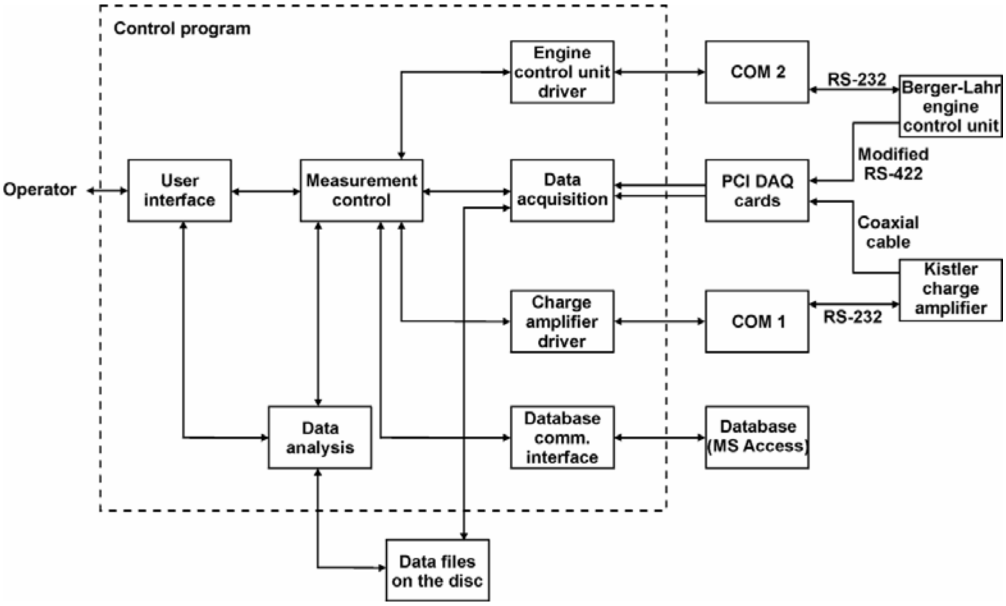


Fig. 5: *Program block scheme*

3.1 BERGER-LAHR ENGINE CONTROL UNIT DRIVER FOR LABVIEW

For controlling the engine control unit, it was necessary to understand the Berger-Lahr communication protocol [3] and implement it into the LabVIEW - to create the engine control unit driver for LabVIEW.

3.2 KISTLER CHARGE AMPLIFIER DRIVER FOR LABVIEW

The Kistler Company has created the charge amplifier driver for LabVIEW, unfortunately the driver works correctly only with older LabVIEW versions. Therefore, it was necessary to adapt this driver to work also with 7.0 version using the communication protocol description in [4].

3.3 DATABASE COMMUNICATION INTERFACE

The measurement data are stored in text files but the measurement results and settings are stored in the database (MS Access format), so the program contains the database communication interface (created using NI Database Connectivity Toolset v 1.0.1) to perform this task.

3.4 MEASUREMENT CONTROL

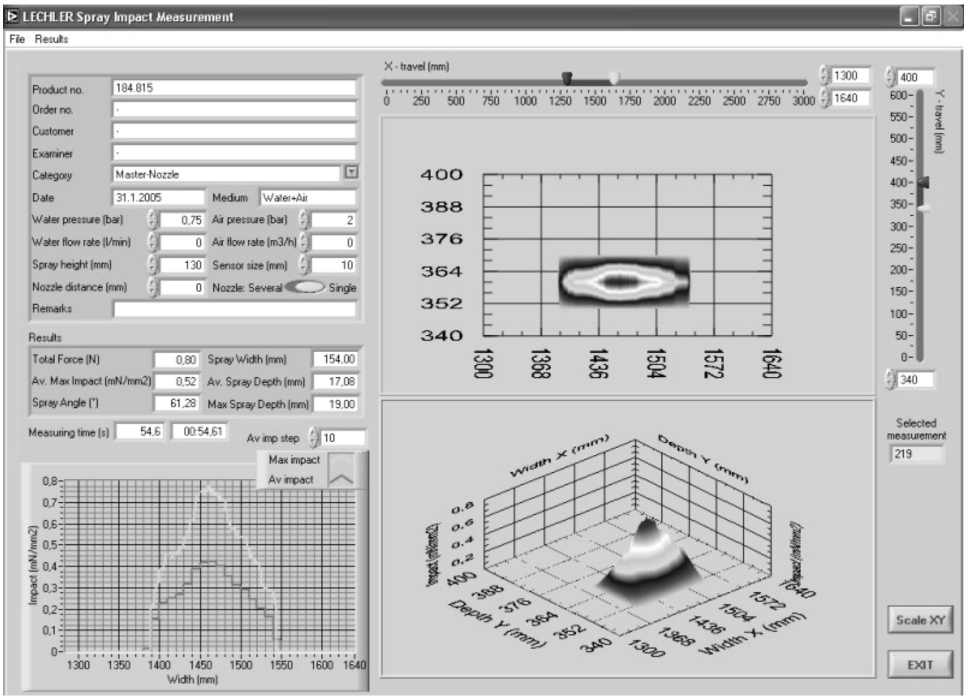
This part is responsible for maintaining the communication with the engine control unit, the charge amplifier and database during measurement and in measurement preparation phase. It also controls the support movement trajectory (there are four different types of movement trajectories implemented).

3.5 DATA ACQUISITION SUBROUTINE

The data acquisition subroutine reads position from incremental encoders and voltage from Kistler charge amplifier. The voltage is converted to the pressure and all values are saved into text files on the hard disc. For communication with both data acquisition cards, NI DAQmx drivers are used.

3.6 DATA ANALYSIS

The acquired data must be passed through the data analysis block to compute following spray parameters: total force [N], average maximal impact = mean value of maximal pressures found in all measurement lines [mN/mm^2], spray angle [°], spray width [mm] and spray depth [mm]. In this part, two 3D graphs representing the pressure distribution in the spray are also drawn onto the main panel together with one 2D graph showing maximal and average impacts in the spray (see figure 6).



LECHLER Spray Impact Measurement

Product no. 184.815
Order no. -
Customer -
Examiner -
Category Master-Nozzle
Date 31.1.2005
Medium Water+Air
Water pressure (bar) 0,75
Air pressure (bar) 2
Water flow rate (l/min) 0
Air flow rate (m3/h) 0
Spray height (mm) 130
Sensor size (mm) 10
Nozzle distance (mm) 0
Nozzle: Several Single
Remarks

Results

Total Force (N) 0,80
Spray Width (mm) 154,00
Av. Max Impact (mN/mm2) 0,52
Av. Spray Depth (mm) 17,08
Spray Angle (°) 61,28
Max Spray Depth (mm) 19,00
Measuring time (s) 54,6 00:54,61
Av imp step 10

X - travel (mm) 1300 1640
Y - travel (mm) 400 340
Selected measurement 219

Fig. 6: *Program main screen - measurement results*

3.7 USER INTERFACE

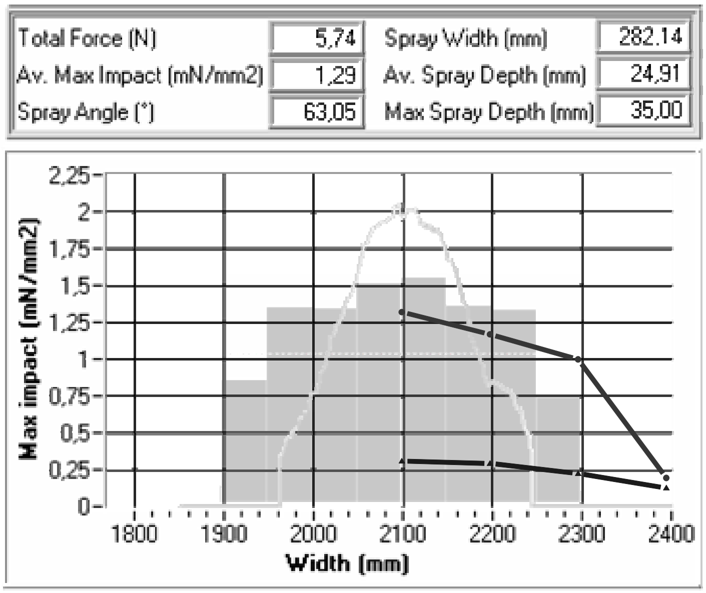
User interface block maintains all communication with user contains windows for measurement settings (velocities, start and stop positions, trajectory, other settings), charge amplifier settings, database manipulation, analysis settings, print window etc.

4 CONCLUSION

The system was successfully tested on several Lechler cooling nozzles including air mist nozzles and was recently transferred to Lechler nozzle testing laboratory in Metzingen, Germany to perform more tests and finally to replace their old version of the test bench. I am currently awaiting their comments and I am ready to make necessary modifications.

The measurement repeatability cannot be determined easily because the spray is not stationary in time. Each measurement of the same nozzle under the same conditions gives slightly different results, the approximate difference is not higher than 5 %. There are several factors influencing the results of the measurement, especially the threshold level used to eliminate all samples smaller than user defined value (fraction of the max value in the measurement).

The results are corresponding to the values obtained by the older test bench (smaller measurement area, no position information, only static measurement, tensometric sensor principle). Figure 8 shows the maximal impact curve, water distribution and HTC (heat transfer coefficient - under and above Leidenfrost point) of one measurement. The correlation between the water distribution and maximal impact is evident, the correlation between the maximal impact curve and HTC has to be found.



Total Force (N) 5,74
Spray Width (mm) 282.14
Av. Max Impact (mN/mm2) 1,29
Av. Spray Depth (mm) 24,91
Spray Angle (°) 63,05
Max Spray Depth (mm) 35,00

Fig. 7: *2D graph showing maximal impact, water distribution and HTC*

REFERENCES

[1] Horský, J.: Experimentální stanovení okrajových podmínek pro numerické modely ochlazování a tváření kovů za tepla, Brno, 2001, 166 s, Habilitační práce na FSI VUT v Brně

[2] LabVIEW: User manual.National Instruments, Austin (Texas), 1998

[3] On-line Command Processing and Upload/Download via Serial Interface for WDP3-014 and WDP3-018 and Series 300 Units. Berger-Lahr, Lahr (Germany), April 1997

[4] Charge meter 5015A – User manual, Kistler Instrumente AG, Winterthur (Switzerland), 2003

[5] DAQ - 6601/6602 User manual, National Instruments, Austin (Texas), 1999