12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25−27, 2002, Zagreb, Croatia

ULTRASONIC MEASURING CHAMBER FOR EXPERIMENTAL SYSTEM USING HF ULTRASONIC SHEAR WAVES

Rudi Čop[1], Mladen Maletić[2], Siniša Fajt[2]

[1]Faculty of Maritime Studies and Transport, Pot pomorscakov 4, 6320 Portorož, Slovenia
[2]Faculty of Electrical Engineering and Computing, Unska 3, 10000 Zagreb, Croatia

Abstract - While developing a measuring chamber for the ultrasonic determination of the kinetics of hydration my interest concentrated on its quality of measurement. This reqoired the testing of its stability of temperature and humidity longitudinally. The testing was conducted using the HP VEE graphical programing language for standard instrumental control. The graphical programing language used is based on PC hardware and the Windows programing environment which decreased the development time by an impressive 60 percent. The development program offers traceable data connected to the ultrasonic measuring chamber, which can then be quickly accessed for further use.

Key words: measuring chamber, graphical programing language, kinetics of hydration.

1. INTRODUCTION

This paper describes instrumentation and the new method of measuring the cement mortar hydration kinetics by using HF ultrasonic shear waves. The advantage of using such method is that the measured data would be obtained quicker than by the standard methods of measuring strength of concrete. [1]. Applications of this measuring method can be seen in:

- continuous monitoring the process of the cement-paste thickening,
- monitoring the cement quality,
- continuous monitoring the process of the cement-slurries thickening,
- defining the time of cement-slurries readiness for a treatment, and the time of cement-slurries binding,
- monitoring the quality of the natural and artificial concrete aggregate,
- monitoring the quality of other concrete admixtures.

The results from the preliminary measurements have shown, that the function of the prototype measuring device had been obstructed by external HF (high frequency) electrical interference and LF (low frequency) electrical interference, from its own power source. Besides, the speed of the ultrasonic wave propagation through a measuring chamber had been influenced by the mechanical forces arising from the tightening of the buffer rod on its holder.

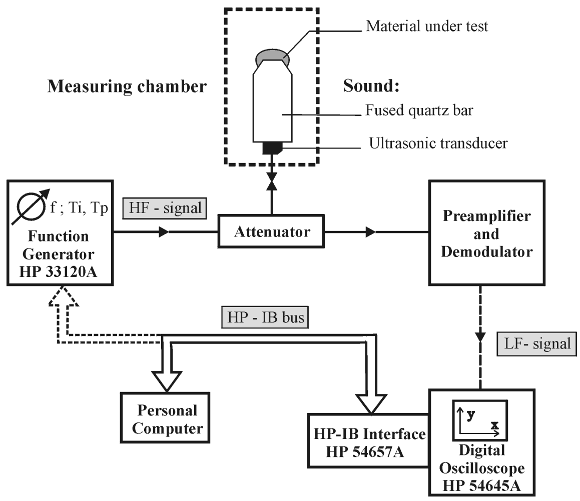

Figure 1: Block Scheme of the laboratory experimental setup for the cement mortar thickening time measurements by defining the amplitudes of the first two reflected HF ultrasonic shear waves.

2. CONCLUSIONS AT COMPLETION OF THE PRELIMINARY MEASUREMENTS

1. The temperature, a principal factor governing hydration, is to be monitored and held constant with accuracy of less than 1 %. Only by helding the hydration temperature constant the consistency of the measurements can be achieved.
2. The moisture is also important factor for the sample strength at any given age, and that is why the humidity in the measuring chamber has to be held within the defined limits. One of our objectives is a comparison of the hydration kinematics measurements results, which demands a relative humidity in the measuring chamber to be constant. The most suitable humidity value for such measurements is near 90 %.
3. Every particular measurement of a cement-paste thickening time took 48 hours. An accuracy of the measurements must be equal or less than 0,5 %. Therefore, the required degree of the instrumentation accuracy was to be quite high and additional stable in the course of time and within the temperature interval from 10 °C to 40 °C.

3. CHOICE OF A NEW EXPERIMENTAL SETUP

The starting point for a choice of the suitable experimental setups for the cement paste thickening time measurements was an evaluation of the prime costs for batch production of the industrial prototype of the ultrasonic testing equipment, which would be specialized for cement pastes.

We have also sent the inquiries to the manufacturers of the industrial universal ultrasonic testing equipment with the frequency above 1 MHz [2]. Should we used an universal ultrasonic instrument the additional device should be coupled to the ultrasonic instrument, which would be able to evaluate the second reflection of the HF ultrasonic shear wave.

Getting the quotations from the manufacturers of the measuring devices [3], we where able to compare its technical characteristics and include them in the final Block Scheme of the experimental setups for the cement mortar thickening time measurements (Fig. 1). After that we have sent the orders for purchasing the appropriate measuring devices.

Table 1. Comparison of the purchase and modification costs of the ultrasonic testing equipment.

Record of Expenses	Ratio / %	Price / %	Modification / month	Probability / %
The Main Material Expenses	52,1	-----	-----	-----
Prototype Experimental Setup	182,8	234,9	12	30
Industrial Experimental Setup	242,7	294,8	4	80
Laboratory Experimental Setup	100,0	152,1	6	60

We have evaluated the time necessary for working out and modification of each experimental setup, to the level needed for starting the laboratory measurements. Finally we have evaluated the probability that each of them would work consistently during the scheduled time.

The total expenses for the experimental setup for ultrasonic measurements are encompassing not only the purchase costs for the measuring devices and the software, but also the main material expenses. These are purchase costs for the ultrasonic probe and costs for working out of the measuring chamber. Besides, to perform its tasks all three chosen experimental setups needed a computer. The completion of these setups needed the computer programming, and this is most complicated in the case of the prototype measuring setup, as the data acquisition software and the graphics data processing software should be completely reprogrammed. Whereas, the experimental setups composed of the basic measuring devices, needed the additional application programs based on the graphic language.

We have decided to purchase the laboratory experimental setup, as according to the quotations its costs were the lowest (Table 1). The purchased experimental setup could be remodeled for different types of measurements, as it is composed of the basic electronic measuring devices. In addition, the analysis of the signals in the frequency domain FFT (fast Fourier transform) could also be made with this setup. The applied frequency was not to exceed 5 MHz and this was limited by the technical characteristics of the function generator HP 33120A. In our laboratory we have worked out an attenuator and put it between the function generator output and the ultrasonic transducer which acts like two-way communications device (transmitter and receiver). The ultrasonic transducer sends the reflected wave back through the attenuator which is linked to a HF (high frequency) preamplifier & demodulator.

4. EXPERIMENTAL SETUP COMPOSED OF THE COTS ELECTRONIC INSTRUMENTATION

The manufacturer of the measuring equipment has performed a comprehensive analysis of the instrumentation costs, which has encompassed numerous users of such experimental setups [4]. This analysis has revealed that the instrumentation costs are relatively low in comparison with the software costs. That is why, for us, the quality and a level of accuracy of the measuring devices have not been enough to make a choice, but equally important were software and possibility of its modification to suit our particular applications, system integration, continuous support and upgrades.

We have expected that the designed experimental setup for hydration time measurements by the ultrasonic shear waves, would assure shortening and simplification of materials testing. This experimental setup has been designed to match the following conditions:

- The system integration should be easy, without or with little help from manufacturer.
- The experimental setup should be easily remodeled for the different types of measurements.
- It should be automatic and should be able to continuously monitor measured data with satisfactory consistency within the scheduled time.
- It should enable static and dynamic measurements.
- The data should be collected, stored in a database and processed in a various ways.
- It should enable modeling and defining the optimal parameters.
- It should be suitable for issuing a final report.

The most of the equipment used for the experimental setup has been taken from COTS (Commercial Off The Shelf System). We have linked the two open systems together: hardware and software system. The testing and monitoring software are designed in Windows environment for the PC hardware. Such system enables very fast development of the testing techniques. It makes available the numerous data, which can be easy reached. The data can precisely describe a measured sample, and they are suitable for data processing, image processing or simulation modeling.

We have chosen digital multi-meter HP 334401A, function generator HP 33120A and digital oscilloscope HP 54600B or HP 54645A. All these measuring devices can communicate on an interface bus HP-IB directly, only for digital oscilloscope the additional module (HP-IB interface HP 54657A) was needed. The instrument's reliability and longlife on market, were two main criteria for purchasing it. As our system has been composed of the basic measuring devices, it has had all advantages of a modular system and that is fast and easy modification and configuration.

To implement configuration we need the visualization of the measuring devices. For this purpose we have developed an application program on the basis of the graphical programming designed for HP VEE. Such graphical language is applicable in the different types of demanding measurements, as in: research work - for evaluation of research achievement, production - for final testing of products, delivery - testing the delivered products.

The chosen experimental setup enables very fast remodeling to a system for different types of measurements and at the same time the correspondent software can be designed, what is its greatest advantage. This is possible due to program library where all programs are collected and made available for every time use. Therefore, our development time for every new experimental setup has been a great deal shorter. The same thing was reported by the users of the similar systems in industry [5].

5. GRAPHICAL PROGRAMMING LANGUAGE

Graphical programming language HP VEE enables the two types of accesses to a measuring device: through its virtual control panel on the computer screen (through its drivers), or directly through I/O object. The first type enables easiest work and fastest development of the application program [6]. The second type requests some more work and development time, however provides very fast execution.

6. THE TESTING SYSTEM FOR VERIFICATION THE QUALITY

On the basis of the conclusions from the preliminary measurements we have made the measuring chamber (Fig. 2), which would match the conditions of the industrial laboratory and be used for standard measurements. According to the standard (CSA Standard A5, ASTM Standard C190) for aging of the standard cement mortar test tube, we have chosen the external conditions. Whereas the measuring chamber temperature is stabilized by water circulating through its exterior surface, monitoring of the temperature and humidity in the measuring chamber has been necessary only at the start of the measuring and as checking at varied time intervals.

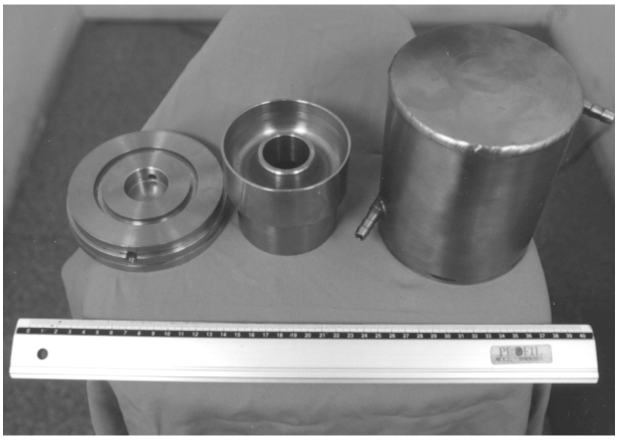

Fig. 2. Dismantled ultrasonic measuring chamber for hydration kinetics measurements by ultrasonic shear waves.

The application program development, with the graphical programming language, depends on the technical knowledge of the researcher who makes such program. If the researcher has a lot of knowledge about measuring equipment, he can be very creative in his work. Graphical programming language enables simple and intuitive way of writing programs for measuring and monitoring systems. (Fig. 3).

The completed experimental setup has been verified as follows: first we have measured the known electrical data and then output voltage data, at the output of the probe for measuring temperature and humidity; this probe transforms temperature with an accuracy of 0,5 °C and relative humidity with an accuracy of 2 %, to an output electrical signal from 0,5 V to 2,5 V. The results of the ultrasonic measurements have shown applicability of the experimental setup for temperature and relative humidity measurements, during a continuous period of 120 h.

7. CONCLUSION

This paper has demonstrated the course and the results of the preliminary measurements at hydration temperature and at cement paste hydration kinetics by the ultrasonic shear waves. We have designed the application program Theta written in programming language C++ to implement experimental setup for chosen measurements. For defining the ultrasonic measuring chamber characteristics we have designed the similar application program on the basis of the graphical programming designed for HP VEE. The latter program took us 40 % of the time spent for designing the application program Theta. The application program Theta for the chosen measurements have been verified and proofed as applicable and accurate for longer periods of continuous work as well. The experimental setup for hydration kinetics measurements has been composed of the basic devices and therefore it can be remodeled to the new systems for different types of measurements, what is one of its significant advantage. This fast remodeling is also enabled by the program library which memorizes all previously used programs and makes them available for the future applications. For these reasons we expect to shorten the development time significantly and to attain the objective of this research, and that is development of the Experimental setup for measurements at hydration kinetics by ultrasonic shear waves.

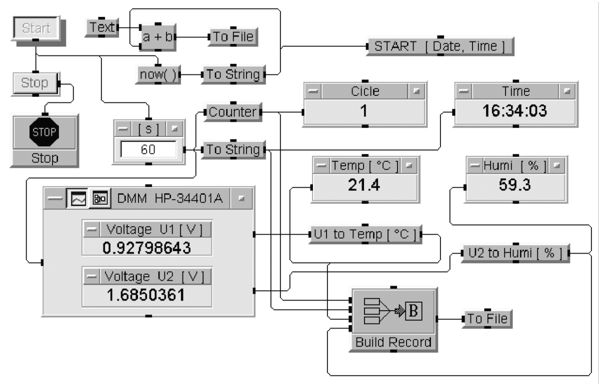

Fig. 3. A basic part of the application program, written in the graphical programming language, for measurements at characteristic of the ultrasonic measuring chamber.

REFERENCES

[1] Model 5800PR: Computer Controlled Ultrasonic Pulser-Receiver. (USA): Panametrics, September 1993.

[2] Preamplifier Set-ups. NDT Applications, Number 14, Rev.'90. (USA): Panametrics; NDT Division.

[3] UT340 ultrasonic pulser receiver system: Data acquisition software for NDT. Mississauga (Canada): UTEX Scientific Instruments, 1997.

[4] G. Colton, Automative test-putting the brake on hidden cost. Applications. Test System News, Loveland (USA): Hewlett-Packard, december1997, no. 7.

[5] S. Hoog, VXI – seamless solution for welding machines. Applications. Test System News, Loveland (USA): Hewlett-Packard, September 1998, no.9.

[6] R. Helsel, Graphical programming: a tutorial for HP VEE. Hewlett-Packard professional books. Upper Saddle River (USA): Prentica Hall PTR, 1995.