Multi-Pass Rheometer using National Instruments LabVIEW and Real-Time Module

The Challenge: To automate the measurement of complex fluids, improve machine control performance and accuracy, and to maintain a user interface that allows extensive reporting techniques.

The Solution: Combining the National Instruments LabVIEW graphical programming environment and FPGA technology with desktop computers to improve the processing, control performance and determinism of the MPR (Multi-Pass Rheometer).

LabVIEW Real-Time module and FPGA is at the core of the MPR system. The deterministic environment is essential to MPR's precise calculations

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In 1995, Professor Malcolm Mackley and engineers at Cambridge University's Department of Chemical Engineering and Biotechnology constructed the world's first Multi-Pass Rheometer (MPR): a two-piston capillary solution to the inflexibility of existing rheometers. This high precision machine combined the testing flexibility of a rotational rheometer with a piston driven device, creating new modes of rheometric experimentation. However, uncontrolled rapid velocity changes caused a consequent inaccuracy in results. Omiga Technology developed and provided a complete new control system which has provided improved control provided greater experiment flexibility and consistent data.

Constructing the MPR using LabVIEW

Development of the MPR focused on improving three core areas: accuracy, flexibility and speed. Using LabVIEW engineers designed a digital control system that broadened the functionality of the machine and the capability of the analysis software. Piston control was redesigned to produce a smooth movement and with waveforms now generated to achieve piston velocity in excess of 200 mm/second, the resolution of results has also been improved. With suitable hardware, the MPR system has the potential to run at speeds well in excess of 200 mm/second. The current system has been tested up to 500 mm/second piston velocity, but the current hydraulic system can only sustain 200 mm/second for long durations. This could be increased with a revised servo system which may be considered in the near future.

NI technology is at the heart of the new MPR system. The deterministic environment of the LabVIEW Real-Time operating system is crucial to the successful functioning of the MPR, since this platform is unlike other pre-programmed systems, such as Windows, which do not have the reliability of Real-Time software. LabVIEW is the platform used for all areas of MPR's digital control system, user interface and data acquisition.

The Real-Time system is used in conjunction with LabVIEW Field-Programmable Gate Array (FPGA) to drive the MPR's servo system. Only the Real-Time and FPGA modules can generate the required speed for controlling and returning data, since it is the only hardware capable of operating the rotary and oscillatory operations necessary for the MPR's specialised testing. The FPGA and Real-Time architecture enables the generation of high frequency waveforms and PID control that can control a signal of 50 Hertz.

Omiga then redesigned the MPR's existing data acquisition and control architecture, which has been replaced with a TCP/IP layer to stream data between the Real-Time system and the Microsoft Windows control and analysis computer.

This mode exploits Windows-based software to provide the MPR with a user-friendly operating system. The extensive compatibility of popular PC-based software also offers the benefit of readily available analysis software such as Microsoft Excel.

Significantly, data synchronisation allows for direct analysis during testing. Additional instruments can also be added, with the current system having direct control of the system's heat-cooler pack for temperature sweep testing.

Following a development and production program lasting five months, the MPR was tested by Cambridge University engineers with polymer substances. Omiga developed the MPR's complex test requirements with Dr. Simon Butler, Senior Technical Officer in the Department of Chemical Engineering and Biotechnology at the University of Cambridge. The MPR was tasked to complete continuous multipass, oscillatory, cross-flow and single shot tests. Using calibration oil and other polymer substances in developing the system, the successful operation of the MPR proved the feasibility of the Real-Time concept and FPGA solution.

Using the MPR

With a maximum shear rate of $160{,}000s^{-1}$ and an operating temperature that ranges between -20 and +200 °C, the MPR is capable of investigating a vast array of materials, rheological parameters and reactions.

Fluid is pumped into an inlet valve and, once saturated, two 10mm diameter servo-hydraulically driven pistons compress the sample. These pistons put the fluid under controlled pressure and measurements of compressibility, maximum wall shear strain, shear storage/loss modulus and apparent and complex viscosity are then recorded using LabVIEW.

Advantages of a System based on NI Software and Hardware

As a National Instruments Alliance member, Omiga Technology base 90% of their systems on NI equipment. The FPGA hardware was essential to establish the necessary operating speeds, whilst the deterministic qualities of the LabVIEW Real-Time module were vital for reliable control and data capture.

The MPR uses the C Series strain gauge bridge, thermocouple and digital I/O modules with the interface module expansion bus C Series 9151 chassis to provide signal conditioning for the MPR's pressure transducers and thermocouples. The thing that sets National Instruments software and hardware apart from other technology is that NI equipment is quick to set up and easily maintained when compared to other vendors. It is also important that the LabVIEW FPGA module creates standard VHDL code, allowing the integration of existing IP into your application. With this flexible technology the NI platform secures the future development of the MPR.

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