Endurance test bench for hydraulic components with NI DIAdem and EtherCAT

Abstract

Ever-increasing customer demands regarding the quality of industrial hydraulic cylinders are resulting in a growing testing workload even during the development phase. This also applies, in particular, to fatigue strength. As the parameters of such tests vary considerably due to different applications and designs, automation hardware and software based on standard components was developed at the customer's request for the modernisation of an endurance test bench; this system can be flexibly adapted to new test tasks. Key elements here are the NI DIAdem application software and the high-speed industrial Ethernet standard EtherCAT.

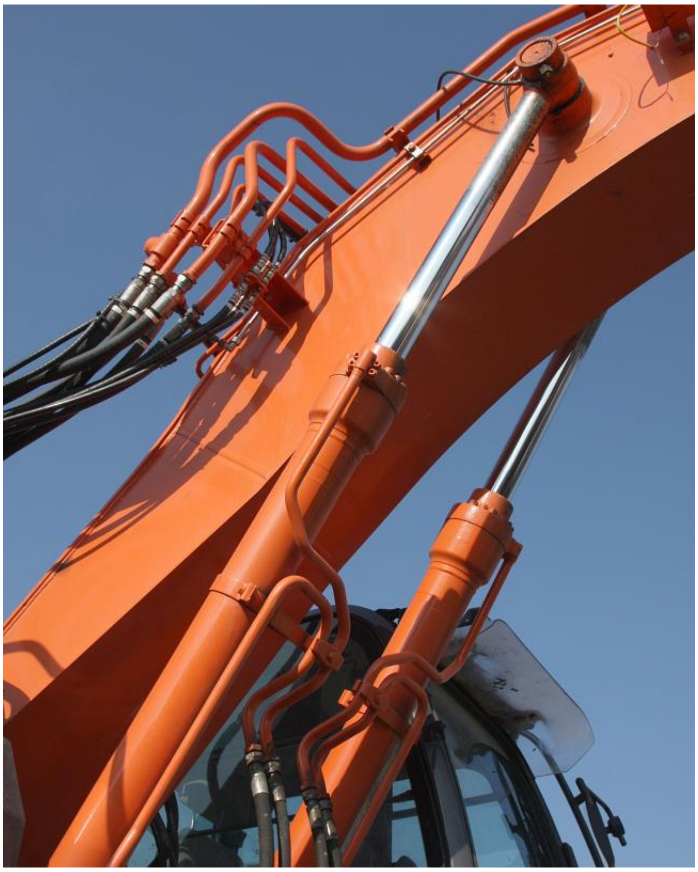

Figure 1: Hydraulic cylinder in use on an excavator (Holger Müller)

Adaptable thanks to standard software

Hydraulic cylinders for industrial applications must meet the most stringent requirements, not least in terms of their service life. For this reason, the utmost attention is paid to this aspect right from the development stage of such components. And, of course, new designs must be tested for fatigue strength before the product can be put into series production. To this end, test departments have specialised test benches that enable components to be subjected to long-term loading in order to determine their service life behaviour in terms of mileage, operating hours and load cycles. Furthermore, such facilities allow system tests to be carried out with the introduction of disruptive influences in order to simulate fault conditions and investigate their effects and possible remedies.

A leading manufacturer of hydraulic cylinders was due to modernise one such development test bench. Whilst the hydraulic assembly can largely be reused, the measurement and control hardware and software need to be replaced. Spare parts are no longer available for the proprietary measurement and

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control system previously used, and some components are already defective. Furthermore, the available sampling rates are no longer sufficient for current tasks and, above all, the lack of configurability limits the range of possible applications.

The requirement is therefore to implement a system using standard components available on the market that enables endurance tests – i.e. cyclic loading of test specimens – over several months, which corresponds to approximately 10 million load cycles in typical applications. A configurable sampling rate of up to 2 kHz per channel is to be achieved, whereby each sampling channel must be configurable via software for different signal and sensor types.

Due to their lower susceptibility to signal interference, only bus systems are to be used for signal exchange between the components. Furthermore, based on experience with the legacy system, it is required that the software be open-source and modifiable by users, and that it facilitate simple data exchange between test personnel and developers.

A system comprising three independent individual test stations, which can be operated and monitored from a central location, is to be implemented. Each test station must be equipped with 16 analogue inputs, two analogue outputs and eight digital outputs. A threshold monitoring function must be implemented for the analogue inputs, which reacts to critical signal conditions with response times of less than 10 milliseconds.

Based on positive experience with other applications, the customer has selected National Instruments' NI Diadem as the application software. NI C-Series modules are to be used as measurement amplifiers due to their wide signal range and good signal quality, whilst Bosch Rexroth HNC hydraulic controllers with a Profinet interface are to be used. This interface is also specified for communication with the hydraulic supply control system.

In order to meet the requirements described, a distributed system is being set up comprising three test PCs (one per test station) and a central control PC for operation and visualisation.

Key component: EtherCAT

The connection between the components – both between the measurement amplifiers and the test PCs, and between the computers themselves – is crucial to the functionality of the overall system. This connection must transmit data at high acquisition rates and in real time in order to ensure the required response times for limit value monitoring. This is made possible by the high-speed Industrial Ethernet standard EtherCAT. Access to EtherCAT is provided via the DIAdem real-time extension developed by müller+krahmer and based on TwinCAT, enabling control and regulation tasks to be implemented optimally. The problem of synchronising different hardware is eliminated,as the data from all bus participants is transmitted in a single telegram. Distributed measurement points also pose no problem, as the Fast Ethernet physical layer allows distances of up to 100 metres between two participants.

Each test PC is therefore assigned an 8-slot EtherCAT slave chassis (NI 9144), which, with the modules inserted, provides the required 16 acquisition channels. Whilst standard master-slave communication is implemented here, a different approach is required for the connection between the control PC and the test PCs, as direct master-master communication is not possible. The computers therefore exchange data with one another via a Beckhoff EL6692 EtherCAT bridge. The acquisition of measured variables from central components, as well as the output of analogue and digital control signals for all test stations collectively, is handled by an EtherCAT slave chassis NI 9144 – equipped with analogue and digital input and output modules – which is connected directly to the control PC.

The Bosch Rexroth HNC100-3X digital axis controllers were not integrated into the EtherCAT system due to their Profibus interface. The devices, which control the hydraulic cylinder axes via downstream 4-way servo valves, are connected to the test PC via Hilscher cifX 70-RE Profinet IO controller cards. The control PC is also connected to the test bench PLC via such a card. The synchronisation of Profinet and EtherCAT signals is carried out in the DIAdem software.

Computers, measurement amplifiers and axis controllers are housed in a single control cabinet. Also installed there are peripheral devices, such as an uninterruptible power supply (UPS), which ensures the safe shutdown of the system in the event of a power failure. Signal cables are routed to the measuring points via a support arm system with appropriate connection technology, to enable the

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simple and secure connection of all sensors and actuators, even with geometrically varied measurement set-ups.

Distributed system – centralised operation

The central operating interface of the endurance test bench is the control PC, which, like the test PCs, is a standard 19-inch PC to ensure that it can be easily replaced if necessary. The test sequences are defined on the control PC, as is, optionally, the initiation of a set-up or test run on the test PCs. In addition, analogue and digital signals are exchanged with the test specimens via the EtherCAT slave chassis, whilst bus signals are exchanged with the test bench PLC via Profinet.

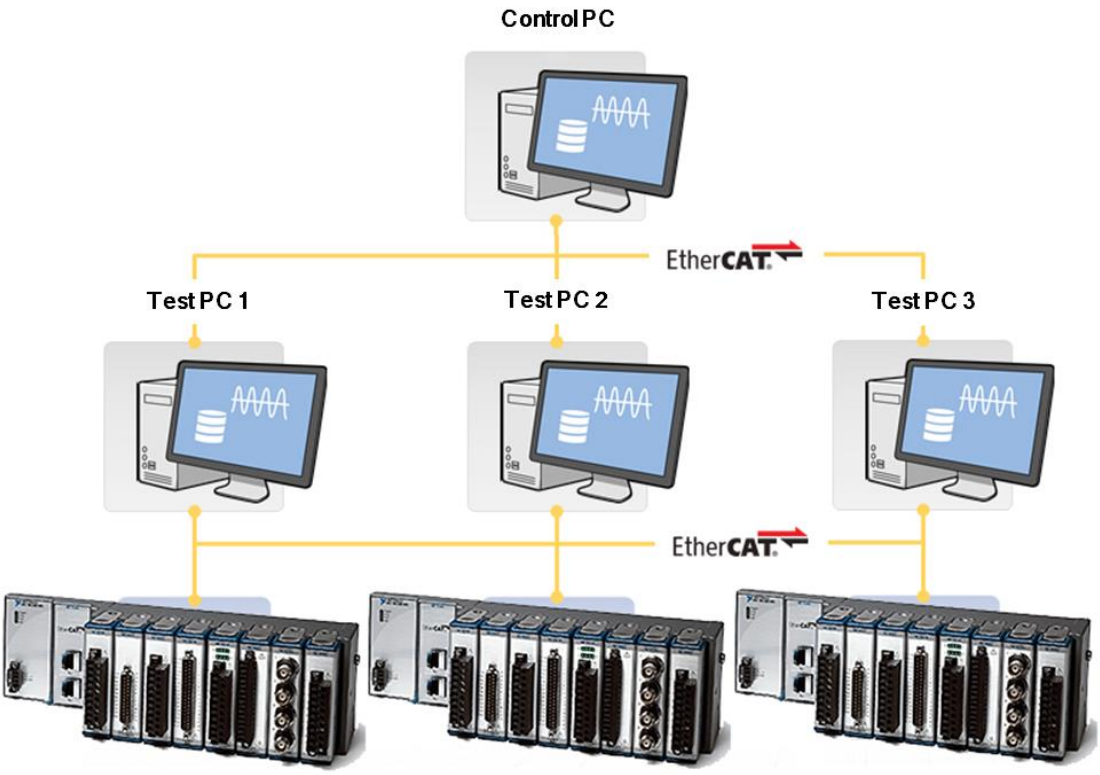

Figure 2: Configuration of the distributed measurement and control system

Signal acquisition on the test PCs takes place via the measurement amplifiers. Only those signals that have been configured on the control PC are taken into account. The sampling rate for data acquisition is also set in accordance with the specifications from the control PC, within the range of 500 to 2000 Hz.

Furthermore, the test PCs monitor up to 10 acquired signals per test station with regard to static and dynamic limit values specified on the control PC. If critical limits are exceeded, the respective test station is shut down via the control PC, the test bench PLC and the axis controllers. Alternatively, the system can be configured to output analogue and digital signals when specific signal thresholds are reached. Parameters relating to limit value exceedances are logged for fault analysis.

During the tests, cyclic data storage in a freely configurable cycle grid and event-driven data logging are active. The latter responds, for example, to a test termination due to a limit value being exceeded. In addition, the measurement data from the last few cycles is permanently stored in a ring file so that, even in the event of a power failure, at least the last state of the test bench can be reconstructed.

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Via cyclical Profinet communication, the test PC activates or deactivates the output of predefined setpoint curves by the axis controllers or adjusts their parameters. The setpoint curves themselves are generated within the axis controllers.

To minimise system load, the application on the test PCs has only a rudimentary interface for diagnostic purposes. All operating procedures and all visualisations required for operation are carried out on the control PC.

In addition to the functions described for automatic testing in endurance trials, the application software enables set-up mode and a so-called run-in measurement.

In set-up mode, test PCs and axis controllers can be controlled manually. For operating the axis controllers, a step mode with a choice of position or pressure control is available. Parameters for setpoint generation can be entered manually and tested directly.

The run-in measurement enables the recording of measurement data from a cycle as the basis for the limit value monitoring described above. Once the recorded signals are available, they can be loaded via a special function within the application and graphically and interactively enclosed in sections by envelope curves, which then define the setpoint band for the monitored signals during the test.

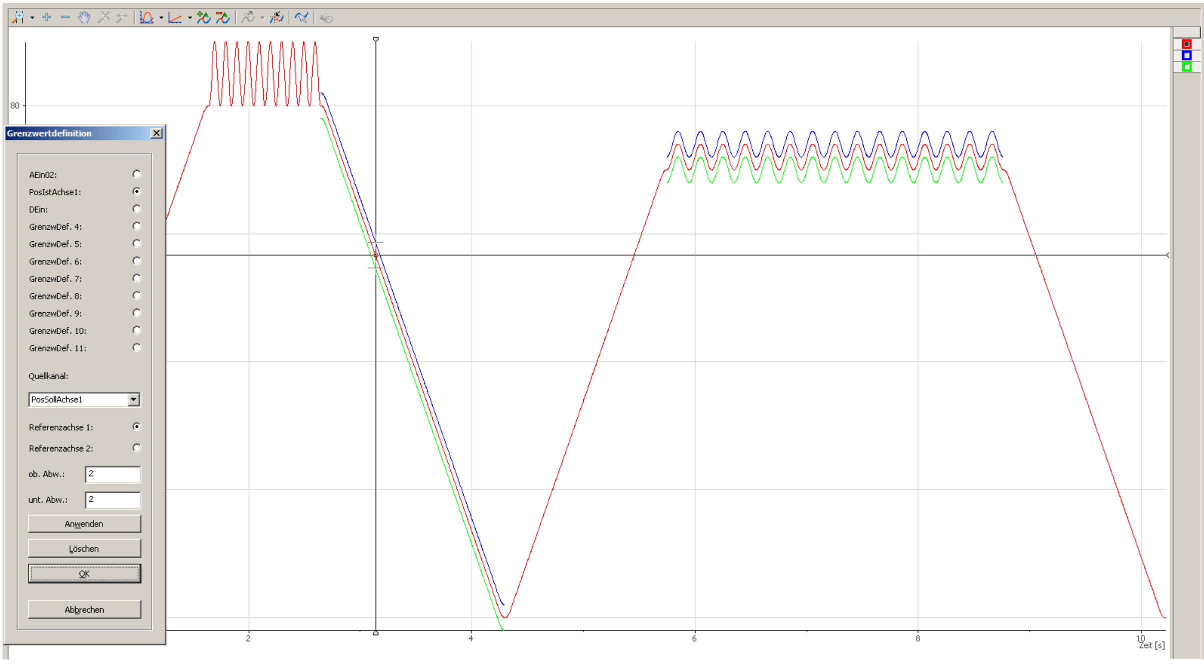

Figure 3: Based on recorded signals, target bands for the monitored signals are defined graphically and interactively during the test.

The evaluation of the measurement data is carried out in the same graphical manner as the generation of target bands. To this end, even whilst the test is in progress, individual cycles or freely definable time ranges within the recorded data can be selected at the touch of a button and displayed using DIAdem's cursor graphics. The user then has access to the full range of graphical and mathematical analysis functions for evaluating the recorded signal curves.

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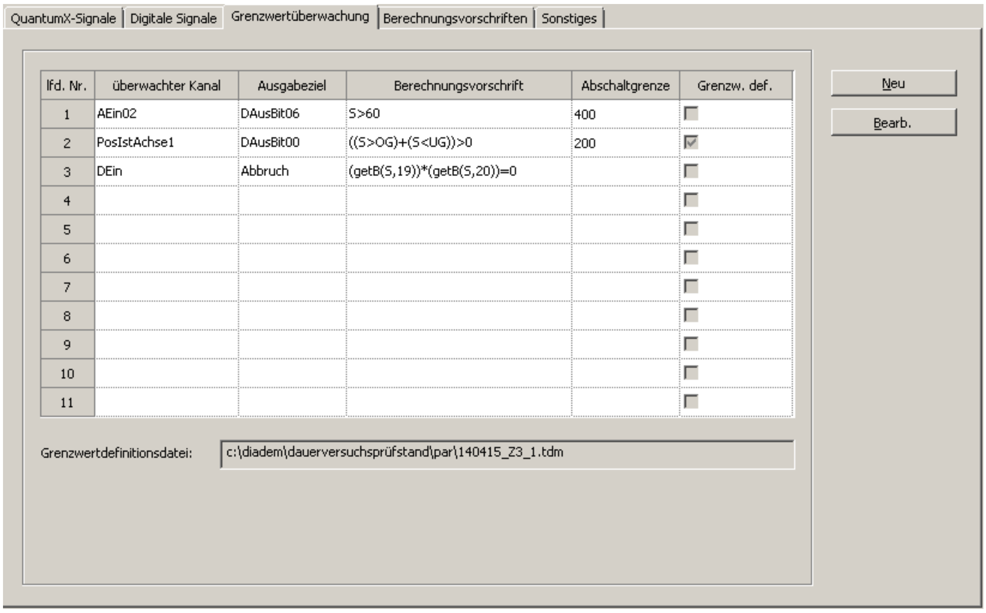

Figure 4: For limit value monitoring, static or dynamic parameters can be specified; if these are exceeded, the system will either shut down the relevant test station or output analogue and digital signals.

Summary

The endurance test bench for hydraulic components provides customers with an application that enables the solution of complex test tasks using standard hardware and software components. Thanks to NI's configurable C-Series modules, signal acquisition can be flexibly adapted to a wide variety of test set-ups. Signal acquisition and output via the NI 9144 EtherCAT slave chassis and the DIAdem real-time extension ensure that a distributed, Windows-based system responds to critical signal conditions in real time. The open software architecture based on NI DIAdem enables the customer to adapt the application to future requirements.

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