EtherCAT enables revolutionary new automotive test bench concept with no gyrating mass

Synchromesh mechanism for gearboxes on test benches

At its location in Recklinghausen, Germany, EDAG-Prüftechnik has offered comprehensive services in the conception, development, construction and assembly of test benches for over three decades. EDAG's clientele includes renowned manufacturers from the automotive industry as well as customers from the general mechanical and electrical engineering industries. The company received an order from Audi to develop an endurance test bench for investigating the life span of the synchromesh mechanism of the gearbox of an Audi A4 2.0 TDI. It was possible to realize the new solution, which makes do without a gyrating mass, on the basis of the fast EtherCAT I/O system from Beckhoff.

EDAG GmbH's range of services include the development of complete vehicles as well as the construction of model, prototype and special vehicles as well as the production of small series. Beyond the development service, EDAG offers the realization of complete production plants for body shells and vehicle assembly from one source. EDAG Prüftechnik specializes in the development and construction of the necessary test benches for quality assurance and the production of vehicle components. This way, for example, the mechanical and thermal load conditions of vehicle components are simulated realistically on endurance test benches. The series of measurements is executed using the time-lapse method; beginning damage is detected by the use of measuring sensors and the service life of the test specimen is determined as a result.

Gearbox synchromesh mechanism from the Audi A4 in the endurance test

Among the newest EDAG-Prüftechnik projects is an endurance test bench for the gearbox synchromesh mechanism of an Audi A4 2.0 TDI. While the gearbox is driven at a constant speed under no-load conditions, two gear changes are performed per minute and the important characteristics such as shifting force, speed of the drive motor, shifting stroke and noise development are recorded, archived and displayed.

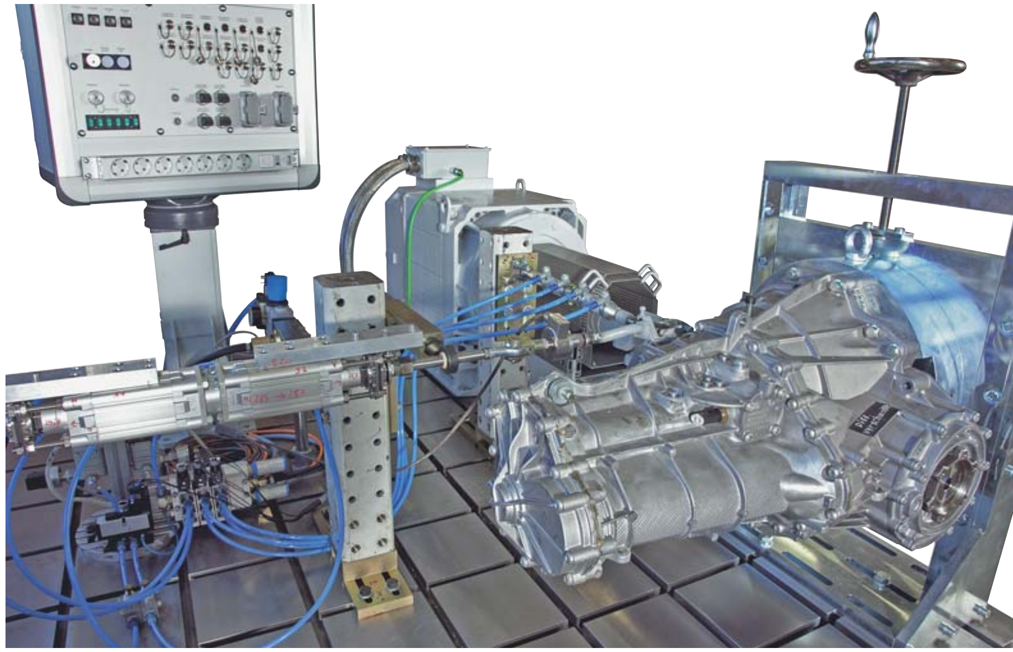
The main motor drives the gearbox on the output side; the differential in the gearbox is disabled in order to allow single-sided driving. The inert mass of the vehicle is thus simulated, so that the driving speed is not reduced, for example when shifting from second to first gear, but instead the gearbox is brought up to a higher speed.

One of the main requirements is to keep changes of speed as low as possible during the individual gear changes. Audi specified a maximum permitted drop in speed of 15 rpm on the engine side. In the past, a large gyrating mass was used for this test method. However, this has serious disadvantages, such as high weight and high space requirements. Not only that, the gyrating mass is potentially very dangerous and the concept does not allow dynamic tests to be performed.

One of the principal objectives of the development of the new test bench concept was to dispense with the gyrating mass while at the same time achieving the same or better test results. The new solution foresees the acceleration of the gearbox on the output side in second gear up to the nominal speed followed by energy-free shifting to first gear at t=0. As a result of the existing mass inertia, there is a drop in speed that needs to be compensated by the electric drive. The latter must also supply the energy required to accelerate the clutch disc when shifting from second to first gear. Purely mathematically, there would be a drop in speed of 140 rpm due to the acceleration of the existing mass inertia, or a necessary torque of 1166 Nm to compensate the drop in speed, which the drive would have to supply.

EtherCAT solves high control requirements

Apart from the necessary technical control know-how, a fast, deterministic I/O system for the acquisition of the actual speed data and the transmission of the control setpoint values (max. cycle time 500 µs) as well as a correspondingly fast and deterministic control computer for the calculation of the setpoints (max. cycle time 500 µs) are necessary to solve this task. A very demanding task in terms of control technology – and the number of possible system suppliers was accordingly small.



Structure of an endurance test bench for the synchromesh mechanism of the gearbox of an Audi A4 2.0 TDI

EDAG project manager Michael Hahn says: "The first use of the Beckhoff technology proved for us to be surprisingly efficient and simple."

EtherCAT and the CX1020 Embedded PC from Beckhoff were ultimately chosen. At the same time, this satisfied a system request from the car manufacturer Audi, which had requested at an early stage the use of the EtherCAT technology.

Data transmission from the sensor to the controller in less than 100 µs

The CX1020 Embedded PC with TwinCAT PLC forms the integrated platform for the real-time control and the PLC tasks. The drive and the remaining I/Os are networked with the CX1020 via EtherCAT. Of crucial importance is the fast reaction to the 'gear change' information, so that the drive can compensate the imminent drop in speed in real-time. This information is transmitted from the sensor to the controller via EtherCAT in less than 100 µs and enables an immediate reaction of the drive to the gear shift.

The speed deviation is better by a factor of 3 than that demanded by Audi

Just as important as the control of the system is the display of the results. The demands on the system components in terms of time are high here also. For example, the actual speed value must be transmitted in the 500 µs pattern in order to successfully display the speed with sufficient accuracy. An Industrial PC with Labview is used to display the results. This is networked with the controller via Ethernet TCP/IP; the transfer of the process data to be displayed takes place block-by-block via TwinCAT ADS (integrated TwinCAT router). The basic scope of TwinCAT contains an appropriate ADS communication DLL for the simple integration of the TwinCAT process data in Labview. A second Industrial PC with a Delphi user interface for the operation, monitoring and parameterization of the test bench was connected in the same way.

As fig. 2 shows, impressive results were obtained. The maximum speed deviation was < 5 rpm. It is thus better by a factor of 3 than Audi's requirement.

Dynamic testing assured with EtherCAT

"The first use of the Beckhoff technology proved for us to be surprisingly efficient and simple," explains EDAG project manager Michael Hahn. "For example, the third party drive that we employed was put into operation on the EtherCAT bus within an hour. The realization of the test bench without a gyrating mass would not have been possible without the performance of EtherCAT. Therefore, we succeeded in realizing what is – as far as we know – the first synchromesh test in the world without a gyrating mass. On top of that, additional dynamic tests can be carried out, such as fast changes of speed or shifting through all gears in quick succession, which were not possible in this way before. In addition, the elegant integration into TwinCAT and the ADS communication with TwinCAT's standard interfaces has facilitated our work very much."

Well prepared for the future

EDAG considers itself to be well prepared for the future, too, with this control architecture. "In the future, we will be using the high performance of EtherCAT and the availability of a large number of devices with EtherCAT interfaces. We will also continue to rely on the open TwinCAT system architecture and the scalability of the hardware platform, with upwardly open computing power, to expand our range of tests, such as shifting force control, dynamic shifting profiles, mass simulation, etc.," explains Michael Hahn. "The first project with Beckhoff will certainly not be the last."

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