High-Volume Production Quantities Guaranteed

At ZF, one of the worldwide leading automotive suppliers of drive and chassis engineering products, everything has to do with the subject of mobility. For about two years, the CTM system from the company ARTIS has been successfully watching over the high availability and quality of production of transmission components at the plant location in Passau. Yet ZF is pleased not only with the reliability and efficiency of this tool and process monitoring system but also with the product-accompanying service.

Tool Monitoring System CTM from ARTIS

The gears and transmissions that were manufactured according to a new patent by the company Zahnradfabrik Friedrichshafen GmbH soon after the company was founded in 1915 were actually intended to ensure optimum power transmission between the engines and propellers in the Zeppelin airships. And even 91 years later, the products of ZF Friedrichshafen AG, the biggest company out of the Zeppelin legacy, still make a weighty contribution to the subject of mobility. One of the worldwide leading groups of automotive suppliers in the drive and chassis engineering industry with 56,000 employees at more than 120 company locations, ZF develops and manufactures transmissions, steering systems, axles, and chassis components, including complete systems for cars, utility vehicles, and industrial machines. This also includes drive engineering products for special vehicles, rail vehicles, ships, and helicopters.

On 12 August 1946, the company Zahnradfabrik Passau GmbH was founded and started off with the production of tractor transmissions. Today ZF Passau is in charge of the industrial machinery drive engineering and axle systems division within the ZF group. ZF Achsgetriebe (AGT) GmbH in Thyrnau, a subsidiary of ZF Passau, exclusively manufactures axle transmissions for cars. Customers include VW, Mercedes, Porsche, and Audi. Next to the main plant in Thyrnau, ZF AGT has rented a plant site from ZF Passau where shafts, among other components, are manufactured for the 6 HP transmission.

Weight-Optimised 6-Speed Automatic Transmission Reduces Fuel Consumption

In addition to the 5-speed and 6-speed manual transmissions, ZF also has 4-speed automatic transmissions and the economical 5-speed automatic transmissions in its production programme. At the moment, 6-speed automatic transmissions and continuously variable automatic transmissions represent the absolute peak of technical developments in the field of automotive drive engineering. Compared to the initial 3-speed automatic transmissions, 6-speed automatic transmissions like the ZF 6 HP 26 for the BMW 7 Series reduce fuel consumption by about 15 percent. The reason is the further spreading of the gear ratios. The high-gear sixth speed, in particular, provides high car driving speeds at comparatively low engine speeds. In the case of the 6 HP, the ZF research and development engineers attached great importance to reducing the components and the weight while coping at the same time with constantly increasing requirements with regard to input torque. In the shaft manufacturing division at the rented plant site in Passau, about 150 employees are engaged in the production of two components that are built into the oil supply system of the 6 HP transmission: the sun gear shaft and the stator shaft. High availability of the manufacturing systems and constant good product quality are extremely important factors in the production of these mass-produced parts.

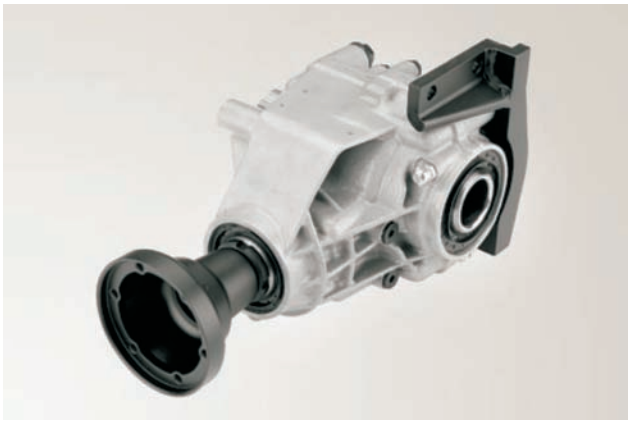

Fig 1: **PTO** (Power Take Off) the very compact design is individually adapted to the installation situation in the vehicle.

Fig 2: **Differential** Two-piece differential with lengthened axle bevel gears for guaranteeing a sealed transmission.

Every day, 2,200 sun gear shafts and 4,200 stator shafts leave the plant in Passau. "In order to maintain our mass production process, we are very careful to avoid cycle time losses," explains Christian Küblböck, foreman in the sun gear shaft/stator shaft production division at ZF AGT. "In our line production process, a metal-cutting tool breakage means not only a sensitive operational disturbance and high costs. If the breakage is not detected in time, there is a risk that many parts will sustain a loss of quality and even get to the customer in that condition." To prevent that, ZF AGT uses the CTM tool monitoring system made by ARTIS on every metal-cutting machine tool. That involves about 25 machines in the shaft production division and roughly 100 in the entire Passau plant. "The ARTIS system is able to safely protect expensive workpieces and tools," says Küblböck, "but we need to guarantee high-volume production quantities with a constant level of quality." The decision in favour of ARTIS was not difficult: due to the fact that the monitoring system is already in use at the parent company plant in Passau, a lot of positive experience had already been gained. "ARTIS has not

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only fulfilled our requirements for a monitoring system but has also given its undivided attention to our individual needs and extra requests," confirms Küblböck.

Integrated System for Tool and Process Monitoring

CTM (Computer Integrated Tool and Machine Monitoring) is a system that is completely integrated into the machine control system and is used for tool and process monitoring. The CTM system detects missing, broken and worn tools in metal-cutting production facilities. The so-called DTA (Digital Torque Adaption) method transmits the current torque values from the drive unit regulators of the spindle and feed drive units via the Profibus to the CTM system. The values are refreshed at a high clock rate and normally reflect the torque output by the drive units. On the CTM card, the central monitoring unit of the CTM system, this data is evaluated instead of the usual sensor data. Similar to the shaft production process at ZF AGT, DTA therefore also does not require the installation of sensors. The CTM card, as the central monitoring unit, has the form of a PC plug-in card that is equipped with standard interfaces and is inserted into the operator panel of the machine control system. This means that the CTM card requires neither its own housing nor its own power supply. Furthermore, the card is easy to install. The CTM card offers four completely independently operating monitoring channels that may, however, also be interconnected if required.

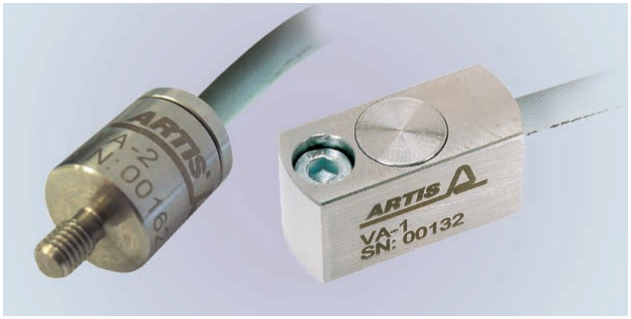

Fig 3: **ARTIS** ARTIS acceleration sensors VA-2 und VA-1

However, the CTM system can also be used for machine condition monitoring. For the purpose of monitoring the spindle bearings for impending bearing damage, an acceleration sensor VA-1 or VA-2 is attached to the spindle. This acceleration sensor records the acceleration values for the vibrations emanating from the rotating spindle. In the measuring transducer VG-4, the measurement values are converted into vibration velocity values and retransmitted to the CTM card. There the results of previous measurements are stored and can be used to make comparisons and recognise trends on the monitor of the machine control system. In some cases, however, sensors are also required in order to generate a usable signal. This is why the Artis production programme includes sensors for force, strain, torque, true power and acoustic emission that come from in-house development and fabrication.

Continuous In-Process Monitoring Provides Advantages

The CTM tool and machine condition monitoring system is destined for use in series and small-lot productions. In contrast to a post-process monitoring system based, for example, on the use of optical or mechanical probes, the continuous in-process monitoring of the torque on the spindle provides advantages with regard to cycle time and response time after a tool breakage. This method requires no separate process step and detects tool breakages reliably and immediately. But the torque monitoring function can also provide information on the state of wear of the metal-cutting tools. "If the cutting edge of a tool becomes increasingly worn during the machining process, the measured torque rises. As soon as the value approaches a previously defined upper limit, an alarm is activated. We can then intervene in time and replace the drill or turn over the plate tool," explains Küblböck. In the past, when it was still necessary to rely on mere guesswork and inaccurate experience figures, it is now possible to make precise predictions. "Tool monitoring enables us to maintain the production flow and to reduce the effort and the costs in the event of tool breakage," summarizes Küblböck.

Nowadays, however, what matters is not only a functioning product; completely satisfied customers also demand additional services. After the monitoring system has been implemented, it may, for instance, be necessary to optimise the software to suit specific conditions in the production process. This is usually accomplished in a relatively short time, except when external sensors for acoustic emission, for example, are required in order to generate a signal for the monitoring system. And, needless to say, no system is invulnerable to problems during normal operation. Küblböck adds: "The ARTIS system requires very little maintenance, and no major malfunctions have occurred so far. In the event of minor problems, for instance, when we are not able to identify the cause of an error message on our own, an ARTIS staff member comes to our company."

Staff Training by ARTIS

Furthermore, ZF AGT strives to improve the motivation and knowledge of its staff by means of training programmes. This also applies to proper use of the CTM system. "Although a training programme was carried out by ARTIS staff at our company two years ago when the system was introduced, we still need a refresher course from time to time. We would like to make sure that our staff know how to operate the system and how to use the possibilities it has to offer. Besides, it is often also necessary to instruct new staff members who have just joined us. When we require staff training, we simply ask ARTIS," explains Küblböck. The training programmes include a theoretical part and a practical part; during the practical part, the staff members are taught using their own machines. If a software update is pending, it is usually sufficient to inform the shift managers and system supervisors about the innovations. After all, the updates do not include fundamental modifications but provide simplifications in software operation instead.

In autumn of this year, ZF AGT is planning to equip a new machine tool with a CTM system and an AC regulating system on a trial basis. "This regulating system is supposed to shorten our cycle times. If this technology proves to be a success in the production division, then we will certainly also use it for other machines," AC stands for Adaptive Control. This regulating system influences specific parameters of the machining process depending on the properties of the workpiece and the tool. This helps cut manufacturing costs by means of shorter machining times which are attained by means of higher feed speeds. But tool breakage caused by overload and the resulting downtimes can also be avoided. With ACC (Adaptive Control Constraint), a limit regulating system is available in which a process quantity is kept constant within specified limits, such as the torque output by the motor of a milling spindle. Shorter machining times are the result of operating with high feed values in the case of low cutting forces or empty runs and with lower feed values only at machining points with high cutting forces. As opposed to the ACC system, however, the strategy applied in the case of the ACO (Adaptive Control Optimization) regulating system is more oriented toward the properties of the workpiece. A learning curve that was recorded and stored during the first machining process of a new workpiece is considered to be the setpoint value. At the same time, a worn tool corresponding to the end of the tool life period is used. With this type of regulating system, the machining time with a sharp tool is short and increases successively with an increasing degree of tool wear. The withdrawal of feed results in a more even application of load to the tool as it gradually becomes more worn and can contribute to increasing the tool life and to extending the period of utilisation.

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