Gear Inspection in a Shop Floor Environment

Günter Mikoleizig

As in nearly all industries, more cost-effective solutions are currently called for in the gear manufacturing industry.

In many respects, quality assurance of gearing plays an important role in achieving such solutions. In the automotive industry in particular, there is now a demand for gearing with more complex designs and individual variants while meeting higher quality requirements, all at a lower cost.

In this regard, an organizational structure with the goal of carrying out quality assurance on the shop floor offers advantages in this context, just to name a few:

- Ready availability of measuring results, for instance, following a tool change on the machining equipment
- Immediate performance of random sample measurements in series production
- Avoidance of rejects due to shorter and faster response times

The following article will address the most important prerequisites for implementing gear measurement in a shop floor environment. In addition to requirements pertaining to the measuring devices, the prerequisites for safe operation of the device will be described, and measuring accuracy will also be examined more closely.

Introduction

New transmission concepts are needed in the automotive industry, with a view to modern drives providing greater energy efficiency. Increasing power density, greater gear ratios, lower noise emissions and improved efficiency result in higher quality requirements for the gearing used in the industry. For this reason, quality assurance for the relevant components must be more comprehensive, but without exceeding the budget.

Quality assurance performed on the shop floor bridges the gap between quality improvement and simultaneous cost limitation. Of course, shop floor quality assurance also involves risks. With careful planning, however, these can be largely minimized.

Installation Location Requirements for a Shop-Floor Measuring Device

The installation conditions of a measuring device are crucial for ensuring the accuracy and reliability of the measuring results (Figure 1). Major influences include the effect of temperature on the measuring device and on the workpiece undergoing inspection, as well as the effect of vibrations on the device and the cleanliness of the workpiece.

The influences shown here are largely absent in an air-conditioned measuring chamber. A measuring chamber has known disadvantages, however, such as long distances and wait times for measurement, air-conditioning costs, and additional staff.

With smart planning, the effects of negative influences can be minimized, even when the measuring device is used on the shop floor:

- Avoid drafty installation locations
- Avoid direct sunlight on the measuring device through windows or roof openings
- Keep blower air from processing machine cooling units away from measuring devices
- Place the workpiece undergoing inspection alongside the measuring device (for temperature regulation)
- Do not install the measuring device next to transport routes (risk of impact, vibrations)
- Keep the measuring device location free of significant sources of vibration (test stands, heavy-duty machining operations, etc.)
- Ensure that the installation location is generally clean

The negative influences outlined here can frequently be found in production lines set up according to outdated standards. Newly installed, modern production lines, by contrast, provide significantly improved prerequisites for shop-floor quality assurance. This is because modern machine tools are completely encapsulated and are frequently equipped with exhaust systems. Quite often, partial air conditioning systems are installed to maintain narrow production tolerances.

Figure 1 Gear inspection in a shop floor environment.

Measuring Devices on the Shop Floor

Measuring devices used on the shop floor must be capable of compensating the prevailing negative effects of this environment. This includes factors such as temperature effects, vibration loads, and dust and dirt at the installation location, among others.

Precision measuring centers for gear measurement, as shown in Figure 2, provide the appropriate prerequisites:

- The measuring centers are made from a single material throughout (cast iron or steel) to avoid material deformation (bi-metal effect) due to temperature influences.
- Moreover, metal (cast iron/steel), when used as a design material for a measuring device, provides the advantage of being identical to the material of the workpieces undergoing inspection. Thus under the influence of temperature, both components exhibit the same behavior, and a natural temperature compensation takes place due to physical effects.
- As the length measuring system, temperature-neutral gauges made of a special glass alloy (Zerodur) are used, with a constant dimension relative to the reference temperature of 68°F.
- Integrated temperature sensors measure the ambient temperature and the temperature of the measuring device. Combined with a software compensation model, the measuring accuracy remains nearly constant over a broad temperature range (64.4°F–86°F). A test conducted over 12 hours comparing measurement results with and without temperature compensation is shown in Figure 3.
- The current workpiece temperature can also be measured and compensated for with an additional sensor.
- High-precision guidance systems for the linear axes and workpiece rotary axis have an anti-friction guideway design and require no energy supply, e.g., via purified compressed air.
- All guidance and measurement systems are installed covered and are protected against soiling and external influences.
- To insulate the measuring device against vibration effects, the device is installed on three diaphragm air spring elements, as seen in Figure 2. Low-frequency vibrations and impacts are thus reliably absorbed.
- The measuring device features a highly accurate 3D tracer head for recording measured values on gearing. In addition to software monitoring of the measuring ranges, the system also includes mechanical protective devices to prevent damage in the event of improper operation or collision.

Figure 2 Precision measuring centers.

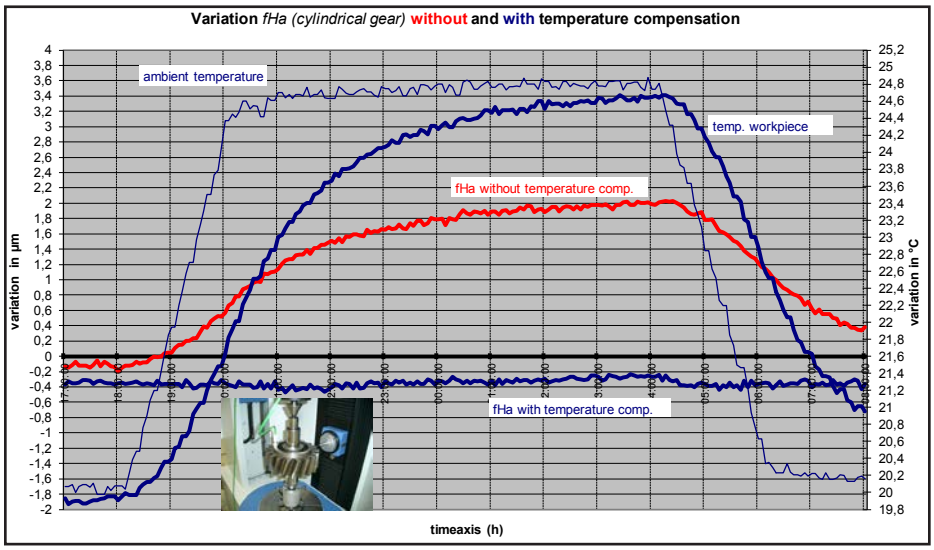

Figure 3 Temperature compensation test results.

Gearing measuring centers as shown in Figure 2 also have the advantage that measured value recording takes place for cylindrical gears with involute gearing according to the generation principle (Figure 4). The involute curve is generated automatically through the coupled rotational movement of the workpiece with the tangential measuring axis, resulting in stable measurement results, even in the case of positional deviations of the probing system due to environmental influences in production, for example.

By contrast, profile measurement based on polar coordinates, as is common in general CMM, is significantly more sensitive to positional variations.

Prerequisites for Reliable Performance of Shop-Floor Measurements

An important feature of shop-floor measurement is that the operating staff for the production equipment (hobbing machines, grinding machines, etc.) also carries out the gear measurements.

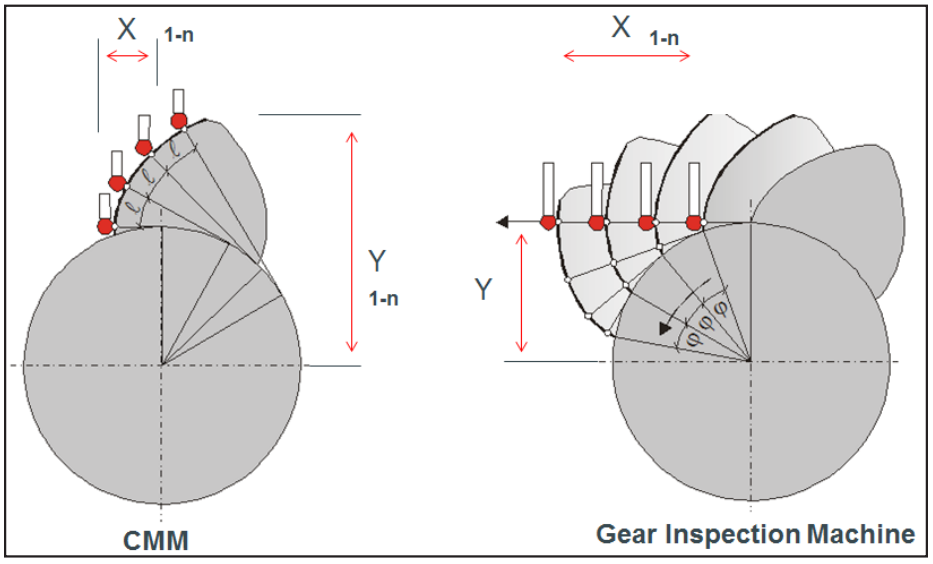

Figure 4 Measuring principle.

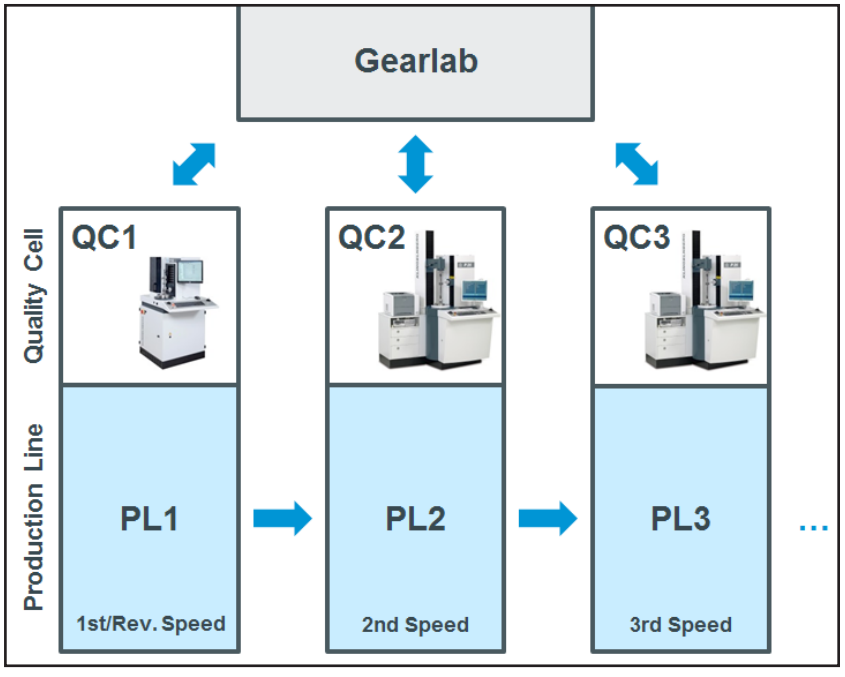

Figure 5 Layout of a gear component factory.

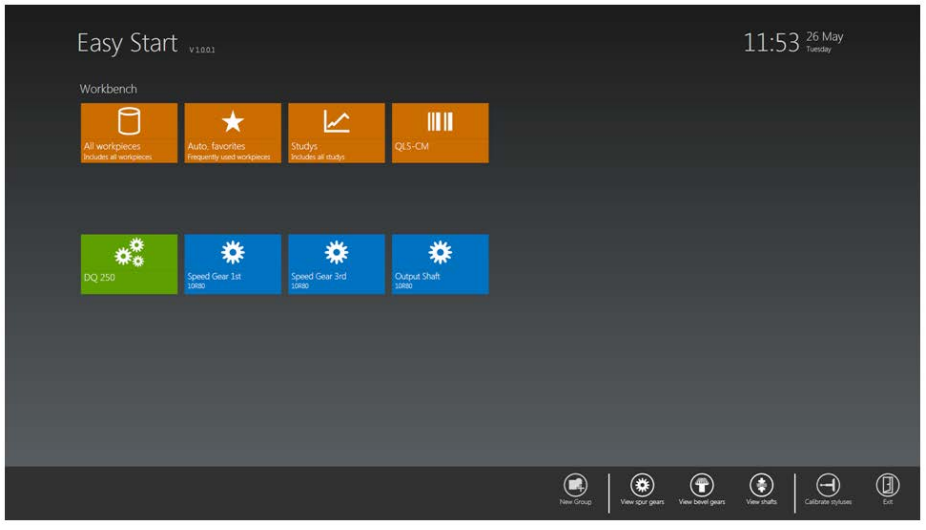

Figure 6 Software HMI.

The purpose of the measurements is to inspect gearing quality following a workpiece change, for instance, or during ongoing production.

This means that the measurements are not carried out by trained measurement technicians, but rather by machine operators. Additional measures are therefore required to perform reliable, accurate measurements.

Figure 5 shows the layout of a shop floor with an integrated measuring station. There are production lines (PL1–PLn) for the individual components of a transmission. Each production line has its own test station (QC1–QCn). Each test station is also networked with a central measuring chamber. In this central measuring chamber, prototype measurements are carried out, and the individual measurement programs that will subsequently be transferred to the test stations in production are created. The measuring results recorded on the shop floor are then transferred back to the measuring chamber, where approval will be granted or additional evaluations, such as statistical analyses, will be carried out.

The objective is to enable the operator to carry out the necessary measurements on the shop-floor measuring machine with as much ease and reliability as possible. This relies in part on a simple, precise workpiece fixture. A workpiece fixture between centers lends itself well for shaft-type workpieces. For disk-shaped workpieces and internal gearing, a chuck is the fixture of choice. The chuck should be designed so that few or no exchange parts are required for different workpieces.

An automatic probe change rack on the measuring devices is recommended when using different probe elements for gearing measurement. The probe change rack enables all necessary probe elements to be calibrated automatically at fixed intervals (once per day or once per shift).

The individual measurement programs are accessed by means of a simply designed graphical user interface, as shown in Figure 6. All measurement programs needed for a measuring station or specific transmission components can be programmed into this page as on a desktop and launched as necessary.

The system also includes measurement program retrieval via a barcode scanner.

As already mentioned at the out-

set, workpiece cleanliness is important for obtaining accurate, reliable measuring results. The measuring station should therefore also have a workpiece washing station nearby. The advantage of a cold-water washing station is that the workpieces are not warmed, thus obviating temperature-induced measurement variations.

Workpiece temperature is generally a consideration for accurate measurements. In gear measurement, certain measurement parameters are insensitive to temperature, while others respond with greater sensitivity.

Due to the relatively small gearing dimensions in the automotive industry, temperature-induced changes in length are relevant here only for certain parameters. The relative test parameters for profile, tooth trace, pitch and concentricity measurements are rather insensitive. Large, temperature-induced variations can occur, however, when determining tooth thickness or dimension over balls, when the temperature of the workpieces deviates from the reference temperature of 68°F. In this case, a measuring device with workpiece temperature probes is used for compensation.

Maintenance and Calibration of Shop-Floor Measuring Devices

Use of a measuring device on the shop floor generally requires slightly more maintenance and calibration.

Fixed procedures should therefore be specified for individual measuring stations as follows, for example:

Daily maintenance

- Inspection of traversing paths of measuring device axes
- Monitoring of the device for unusual noises during the measuring procedure
- Calibration of the probe elements used (once per shift)

Weekly maintenance

- Inspection of the measuring device for measuring accuracy by means of comparative measurements against the reference standard
- Compressed air supply check
- Cleaning of workpiece fixture components

Quarterly maintenance

- Replacement of filter elements in the control cabinet
- Emptying of condensate from the compressed air service unit

Annual maintenance

- Inspection of the measuring device by an OEM service employee

As regards measuring accuracy, a comparative measurement against a reference standard across all measuring devices is also needed at regular intervals.

Of course, the manner in which the operating staff handles the measuring device is an essential factor in maintenance expenses and in ensuring consistent measuring accuracy. It is certainly an advantage if staff members receive basic training in the proper handling of high-precision measuring devices.

Summary

Quality monitoring of gearing workpieces carried out on the shop floor offers a number of benefits:

- Variations in measuring results are identified more quickly, thereby reducing the number of rejects.
- When changing tools on the machining equipment, the operator can immediately verify the settings by measuring the workpiece and can make any necessary corrections without lengthy production breakdowns.
- The machine operator is thus directly involved in the quality assurance process and consequently performs with a greater overall focus on quality.
- The number of complicated measuring chambers can be reduced.

To successfully introduce quality assurance on the shop floor, however, appropriate prerequisites must be in place. Careful planning is absolutely necessary.

Exchanges of experience with other companies that have successfully introduced this production structure can certainly be helpful.

Dipl.-Ing. Günter Mikoleizig currently heads the Product Management and Application Engineering-Department for gear inspection machines at the Klingelnberg GmbH, Germany. For more than 30 years he is working in the field of gear inspection technology and he is well experienced with the design and development of inspection machines and the product management. He developed a product line of inspection machines for all kind of gears and other related parts with small dimensions up to very big sizes. Mikoleizig presented papers about gear inspection worldwide and is also an active member of national and international standardization committees.