LEAN MEASURING PROCESSES WITH PRECISION MEASURING CENTERS

In recent years, modern gearboxes – and other drive systems – had to change significantly to increase efficiency requirements. Duplex clutch gears or other innovative automatic transmissions, for example, are now characterized by their intense focus on integrated functions and designs that reach physical boundaries – thereby imposing stringent demands on geometrical accuracy in the production of the gears. In turn, these tight tolerances call for suitable measuring technology that is capable of monitoring and controlling the production process. Ultimately, this is the only way to guarantee the quality of the final product.

Typical shaft-like components (e.g. those used in duplex clutch transmissions) call for a large number of quality-related factors to be measured (Fig. 1). These measurands are usually divided into three groups:

1. Coordinate measurement
   (e.g. distances, diameters, widths)
2. Form measurement
   (e.g. roundness, flatness, concentricity, perpendicularity)
3. Gear measurement
   (e.g. profile, lead, pitch, tooth thickness)

Traditional Measuring Process

These categories are also clearly relevant in the choice of measuring room equipment and the selection of quality management processes. Today, measurement processes usually proceed as follows: the finished components are taken to the measuring room, where they undergo consecutive measurement processes on a coordinate measuring machine, a form measuring machine, and a gear tooth measuring machine (Fig. 2). Delays occur as the components pass between the individual stations, because the measurement requirements out of the production lines cannot be planned. So a backlog of components can build up, e.g. at the start of a shift. Furthermore, the measuring machines are often busy and not every employee is trained to use all of them. Once the quality-related parameters have been determined, the measured components are sent back to production and, where necessary, the measurement results are used to compensate any process errors on the production machines.

This procedure can take a long time, depending on the production's size and how much of the measuring room capacity is being utilized. In the meantime, production either waits for a release to be issued, or carries on working, with the risk of producing defective items. This can severely impair the overall effectiveness of the line, particularly in the case of small batch sizes and production processes that are unreliable due to the tight tolerances involved.

Compact

Lean Production at its Best

Getting everything "in line": integrating gear measurement into production lines creates small, fast quality loops that are tightly synchronized with the production process. Transportation and waiting times can be minimized, as can reworking and scrap.

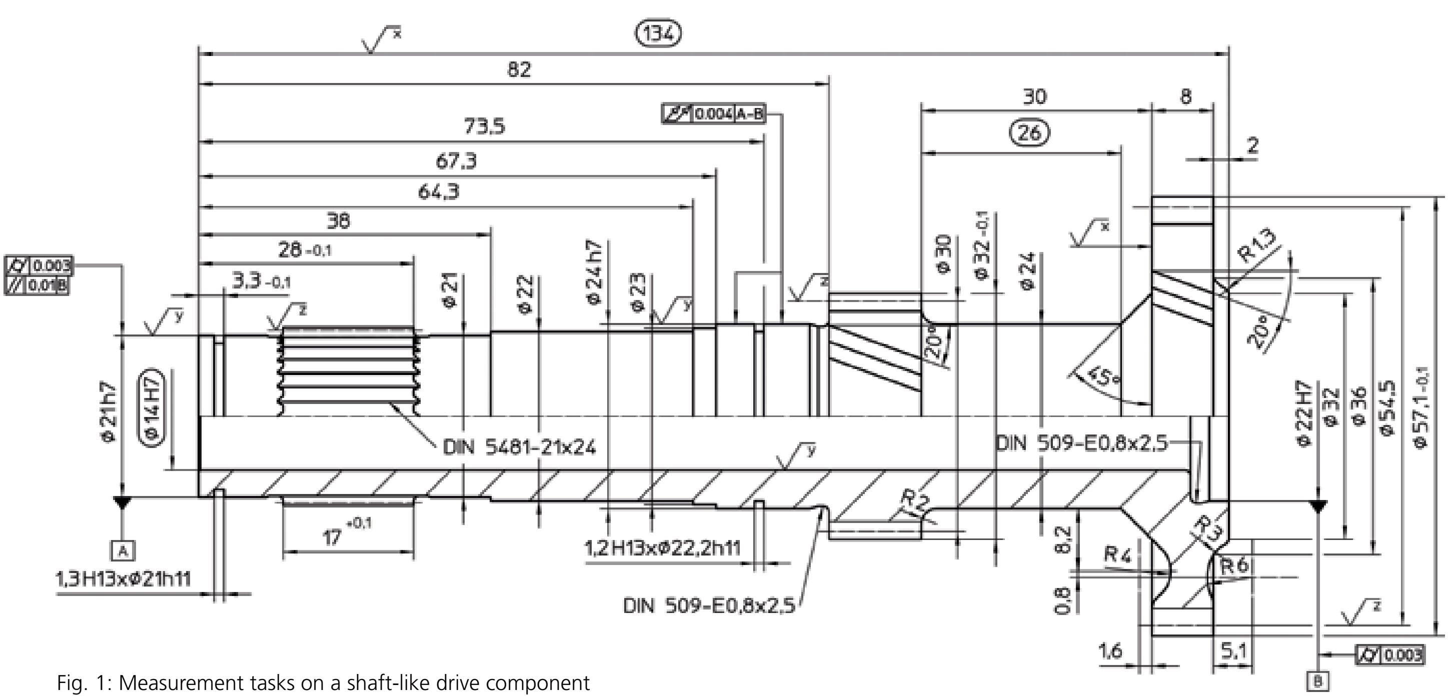

Fig. 1: Measurement tasks on a shaft-like drive component

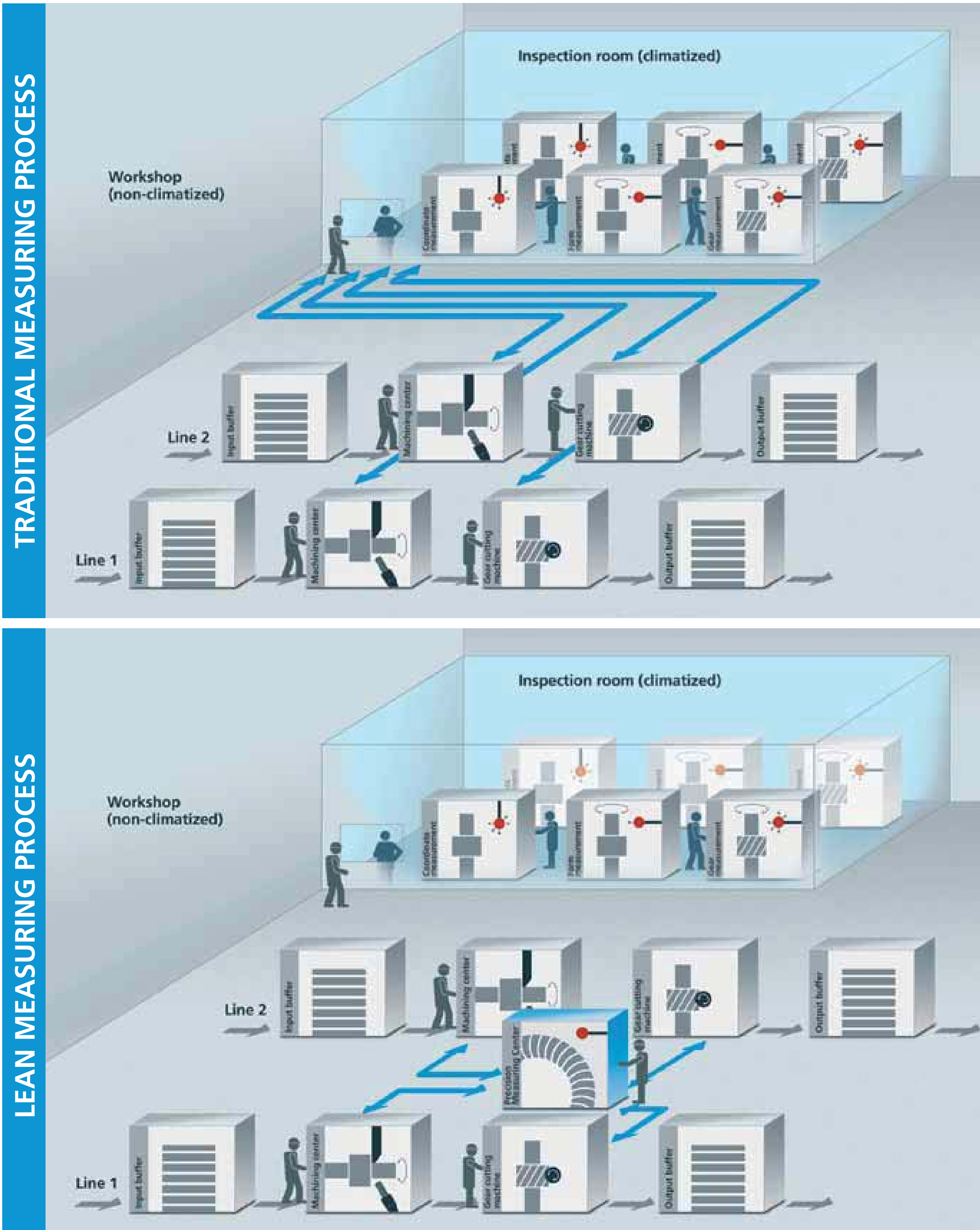

Fig. 2: Traditional and lean measuring process

Analogies from Production Technology

There are two striking major differences when metrological processes are compared with production processes: Firstly, we have moved on from having one machine per operation to having integrated machines that are capable of performing multiple production operations at once (machining centers, inline machines). Secondly, lean production concepts have been consistently implemented, particularly with regard to ensuring a process-oriented approach.

Integrated Functions

Even in the case of large production quantities, technology is increasingly relying on machines that combine multiple machining processes in one system, e.g. turning, drilling, and cutting. This strategy offers all kinds of benefits:

- Complete machining in one automatic sequence (short throughput times, fewer personnel, less training)
- A single clamping operation (reduces the level of effort required for handling and transport, and results in smaller buffers)
- Only one machine required (lower levels of investment, greater flexibility, high utilization rates, requires less space)

However, this approach of integrating multiple functions is difficult to achieve with measuring technology, as the requirements of the three measurement methods are so different. A cylinder is a good example to illustrate this problem: although a coordinate measuring machine is capable of determining the height and diameter of a cylinder (absolute measurement), it cannot identify its roundness. Meanwhile, a form measuring machine is capable of analyzing the roundness and evenness, but not the diameter (relative measurement). Consequently, the only viable candidates for creating a "measuring center" are gear tooth measurement devices, as they are the only ones capable of performing absolute measurements (dimensions such as the pitch or tooth thickness) and relative measurements (shapes such as the profile or lead) at the same time. And even within this category of device, there are still two challenges that must be overcome: for form measurement to take place, the machine must have a very precise rotary table and an extremely sensitive measuring head – and to enable coordinate measurement, the required level of absolute measuring accuracy would have to be ensured along the entire path of the linear axes.

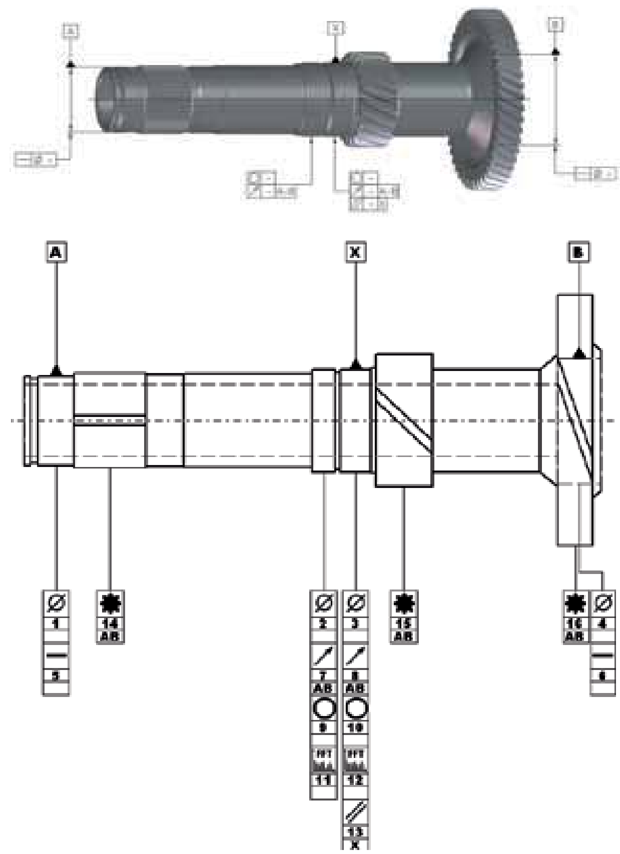

Fig. 3: Programming the component in the "Shaft" program

Lean Production Concepts

Nowadays, the concepts of lean production and enhancements of the original Toyota Production System (TPS) are being put into practice at virtually every production plant. The key priorities here are to avoid waste (known as "muda") by introducing synchronized workflows, to ensure processes are continuously improved, and to put a consistent quality management system in place that immediately eliminates errors for good. If these principles are applied to in-production measuring technology, it becomes clear that it should be synchronized

"Our measuring machines can be installed directly within the production line, where they take measurements of the highest accuracy. They are impervious to the effects of dust and temperature."

Dr. Marcus Stolz, Managing Director Precision Measuring Centers
KLINGELNBERG GmbH

THE P SERIES

The following features make the measuring devices in the Klingelnberg P Series really stand out:

- Suitable for inline use
  (Temperature-stable within the range of 15°C to 35°C thanks to a combination of design features and software measures for both the machine and the component, sturdy design, i.e., high-precision roller bearing guides, machine bed made from cast steel)
- Suitable for coordinate, form, and gear measurement
- Roughness measurement
  (Surface microstructure evaluated with an automatically exchangeable roughness probe)
- Maximum accuracy
  (Gear measurement superior to VDI Group 1, measurement uncertainty $U1 = 1.8 + L/250$, radial and axial runout $< 0.5\,\mu m$)
- Easy to use graphical programming environment
  (You can use the "Shaft" program to model an axially symmetrical component that matches your drawing and to add the measuring and analysis operations by drag-and-drop.)
- Fully automated measuring process
  (For serial measurement, the component is selected from a central database, but otherwise the measurement is performed without any user intervention. The measurement reports can be printed out or archived in a document management system. The employees on the production line only require minimal training.)
- Vibration isolation
  (To enable inline form checking, particularly with regard to waviness analyses, the machine can be equipped with a vibration isolation system.)

with the production process with the aim of achieving short quality control loops that take virtually no time at all. Moreover, it should be perfectly coordinated with the production process in terms of where it is located and how it is organized. This is the key to minimizing four of the seven types of waste identified by the TPS: motion, waiting, transportation, and defects (including repair and scrap). In light of this, it is all the more astounding that many companies (even those that have a strong process-oriented attitude in every other respect) still organize their measuring technology in a workshop-oriented way, i.e., located in a central measuring room. There are many reasons for this:

- Ambient conditions in the production area: inside a measuring room, the temperature remains constant. Phenomena that could interfere with the measurement process (i.e., dust, oil, or ventilation) are largely eliminated.
- Employee qualifications: specialist employees are required to program and operate the measuring devices.
- Focus on capacity utilization: when production processes are stable, the quantity of workpieces that require checking is relatively low. If, on top of that, you need to have three different measurement systems for a single production line, the cost of the investment cannot usually be justified given the low rate of utilization.

In order for the measuring technology to be consistently integrated into production sequences alongside other types of technology, you need measuring devices that are just as capable of taking precise measurements when moved to an inline environment, that are easy to operate, and that can (as far as possible) perform all the measurement operations required by the line.

An All-In-One Solution: The Klingelnberg P Series

For years, Klingelnberg has enjoyed a reputation as a full-range supplier of bevel-gear production solutions that not only helps its customers to design the actual components, but also the associated production processes. This is because Klingelnberg offers an integrated system that covers every process, from component design, tool manufacturing and adjustment, machining before and after heat treatment right through to final quality control. One of the key aspects of this system is the way it builds small quality control loops (closed loops) in the bevel-gear production line to ensure that parts can only proceed to the next step if they are free of defects.

In this regard, Klingelnberg measuring technology has always had to satisfy the demand for inline machinery that can not only meet the highest standards of gear quality, but is also capable of measuring other components as well, such as tools.

Lean Measuring Process

In this spirit, the traditional measuring process can be made much more efficient by installing an inline precision measuring center in the form of a Klingelnberg P 26. In this lean measuring concept, all measurement operations are fully integrated into the line (Fig. 2). The production employees check the components they produce themselves, and take corrective actions if they identify any deviations. A central Quality Department is responsible for programming new parts and overseeing the machines (including training, probe calibration, resolution of problems, etc.).

This kind of structure was established in the bevel-gear production sector some years ago. Since then, it has been gaining more and more supporters in the automotive and automotive supplier industries. In addition to the advantages already described, what users like about this concept is the way it introduces standardization. For example, they only have to be trained in one piece of software, only have to worry about servicing one type of machine, and can also benefit from flexible backup strategies in the event of failures. In the case of the example of the shaft from Figure 3, the component was clamped in the chuck and then measured in full without any need for reclamping. Measurements are taken at the bearing seat to determine the diameter and the concentricity relative to a previously measured workpiece reference axis. The waviness can be calculated from the form deviations by means of a Fourier analysis. In turn, this allows important conclusions to be drawn about the production process (e.g. vibrations, clamping errors, process-related deviations) and how the component will behave later, when it is used in the transmission. As far as the gearing is concerned, the standard parameters are determined (e.g. profile, lead, pitch).

Outlook

Klingelnberg is currently working on how to transfer the waviness analyses used in form measurement so that they can also be used in the context of gear measurement. This will make it possible to identify manufacturing faults that result in a noisy transmission, for example. Although there are no standardized parameters available for such faults yet, leaders in technology have already realized that waviness must be considered in measuring technology because of the increasingly stringent acoustic requirements. In light of their suitability for form and surface measurement, it is already verifiably clear that Klingelnberg measuring centers are perfectly equipped to handle these tasks. ◆

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