GEARENGINE® – STRATEGY INSTEAD OF HAPHAZARD DATA COLLECTION

All too often when implementing Industry 4.0 concepts in the gear cutting industry, a "technology first" approach is taken, where data are simply collected without deeper knowledge of the processes. But a unique customer advantage is only gained when relationships are established between data, for targeted issues, right from the very start. Along with the specific process parameters, information on the status of the production equipment (such as tools, clamping devices and machines) must be linked to the component produced to form a single, consistent database.

Why does the quality of manufactured gears continually fluctuate? Why does productivity in two different plants differ despite identical equipment? Why are some gears noticeably noisy and others not?

These questions that arise during routine gear manufacturing are certainly familiar to many. Despite the presence of ultra-modern CNC machines on the shop floor that have a wide range of sensors, there is a clear lack of manageable solution strategies for finding answers to these questions. The data are always somewhere. But it is unclear just where to find them and how to establish relationships between them. Even today, manually recording an entire data collection with pencil and paper remains quite common, throughout the manufacturing process. Only with this tediously obtained information can the question of anomalies be clarified in a scientific manner – a popular subject for Bachelor and Master theses. Generally speaking, at the end of these theses, there is a technically valid reason for the causes of the anomaly, however it manifests, which can be eliminated on this basis.

GearEngine®: Interlinking data

The challenge therefore lies not in the data collection itself, but rather in the logical linking and utilization of the available information. This is the concept that marked the birth of GearEngine®. GearEngine® is not a new Industry 4.0 platform for collecting just anything; it is Klingelnberg's way of bringing design, production and quality control loops for gears into the digital world (see Fig. 1). With the intelligent integration of all data in GearEngine®, it becomes a platform that supports users in all higher-level jobs and analyses in manufacturing.

GearEngine® takes on multiple roles, acting as a:

- Management tool for a gear's design and production data
- Communication interface for all machines involved
- Central interface for the user's existing IT infrastructure

Compact

The ultimate in data and process management

Modern CNC machines collect a broad range of data. The challenge, however, lies in achieving a complete acquisition and interlinking all of this information. The objective here is to attain transparency and to optimize the entire process. GearEngine® from Klingelnberg takes on this task, creating an optimal foundation for Industry 4.0 processes.

Fig. 1: The GearEngine® concept

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COMPLETE SYSTEM: GEARENGINE® AND SOFTWARE/APPS

GearEngine® is the platform that links and evaluates data collected via the following apps/software, among others:

- **Gear Designer:**
  Tool geometry, manufacturing kinematics and thus the manufacturable tooth flank form are determined by a manufacturing simulation.
- **Gear Corrector:**
  Deviations between the manufacturable geometry and the measured values are displayed and can be analyzed, and corrections for the manufacturing kinematics, and for the tool geometry if required, can be calculated and made available to the production machine.
- **Gear M-Tracer:**
  Fingerprints of the machine tool's dynamic behavior are managed and thus made usable for predictive maintenance.
- **Gear P-Tracer:**
  Filters the manufacturing history for each component from the GearEngine® data base.
- **SmartTooling:**
  Digitally simulates all production equipment, making it accessible for analysis and evaluation, and enables digital tool management.
- **Pulsar:**
  The geometry of the tool and the machine kinematics for the deburring process are calculated through a manufacturing simulation.
- **KOMET:**
  Provides for shop-floor calculation of nominal data, evaluation of results of topography measurements and, based on this, calculation of corrections for the manufacturing kinematics and if necessary the tool geometry for the bevel gear manufacturing process.
- **Meteorit:**
  Used to prepare nominal data for the measurement of stick blades, evaluate measurement results and determine corrections for the blade grinding kinematics.
- **KIMoS:**
  This design software supports every step in bevel gear design and optimization and lays the foundation for Closed Loop production of bevel gears.

- Source of information for digital twins of the manufactured gears
- Base of information for the production equipment

GearEngine® integrates all systems involved in the existing IT infrastructure of a gear manufacturing operation, becoming a digital gatekeeper for the data lake containing all of the information generated. An information base pooled in this way has tremendous, immediately usable potential.

Talking to one another. Or… communicating automatically

The workflows in bevel gear manufacturing are governed by clear quality control loops. In order for these to be put into practice effectively, however, machine operators must coordinate with each other. A good example of this is the Closed Loop process, well established for many years: A gear is measured after machining. As long as it is within the specified tolerances, no one will change the process. If a trend is identified, or even if measured values are out of tolerance, intervention in the process is required. The technician responsible for quality on the measuring machine must inform the machine operator that a correction is available and that it should be used. If it is not used, the quality control loop is broken. It is strictly up to the individuals involved to determine how this communication takes place.

This is where the potential of GearEngine® as a communication interface becomes clear. Using it, this important exchange of information is ensured. As soon as the technician wants to have corrective settings applied on the machine, GearEngine® transfers this information to the corresponding cutting machine. That is the main prerequisite of a partially or fully automated workflow in production. As soon as the cutting machine control unit knows that a correction should be loaded, the operator can either be notified by a message or the correction can be loaded automatically before the next component is machined (see Fig. 2).

This communication interface creates an essential basis for an automated workflow. In the near future, it will be possible to determine whether a correction should be used by means of algorithms with artificial intelligence (AI) – and then the correction can be automatically loaded on the relevant machining tool. GearEngine® already has the knowledge base required for AI.

Fig. 2: Operator communication and integrated communication

The many factors influencing quality

Who hasn't experienced cutting tools with a dramatic decline in service life during soft cutting, with no identifiable reason? And without anyone having made changes to the process parameters? And who hasn't secretly feared that perhaps the setup process could be a reason for an unstable process? Questions can only be answered about the reasons behind anomalies or quality fluctuations in production, if sufficient information is available. That is because an extremely large number of parameters can influence the quality of a gear (see Fig. 3). At the end of such a gear case history, there is always a clear technical initiator for the effect. Often enough, the causes identified are so trivial that the question is inevitably posed as to why the solution was not found earlier. All too often, however, ideas remain stuck in a jungle of fragmentary, incoherent data – and despite the best intentions, no one can see the forest for the trees.

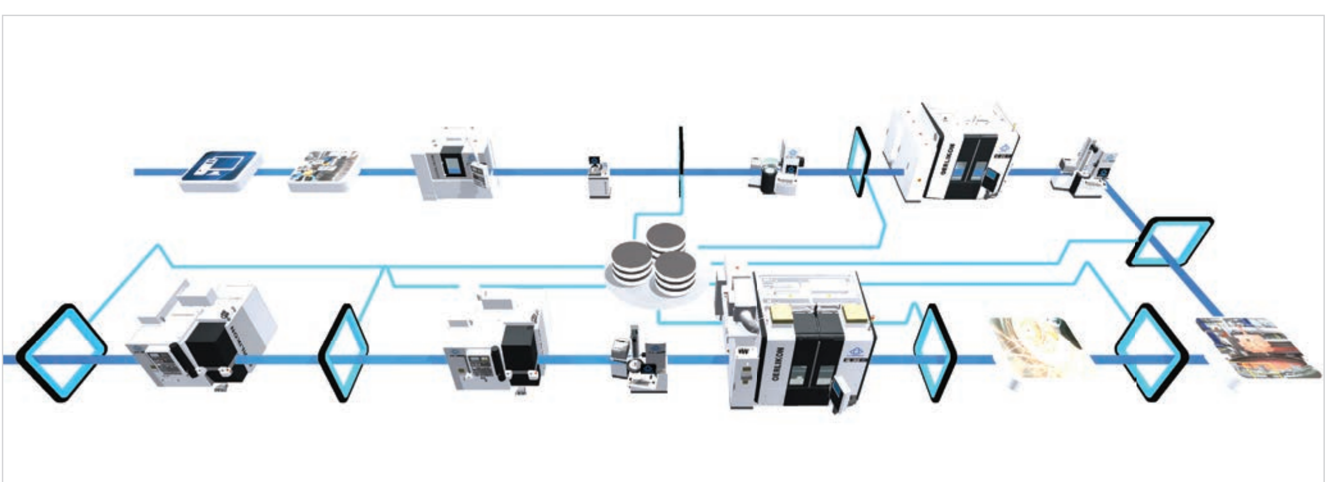

Fig. 3: Production process and quality gates

GearEngine® manages these data

To escape the confusion of haphazard assumptions and speculations, reliable data that can be interlinked is required. To this end, GearEngine® manages three different classes of data:

- Data that describe the geometry of the gear
- Data that describe the production equipment
- Data that describe the manufactured gear

First …

The first "data pot" describes the geometry of the component along its entire process chain. The process begins with the turned part. It is defined by a 3D-CAD model which already contains the allowances for the subsequent hard finishing of the gear body. The next step is gear cutting in the soft stage. Here, the description of the gear cutting tool and the kinematics is stored in order to generate the desired gear shape. The geometric description of the tooth flanks also already contains the allowance for the subsequent hard finishing of the tooth flanks. For the final hard turning or grinding of the gear body following heat treatment, there is a 3D-CAD model that contains the final gear body geometry. For finishing the tooth flanks by grinding, the geometry of the tool or dressing kinematics and the kinematics of the grinding machine are managed in this first data category of GearEngine®. For hard finishing processes that do not have process reliability, such as bevel gear lapping, only the final geometry of the flanks is managed, without the tool geometry and machine kinematics. As a result, in the first database in GearEngine®, there is a specific digital target twin for the gear along the entire process chain.

… second …

The second class of GearEngine® data describes the production equipment. These are the tools, arbors and processing machines. The tools include cutter heads, grinding wheels, hobs and dressing rolls. Arbors are managed here with all of their individual components. A true digital twin of the processing machine (from which the static and dynamic behavior of this machine can be derived) is not possible today in practice or in theory. That is why the digital description of the machine is limited to the data of the dynamic fingerprints, ballbar results and similar machine-specific information.

The first interlinking of GearEngine® data takes place in this second class. That is, the tools and arbors are assigned to a drawing number, and thus to a specific component type. Alongside the geometrical data of the production equipment, the data for the setup process are also managed here. GearEngine® records concentricity at the test mandrel of an arbor, for example. The experienced practitioner knows that concentricity errors can be caused by the arbor itself as well as an inaccurate setup of the arbor on the machine. Measurable data from the setup process are also included so that these factors can be filtered out at a later point.

Fig. 4: Analysis and correction with Gear Corrector

… and third!

Whereas the first data class includes the digital target twin of the gear type, in the third class of GearEngine® data, production data from every gear actually produced can be managed. The essential prerequisite for this is an individual component identification of each gear by means of appropriate coding procedures. When a previously unknown component first appears in the machining process, GearEngine® creates a digital file for this component. For every processing, inspection or test machine involved in the manufacturing process, GearEngine® provides a storage location for process parameters or test results, which are then saved in the relevant component file. The current machining status can thus be retrieved in real time. A measuring machine, for example, then recognizes not only the correct drawing number for the gear, but also whether the nominal data are to be used for the soft cutting or hard finishing. Any corrections for a processing machine are always assigned to the correct machine based on the information in the component file. That is because the software knows which machine was used to machine the respective gear.

Conclusion

GearEngine® does away with manual entries for the quality control loops, resulting in a significant increase in process reliability. It also provides maximum transparency in production and quality assurance. Because the design data are linked to the production equipment data and the production process data, for the first time, GearEngine® makes it possible to know which clamping device and tool were used to manufacture a gear, on which machine and with which process parameters.

GearEngine® takes the dread out of troubleshooting – once and for all. Anomalies and quality fluctuations in gear production will continue to occur in the future. But rather than devoting great technical expertise to keeping a gear history along the entire process chain, GearEngine® allows the integrated database to be used to determine similar patterns in anomalous gears. Modern methods of artificial intelligence, such as those used in big data analytics, are suitable for this purpose. As soon as these patterns have been identified, it is easy to find the cause of the anomaly and then to correct it, once and for all. ◆

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Compact

Troubleshooting made easy

GearEngine® takes the place of time-consuming gear histories along the entire process chain for finding patterns and anomalies in gears. Quality control loops can be automated, and process reliability and transparency in production attain the maximum levels currently possible.

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