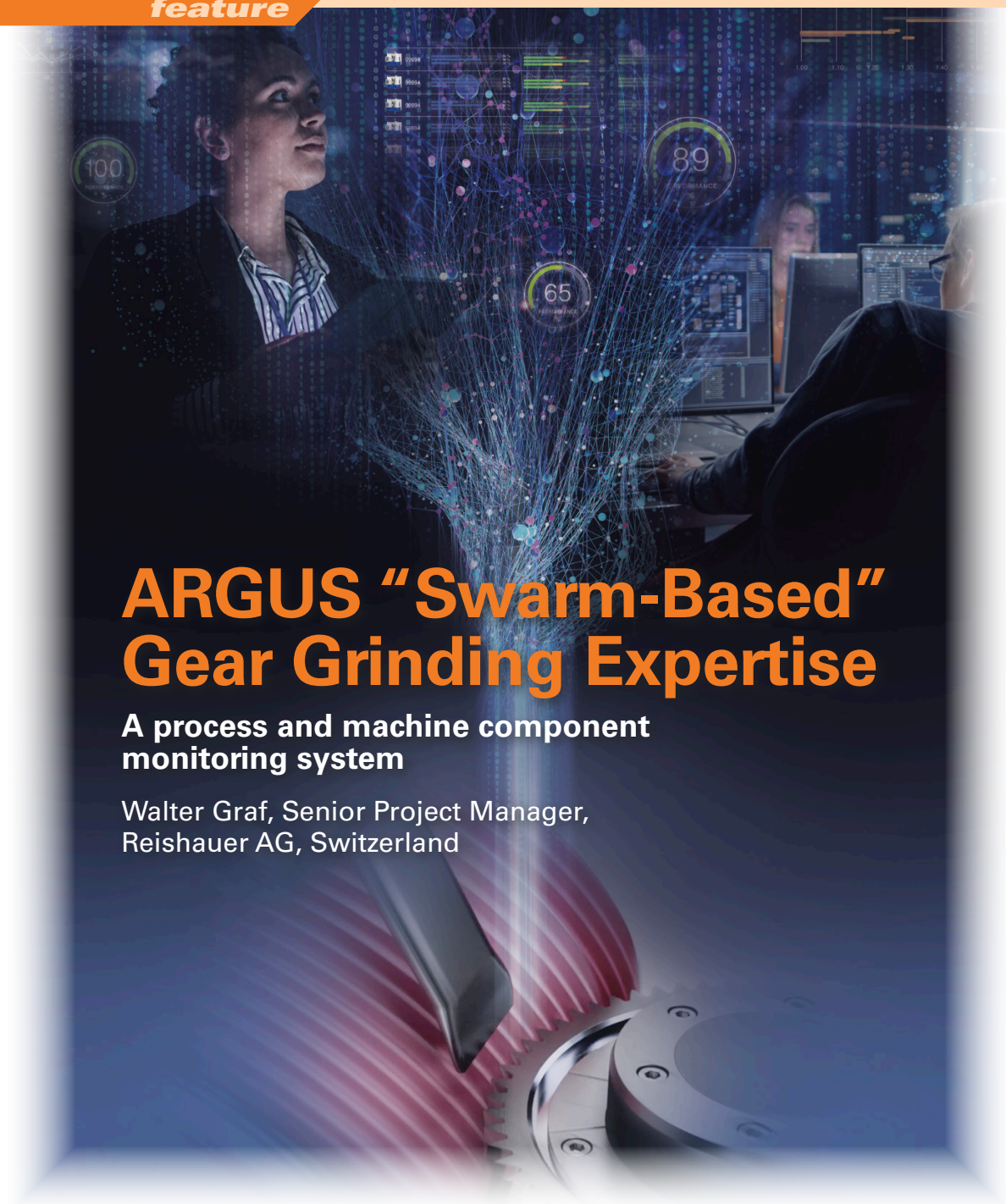


# ARGUS "Swarm-Based" Gear Grinding Expertise

## A process and machine component monitoring system

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This article describes a cloud-based process and machine component monitoring system called ARGUS. The term "swarm" is used for a large population of gear-grinding machines of individual and independent customers connected to the ARGUS system and the ARGUS cloud. These "swarm" machines permanently feed their anonymized process data into a common cloud database. Reishauer uses this database for big data analytics to discover patterns that indicate successful process and machine component

behavior patterns worth integrating into the ARGUS algorithms and propagate them across the complete ARGUS customer base. Of course, should the system also discover detrimental process patterns, such patterns are eliminated by adjusting the algorithms accordingly. While the system can operate as a standalone version at one customer plant, and even if this customer had some 50 machines, their data would never suffice to gain the insight that the much larger cloud-based Reishauer database can. First, an individual customer does not have the range of workpieces that would be stored collectively in the ARGUS cloud. Second, individual customers, for better or worse, have their ideas of an efficient grinding cycle. Within a large group of customers, there are always those who push boundaries and may discover new approaches which, once proven by ARGUS, would enrich the data to benefit all subscribers. This article argues that using the cloud-based variant, which is subscription-based, offers many benefits to individual customers. As a subscription to ARGUS entails automatic updates containing all insights gained, the subscriber constantly benefits by safely making full use of the grinding machines' potential by grinding close to the top performance limits.

Reishauer is continuously expanding its knowledge base. In July 2023, Reishauer already had around 21 million grinding cycles and stored all the associated data points. Moreover, every one of these 21 million cycles encompasses around a million data points each. At this point, it is important to repeat that all the data is anonymous and not linked to any specific customer. With complete parameter data, twenty-one million grinding operations is a large enough data pool to apply Data Science and use artificial intelligence (AI) for pattern recognition and adaptation of algorithms.

These data sets provide tremendous insights into processes with different grinding parameters. For example, Reishauer can gain insights into the optimal setting of grinding intensity limits. At the same time, the individual data sets remain anonymous, which is important for our customers and Reishauer. However, any general insights Reishauer gains from analyzing the data can be continuously fed into ARGUS updates. This way, all the subscribed customers gain a deeper knowledge of the generating grinding process.

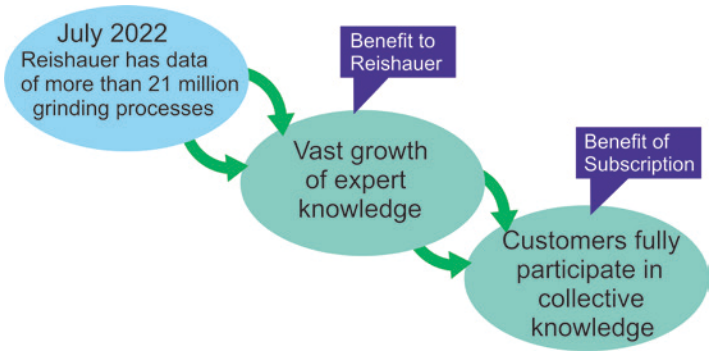
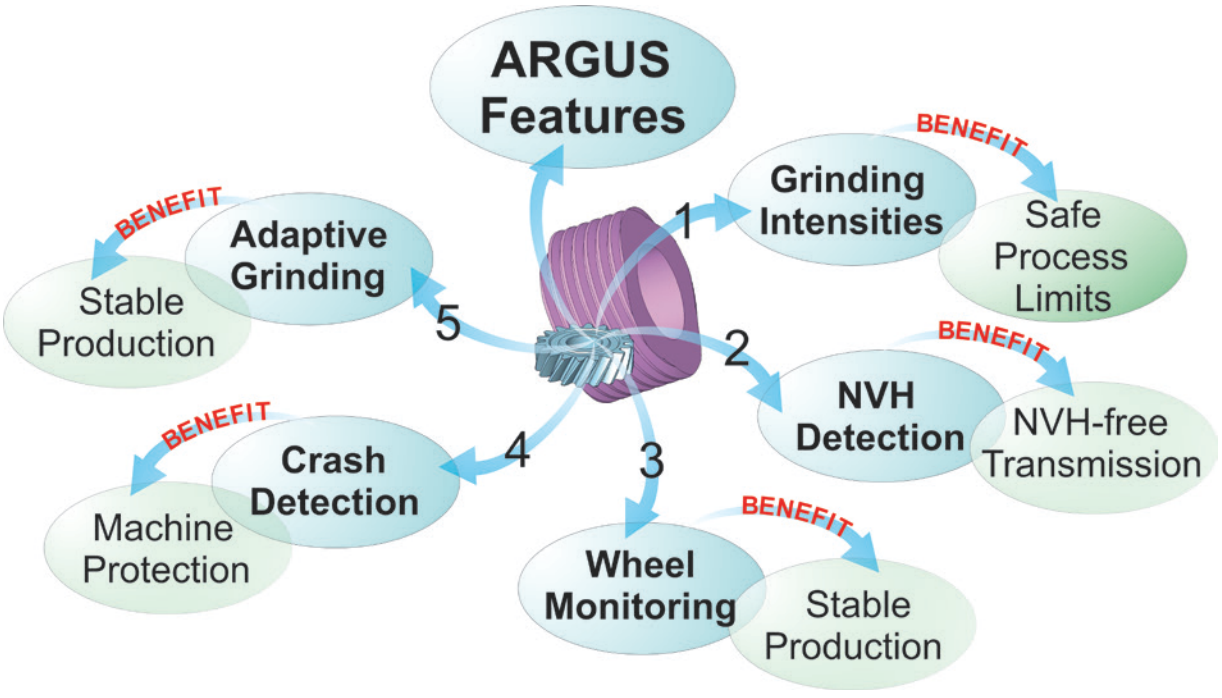



*Figure 1—Benefits of large database model.*

## ARGUS Features




**1» Grinding intensities:**
These parameters are based on a force model describing the Reishauer process's contact condition. Once the grinding intensities of the roughing and finishing process are established, the parts ground within the limit have been proven accurate. In line with the quality requirements, all subsequent parts that are ground within the grinding intensity limits are also acceptable. For example, faulty pre-machined parts would generate grinding intensities that exceed the limits, and the Reishauer machine would automatically identify these parts and remove them from the process. This feature allows 100 percent part-quality control.

**2» NVH detection:**
ARGUS has proven invaluable in detecting and preventing NVH issues. In the best case, ARGUS can detect parts using spectral analysis that may generate NVH once they are put into transmissions. In a second case, ARGUS can be used—via Automatic Component Monitoring or analysis of the grinding data—to pinpoint the origin of the NVH problem.

**3» Grinding Wheel Monitoring:**
In the past, individual operators assessed grinding wheels subjectively. ARGUS offers a clear analysis and monitoring of the performance of a grinding wheel across its full tool life.

**4» Crash Detection:**
This ARGUS safety feature protects the machine tool. If, for example, a workpiece bore is too big and, consequently, cannot be clamped properly, it may move its position. When meshing with the threaded wheels, the out-of-position workpiece may collide with the threaded wheel. However, as ARGUS instantly picks up excessive grinding intensities, the machine immediately retracts into a safe position. This feature also protects the threaded wheel and ensures that only little damage on the threaded wheels occurs and can be easily dressed off.

**5» Adaptive Grinding:**
Adaptive grinding is an effective way of stabilizing the grinding process if the pre-machining is low quality. Varying material allowances and heat treatment distortion often lead to nonlinear and unstable contact conditions. An adaptive grinding process maintains the grinding forces constant, offers safety against overload, and reduces tool wear.

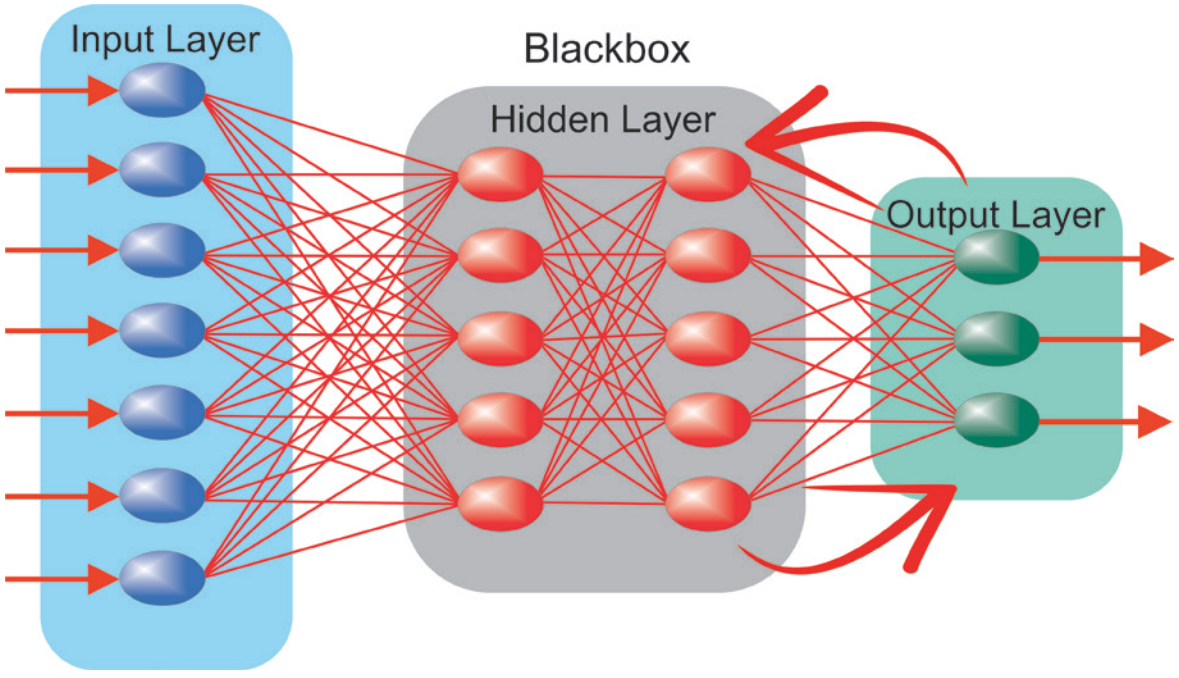



*Figure 2—Neural network and AI.*

For this purpose, Reishauer developed the ARGUS system based on AI. Several prerequisites must be met for artificial intelligence to be effectively used in the first place. First of all, a large amount of curated data is needed, based on which it becomes possible to derive physical regularities on which to design algorithms. In this context, there is also a need for experts and professionals from the gearing industry who can program the algorithms required for AI. In a nutshell: AI must be hard-won! What is called "intelligence" in AI is based on lengthy processes of sending reviewed and curated data sets through neural networks. Subsequently, the data output results must be checked, revised, and sent backward through the neural network. In this manner, the AI system continuously learns, constantly corrects itself, and adjusts the algorithms accordingly. This process is also called deep learning. So, what can artificial intelligence do much better than human intelligence? AI can find the proverbial needle in a haystack at lightning speed. AI is based on pattern recognition, uncovering unusual correlations in enormous amounts of data that would usually escape human intelligence. AI is, first and foremost, a decision-making technology. In the context of component monitoring, speed and accuracy of decision-making are imperative, and AI is lightning-fast.

Automated component monitoring requires a cloud structure for data storage to cope with the large volumes of data continuously generated by countless grinding machines around the clock, as shown in Figure 3.

Furthermore, it requires overarching machine algorithms that can evaluate the anonymized data about the states of the machine components in real-time with AI with the Automatic Component Diagnosis (ACD) feature. The grinding machine runs autonomous cyclic tests that reflect the components' conditions. Since grinding machines generate enormous quantities of signals, the signal quantity is only useful if it can be interpreted. It has been necessary to bring in a highly skilled person who knows how to interpret and analyze signal


*Figure 3—Cloud structure of large machine tool population.*

changes—especially in real time—because it is paramount to interpret the data when any critical process condition occurs. No matter how experienced, this person cannot interpret the multiple problems in the volumes of data generated by the equipment today. The ACD does not wait for errors but is constantly evaluating and thus uncovering tendencies in the deviations. It is only based on analyzing these tendencies that preventive maintenance is possible. Due to the large amount of data, the ACD finds even the smallest errors or deviations. The detected errors can then be traced back to a bearing of a machine axis, to name one example.

Only enormous amounts of data, available anonymized in a cloud, make it possible to train the corresponding algorithms. It is important to mention that the legal regulations concerning data protection must be strictly observed. The machine can be checked as often as required without needing personnel, without interrupting the production cycle, enabling preventive maintenance, and saving user costs, as machine downtimes can now be planned.

Over time, the precision of the algorithms continues to improve as the knowledge gained leads to further developments and refinements. In addition, since sensor technology is constantly evolving and always integrated into the ARGUS system, this also continuously upgrades the analyses and the algorithms. Whereas failure analyses took a huge amount of time, with the help of ARGUS, the Reishauer experts can perform a failure analysis at lightning speed. For example, the specialists can predict a potential NVH problem (disturbing transmission noise) from the signals, preventing faulty parts from being installed in the finished transmission. Previously, such problems required an expensive and time-consuming trip to the user's site.

In addition to Automatic Component Diagnosis (ACD), ARGUS breaks down the previously mentioned million data points per grinding cycle into the following five main features:

## Conclusion

It is very important to understand that the foundation of ARGUS is a sophisticated, properly functioning gear grinding machine. The Reishauer gear grinding machine has proven itself with thousands of machines worldwide. Every other feature of Reishauer's circle of competence, tooling, automation, or grinding technology, is an add-on to the successful machine concepts. This approach also applies to the ARGUS system. ARGUS is an add-on, a part of digital services, and makes the machine even better; it offers transparency and control on a level never seen before. This transparency and control, plus its continuous improvement, offered by subscription as an ever-expanding database, provides the customers with a powerful tool to get the maximum benefits from their gear grinding processes.

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