Finding the needle in the haystack.

Technical cleanliness:
The INNIO Group uses a ZEISS solution to analyze the chemical composition of residual dirt particles.

ZEISS

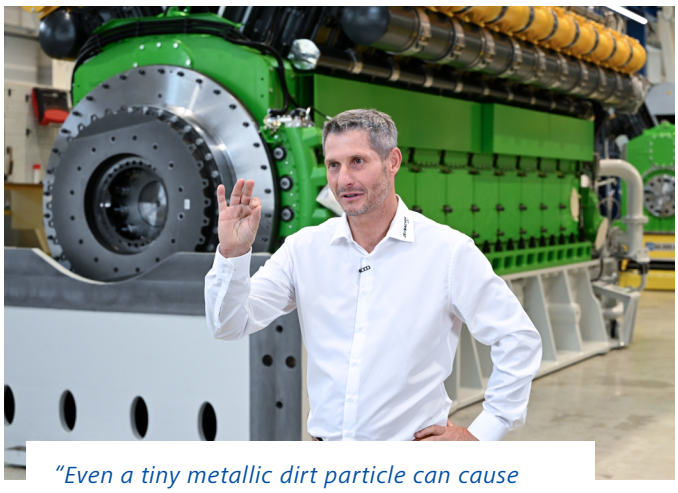
Seeing beyond

Technical cleanliness:

The INNIO Group uses a ZEISS solution to analyze the chemical composition of residual dirt particles.

The INNIO Group is a company based in Jenbach (Austria) that develops and manufactures innovative systems for energy production and compression. Because the large engines are continuously becoming more powerful and the individual components subject to increasing mechanical stress, the INNIO Group in Jenbach introduced standards for technical cleanliness already 10 years ago. To determine the origin of critical residual dirt particles ZEISS EVO electron scanning microscope has been used since 2015.

Christian Troger is Operation Quality Leader at INNIO in Jenbach.



"Even a tiny metallic dirt particle can cause substantial damage in our powerful engines," emphasizes Christian Troger, Operation Quality Leader at INNIO in Jenbach.

For example, were a metallic particle the size of a grain of sand to find its way into the connecting rod bearing, it could cause the oil film in the bearing to rip. Insufficient lubrication increases the friction between the crankshaft and the connecting rod bearing, which can lead to serious damage. Repairing the damage on a motor that, as in the case of the Jenbacher J920, weighs 91 tons and whose connecting rod bearing is almost 7 meters long and weighs 8.5 tons, would be complex and very costly. A repair would also greatly delay the delivery of the engine to customers. The higher the power density of an engine, the more important technical cleanliness becomes.

Industry leader

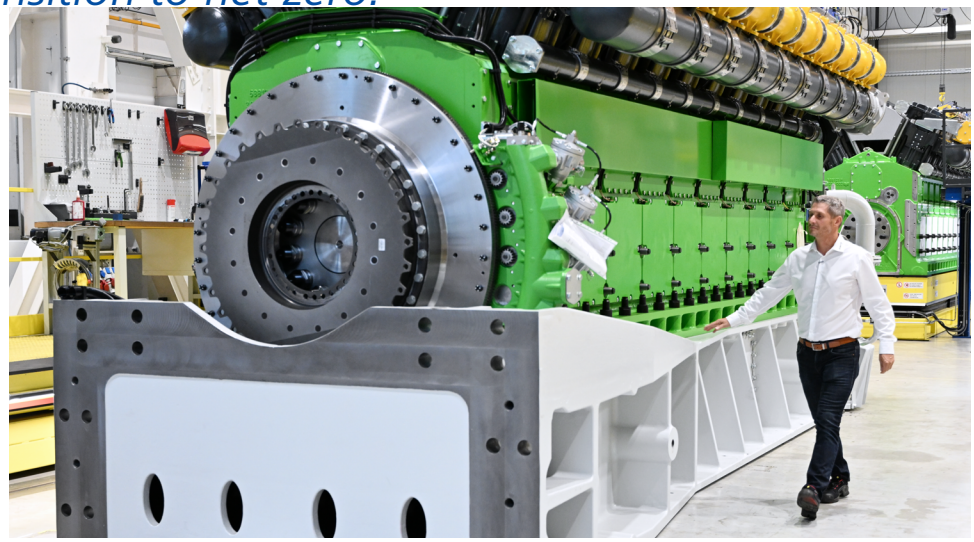
With its engines, Jenbacher is able to offer its customers generator sets and power-heat and power-heat-cooling generation systems in the performance range of 250 KW to 10.4 MW. These can be operated with a wide range of energy sources such as landfill gas, sewage gas, biomethane or hydrogen, thereby supporting Jenbacher's customers in their transition to net zero. To date, more than 25,000 Jenbacher engines have been delivered in around 100 countries. When it comes to the performance and reliability of Jenbacher engines, the INNIO Group sets standards for the industry.

And the development continues – with a significant impact on the components in the Jenbacher engines. The increase of the mechanical efficiency to well over 50% and the fuel flexibility with regard to methane number, proportion of hydrogen, and biogases increases the peak pressures and bearing loads and contributes to a higher thermal load of the engines. This necessitates the use of harder bearings and significantly tighter tolerances. But this also raises the risk of the oil film breaking due to a critical particle.

"Technical cleanliness is very important in our production which is why we test on the ZEISS EVO Mat 25, so we can meet the technical specifications 100%. And our motors can run for a long time with the highest quality."

Martin Mühlbacher, Vice President Operations & Site Manager.

» *Jenbacher engines (...) support customers in their transition to net zero.*



More than 25,000 Jenbacher engines have been delivered to around 100 countries to date.

It's an insight that the INNIO Group gained much earlier than many other companies. But the industry has meanwhile woken up. "For several years now, more and more technicians and people who work in quality departments have been attending symposiums on technical cleanliness," observes Troger.

New standards for production

The decision to introduce technical cleanliness standards in 2012/2013 led INNIO in Jenbach to a big change process. Inspired by the experiences of the automotive industry and following Guideline VDA 19, the entire process was first modelled. Next, cleanliness specifications were defined for sensitive components and highly critical areas of production determined. There was a total of about 800 project steps. But instead of trying to achieve the maximum that would have been possible, the INNIO Group in Jenbach focused consistently on implementing only the most necessary things - and what is necessary is not only determined by quality assurance. "We tried to involve everyone," recalls Troger. That includes management.

» *As technical cleanliness is also a cost/benefit and risk-management issue.*

The INNIO Group has invested approximately 3 million euros in various measures and solutions for technical cleanliness. Air locks were installed, workplaces remodelled, certain areas encased, and cleaning instructions adapted. For example, today the cement floor in production is mopped every day. And in

The crankshaft in particular must be free of particles.

The entire process, from the delivery of goods to production and through to dispatch is monitored with particle traps.

» *And in order to be able to analyze the residual dirt on the components, a laboratory was set up with specially developed equipment for rinsing the components, which weigh several tons.*

order to be able to analyze the residual dirt on the parts, a laboratory with specially developed facilities was set up to rinse the ton-heavy parts. A suction cleaner containing specially designed cyclone filters for the analysis and cleaning of critical areas of the motor was also developed, and the company invested in microscopes capable of investigating the analysis filters that capture residual dirt particles.

The company also switched 100% to plastic pallets after it learned over time that wooden pallets cannot be cleaned and that they contaminated the already-cleaned components with metallic and non-metallic particles. In addition, a cleanliness plan was developed for every workplace. Specifically, it was defined which areas of a workspace must be cleaned and how often. Suppliers also had to be trained accordingly. Troger says it lasted two to three years “until we had a good standard.”

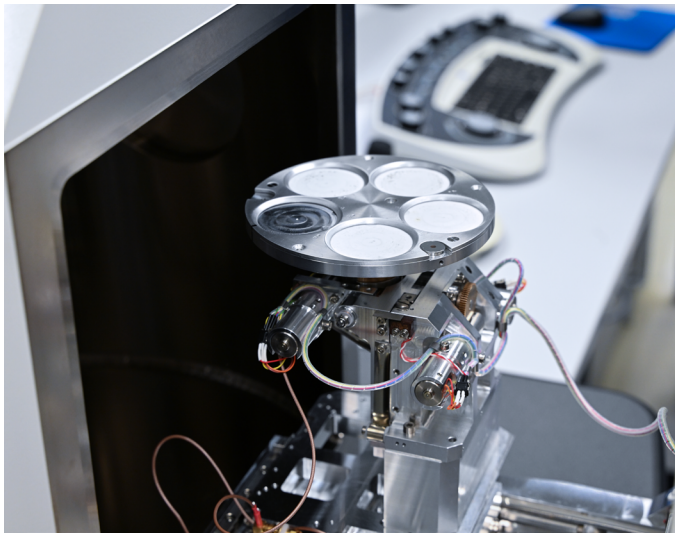
» *To maintain this standard, the entire process - from the delivery of goods all the way to production and delivery - is controlled via particle traps.*

These particle traps show the load and when the limits in specific critical areas have potentially been exceeded. The ZEISS EVO scanning electron microscope plays a key role in discovering and removing potential contamination sources.

The filters are collected at the outlet and analyzed microscopically.

If a limit value is exceeded, the analysis filter with the particles is examined more closely.

Johannes Bachmann, expert for material analysis at INNIO in Jenbach, receives a filter for testing.



ZEISS EVO scanning electron microscope plays a key role here.

A scanning electronic microscope for the determination of materials

To determine the composition of a material and therefore the source of particles using the ZEISS EVO, the particles first have to be separated from the component. This process takes place in INNIO's TecSa laboratory in Jenbach. Residual dirt particles that have been washed off the components by special washing machines are captured in a filter. This filter is then investigated on-site with a light microscope. "By determining the number and size of the particles, we can already know whether certain thresholds have been exceeded and how good our processes are." Because the components are grouped into risk groups and, therefore, into their corresponding cleanliness categories, it is precisely defined which size and number of particles are critical. For example, if a threshold is exceeded for a crankshaft, the analysis filter containing the particles will be closely examined using the scanning electron microscope.

> » *Initially, this analysis was done by an external service provider, but that took three weeks or even longer - too long for the quality assurance department at INNIO.*

Also, involving external parties complicated the communication process, which prevented a fast detection of possible contamination sources. These factors explain why the company decided to invest in its own scanning electron microscope (SEM) in 2015.

The ZEISS EVO SEM works with a software called ZEISS Smart Particle Investigator for the analysis and classification of particles. This software, which fulfills current ISO and VDA norm for technical cleanliness, combines in one single application all aspects needed to operate the SEM, process images, and perform elementary analysis. And because the system does the particle analysis automatically, it can operate continuously and without human supervision. This lightens the workload of Johannes Bachmann, an expert for material analysis at INNIO in Jenbach.

> » *If he receives a filter that should be investigated, he just needs to place it in the device and can come back after an hour or two to get the results.*

In addition to seeing structure and morphology, Bachmann can also see on a screen connected to the microscope the chemical elements of the particles. To gather this information, the primary electron beams in the microscope are directed at the sample. This causes the electrons in the atomic shell to emit Xrays.

Bachmann and Troger both concur: "With the ZEISS EVO MA 25, we find the needle in the haystack."

» Needle found in the haystack.

The REM ZEISS EVO works wih the software for particle analysis and classification software ZEISS Smart Particle Investigator (SmartPI).

» *ZEISS SmartPI combines in one single application all aspects needed to operate the SEM, process images, and perform elementary analysis. And because the system does the particle analysis automatically, it can operate continuously and without human supervision.*

Because the spectrum of radiation is unique for every element, the composition of the particles can be exactly determined through so-called EDX analysis (energy-dispersive X-ray spectroscopy). With this information, Bachmann - who knows exactly which materials Jenbacher uses at its site - can determine where the particles come from.

Stable processes for many years

Ten years ago, when Jenbacher first introduced standards for technical cleanliness and newly defined its processes, Bachmann analyzed at least 20 filters a week.

» *These days, only a few filters a week need to be examined as a matter of routine.*

But even though the processes at INNIO in Jenbach are running so smoothly today, no one at the company can or wants to do without the scanning electron microscope.

Bachmann and Troger both concur: "With ZEISS EVO MA 25, we find the needle in the haystack." For even if an analysis showed that a potentially dangerous particle was made of silicon, it is highly probable that the air locks were open and sand particles contaminated the component, explains Troger.

» *"Without a chemical analysis of the particle by the SEM, we would only know that we have a problem, but we wouldn't know where we should make improvements," he emphasizes.*

Pinpointing rather precisely the origin of a particle also helps Troger and his team to raise awareness among his colleagues about the problem of technical cleanliness and, when necessary, to introduce certain measures, such as modifications. He hardly encounters pushback. "At INNIO in Jenbach, the quality assurance department is not seen as a police force or unfriendly control freak, but as an on-site authority that helps prevent mistakes before they appear and implements improvements." In Troger's opinion, that "has a lot to do with the fact that we implemented standards for technical cleanliness."

Video of the customer story

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