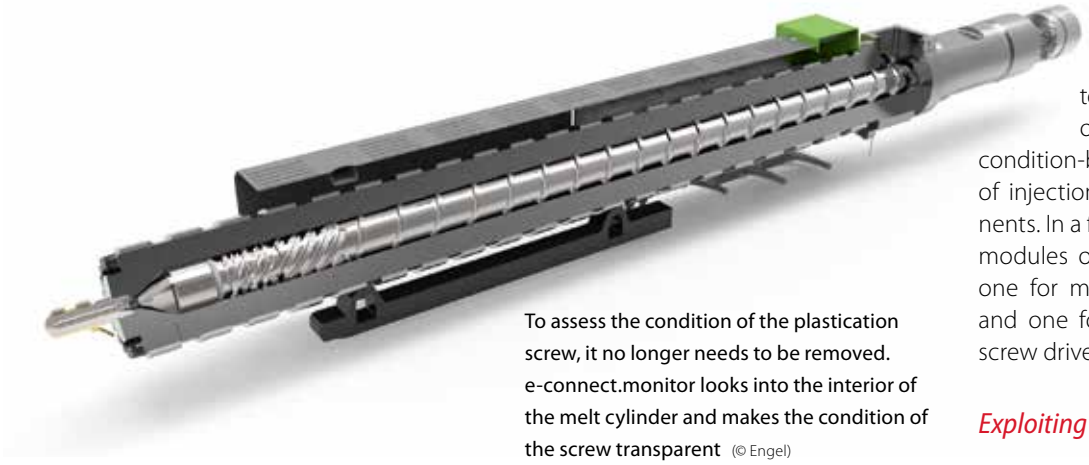
Avoiding Unplanned Downtimes

Condition-Based Predictive Maintenance on Injection Molding Machines

Maintenance personnel have to ensure a high availability of the manufacturing systems and at the same time reduce the costs for maintenance work and the stocking of spare parts. With the increased networking of production systems and systematic use of machine data, Industry 4.0 is opening up new opportunities. At K 2016, Engel has presented a first solution for condition-based predictive maintenance of critical components in injection molding machines.



To assess the condition of the plastication screw, it no longer needs to be removed. e-connect.monitor looks into the interior of the melt cylinder and makes the condition of the screw transparent (© Engel)

Injection molding machines in operation have until now been something of a black box. The condition of process and quality critical machine components is unknown to the machine operator. To prevent unpleasant surprises, some manufacturers exchange wear components on a regular basis. This policy avoids unplanned downtimes, minimizes the downtime necessary for exchange and prevents collateral damage to the ancillary equipment parts. However, the plant operator has to take into account some serious disadvantages. Since the exchange is performed earlier than is actually necessary, the maintenance costs are higher and availability is reduced.

The new e-connect.monitor solution developed by Engel Austria GmbH, headquartered in Schwertberg, Austria, on the other hand, allows the useful life of the machine components to be fully exploited and downtimes to be precisely planned. The system does this by checking the condition of the process-critical components during operation and reliably determining their remaining useful life. The availability of the plant increases and the maintenance costs are reduced. With the new solution, Engel is expanding its "inject 4.0" program in the smart service field, and passing another milestone on the road to the intelligent factory. The system is currently the only one on the market that permits condition-based predictive maintenance of injection molding machines components. In a first step, Engel presented two modules of the new solution at K 2016: one for monitoring plastication screws and one for online monitoring of ballscrew drives.

Exploiting the Full Useful Life of Screws

Plastication screws in the injection molding machines are subject to severe mechanical loading. Though the material, surface treatment and geometry of the screws are precisely matched to the plastics to be processed, they are subject to wear and have a shorter useful life than the machine. To assess their condition, it was necessary to remove them in a lengthy, complicated process. That means interrupting production, cooling

Fig. 1. The new measurement system can be easily installed externally on the melt cylinder, as here at Praher Plastics Austria on a tiebarless machine with 5000 kN clamping force (© Engel)

the machine, demounting the flange and pulling the screw. With large injection molding machines, this procedure requires a production interruption of up to two complete work days.

To reduce this work, Engel has developed a measurement system based on state-of-the-art sensor technology that can be very easily installed externally on the melt cylinder (**Fig. 1**). It works with ultrasound and therefore does not need direct contact with the screw. The sound waves and their reflections can pass unhindered through the cylinder wall and plastic melt. It measures the clearance between the screw flight and the inner wall of the melt cylinder, which increases as the manufacturing time progresses, and must not exceed a particular value (**Fig. 2**). The tolerance value depends on the requirements of the injection molded part, the material used and the surface finish of the screw. In general, abrasion of the screw flight is the type of wear that most impacts the quality of the injection molding process.

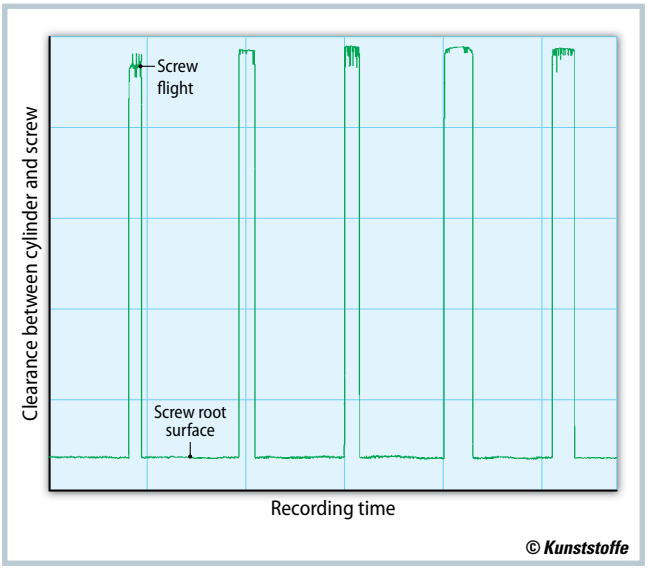


Fig. 2. The clearance between the screw flight and melt cylinder (cylinder wall: top) is measured by ultrasound. The periodic drops in the curve correspond to the screw profile. The screw flights and the screw root surface can be seen (source: Engel)

The measurement is performed by an Engel service engineer, which directly assesses the quality of the measurement signals locally and terminates the measurements as soon as valid data are available (**Fig. 3**). In total, gathering the data only takes a few minutes. The measurement results are transmitted to Engel via a secure data connection, where they are automatically evaluated and interpreted using specially developed mathematical models. In future, the results of the »

Fig. 3. The data collection – at Schöfer in this case, on an Engel duo 16050/1700 with a 135 mm screw – only takes few minutes. The measurement results are evaluated automatically (© Engel)

Fig. 4. The six-way backwash valves of ABS are produced in large quantities at Praher, which is why the state of the screw is regularly checked (© Engel)

evaluation will be available online to the processor via the e-connect customer portal. If the condition of the screw is checked at regular intervals, the system can calculate the remaining screw life within a defined time period based on the abrasion.

The time interval for the measurement depends on the type of application. The decisive factor is the material to be processed. Glass-fiber-filled grades, for example, generally result in wear much faster than, e.g., a standard polypropylene, and therefore require shorter intervals. Other factors that influence wear include the cycle time.

The prediction of the remaining useful life permits the machine operator to exchange the screw at an optimum point in time. He can order the new screw in good time, and time the delivery precisely to the planned exchange schedule. In this manner, e-connect.monitor shortens the downtime, and makes in-house spare parts stocks unnecessary. In the long term, the regular condition monitoring even supports process optimization, because the evaluation of the wear parameters allows critical process settings that speed up the wear of particular components to be recognized and mitigated with suitable process modifications.

Fig. 5. "If there are problems in the process, we can rapidly eliminate wear as a cause thanks to the regular screw control," says Wilhelm Raber, Head of Injection Molding and Manufacturing at Praher Plastics Austria (© Praher)

Fig. 6. "If we can predict the remaining useful life of our screws with e-connect.monitor, there is a win-win situation for Engel and us," says Josef Fröschl, Production Manager at Schöfer (© Schöfer)

Practically Proven even before Market Launch

Like many of Engel's products and solutions, the new e-connect.monitor is based on the system supplier's close cooperation with its customers. Long before market launch, Engel had already tested the system in practical use and further optimized it. The development partners include Praher Plastics Austria GmbH and Schöfer GmbH, both with their headquarters close to Engel's main plant in Schwertberg, Austria.

One of Praher's important business fields is the manufacture of challenging swimming pool valves, fittings and accessories from ABS, PVC, PP, PP-GF and PVDF. The screw module of the predictive main-

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tenance system was installed on different Engel machines, including a 5000 kN tie-barless machine with a 90 mm screw, with which six-way backwash valves of ABS are produced for sand filter systems in swimming pools and wastewater treatment systems (**Fig. 4**). The valves must operate reliably in very harsh conditions. In addition, the part makes severe demands on the precision of the injection molding machine because of the variations in wall thickness.

The valves are produced in large quantities, and the state of the screw must therefore be regularly checked. "Previously, we had to remove the screw in a very lengthy process involving long machine downtimes," reports Wilhelm Raber, Head of Injection Molding Technology and Manufacturing at Praher (**Fig. 5**). "Now the measurement only takes 15 minutes, and we don't have to shut down the machine. That means we can take a look at the screw more often and have more security." As part of the development cooperation with Engel, the screw condition was first recorded every eight weeks for a year. "If problems occur in the process, we can now eliminate wear as the cause because of the short inspection intervals," says Raber. "That can greatly speed up the troubleshooting process."

Focused on the automotive industry, Schöfer specializes in particularly high quality surfaces, processing a wide range of materials, from ABS, through PP and PA to PMMA and PC. "We are only a few minutes' drive from Engel, and therefore enjoy particularly fast spare parts service," says Josef Fröschl, Production Manager at Schöfer (**Fig. 6**). The main critical factor for the plant availability at Schöfer is the fact that very individual screw geometries are required. "For special dimensions, we occasionally have to produce the screw individually. If we can now predict the remaining useful life of our screws with e-connect.monitor, we have a win-win situation. Both Engel and we can plan better. In addition, we prevent stressful situations due to unplanned plant downtimes."

Both the test users Praher and Schöfer have also announced that they want to regularly check the conditions of the screws using the e-connect.monitor module even after the conclusion of the test series. They will also continue to work closely together with Engel as development partner for the new solution.

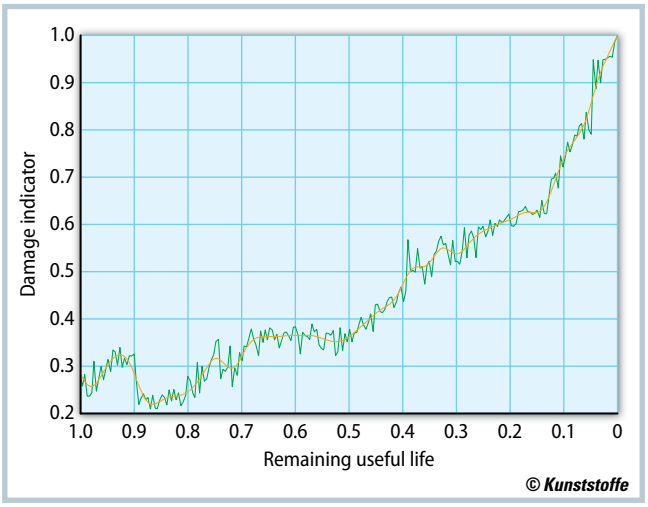

Fig. 7. Using a mathematical model, e-connect.monitor determines the remaining useful life of the spindle based on particular damage indicators
(source: Engel)

Keeping an Eye on the Condition of Spindles Online

The predictive maintenance system is not only suitable for wear parts, but can also support the monitoring of other critical core components of an injection molding machine. In addition to the screw module, Engel presented a module for ball screw drives (spindles), which lie at the heart of an electrical injection molding machine. They convert axial movements into radial and vice versa. Since several spindles are in operation per machine, and the failure of a single one shuts down the complete production line, the condition of the ball screw drives, unlike that of the plastication screws, is monitored continuously.

Different methods are available for this: Among other things, temperatures, frequencies and performance data are determined and analyzed. These data are combined to a damage indicator using a clustering algorithm in order to obtain a reliable statement about the condition of the spindles (**Fig. 7**). This damage indicator is inversely proportional to remaining useful life. The higher the damage indicator the shorter is the remaining useful life of the spindle. By connecting to the e-connect customer portal, the system will be able to directly notify the user in future if a spindle reaches a critical condition. On request, the software can be programmed so that the alarm signal automatically triggers a spare parts order and books a service engineer.

Smart Processes for More Productivity, Efficiency and Quality

The aim of Industry 4.0 is to achieve the intelligent factory, in which all manufacturing machines and their components communicate with one another and continually optimize themselves. As a consequence, the productivity, efficiency, quality and flexibility of production will be significantly improved. It focuses on three areas: machine, production and service. For all these three areas, Engel already has a wide spectrum of products and solutions under the name inject 4.0 in its program, and continues to develop them. In the field of "smart-service" Engel, with e-connect.monitor, achieves sustained added value for its customers with immediate effect. Both of the modules that are presented at K have been registered for a patent. Other modules are planned. ■