In-line eddy current testing of wire rod

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The latest design of in-line eddy current testers for rod mills can detect surface defects down to 0.15 mm at rolling speeds up to 120 m/s. Software evaluates the detected defects and can distinguish between natural material defects and roll-induced defects.

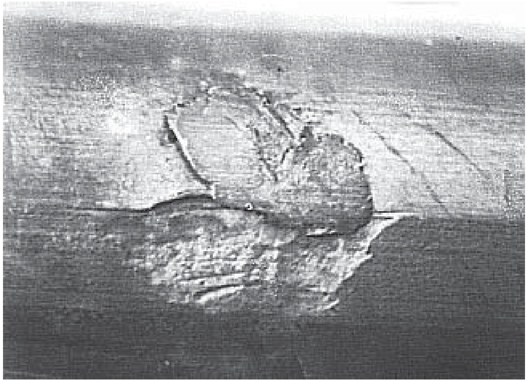
PRÜFTECHNIK NDT has developed a new eddy current testing system that is suitable for the harsh environment of a hot rolling mill while providing immediate feedback on product quality during production – even at high speeds. More significantly, it also identifies defective rolls causing product damage so that they can be replaced. This assures a higher level of quality and minimises waste, resulting in direct cost savings for the rod producer (see Fig.1).

With production speeds of up to 120 m/s and temperatures over 1000 °C, hot rolling mills have special requirements that have led to new techniques in quality and process control during production. These controls are becoming standard procedures as hot rolling mills are being modernised and production is being automated to achieve higher efficiency. With the latest advances in programming technology, networking and materials, eddy current testing offers comprehensive defect detection along the entire length of the product for reliable quality control during production.

Other forms of non-destructive inspection, such as random tests combined with statistical extrapolations, are not sufficient to meet customer demands for fully tested product. Furthermore, destructive testing and sampling is performed only on the ends of the rod and cannot verify the overall quality of the rod. Visual inspection is simply too late.

PRÜFTECHNIK NDT has developed an eddy current testing system that is targeted towards process control. The key is early detection of potential problems in production before they lead to quality loss. Live test data that appears on the screen lets the operator closely follow product quality trends and take measures to correct them at an early stage. Most importantly, the system is capable of detecting process defects caused by defective rolls. Thus the operator has the opportunity to replace the roll before it actually leads to a continued drop in quality.

PRÜFTECHNIK NDT began accumulating experience with its first installation in this sector as early as 1994 and has since expanded its current customer base to include 30 hot rolling mills in many different countries around the world. The latest order from a major Chinese steel complex in the Shanghai area incorporates two EDDYCHEK 5 eddy current testers to continuously inspect the surface of hot wire rod with diameters of 5.5 - 50 mm. Customised software simultaneously displays the test results of two strands in real time and alarms alert the operator to damaged rolls before they can seriously damage the product.



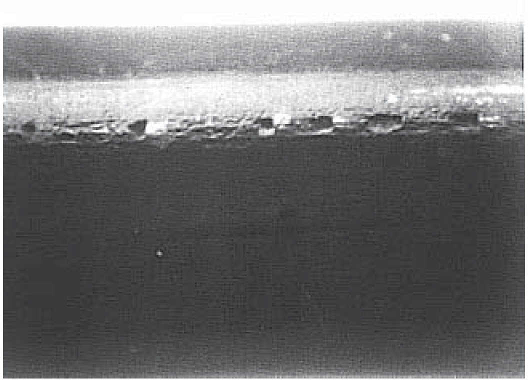


Fig. 2: Natural defects

Types of defects detected

Eddy current testing can find a wide range of defects, whether they are randomly distributed natural material defects or periodically recurring rolling defects such as impressions resulting from roll pass damage and damage from worn rollers. The system can assess the criticality of defects and provides a measure of the depth and extent of the defect to a minimum depth of 0.15 mm. However, tracing one individual defect signal along the rod and attempting to find this particular section of rod over a length of several kilometers is not feasible.

Natural material defects

Detectable defects are cracks, shells, seams, pitting, laps, holes, scale and cross-cracks. The most important evaluation of the overall quality of a rod is made by calculating the defect density, i.e. counting the number of alarms in a predefined length. In this type of application, the test results are evaluated statistically over the entire rod length and the overall quality of the wire rod is evaluated and documented (see Fig. 2).

These are generally much smaller than natural defects and occur at regular intervals, the frequency of which depends on the rolling speed, size of the roll and position of the roll in the production line.

PRÜFTECHNIK NDT has developed a method of determining this frequency and uses it to identify the possible cause of the defect such as a defective roll stand or roll box. (The position of the worn roll before the detector depends on the roll diameters.) This gives immediate feedback to operating staff who can then react quickly to change the worn roll and avoid further production of defective wire rods (see Fig. 3).

Automation of testing

The PRÜFTECHNIK NDT system can be readily integrated in the existing company network and testing can be fully automated. Without any intervention by the operator, testing parameters for a specific production run – such as gain, filtering, signal evaluation criteria – are downloaded remotely in advance of actual production. Process data required specifically for identifying defective rolls (roll diameter, rolling speed, elongation factor, etc.) are also set in advance.

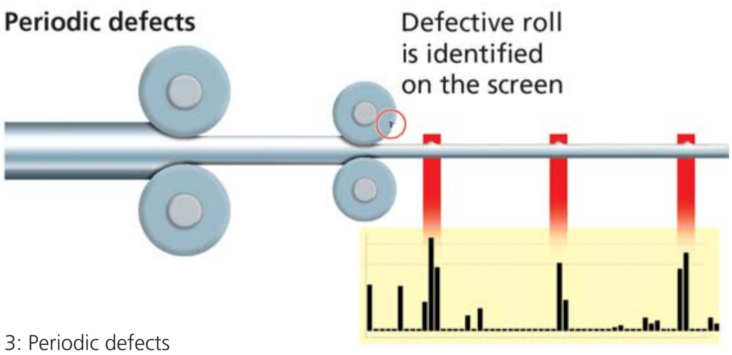


Fig. 3: Periodic defects

After testing is complete, the test results of a coil are stored in a format suitable for databases. The data are either stored on the PC or in a database on a server or host. Thus, customer-specific visualisation, archiving and individual evaluations of the data are simple to realise as is transmission to subsequently connected systems for further material tracking.

Overall configuration of an eddy current system

The basic components of the eddy current system are illustrated in Fig. 4. After the hot wire rod leaves the last mill stand on its way to cooling and coiling, a hot metal detector signals the approach of the rod to the test coil assembly and triggers the eddy current electronics. The rod passes through the test coil and the eddy current signals are transmitted to the eddy current tester, evaluated, and the test results are stored. In systems that are linked to a central production control through the company network, test results are transmitted there for customised reporting and process control functions.

The eddy current system consists of a test coil, its holder and testing electronics, is operated from a PC, and can be linked to a company network for integration in a central process control system. From there, the test system can be remotely operated and testing can be automated to a large degree. Test results are archived and printed out in a variety of reports for subsequent quality checks and verification.

System overview

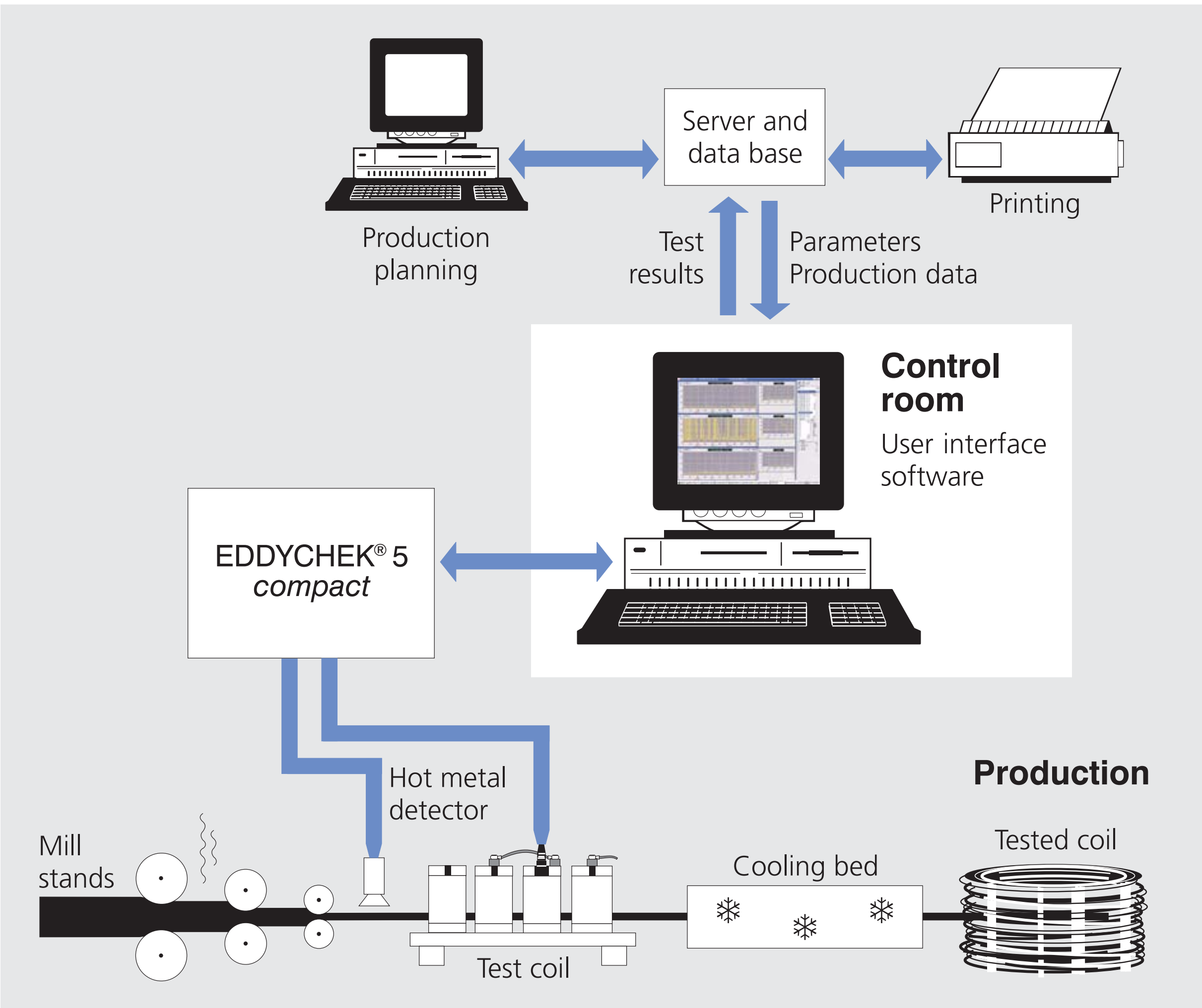


Fig. 4: Basic components of an eddy current hot testing system

Fig. 5: Coil holder in operation with product moving left to right

Details of the coil holder

The holder comprises four elements: an air stripper, a guide sleeve, the test coil and another guide sleeve. The air stripper removes loose scale from the rod surface to prevent dirt particles from contaminating the holder. This is followed by a water-cooled guide sleeve that guides the rod through the test coil and prevents the coil from being damaged by strongly vibrating or twisted rods. The guide sleeve is followed by the encircling test coil which is also water-cooled. Stainless steel liners protect the coil from physical contact with the rod. The last element is another water-cooled guide sleeve. This coil holder can be used to inspect rod with dimensions of 5.5 mm up to 130 mm.

The test coil and the robust, water cooled coil holder are designed to tolerate the high temperatures, strong impact forces, and extreme fouling typical for hot wire rod and bar applications. Cold water continuously flushes through the test coil assembly and coil holder to cool the hardware and an alarm alerts the operator if the water flow stops to avoid burning the test coil. In critical situations, a few rods can still be rolled without cooling if absolutely necessary. The holder can be mounted on a sliding table for rapid removal out of the production line for service. The units can be replaced easily and separately, and the solid stainless steel construction withstands the heavy impacts of cobbles and resists corrosion (see Figs. 5 and 6).

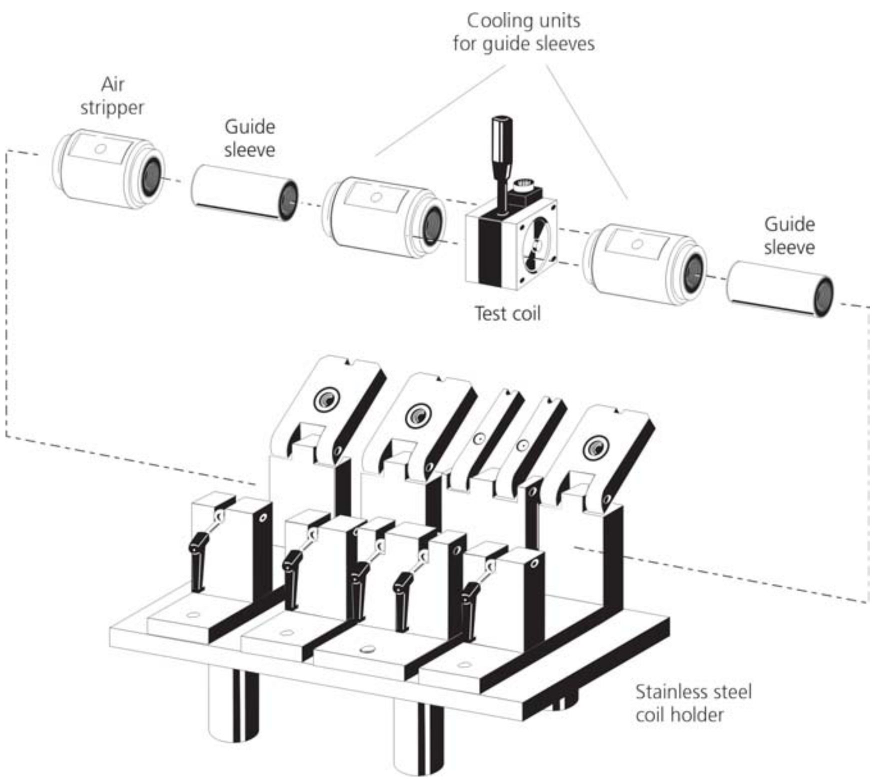


Fig. 6: Components of the coil holder

Details of the testing electronics

The testing electronics are contained in a sealed enclosure that can be mounted out of the way. The system is operated on user interface software that runs on a PC, which is usually installed in an operator pulpit. The PC is connected to the testing electronics via a shielded fibre optic cable which is immune to the multitude of noise sources within a rolling mill and which covers long distances without loss of signal quality. Typical cable lengths in a hot rolling mill can be up to 200 m from the eddy current electronics to the PC. The electronics transmits electromagnetic signals to and from the test coil at high frequencies, typically 100 kHz and higher. The eddy current testing unit transforms the analog signals from the coil into digital information for further evaluation and processing. Signals are evaluated for their amplitude and phase direction and are displayed on the PC screen.

Display

The usual signal display of an eddy current tester shows the signal amplitudes over the product length together with the selected alarm levels. If the signal exceeds an alarm level, a defect counter is activated and other reactions such as the triggering of a warning lamp are also possible. As the test signals are being generated, they appear in a window on the process monitor. The right panel of the same window shows menus in which the user can adjust testing parameters for different materials or sensitivity requirements and save them to be recalled for later use. The multilingual user interface is clearly arranged, logically structured and the user receives guidance through an online help system. Of central importance to early detection of process problems is the historical sequence of the eddy current signals of any three rods. They can be viewed in a separate window as shown in Fig. 7.

Fig. 7: Color screen display showing eddy current signals of three coils

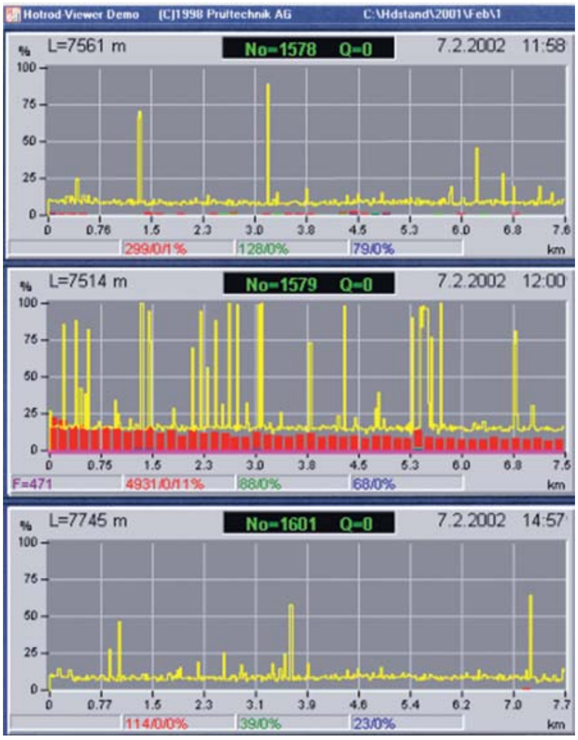


Fig. 8: History of three coils: Top – Before the defect appeared; Middle – When the periodic defect appeared; Bottom – After the roll in question had been changed.

Results and benefits for the customer

The rolls are the parts of a rolling mill that are subject to the greatest use. Wear from contact with hot material under high pressure limits the lifetime of the rolls so they have to be regularly refurbished in the roll shop. However, from time to time, rolls crack or become impaired before the end of their usual production cycle. This, of course, leaves imprints on the surface of the rolled product. The PRÜFTECHNIK eddy current tester clearly indicates signs of damaged or worn rolls and can make an important contribution to the process control of a rolling mill.

A typical example of roll damage was detected and resolved at a customer site in Australia in a two strand hot rod system. The history of the signal traces is shown in Fig. 8, where the signal trace appears in yellow. Initially, the process ran smoothly. The trace at the top shows a normal signal with only a small number of spikes. A periodic defect was then detected during production. The centre trace shows a significant change in the signal indicating many large spikes are now present. The corresponding defect counters have increased and the overall quality of this rod is much lower than the top trace. The frequencies shown on the display indicated that the last rolls as the rod left the finishing block were defective.

As a result, the rolls were removed and inspected. The rolls shown on the left in Fig. 9 were found to have many holes and pits all along the circumference. The roll on the right shows a typical example of a single transverse crack. The rolls were then replaced and testing continued. The trace at the bottom shows the eddy current signals of the first rod tested after replacement of a broken roll. The signals returned to their normal level and were even smoother than before because the surface of the roll now had no signs of wear.

Such signals can, of course, be due to individual billets of poor quality. In such cases the spikes appear sporadically, however, if such signals suddenly appear and then continue rod after rod, a change in the process such as wear to the rolls has occurred.

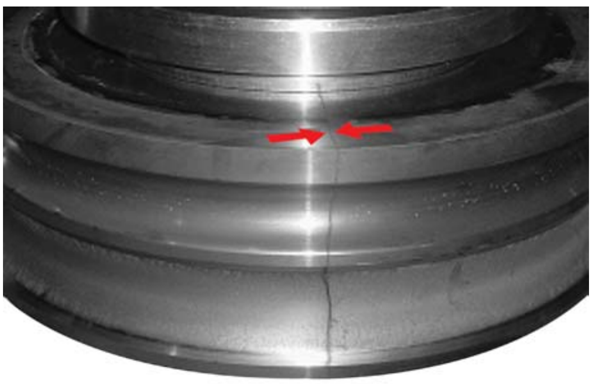


Fig. 9: Examples of worn and cracked rolls. Such defects on a roll surface lead to the typical signal sequence shown in Figure 8.

Of course, such signals can be due to individual billets of poor quality. If spikes appear sporadically, the raw material could be the reason. However, if such signals suddenly appear and then continue rod after rod, a change in the process such as wear to the rolls has occurred.

Conclusion

The eddy current tester has proved to be a very useful device for finding many types of surface defects on hot-rolled wire rod and bar. The main benefit of testing for defects in rolling mills is that the mill operator receives immediate information about the momentary process conditions of the mill. Any changes in the process, deliberate or unplanned, are reflected in the quality of the coil and are detected soon after they occur. Thus, for example, a damaged roll will become apparent in the coil quality as soon as it occurs, and the decision to inspect the rolls can be made after only a few rods have been produced. The short downtime for the roll inspection is well worth the effort as continuing production with broken rolls would result in poor quality rods and greater levels of scrap – with all the associated costs.

Eddy current testing offers a considerable cost advantage over traditional visual inspection where a significant delay arises as a result of transport and cooling before a rod can be inspected thoroughly by a human inspector. By the time the inspector offers feedback on the product quality, rod after rod has passed the defective mill and has received surface damage.

Future developments

PRÜFTECHNIK NDT is committed to the continuous development of its eddy current testing systems and works closely with agents and customers around the world to advance its solutions to many different problems within the industry.

Specific future developments in this sector will include the further evaluation of periodic defect signals to identify the specific rolling mill element (roll or guide) causing the periodic signal as well as automatic data exchange with rolling mill data management systems (heat numbers, order numbers, customer reference, results report) for efficient administration.