INTERPRETATION OF UT AND EC RESULTS IN ROLL TESTING[1]

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Abstract

In recent years roll manufacturers have developed different kinds of high performance rolls. To achieve higher performance these rolls have complex alloy designs and higher hardness shell material. Due to the complex heat treatment necessary to achieve the full benefit of these alloys, residual stresses in the rolls have increased. To ensure a high safety level during operation, the monitoring of the transition zone of double-poured high performance rolls has become increasingly important. From the roll manufacturer's point of view, only the roll-related factors can be influenced, and this is why excellent rolls may sometimes show unexpected results. The high number of campaigns sustained by each roll leads to a situation where fatigue becomes an increasingly significant factor. This paper describes the possibilities of a roll maker and the chances of the roll user to bring a roll through the expected lifetime.

Key words: UT testing; EC testing; Surface wave; Work roll.

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1 UT TESTING AT ROLL MANUFACTURER'S PLANT

Work rolls are produced in a spin casting process. The first step is the spinning of the shell sleeve. Spinning is carried out until the shell material is fully solidified. Then the spin casting chill together with the shell sleeve is removed from the machine and the rest of the mould is assembled together. The last step is the filling of the mould with core iron.

The most important process parameters are the core temperature and the sleeve inside temperature. The core metal has to re-melt the solidified shell. If this is not done properly, inclusions of slag or other non-metallic particles lead to a bonding defect.

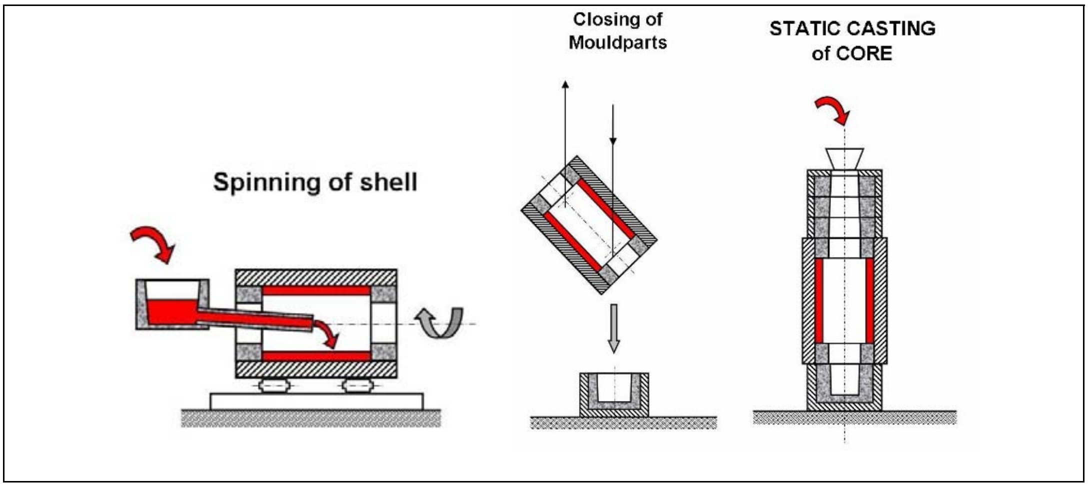

Figure 1. Double poured cast roll production process

1.1 Automatic Roll Inspection System at ESW

To ensure the highest degree of safety for our customers, ESW installed highly sophisticated testing equipment. The system was delivered by Lismar and is called Datames; it contains the control unit and PC, pre-amplifier and automatic probe positioning system and different probes.

Figure 2. UT System on grinding machine

The coupling of the probes to the roll is made with a thin water film. The testing is performed with either a normal single crystal probe to check the integrity of the bond or by a twin crystal probe to monitor the shell material for small inclusions.

The testing is performed by the operator of the grinding machine. The whole testing procedure is as simple as possible. The operator merely has to enter the main data, such as roll number and testing dimensions, choose the appropriate set-up file and the rest is taken from the database.
At the end of the reading a special algorithm calculates whether the roll is ready for further machining or whether the roll is on hold for re-inspection by an ultrasonic specialist.
By using a special post-testing procedure the UT specialist has the possibility of changing the algorithm parameters, and selecting the most indicative areas to perform manual testing on precisely defined local areas.
The test result is shown on a C-Scan, and if there are indications, they are listed with position, echo intensity, area size and depth of the area.

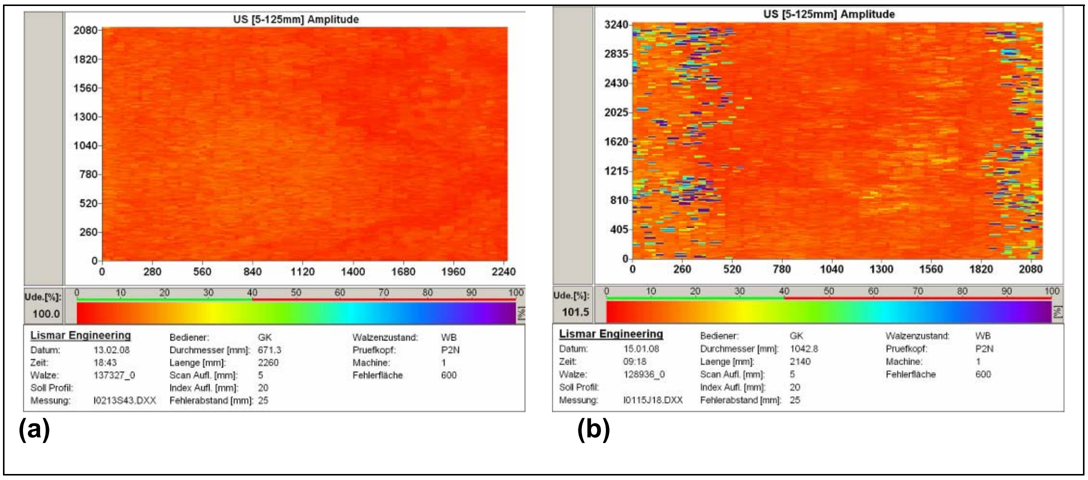

Figure 3. (a) roll with no indications; (b) end areas with indications

2 ROLL TESTING IN THE ROLL SHOP

More and more customers are convinced by proven results that modern testing equipment in the roll shop makes a big contribution to operational safety. The reduction of down time in a mill is a very important cost factor. Unexpected roll changes can be reduced and major incidents are reduced to a minimum.
Many of our customers also use Datames testing systems. The system elements can be Eddy Current as single or combined with Ultrasonic testing, as well as in combination with a specially developed UT surface wave inspection system.
The first test cycle begins when the roll arrives in the mill before it is sent into service for the first time. The tests are most often repeated after each campaign, depending on the priority of the customer's ability and capacity in the roll shop. Once a roll is registered in the DATAMES system, every test performed will be stored in the same roll folder and the test results can be referred to whenever necessary.

2.1 Eddy Current Test

The eddy current test is a test to reveal open surface cracks and to prevent a roll from going back into service with cracks. It depends on the customer's experience to decide which level of crack indication is accepted for which roll and application.

The results can be displayed either as a C-scan or as a Z-plot. Automatic evaluation for pass criteria can be introduced and operated. The principle of eddy current is shown in Figure 4 a)

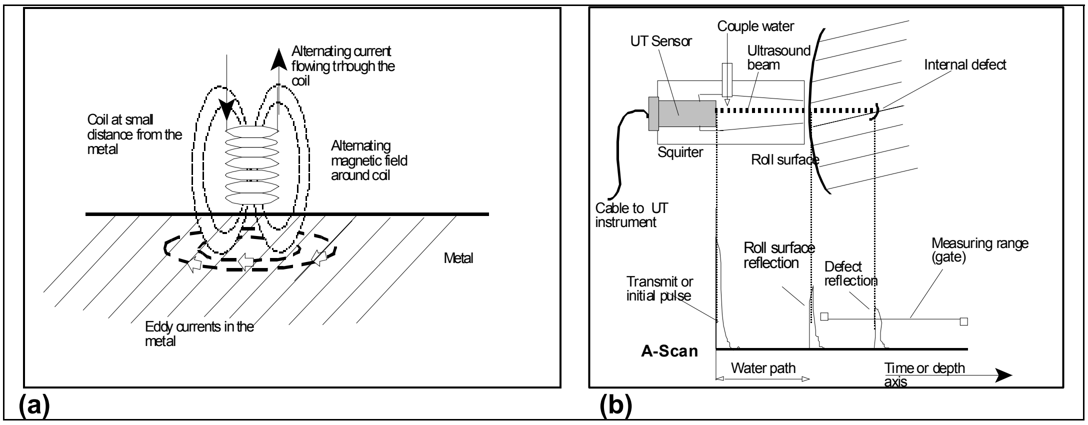

Figure 4. a) Principle of eddy current; b) Principle of UT testing

2.2 UT Test Normal Probe

The testing with normal (single crystal) probe is performed according to ESW's practice. The difference is the frequency of the UT probes. In the mill, the probes have a higher frequency to achieve better lateral resolution and to find defects, such as delaminated areas in the shell material, due to overload or due to crack propagation into the shell. The measuring principle is shown in Figure 4b).

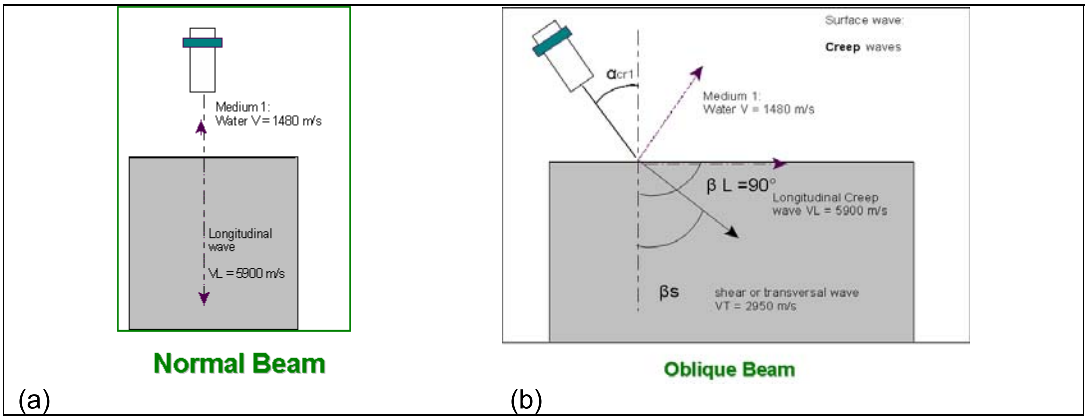

Figure 5. a) Principle of normal beam; b) Principle of oblique beam

2.3 UT Test Surface Wave

Surface wave testing is the ideal addition to the other above- mentioned testing methods. The limitation of the EC, just to find cracks which reach the surface, and the limitation of the UT normal probe test, which is effective starting only at a depth of about 5mm from the roll surface, can now be overcome by covering the area, which was more or less not available for the other methods. From the technical side far greater knowledge is needed to perform this test. The principle of UT waves is drawn in Figure 5.

2.4 Supervision and Calibration of the Testing System

Since the introduction of the ISO 9000 series, everybody should have recognized that each testing facility has to be supervised. Nevertheless, many users believe in automatic testing equipment results without questioning.

Even on automatic systems parts are influenced by wear, temperature and all kinds of waste in the surroundings. Electronic parts in adverse conditions can also lose their properties just like mechanical parts do. The best form of supervision is a standard tool, either small solid parts, or even better a roll which has already shown indications during testing. A step forward is the preparation of a roll with typical failures. This means the possibility to drill deep holes into the shell at the end of the barrel or a deep scratch to simulate cracks. The surveillance of testing equipment is as important as the testing of rolls.

Periodic supervision and if necessary calibration ensures reliable test results.

3 INTERPRETATION OF TEST RESULTS

Automatic systems are calibrated and set up with standard parameters. The variety of testing parameters in a roll shop is limited because a lot of different types of rolls have to be tested. A minimum of different testing set-up possibilities should be used to avoid choosing the wrong set-up. Reducing the set-up possibilities implies greater knowledge of the supervisor of the test reports. For the machine operator, the decision should be as easy to understand as possible. If there are unusual indications, it is important to have experienced personnel. The modern policy of replacing manpower by machines is limited when test results may be complex. Deeper knowledge is needed to interpret and adjust the equipment to the required status.

Another option is the data exchange with the supplier. If roll user and supplier are using the same testing equipment, the testing data can be exchanged and the evaluation of untypical test results can be made including the experience of both parties. The aim is to minimize the risk of re-introducing a roll with possible faults into operation again. This is useful for both parties. The producer will receive better feedback and will be able to see whether the decision based on his experience was right or not. The influence of different rolling conditions in different mills will then lead to adjustments in the set-up of testing parameters at the supplier.

Two real examples are discussed on the following pages. The interpretation and evaluation of testing data from two different viewpoints can lead to a concept of a new set-up for further treatment of rolls.

3.1 Roughing Mill Work Roll Ø 1100x1850mm

The roll was sent to the customer with Ø1100mm and a shell thickness of 80mm radial. The planned use of shell radial is about 60mm, the scrap Ø about 980mm.

The UT test performed at ESW showed a very good bond between shell and core.

The first inspection of the roll on the part of the customer produced the same result. Both scans are shown in Figure 6. Both scans are more or less red. The intensity bar at the bottom of each scan shows in red that echo intensity is up by 10%, which means the UT is hardly reflected at the bonding zone.

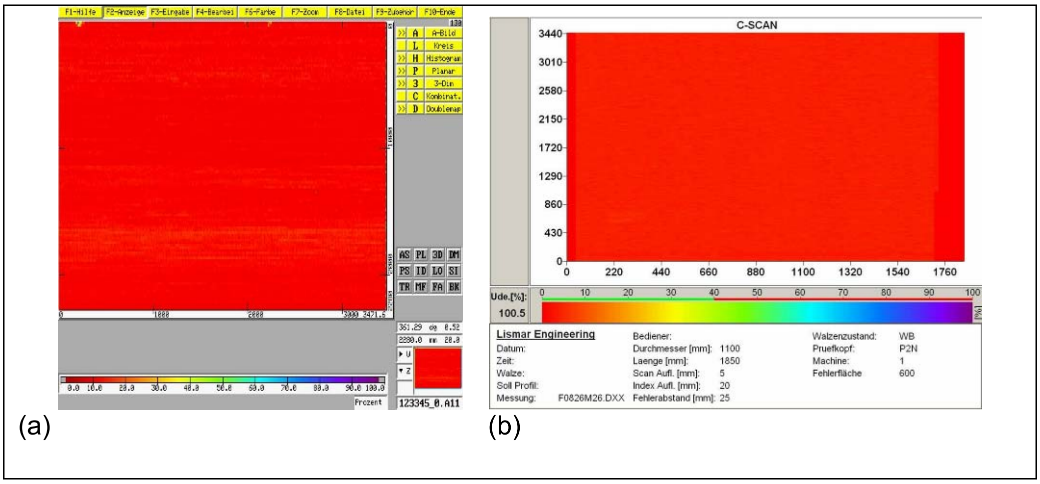

Figure 6. a) roll tested at ESW; b) first inspection at customer

After more than 50 campaigns, the roll was put on the grinder and the UT test showed an indication. The roll was at that time at Ø 1023mm. Manual inspection of the roll showed a clear echo from the bonding zone.
The normal test result on the part of the customer is shown in Figure 7. The left part gives the C-scan, with the blue dot. The right part the corresponding Z-plot of the roll. Where the echo intensity in the Z-plot crosses the threshold of 50%, the blue dot in the C-scan appears.

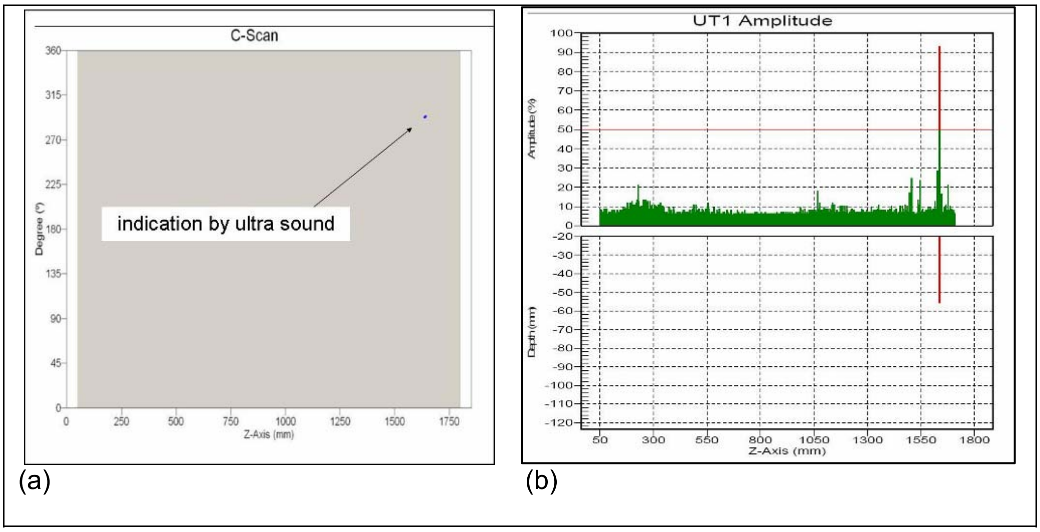

Figure 7. a) c-scan with indication; b) z-plot with indication

A spontaneous delamination in a roll without any overload in the mill is very unlikely. Therefore we took all the data and tried to find out what was registered in the former tests. In this case the software Lirias from Lismar gave us the possibility to view all data with less effort. The possibility to click from one test to the other makes it possible to find out when an indication starts, even if it did not reach the threshold and therefore did not appear in the C-scan. In such cases the roll will always be declared as good and goes back into service.
The analysis of the data gave the answer to the phenomenon. About 1 ½ years ago, the roll was in a campaign where a local distortion of the surface was seen afterwards. This was at Ø 1076mm. The customer took pictures and made replicas, and filed them in his database. On the EC one could see the distortion of the

microstructure. Figure 8 shows the EC at Ø 1076mm. The roll had to be ground till Ø 1068mm to remove the destroyed area.

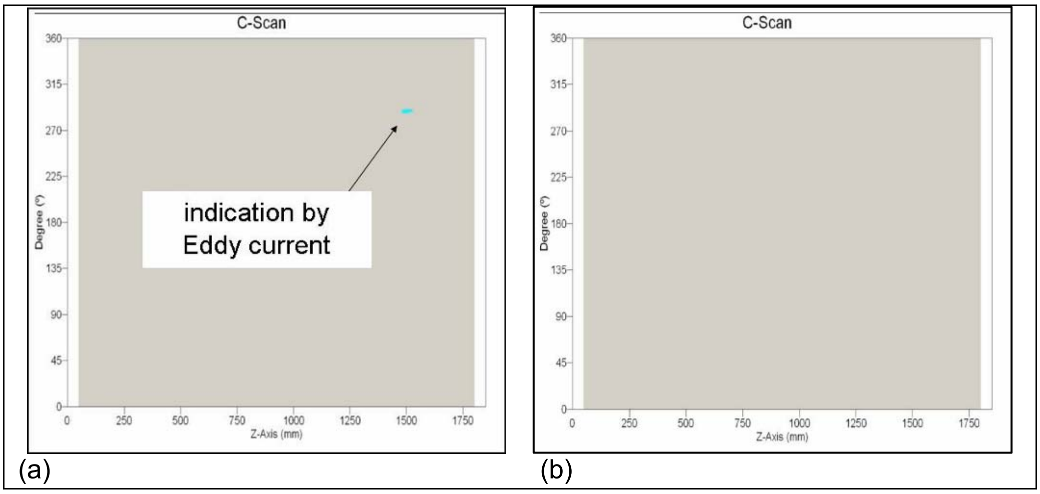

Figure 8. a) Ø1076mm after incident; b) after grinding to Ø1068mm

A review of the historic data gives the chance to see that the damage in the bonding zone was already created during this incident in the mill. It seems that the high pressure on the surface created a kind of shock wave, which resulted in a minor delamination of the shell and core.

Figure 9 shows the Z-plot of the testing right after the incident, with a reduction of the threshold from 50% to 8.36%. The UT already gets the signal, and the signal stays at the same position till the Ø has reached 1023mm. Due to the physical properties, in this case the reduced distance between UT probe and defect gives a higher echo intensity from the defective zone.

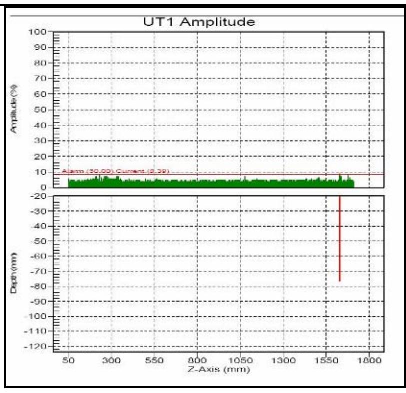

Figure 9. Ø1068mm after incident with lowered threshold

The roll was then in operation several times without any indication, because the echo intensity did not reach the 50%threshold. Figure 10 shows the graphs at Ø 1035mm. The reduction of the threshold to 25% clearly shows the defective zone.

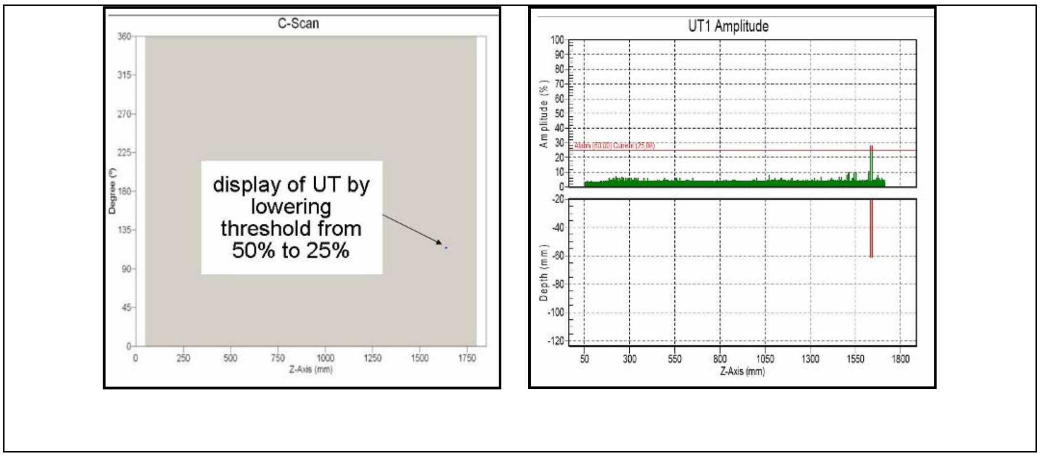

Figure 10. Ø1035mm lowered threshold from 50 to 25%

Now a very interesting conclusion is possible, if we remember the physical background of the echo intensity. The reduction of the roll diameter, which leads to a reduced distance between probe and defect leads to higher signals. This is highlighted in a graph in Figure 11. The most interesting point in this example is that the area of the defect did not grow at all.
The roll is still in operation and is subject to special monitoring.
This is a very good example of how a good roll, which was damaged in a mill incident, can still be used. At times when the roll stock is reduced and the delivery time is very long, this means a big improvement for the customer.

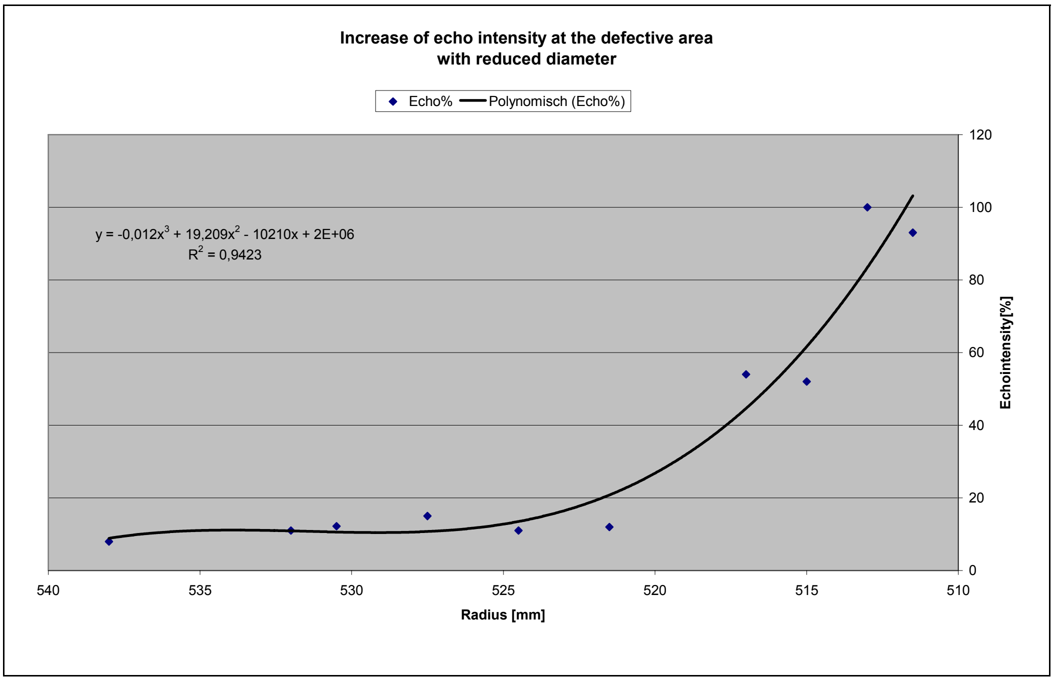

Figure 11. Dependency of echo by reduced diameter

3.2 HSM Mill Work Roll Ø 812X2050mm

The roll was tested at ESW at Ø833mm. The test result showed very small areas where the bond gave reflections. The manual testing according to the internal standard was decided to be adequate for delivery.

The customer for his part made the first inspection before the first run in the mill at Ø812mm. The transmitted data from the customer shows in general a higher reflection level than the measurement at ESW. This is probably due to a different coupling of the probes. Figure 12.

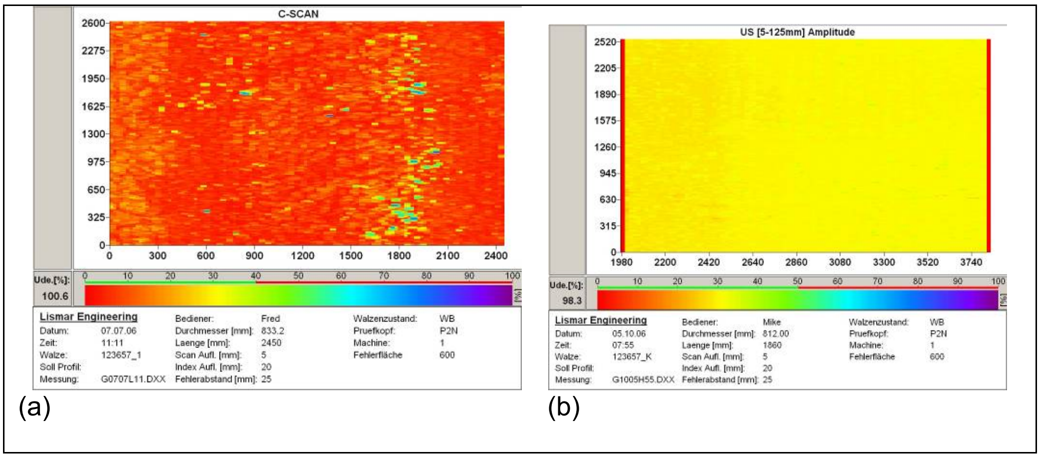

Figure 12. a) roll tested at ESW ; b) first inspection at customer

The roll was in service about 70 times; no abnormalities were registered. Slowly a growth of the echo intensity, in the area of 1800 in Figure 13 of the ESW scan was also visible at the customer's testing. Then it disappeared and came back again.

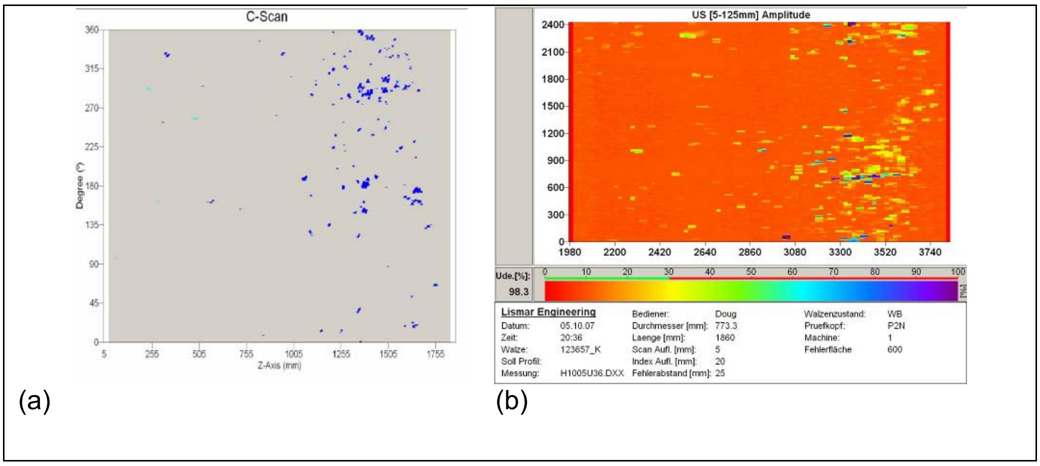

Figure 13. a) c-scan at Ø773; b) same scan converted in ESW system

What is regrettable in this case is that for a period of over 70 times of testing, the automatic system showed that the roll had increasing areas of indications. Nobody was able to interpret these results. The indications of pinches and bruises of the eddy current are well known. The roll is ground till the test shows a result without indications. Ultrasound results were visible, but no action was taken. Finally the areas grew faster and the bond was destroyed, resulting in a roll spall.
The final test results are shown in Figure 13.

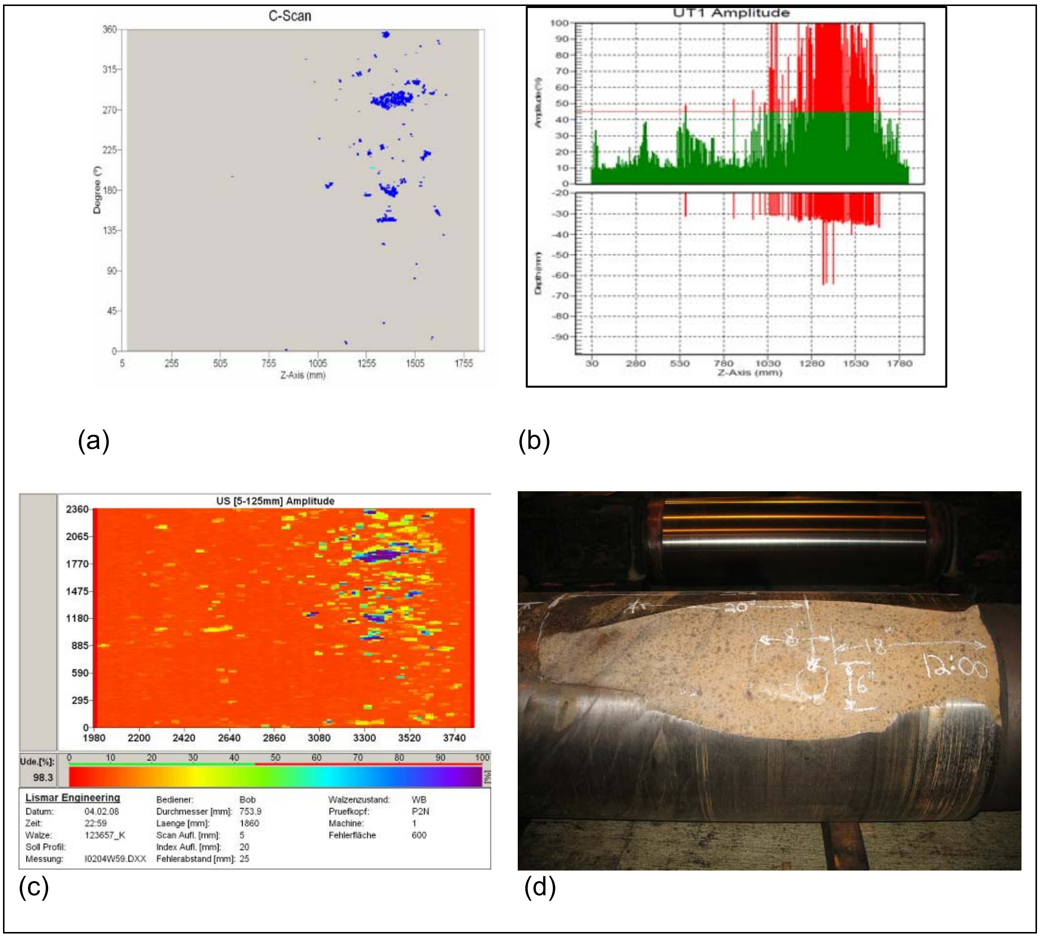

Figure 13. a) c-Scan before spalling; b) z-plot with massive indications; c) c-scan at Ø754; d) finally spalled roll

4 CONCLUSION

The industry has developed very good testing facilities. Most of these are computerized and are more or less fully automatic. The main interest in buying such equipment is to get comparative results, more safety and a reduction of manpower, which all together saves money. The belief that simply having an automatic system is sufficient to achieve the full benefit from the best testing technique is incorrect. The materials and the application are changing very fast. The experience of trained personnel is very important to interpret data and take counteraction to prevent losses, due to wrong calibration or the misinterpretation of testing results of automatic testing equipment.
Another option is the data exchange between customer and supplier. This can lead to decisions based on experience from both sides.
The best solution in future will be to have excellent personnel combined with the best testing equipment.

REFERENCES

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