SURFACE INSPECTION - FROM INNOVATION TO PRODUCTION OPTIMIZATION[1]

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Abstracts
The purpose of this paper is to demonstrate how innovations in surface quality inspection will contribute to the metal producers' efforts to increase production efficiency and product quality. Examples will be given, how leading metal producers have turned surface quality information into production excellence. Surface defects impair the quality of the metal strip – the manufactured product – to a high degree. They may even cause strip breaks, hence leading to material waste, equipment damages, and machine down times: less throughput, higher costs, and less ability to deliver high quality are some of the consequences. Parsytec offers leading-edge technology for an outstanding inspection performance: its surface inspection systems deliver defect data, which are turned into quality information that constantly supports the metals manufacturers in the enhancement of both, the process efficiency and the product quality. *espresso SI* by Parsytec entails innovations for nearly each and every aspect of surface inspection. It is the only inspection solution worldwide, which allows access to the inspection results via the internet, is based on GBit Ethernet camera technology, and deploys standard compact PCIs. By this, users benefit from doubling the detection sensitivity, a guaranteed high system availability, as well as an accelerated access to relevant data.
Key words: Surface inspection; Production optimization; Quality information.

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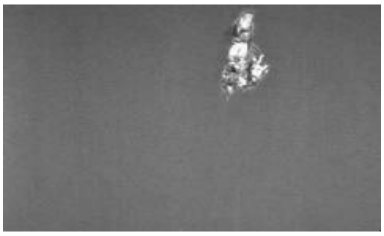
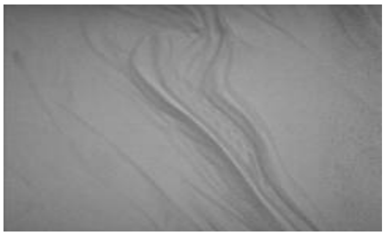
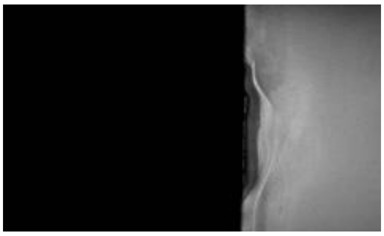
1 INTRODUCTION

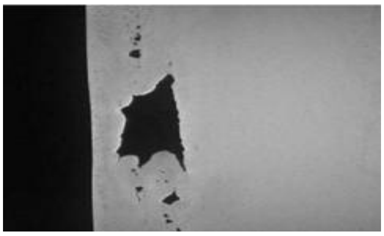
Metal production like steel, aluminum or non-ferrous metals comprises of a complex chain of various production steps, such as hot rolling, cold rolling, pickling, annealing, galvanizing, tin-plating, tempering, or coating etc.
This complexity of the production chain may simultaneously also endanger the frictionless production within required quality specifications. Any kind of defects induced at any position in the process may impair the material quality immensely. On rolled material, this impairment will be reflected mainly on the produced material's surface, hence surface defects play a crucial role with respect to the quality of steel strip.


Shell (Pickling Line)


Roll In (Pickling Line)


Pinch Tree (Continuous Annealing Line)


Edge Defect (Electrolytic Galvanizing)


Hole (Continuous Annealing Line)

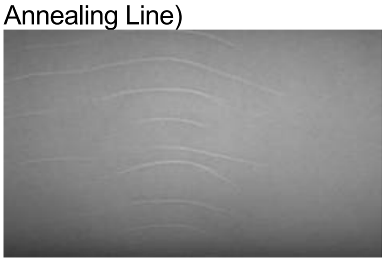

Sticker (Electrolytic Galvanizing)

Figure 1. Examples of common surface defects

The consequences of surface defects are numerous: they range from lower sales prices via additional expenses caused by extra material, personnel, or operating and other production costs, up to line standstills or even equipment damages. All in all, the metal manufacturer will not be any longer in the position to keep delivery terms or will not produce high-quality material as scheduled.
Hence, productivity initiatives are called for which are dedicated to the improvement of the product quality and to the enhancement of the process itself. In today's highly optimized production processes, security of delivery counts for a large extent of the metal's value, which means delivery quality, time, and reliability. Pointing in the same direction, but with a different focus is the increase of throughput. In undertakings to improve existing production lines, metal producers are supported by the quality information of a surface inspection system.

2 SURFACE INSPECTION SOLUTION

A Surface Inspection System (SIS) detects and classifies all kinds of surface defects, which affect the quality of the manufactured product. In general, a surface inspection system scans the complete surface of a coil (mostly top and bottom side) by using camera-based sensors. It identifies and classifies all relevant surface defects by processing the images in a processing unit, and finally provides the operators with the results on a screen, a coil map, in the form of a statistic overview, or in any other form fitting to the quality processes of the user, usually including defect images.

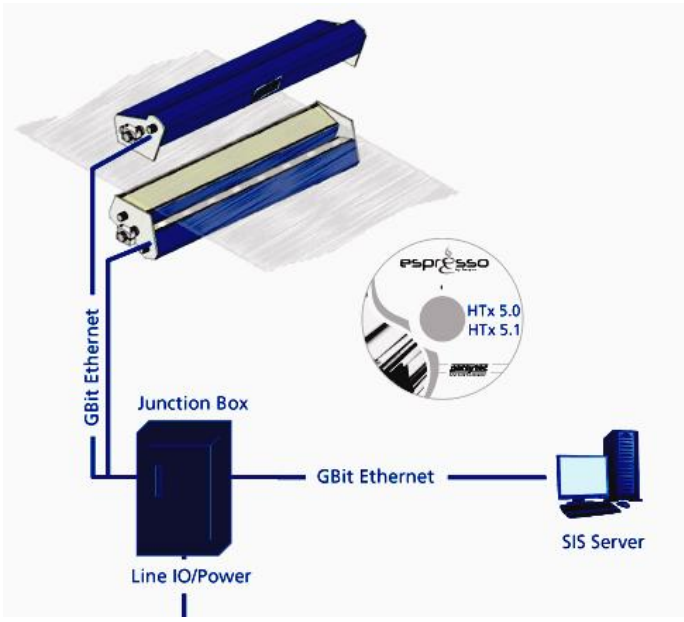


Figure 2. Surface Inspection System by Parsytec

In each of the processing steps of the metal manufacturing, the surface inspection of metal strip requires the appropriate sensor, which is optimally adapted to capture images of the relevant defects in the specific environment of the processing line. The most significant characteristics of surface sensors are:

- the arrangement of cameras and illumination with respect to the strip surface, like bright field, dark field, cross field, transition field, etc., or combinations of those;
- the type of cameras used, like gray-level or color, line scan or matrix;
- the type of illumination used, like LED lines or areas, gas discharge tubes, etc.

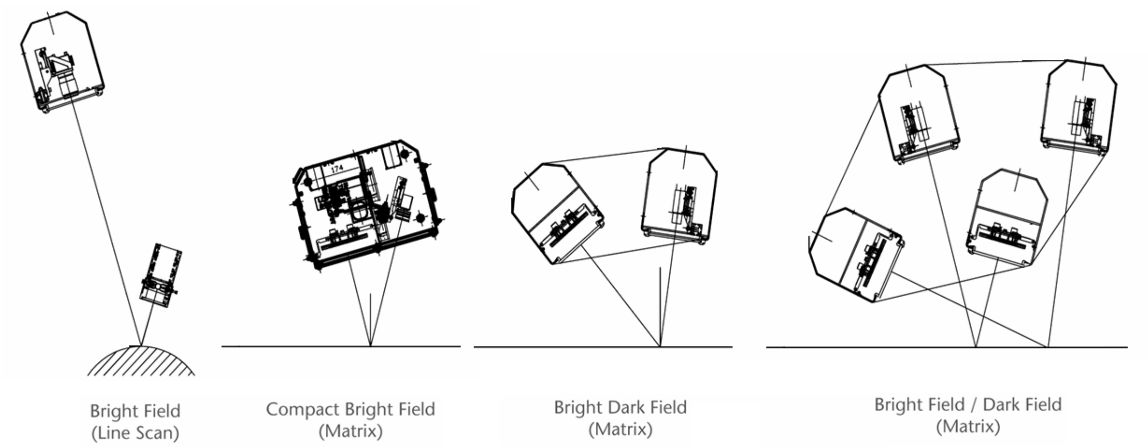


Figure 3. Surface Sensor technology

The SurfaceSensor of the new Parsytec *espresso SI* system generation is equipped with Gigabit Ethernet cameras (line scan or matrix) and LED illumination, capturing images from 100% of the strip surface. The image acquisition technology and configuration is selected to suit the inspection requirements of a specific production

line perfectly. The broad experience of Parsytec with all kinds of production lines in the metal manufacturing process is condensed into a portfolio of Sensor configurations, well adapted to the individual line types, thus providing optimum image acquisition for all kinds of production lines during the metal production. Where necessary, complementary illumination technologies are combined to ensure the detection of all relevant defects of the specific production line.
The SurfaceSensor captures the images and transmits the captured images to the junction box, where the image processing will take place, basing on standard CompactPCI. Here, all images are analyzed and processed by the powerful Parsytec inspection software and finally condensed to the inspection data.
All technology required for the inspection process, such as image processing, camera and illumination synchronization, and all interfaces for integration in the production line is contained in the Junction Box. Connecting the Junction Box to the Inspection Server as well as to the SurfaceSensor is done via Ethernet; hence, a "plug and play" operation of the system is enabled. This approach makes system extension by additional cameras or sensors, or performance enhancement very easy.
The user interface displays the surface data continuously online at the Inspection Terminal. It is in a wide range adaptable to the needs and internal operational quality processes. Additionally, commissioning and tuning of the system is strongly supported with easy-to-use tools and can be done by the users without problems.
The Thin Client technology employed in Parsytec's Surface Inspection System reduces the system's dimensions as they refer to network computers without a hard disk drive. Thereby the data processing occurs on the server and increases the system's efficiency by decreasing the processing time. Also, maintenance efforts are reduced significantly because of less critical components of the systems (no hard disks) and merely one single access point for software maintenance.
A Surface Inspection System by Parsytec guarantees thorough and consistent defect detection. Through an individual set-up of the system, it will be adapted perfectly to the specific mill situation for the best possible recognition results. Furthermore, Parsytec offers valuable software for further, indispensable processing of inspection results. Hence, the respective so-called *parsytec 5i* software works as extension of the SIS - it further processes the inspection results and turns them into real quality information.

3 THE CONCEPT OF INTELLIGENT CLASSIFICATION

The guiding principle of state-of-the-art intelligent classification technology is to make surface inspection systems work like metal producers use to work. It allows defect class naming according to the metal producers' conventions. In the daily decision making processes, defects are checked by appearance, judged by experience, and subsequently appropriate conclusions and measures are taken. SIS technology must support exactly this process in order to become accepted part in the decision loop.
Of course, the source for each kind of classification is the detection of non-perfect areas of the strip. Such appearances on the strip are then described by their characteristics. With these so called "features", different defect classes can be distinguished by establishing appropriate classification rules. Obviously, more features imply a more precise description of a defect and thus better classification resulting in more specific and reliable results. Parsytec's classification software calculates more than 800 features for any of the selected images and additionally employs metal producers' expert knowledge for achieving the best inspection results.

By this, surface inspection generates appropriate information for value chain optimizations. This will be outlined with two examples stemming from the metal manufacturing applying the Parsytec technology – and thus gaining competitive edge by being enabled to improve their operations in real-time.

4 APPLICATION EXAMPLE 1: TANDEM MILL PROTECTION

Based on the above described detection and classification technology, Parsytec has managed to develop a unique and innovative tandem mill protection solution. Severe surface defects after pickling can cause strip breaks in the subsequent tandem line, leading to loss of material, equipment damages, and machine downtimes. Identifying these defects in-time for immediate process changes provides significant yields in terms of runability and throughput.
Coupled pickling/tandem lines and also non-linked tandem lines have to deal with strip breaks. Roughly half of the breaks occur due to surface visible material faults. The costs of strip breaks are high, taking time to get the mill up and running again, additional costs arise due to roll shop cost, material loss, and overall attention to this problem. As strip breaks due to material faults often form the majority of strip breaks at the tandem line, eliminating those allows to put a clear focus on the operational issues and helps to decrease the rest of the tandem breaks as well.

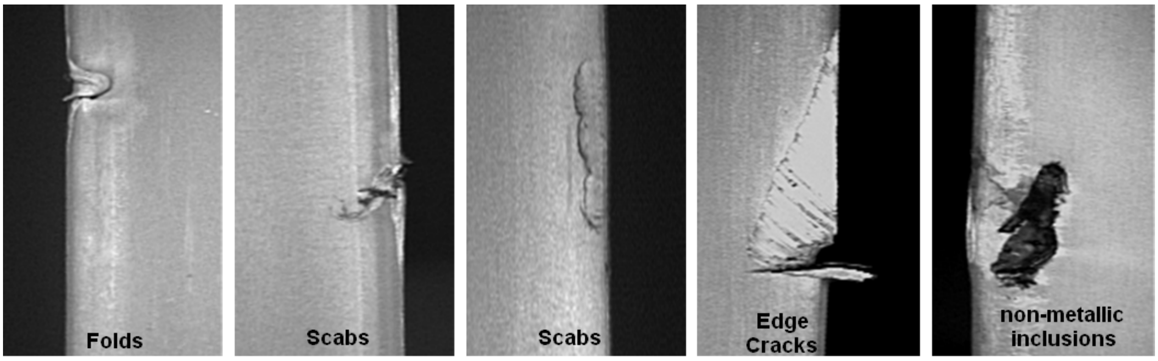


Figure 4. Harmful defects at a tandem line

The surface inspection system is intended to find all harmful defects at the pickling line and let the tandem operator know about their upcoming.
In a coupled pickling-tandem mill, processing of the coils will be as follows: from the pay-off reels, the coils will pass through the pickling section before going through the looper to the tandem mill. Two stations may endanger the product quality immensely: the pickling section and the cold rolling tandem mill. Hence after the pickling section, a surface inspection system is integrated into the line, which sends defect reports to the pickling control pulpit.
In case of process-critical defects, the operators at this pulpit will be able to grade the defect severity and take appropriate measures. The inspector decision will then be forwarded to the process level computer. The decision-making is a rather time-critical process as it must be made before the respective defect reaches a certain position further down the line. The Process Level Computer triggers a signal that tracks the defect through the looper and sends a halt or slow-down instruction to the tandem mill. By slowing down or even halting the line, the possibility of repairing the defective

material, avoiding strip breaks or severe damages of rolls is given. The diagram below illustrates this processing:

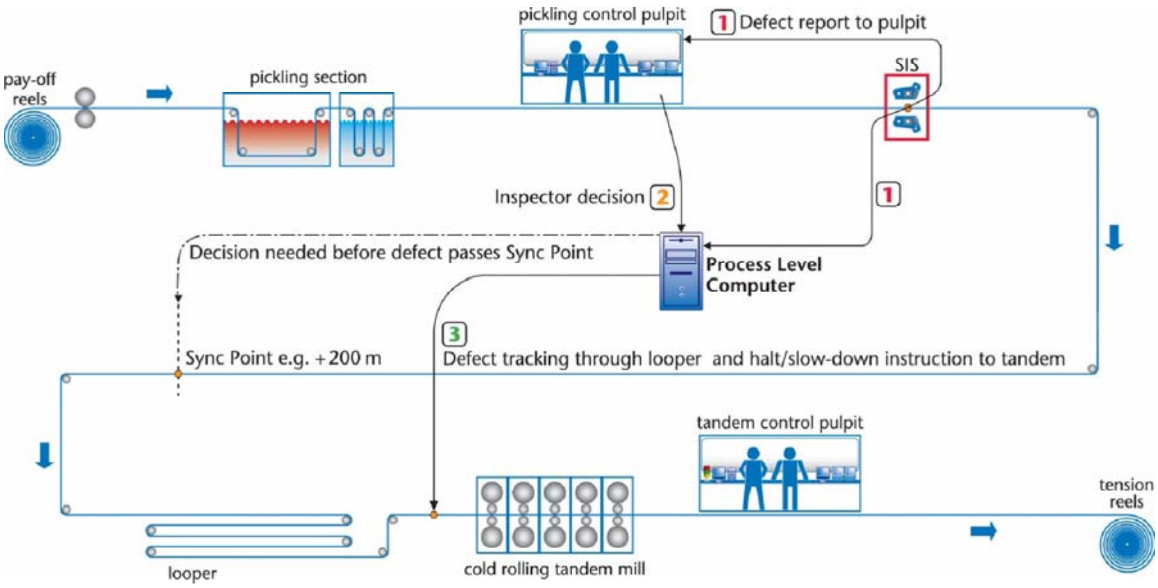


Figure 5. Processing at a coupled pickling-tandem-line

At the pulpits, inspection terminals are positioned on which the Operator Display Software (ODIS) shows the defects with detailed defect information as well as the Tandem alarm. The alarm will be triggered by critical surface defects, which must be evaluated and ranked by the operator in one of the following categories: Stop (open the tandem or cut out); Slow (decrease speed in cold rolling); Info only (for tandem operator); Ignore. These categories will be marked in the Coil Map.

By viewing the results in the Operator Display, the inspector can finalize his decision on the defect evaluation. The inspector is able to “look back” on the strip, but to also see which defects will come next. By seeing the context of the strip and not only one critical defect, the decision on the defect severity will be more substantiated due to a more complex perception, and by being aware of a defect in advance, the inspector will be able to take appropriate reactions and measures in time.

By means of the tandem protection, tandem breaks will be prevented efficiently and finally the produced material quality will be enhanced considerably. This concept has been put to use successfully at various production lines.

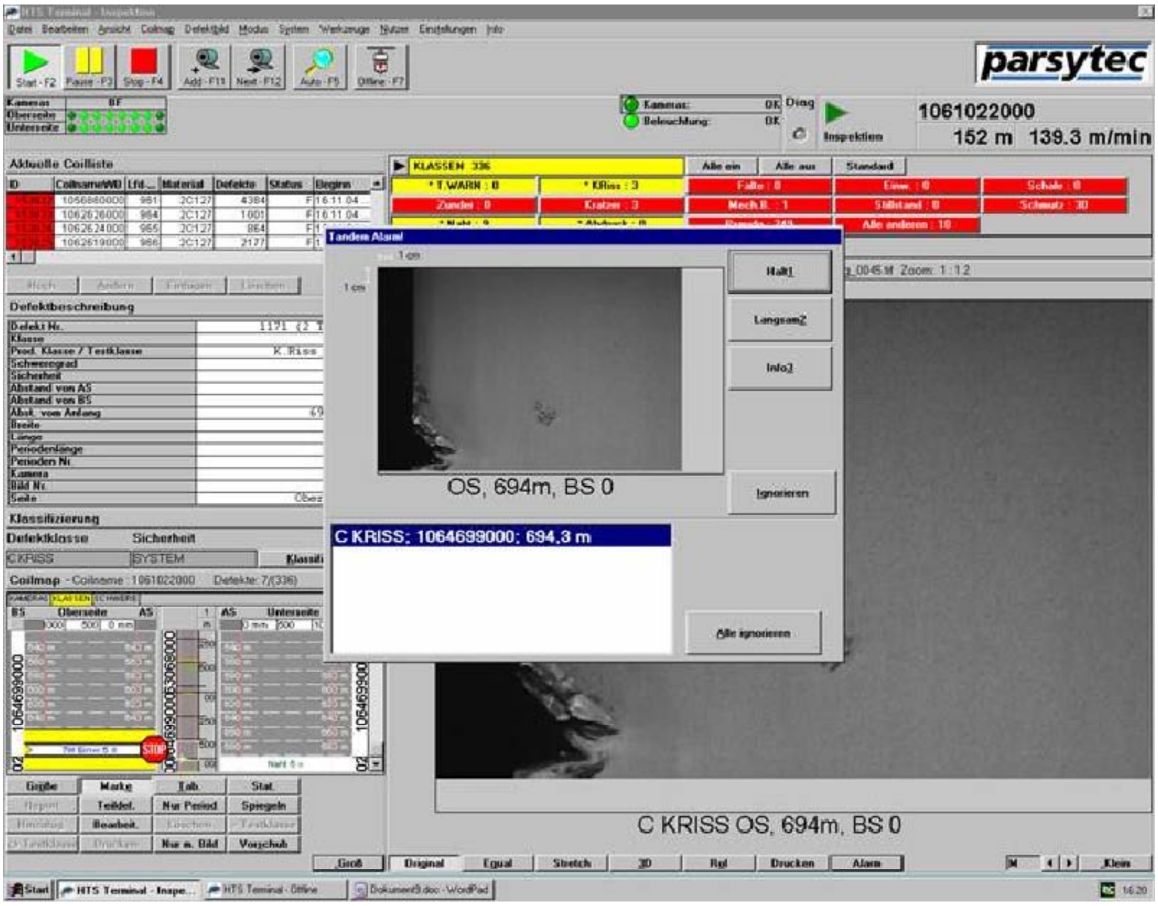


Figure 6. Operator Display Software (ODIS)

5 APPLICATION EXAMPLE 2: DEFECT MARKING IN AUTOMOTIVE MANUFACTURING

Steel producers that are simultaneously supplier to further processing industries such as automotive manufacturers have been asked to physically mark defective strip areas of the produced steel.

The goal to be achieved is to potentiate discharging marked plates in the automotive manufacturing process. Hence, the highest possible quality standard of the produced material can be assured. At electrolytic tinning lines, marker lines indicate different tin coating weight by their particular pattern. As no standard solution could be applied in that particular case, Parsytec developed a customized construction in order to fulfil the expectations to full extent: the Defect Marking.

During production, potential defects will be selected electronically for the marking process. This selection will be reviewed, validated, and defects relevant for marking will be released. After unwinding the material, the relevant defects will be marked automatically. If applicable, a trigger of actions concerning the line can be set.

Parsytec decided to additionally involve a customized software application as interface between the line(s) and the actual defect marking during the processing. The solution sketched above can be divided into three steps:

1. semi-automatic selection of potential marking defects during online production
2. review of marking coils with decision support to create final marking Coil Maps
3. automatic defect marking at a Rewinder Line

During the strip production, the potential defects will be selected and marked electronically. This process bases on a rule set which is defined and adjusted according to the requirements of the customer.

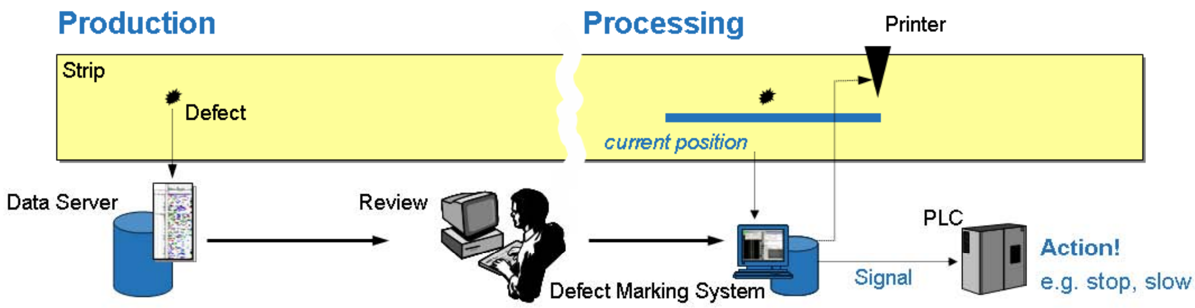


Figure 7. Defect Marking

The inspector can then view the defects and re-evaluate the decisions made before. Besides the image of the defect to be marked, detailed and precise defect information is shown. Additionally, a list with the upcoming defects is offered, in which the distance from the inspector's position to the defect is indicated. The inspector can make the final decision, if a defect is to be marked or not.

At any time between the strip production and the defect marking process, the respective coil map can be reviewed. Typically, the quality personnel re-examine the blocked coils in the operator display and evaluate the potential defects for marking. Once again, the quality personnel can accept or reject the defects, add further defects, and - after finalizing this review - create the final coil map defects for the marking process. The number of times this process can be applied is not limited.

The Defect Marking System (DMS) - the third and final component of the Marking Solution - is located at an inspection line. The DMS basically functions as an SIS-Server and is fully integrated into the customer's mill network via process data integration (PDI). Its task is to run the software of the Defect Marking System, being capable of loading and displaying the coil map for the currently inspected coil. Via the inspector's command, the speed of the line can be decelerated, when a defect to be marked reaches the printer position. This source is able to handle mother- as well as daughter coils.

This Defect Marking solution helps providing material of a much higher quality. The above illustrated construction supports the decision-making process of the inspector without releasing him from this task but providing decision support in the form of suggestions, which he can accept, review, or reject. By means of the DMS, line speed can be adapted to each decision situation. This whole process enables a very thorough and high-quality inspection of the marked strip.

6 FURTHER APPLICATION SOLUTIONS

The two case-studies mentioned before show the high flexibility of the inspection software, which enables the adaptation of a Surface Inspection System to a great variety of requirements and demands. These special solutions support production-crucial decision-making for the increase of manufacturing throughput and the enhancement of the production process. Further application solutions have been developed, which are also part of the Parsytec inspection product:

Parsytec's latest software generation enables the taking of strip width information in regular cycles during inspection. The information on the current strip width is available via the OPC interface and will be presented on the operator terminal.
When strip products are cut to sheets, not all of those sheets are of the same high quality. Sorting the sheets automatically according to their quality can be enabled by an inspection system, specially trained for triggering this sorting process.

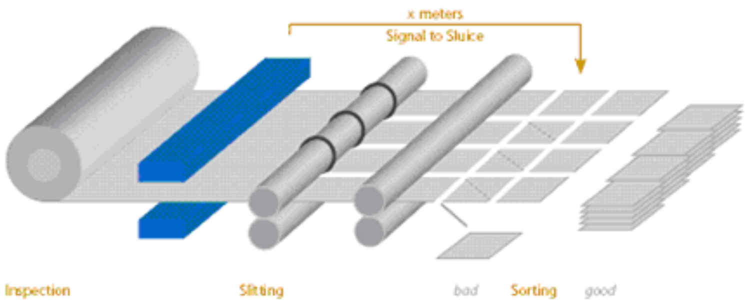


Figure 8. Automatic Sorting

Also, the coil grading works automatically as well. A customer-specific grading algorithm will be performed and the current coil grade is displayed as a kind of traffic light in the inspector's software.
Surface Image Recording is yet another technique of capturing the surface by taking video of a defined part of the currently produced coil and allows the operators to view this video for various quality assessment tasks afterwards.
All these mentioned applications support the enhancement of the metal production processes, which will ultimately result in higher production quality and throughput.

7 CONCLUSION

Surface defects make surface inspection indispensable for each and every metal manufacturer. Surface Inspection Systems – in short: SIS - enable the detection of surface defects and thereby give the possibility to repair defects where possible or to eliminate their causes. Hence, an SIS contributes to the enhancement of the produced material by reducing downtimes of the system due to fewer coil breaks, by producing less scrap and thus lowering the manufacturing costs, and by finally gaining high-quality metal. Surface inspection should be – and as of today, already is – an integral part of the production process chain in the metals industry as it guarantees a high level of surface quality. Surface Quality is represented by machine generated data with a constant reliability. The resulting data is stored, creating complete quality documentations for the individual coil as well as for the entire production. Online Surface Quality control has an immense economic effect on increasing the overall production extent and quality by earning additional benefits.