STATE-OF-THE-ART INSPECTION SOLUTIONS FOR QUALITY YIELD MANAGEMENT[1]

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Abstract
Purpose: Producers for high-end coated steel often have extended requirements for highest surface quality. The recently merged inspection experts PARSYTEC & ISRA exploit their technology portfolios resulting in an enhanced inspection product: *espresso SMASH,* serving all coating line applications from hot dip galvanizing and electrolytic galvanizing via tinning to color painting and other organic coating lines. Methodology: Even most subtle defect occurrences on coated material can be recognized, e.g. streaks, coating spots, bubbles, pits, or scratches. With the improved scalability of line-scan cameras, higher resolutions, applicability and detection performance are now possible. The high processing power of the SMASH WEB FPGA is used for further enhancement of the proven advanced defect detection. The image data acquired by the linescan cameras is analyzed and filtered to selectively amplify or suppress particular image contents for best results. Recognition of e.g. low contrast streaks or -large area defects reaches a new level. Results: Leading-edge surface inspection systems (SIS) deliver defect information to be turned into quality data. PARSYTEC SIS combine leading detection and classification algorithms with virtually all available camera and illumination technologies for highly advanced inspection performance. For metals producers, this approach guarantees proven quality, high productivity, and efficient processes. Application examples illustrate the possibilities of simplifying the operator's decision processes in favour of high-end production results.
Key words: Surface inspection; Quality control; Process improvement; SIS.

SURPRESAS SOBRE OS DEFEITOS SUPERFICIAIS DA LINHA DE LAMINAÇÃO A QUENTE A LINHA DE GALVANIZAÇÃO

Resumo
Propósito: De forma aperfeiçoar a liberação e o remanejamento de uma bobina, faz se necessário analisar a evolução dos defeitos e seu o impacto correspondente durante os processos de produção. O software de Rastreamento de Defeitos possibilita à associação dos defeitos ou regiões selecionadas com as observações a jusante do Sistema de Inspeção Visual de Superfície. Como resultado deste impacto, pode-se aperfeiçoar as regras de decisão para liberação ou remanejamento de uma bobina. Metodologia: O processo de Classificação deve ser preciso e seguro com respeito à severidade dos diversos graus de defeitos. Deve permitir comparar os graus de defeitos começando pela linha de laminação a quente com todas as linhas de processo subseqüentes. Além disso, o aplicativo *5i* mostra quais defeitos desaparecem durante os próximos processos – por exemplo – no processo de desoxidação ou de tempera – dando o exato número de defeitos. Estas informações adicionais ajudam a salvar custos no processo de reparo, o qual pode estar sendo aplicado de forma desnecessária. Entretanto, a diferença do número de defeitos podem também depender da direção da análise: a favor ou contra o fluxo. Resultado: O aplicativo gera informações instantâneas sobre a ocorrência dos defeitos incluindo a possibilidade de filtrá-los por classes de severidade. Quando se rastreia a bobina com os dados do SIS, o aplicativo mostra um mapa da bobina do corrente processo juntamente com um mapa do processo anterior seguindo a mesma orientação. O aplicativo *5i* associa os defeitos selecionados pelo cálculo de sua posição e de padrões geográficos procurando a melhor associação do conjunto de defeitos selecionados. O aplicativo, então, permite decisões confiáveis baseadas nos defeitos da bobina determinando de forma precisa o grau de severidade de cada linha.
Palavras-chave: Inspeção de superfície; Controle da qualidade; Melhoria de processo; Sistema de Inspeção Visual de Superfície.

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Introduction

Surface defects impair the quality of the manufactured metals to a high degree. They lead to waste and numerous customer claims: less throughput, higher costs, and less ability to deliver usable quality are some of the consequences. Operator decisions at the line concern the elimination of these defects, their prevention or the decision on optimizing process routes. Surface inspection hence aims at supporting quality decisions at all production stages.
In order to achieve an actual optimization of production processes, operator tasks must be easy to handle. The faster inspector decisions can be made, the more efficient the resulting consequences will be for the production throughput and quality outcome.
In order to achieve a reliable overview over benefits of production optimizations, the results must be comparable. Certification of the Parsytec camera systems makes this possible. Software releases will each base on the same production conditions and thus achieve similar analyses.

Enhanced ease of use for efficient system operations

Following the metals producer's continuing efforts to optimize their production processes, also surface inspection technology must be enhanced continuously. Next generation surface inspection technology takes up on this challenge and provides software functionalities in order to reduce the cost of installing and maintaining the system and to ease using the systems and its results.
User-friendly operator software is the key to efficient usage of detected defect data. The more comfortable the operator interface can be handled, the faster quality information can be gained and put to use efficiently.
Parsytec's inspection software delivers an improved recognition of defects from the installed inspection system in order to find more defects and classify them more accurately. Parsytec's surface inspection systems detect the sharpest images – due to very high detection sensitivity and 12bit digital cameras. In order to exploit the system's recognition abilities, two key technologies facilitate the operability: the merging of part-defect images into one complete defect image makes classification of defects more effective and the use of SVM classifiers via the new classifier plug-in including a voting step boosts classification results on particularly difficult defect types.
Previously, the scenario in the inspection with Matrix cameras was the following: If three or more cameras capture each a part of a large defect, only these partial defects could be classified – and only individually. Hence, the classification results for the complete defect have often been far from accurate. Now – even for Matrix camera systems – these partial images can be merged together cross web and down web by the software in order to create a merged defect image that can be classified completely. In real-time, trapezoid and brightness are corrected. During the following process steps, segmentation and classification on entire defects takes place.

Figure 1: Image Merging

Merged images can be displayed completely in a full strip option. Nevertheless, the possibilities to zoom in on the defects, to pan or scroll the image are still given. The benefits of this feature are obvious: merged images decrease the image count and thus take away less storage space. Merging of images also helps achieving better and more accurate classification results for large defects.
The Image Merging technique guarantees that defects are presented in one image as a whole independent from the amount of single images taken by the cameras.
Additionally, the feature “Live View” enables the online live view of the entire strip surface, in parallel to the “normal” inspection. Top and bottom side surfaces will be shown moving. Functionalities such as zooming and panning are also supported for a detailed and overview viewing. Zooming factors are selectable for displaying details or the entire strip width in order to enable evaluating event the smallest anomalies on the strip. Furthermore, this complete strip view eases the subsequent classification since the defect context can be crucial for assigning the correct defect class or for identifying the defect cause.

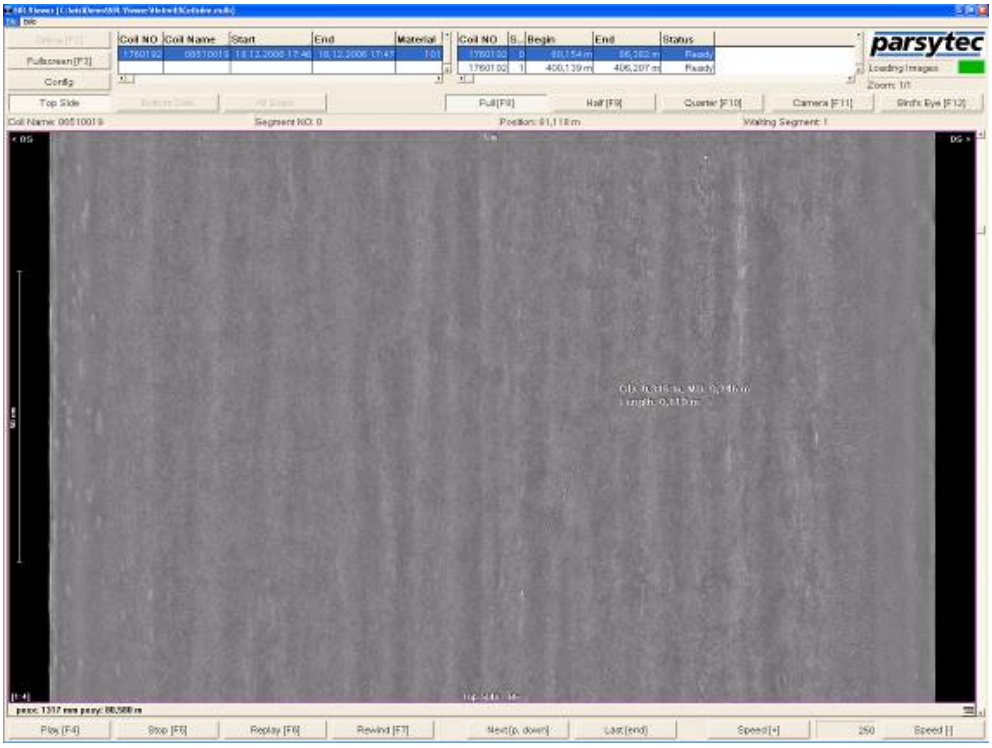

Figure 2: Full metals strip view in the Operator Display Software

The automatic classifier build environment (CBE) facilitates classifier building drastically via its intuitive operated user interface. It helps building the classifier in a tenth of the previously required time. The benefits of this intuitive operable tool are the following:

- Workflow-oriented
- Easy to use
- Fast and efficient
- Direct user feedback
- Complete overview over all collected images

The interface for the classifier building guides the user through the training of a defect class, where defect classes can also be added manually resulting from visual .strip observations. Subsequently, unclassified defects can be worked on manually and can be sorted, discarded or added to defect classes. In order to train defect classes, images can be selected in order to find more defect images similar to these in shape and appearance.

When concentrating only on the relevant defects, finding similar defects is facilitated immensely. The CBE reduces the number of images to look at by a factor 100 to 1000.

Feedback on the classifier performance can be given to the inspector or operator directly. New classifiers can be tested on any archived coil. If critical coils are stored in the database, the inspector has the opportunity to test the classifier on the most severe defects and thus test the actual classifier load. Afterwards, the reference or production classifier can be compared to the new classifier. After successfully testing the classifier, it can be activated online.

In contrast to previous classifying technology, this new environment encompasses several tools that had to be used for pre-classification and classifier testing in just one intuitively manageable tool for the most convenient classifier building possible.

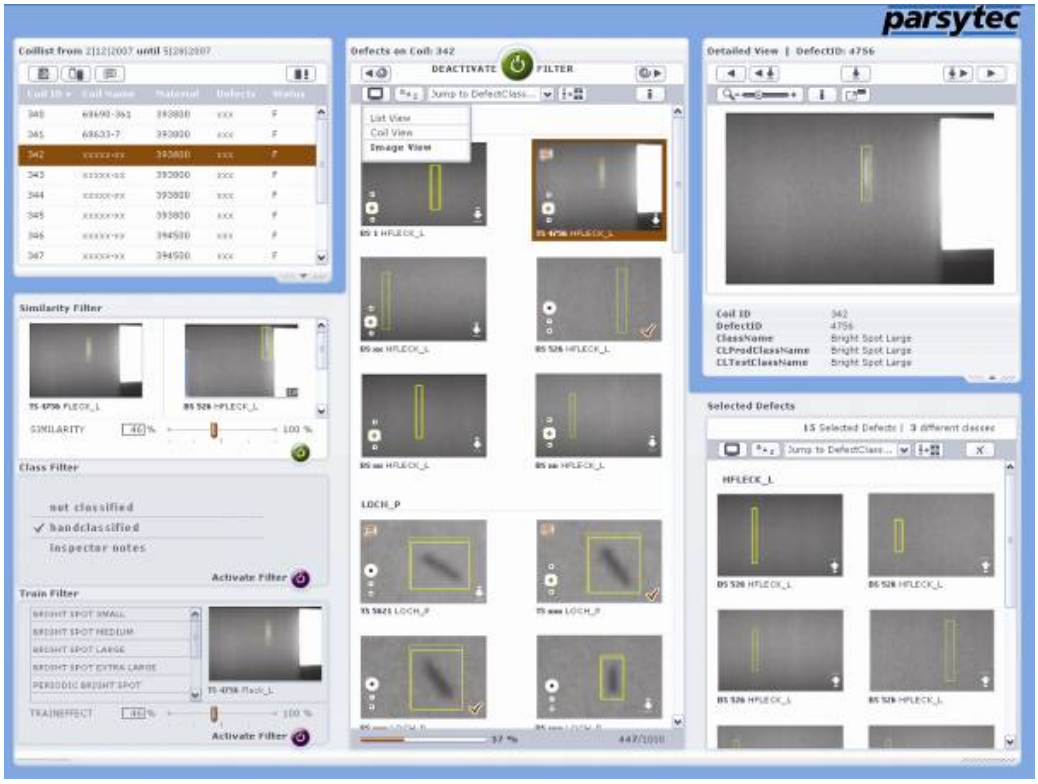

Figure 3: Automatic Classifier Build Environment

Parsytec's Dual Mode™ technology describes the classification process while using two classifiers at the same time. The first classifier is the production classifier, which ensures unchanged results for different production decisions. The second classifier, the test classifier, is the improved classifier version displaying the changed results.

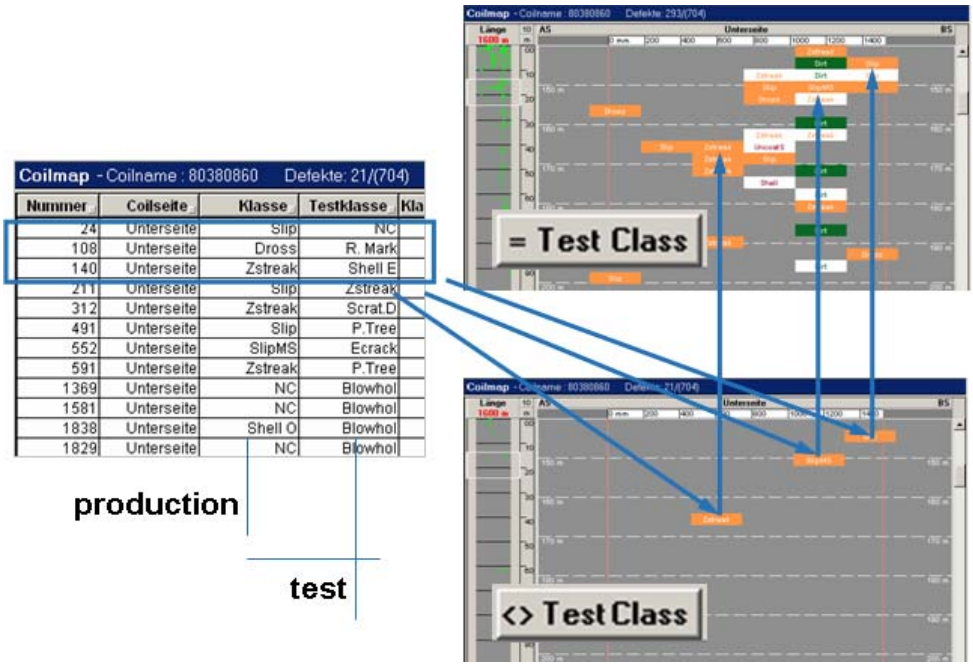

Figure 4: Dual Mode

A third factor for operating simplicity is the improved performance on noisy surfaces by enabling a sensor-based texture suppression. Parsytec's sensor technology has been improved considerably for several line types such as hot strip mills, pickle lines or coated strips. The combination of sensor types – Parsytec's patented Dual Sensor™ technology – guarantees optimum detection performance in even the most challenging inspection environments. Additionally, the sensor will be placed optimally in the line; at annealing lines, no annealing textures can be found before the cooling section, for example, which will be taken into account. The detection thresholds will be adapted based on measured texture degree. Sensitive regions for safe periodic defect detection are also considered on highly textured surfaces. A scalable processing performance in conjunction with high definition classification technology supports discarding ‚texture defects'.
Parsytec's inspection software not only enhances the user-friendliness, but also decreases the system maintenance effort and hence the total cost of ownership (TCO).

1. A new classification tool reduces the time for building or maintaining a classifier dramatically. Reductions of 75% are easily achieved, so only a quarter of the effort is needed.
2. The use of merged images and the corresponding reduction in number of images for the MSoS cuts the time needed even further.
3. The new (remote) diagnostics tools cut the time to determine the system status and schedule the desired preventive maintenance actions.

espresso SMASH

ISRA & PARSYTEC are joining forces and have created the largest and most capable supplier of surface inspection solutions. Exploiting the technology portfolios of both companies now results in an improved coated steel inspection product - *espresso SMASH*.
A number of key product features serve the extended requirements of producers for high-end coated steel: utmost image clarity is achieved with new digital cameras at higher resolutions, improved illumination and additional analysis power to recognize anomalies in surface images - all driven by Parsytec's HTS Inspection Software Suite.
espresso SMASH is available for all coating lines:

- Hot Dip Galvanizing
- Electrolytic Galvanizing
- Tinning Lines
- Color Painting Lines
- Organic Coating

Now, even most subtle defect occurrences on coated material can be recognized, including streaks, coating spots and bubbles, pits, or scratches. With the improved scalability of line-scan cameras, higher resolutions are now possible for materials with low surface roughness, e.g. electrolytic galvanized steels or organic coated steels. In addition to the standard of 250µm *espresso SMASH* now supports 125µm resolution.

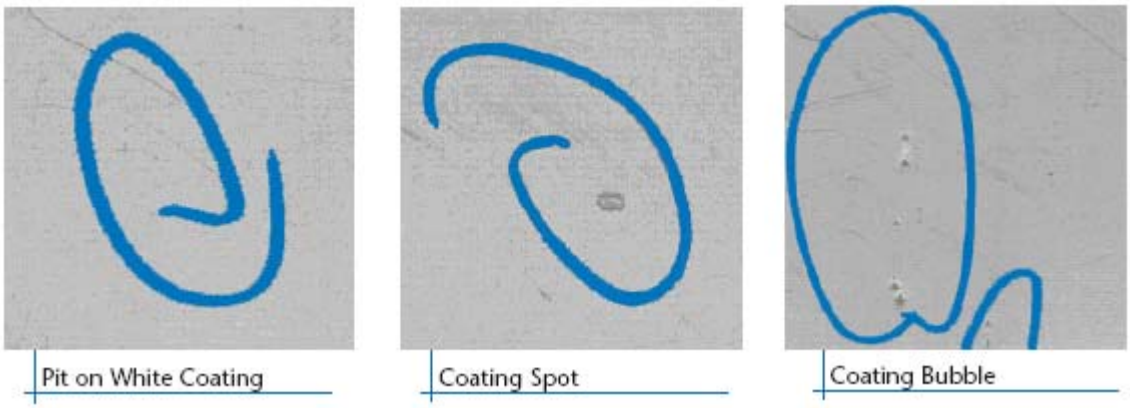

Figure 5: Typical Defects

Detection

The high image processing power of the SMASH WEB FPGA is used for an acceleration of the proven HTS defect detection mechanism. The image data acquired by the line-scan cameras is analyzed and filtered in order to selectively amplify or suppress particular image contents for best results. Recognition of e.g. low contrast streaks or low contrast large area defects can therefore reach a new level.
Image Analysis via SMASH WEB FPGA handles data input as large as 240 MByte/sec, up to 12 Bit per channel and performs real-time operations at 800 MByte/sec for

- camera exposure control
- shading correction
- edge tracking
- multi-scale detection

For steel coating applications, a line-scan configuration with brightfield and darkfield illumination is the standard (but not mandatory), with lighting being a choice from fluorescent lamps and white light LED (dependent on the coating type).
Installation is typically on a roll, with flat strip installations (reduced pass line variation required) being an option.

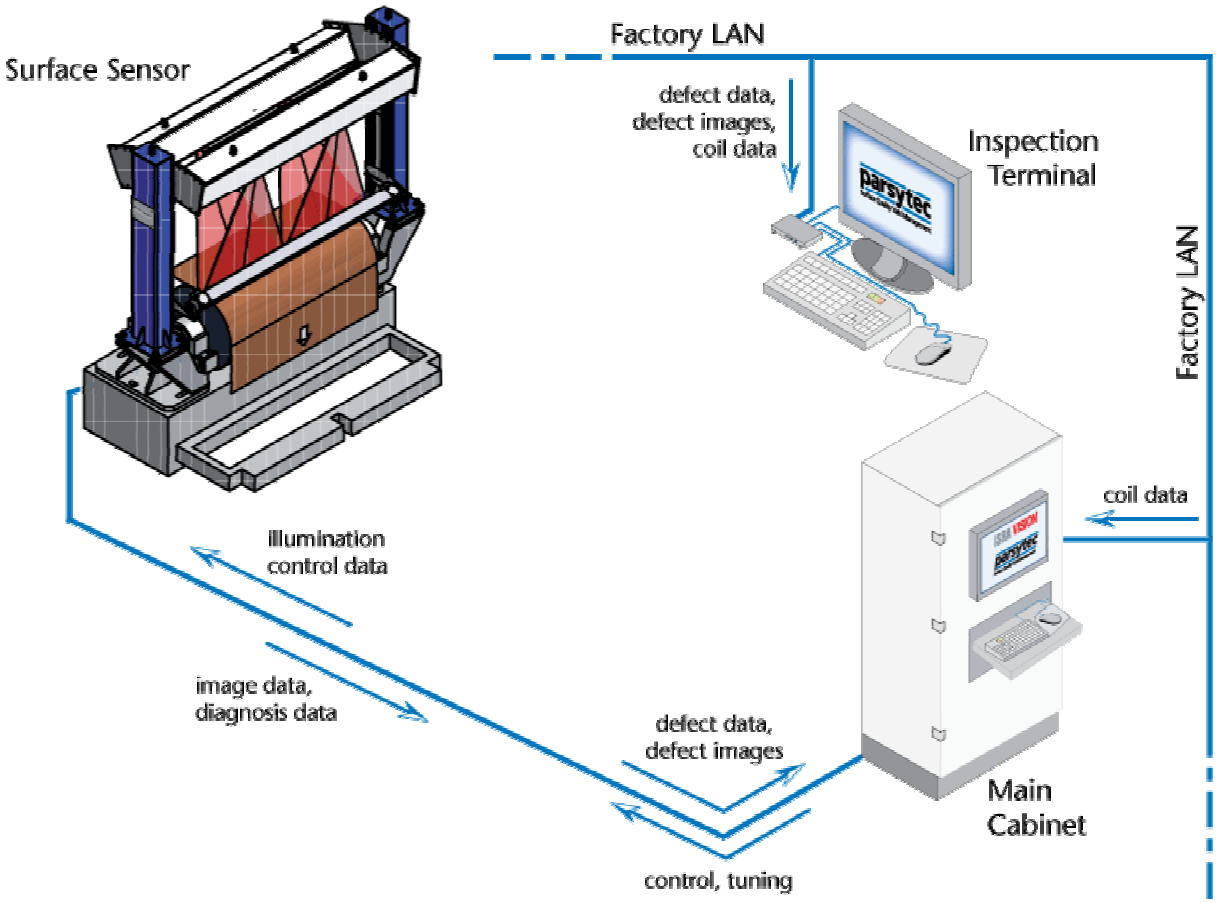

Figure 6: System Configuration

espresso SMASH thus delivers the highest detection performance for coated steels through:

- digital line-scan cameras and LED lighting for enhanced image quality
- FPGA capabilities for advanced image analysis
- easy scalability in resolution for smallest coating defects

Quality Yield Management

Automatic surface inspection already provides a great variety of different information in different forms. A coil report includes inspection information as well as defect images and even videos. The shift report is configurable for a specified time period and informs about the defect history. The width report gives an overview about the produced material widths and potential deviations from given specifications.
parsytec 5i supports unlocking a huge amount of additional data retrieved from different databases to be transformed to quality information aiming at fast and reliable decisions in the process flow. *parsytec 5i* was designed as a highly flexible tool that can be used for a great variety of data- and result evaluation. Data from various sources can be integrated in order to support the operator's decisions of how

to treat the coil or deal with a surface defect. These assessments include decisions about a coil after each processing step in order to determine the coil's future, ship or block, process, repair or re-route. For the first time, the full spectrum of gauge data including surface inspection can be exploited to generate intelligent quality decisions. Going further than just acquiring inspection information, *parsytec 5i* addresses quality decision applications as quality is related to more than just surface defects.

- *5i* is able to integrate all relevant data from different databases
- *5i* calculates rule based decision recommendations
- *5i* collects and synchronizes information from more than one line

Recent market trends show that metal producing companies tend to consolidate and thereby join and optimize their strengths. This in particular effects the selection of the best process route under technical and economical conditions. In order to enable customer deliveries of specialized products, matching coils to detailed mechanical, chemical and quality requirements via a variety of process routes, the product qualification data needs to be available from every line and decision making needs to be formalized to be executed everywhere – regardless the actual process route.

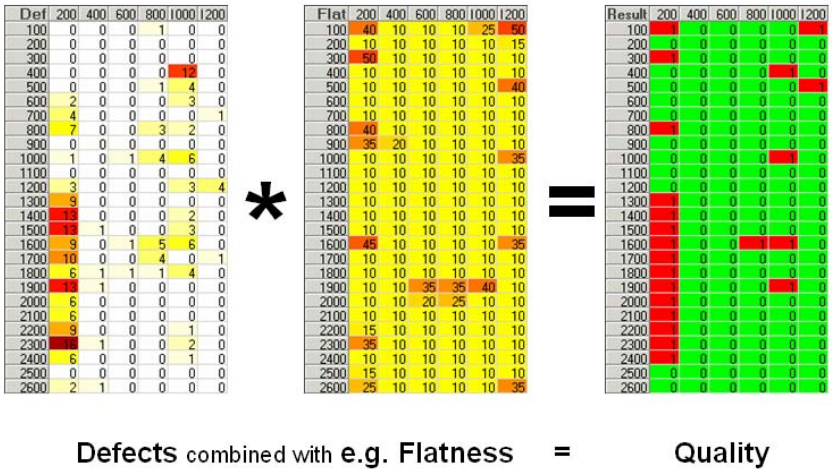

Figure 7: Grid-based calculations

Material Reassignment

Re-assigning coils to alternative customer orders is a demanding task for quality departments. The *parsytec 5i* application "Material Reassignment" now eases this job and allows additional re-assignments of 50-300 coils per year matching customer specifications. Potential savings total up from 150,000 - 900,000 US $ per year depending on grades.

The *parsytec 5i* application "Material Reassignment" assists the metal producer in reassigning produced but blocked coils to alternative orders. The benefits of the automated reassignment process are obvious:

1. eliminates time-consuming and error-prove process of matching hundreds of characteristics of the actual product with customer requirement
2. more comprehensive due to integrated data comparison functionalities
3. guaranteed highest yield when searching for new orders

Although "Material Reassignment" is a standard application, it is still customizable to specific requirements - in order to make the application work for the customer and purpose as efficient as possible.

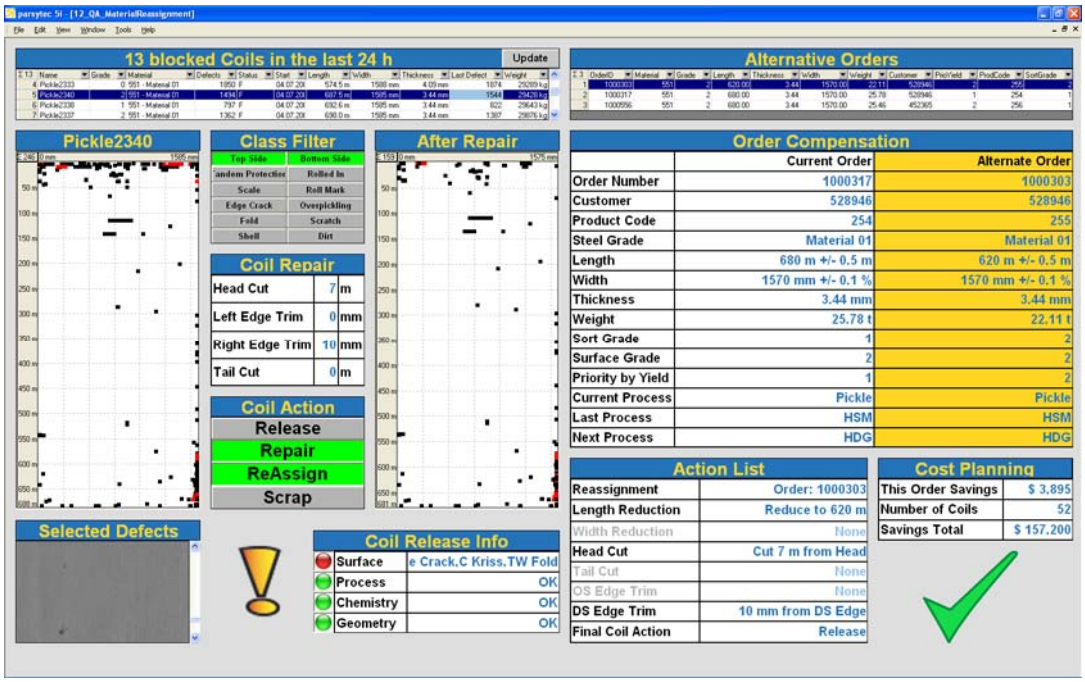

Figure 8: Material Reassignment

Coil Decision

The *parsytec 5i* product application "Coil Decision" enables taking objective and reproducible decisions of the upcoming action for the produced coils. The coil quality is not determined by just surface quality, there are numerous other criteria such as roughness, flatness, coating quality, … The coil judgement is done by a rule set, which is not limited to the world of only the surface inspection system, but is able to use any kind of information with which it is supplied.
The "Coil Decision" application can either run automatically on the last finished coil (online) or process a coil you provide by selecting from a list or typing in a coil name (offline).
The application can judge the coil automatically or provide a suggestion and decide by user feedback. The taken decision can be written back into the database as well as printed in a report.

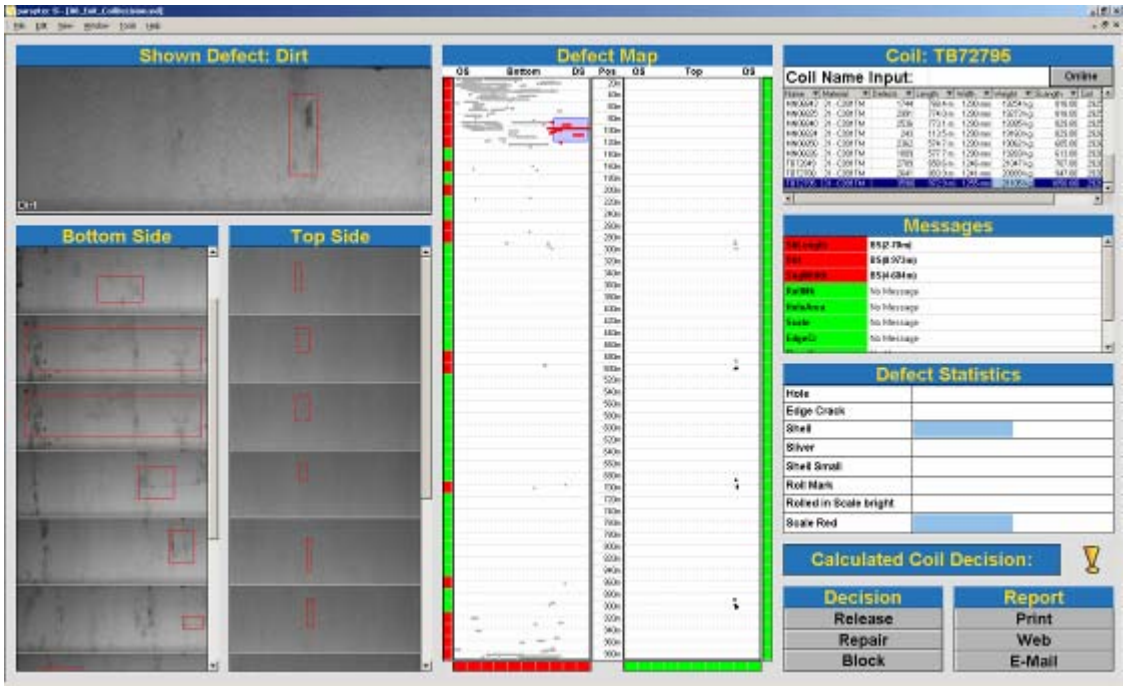

Figure 9: Coil Decision

The larger the mill, the more inspection systems are usually integrated. In order to build a company-wide infrastructure, *parsytec 5i* enables the connection of all inspection systems via the mill network.

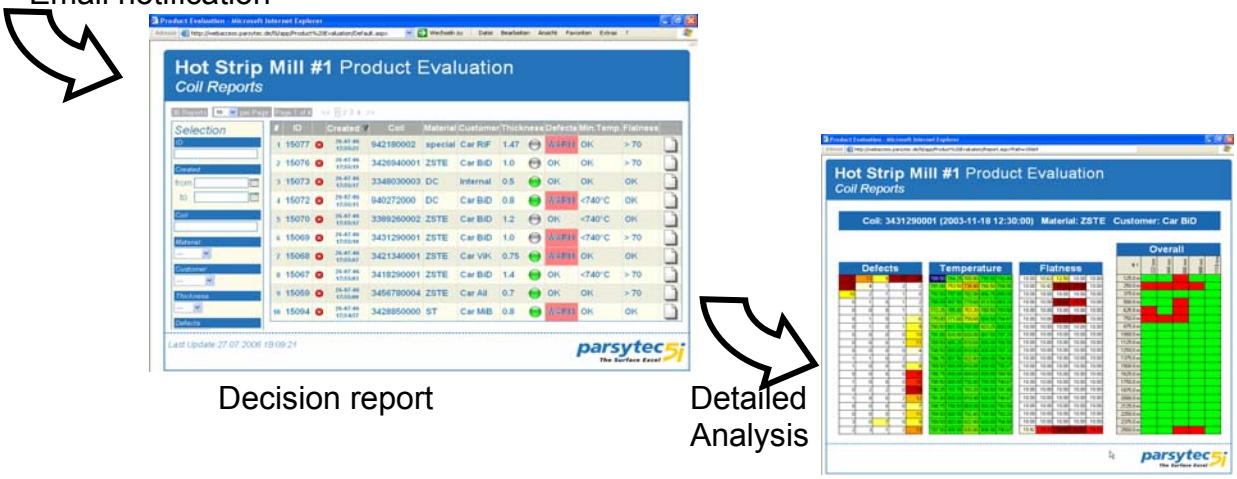

Figure 11: Promoting coil decisions via WWW

In order to support worldwide operation, *parsytec 5i* goes WEB - and makes further user-friendly functionalities possible: automatic reports, statistics, automatically sent e-mails or SMS on pre-defined events. Easy and fast delivery and access of quality information data are thus guaranteed. Product summary, daily reports and detailed analyses are all made available.
parsytec 5i also integrates a web extension module for creating coil reports basing on HTML. Reports will then be generated in the internet containing information on the coil, the defect, the required or recommended action as well as the defect image itself. This enables also the access to *5i* results within the company intranet.

parsytec 5i is able to design WEB pages automatically and updates them continuously online with the latest changes. The usability for the operators is simplified significantly, as no HTML specialist and no web page maintenance will be needed. It is accessible from any place, where intranet and/or internet are available. The WEB information is password-protected against external access.

Conclusion

Surface defects make surface inspection indispensable for each and every steel manufacturer. Surface Inspection Systems – in short: SIS - enable the detection of surface defects and thereby give the possibility the repair the defects and also to eliminate their causes. Hence, an SIS contributes to the enhancement of the produced material by lessening the 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 steel. To cut a long story short: surface inspection should be – ands 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.