Real-time surface inspection of steel strips

INTRODUCTION

Quality control of production has always been a necessity in steel mills. The users of steel set ever-increasing requirements on product quality. The purpose of a surface inspection system is to detect and classify surface defects that impair product quality with regard to the requirements set by the user. Critical defects are also those which cause production disturbances.

Automatic inspection systems for metal surfaces have been available for some time, but not until recently, the development of electronics and information technology have made the actual image analysis applications possible. The current systems use CCD-sensors to produce grey scale images of the defects. These images provide new opportunities for defect classification.

THE NEED FOR SURFACE INSPECTION IN METAL INDUSTRIES

There are many types of metal surface imperfections. In general, large defects are more critical than small ones, but steel users may also be concerned about defects whose diameter is only tenths of a millimetre. There are two main categories of reasons for steel mills to strive for defect free material: internal and external ones. When making a continuous strip product at a high speed, the imperfections in the strip quality often create problems in production. External requirements come from the users of the material. Out-of-quality end products may cause returns or even result in loosing a customer.

Worst problems that material defects may cause in a steel mill are coil breaks. With the help of surface inspection system coils with critical defects, that can cause coil breaks in the rolling mill, can be blocked. Such critical defects are for example edge cracks, holes and heavy slivers.

Steel producers want to know emergence of such defects that may prevent running the process smoothly and to make sure that the product quality meets the customer requirements. The causes of different defects should be located and removed as soon as possible. If defects are present they also should be recorded for different types of statistical quality reports. Without a surface inspection system, surface defect identification and root cause tracing can easily take a long time. During this delay the problem may repeat causing even more downgraded production.

BENEFITS OF AUTOMATIC SURFACE INSPECTION COMPARED TO VISUAL INSPECTION

Traditionally, many annealing and pickling lines have visual inspectors to do the surface inspection. Compared to this method, automatic surface inspection offers several benefits. With an automatic system it is possible to be sure that 100% of the material will be inspected. When a certain defect type starts occurring it will be noted immediately. Also, consistent inspection result is achieved. Better reporting is possible since pictures of every defect can be saved. Flexible reports are available when the defect data is saved in a SQL database. For modern high-speed production lines an automatic system is the only possibility because the speed is too high for visual inspectors.

As a summary, important facts provided by a web inspection system are, e.g.:
- Providing consistent 100% surface quality inspection
- Reducing costly reject production and customer claims
- Improving real-time process control
- Identifying preventive maintenance
- Facilitating quality grading of products
- Defect statistics for quality follow-up

STAINLESS STEEL DEFECT TYPES AND THEIR CLASSIFICATION

Most of the defects are optical surface flaws, which are detectable also by a human eye. For this reason, surface inspection systems also use optical principles for detection. Accordingly, as defective are regarded those areas of steel which deviate enough from the average steel.

The number of surface defect types in stainless steel is large. Defects can be divided into 30 – 40 different classes on an annealing and pickling line. Also the naming of similar defects may differ from plant to plant. But the basic idea is that with flawless steel the system produces a certain signal level. If the signal gets weaker, a detection of a dark defect is the result. If the signal becomes stronger the system indicates a light defect. The final classification depends, of course, also on the spatial distribution of the varying signals.

Most common defect types are shells, inclusions, scales, scratches, blowholes, roll imprints and pimples. Scratches can be caused in hot rolling mill, annealing and pickling line, cold rolling mill or skin pass mill. For process development purposes it is important that the system classifies different scratch types correctly.

Pimples are repeating elevations made by work rolls. Some of the pimples are extremely difficult to detect because of the small size and low contrast of the defect. On the other hand, whenever the pimples occur they can be found in the entire coil at certain intervals. Visual inspectors often check the pimples by slowing down the line and touching the surface by hand. ABB has developed a sophisticated SW algorithm to detect pimples. It is based on the repeating nature of the pimples.

In addition to these most common defect types several defect types can be found.

It is necessary for the metal surface inspection system to classify defects correctly according to the causes of defects. Also, the severity of the defect should be identified, for example, to find out if product fits the intended use. ABB is using neural network method to classify the defects.

The starting point for classification is the image captured by the camera. The first step after the image capture is segmentation i.e. separation of the defective area from normal material. Traditionally defect segmentation has been very rough. The advanced segmentation method developed by ABB follows the borders of the defect very accurately. This improves the classification result remarkably compared to conventional methods.

After segmentation different features are calculated from the image. These features can be for example length, width, area, borderline regularity, convexity and grayscale level distribution. Typically a couple of dozen features is used, but there is no limit to the number of features used in the classification. Adding more features after a certain level does not contribute classification of the defects. When the features are calculated a feature vector can be put together. Defects with about similar feature vectors are classified in the same class by the neural network.

The neural network has to be teached. The best way of doing that is that the operators gather defect images and give the correct class to them. Different computer based tools are available for making this stage easier for the user.

ARCHITECTURE OF A MODERN SURFACE INSPECTION SYSTEM

Figure 1 shows ABB's surface inspection system. It consists of camera beams, light source beams, defect information processing electronics and operator station, classifier and database PCs. Standard local area networks are used for distributing information between operator and office stations. The camera beams contain several cameras so that all the strip width in cross direction is covered and resolution requirement is met on both sides of the strip. Defect information is sent to operator station via optical link to prevent electromagnetic interference. The operator station is a standard PC and combines the information coming from different cameras to form various user displays and reports. The classifier PC classifies the defects and the defect data is saved in SQL database to facilitate flexible reporting.The light source beam is needed to achieve sufficiently strong and even illumination on the surface to be inspected. The type of the light source varies according to the specific needs of the metal grade. E.g. wide spectrum tungsten, fluorescent tubes or fiber optic light sources are typically used. The need for ripple-free illumination calls for special arrangements in lamp power supply units.

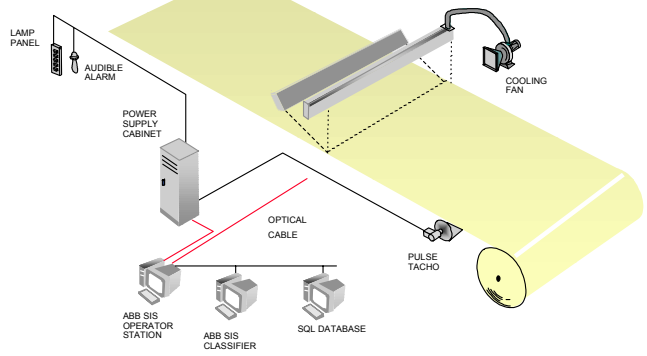

Figure 1. Surface Inspection System

Line scan cameras have been widely used because the second dimension is achieved with the help of strip movement. Their benefits, when comparing to matrix cameras, are that they have been designed for demanding industrial applications with high quality requirements what comes to sensitivity, signal/noise ratio, and pixel to pixel evenness. Also, it is easier to realise a strong and even illumination to the surface area to be inspected for a line scan camera.

SINGLE SENSOR CAMERA AND SIGNAL PROCESSING

The sensor itself (Fig. 2) consists of two main parts: CCD and signal processing unit containing electronic modules. The camera signal processing can be distributed to different electronic modules, which are installed on the same motherboard. The functions are divided between these modules and processing done in parallel to get as high throughput as possible.

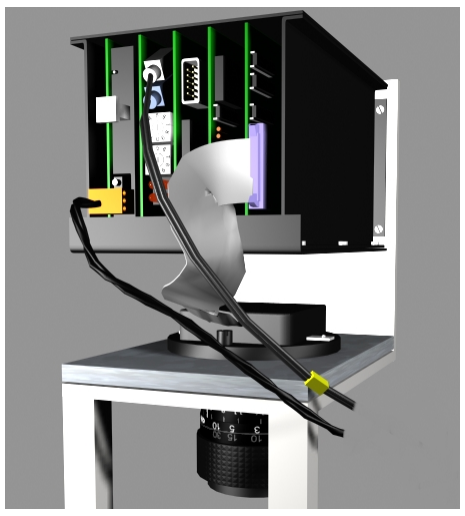

Figure 2. Digital camera of ABB SIS

The solution developed for the ABB SIS is an intelligent multifunction line scan camera. The camera is based on modern digital signal processing and processor technology utilising DSPs and PLDs. An advantage of this special camera is that in it a desired number of truly parallel computations and algorithms can be run at a high speed.

OPERATOR'S DISPLAYS

The operator station displays consist of multitude of video pages, e.g. defect maps, trends, profiles, repeating defect and formation developed for Windows NT operating system. Figure 3 shows one example page of the information presented to the machine operators.

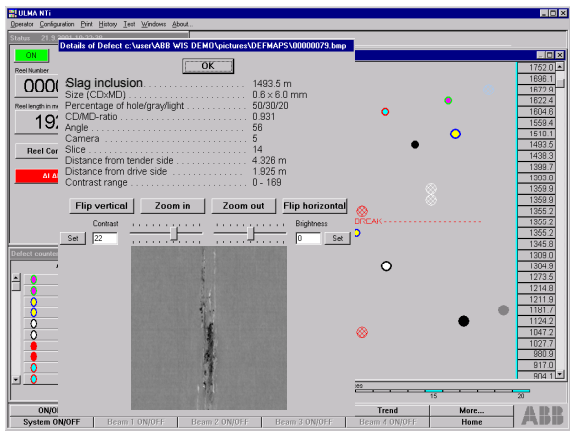

Figure 3. Operator's display

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