Surface Quality Inspection and Quality Data Application for Hot Strip Coil

Haiwei XU(1) Huili JIAO(2) Ray KIEHL(1) Wei YU(2) Fei LI(1)
(1)Shougang Research Institute of Technology, (2)Shougang Qian’an Steel Company

Abstract: Prior to implementing an online surface inspection system, the Shougang Qian’an Steel Company could only inspect the hot strip surface quality using tail end coil samples. This procedure was inadequate for daily production of steel with high surface quality requirements. In July, 2009, ISRA Parsytec 5.1 HTS Inspection software was installed and optimized by comparing detected and actual surface conditions, collecting defects photos, and building the defect classifier. Currently, the system is operating with a high ratio of defect detection and classification. It has also been integrated to provide surface quality grade classifications and online alarms for serious surface defects. Using the Parsytec system to identify typical surface defect locations, combined with microstructure analysis of the defects, has helped establish root cause and subsequent reduction or elimination of several surface defects such as pipeline steel chill cracks, edge cracks on LCAK, transverse cracks on HSLA wheel steel, edge slivers on IF steel, etc.

Key words: Parsytec online inspection system, online surface inspection, surface defect

1. Review

Construction of the No.1 hot rolling mill of Shougang Qian’an Steel Company was completed in December, 2006. For the first 2½ years of production, without the use of an online inspection system, real-time strip surface quality could only be checked using tail end coil samples. During this time, customer complaints regarding surface quality were all to common. In July, 2009, Shougang Qian’an Steel Company began using a Parsytec online inspection system. Through regular instrument maintenance, surface defect image collection, and establishment and optimization of classifiers, the superiority and stability of the system has been achieved. As such, the Parsytec system now plays a very important role in controlling strip surface quality.

2. Optimization of the Parsytec System

2.1 Main Maintenance

Parsytec version 5.1 was installed in the Shougang Qian’an steel company in July, 2009. As shown in Fig.1, top surface inspection is performed after F6 and bottom surface inspection is performed just ahead.
of the first down coiler pinch roll. After installation, much work has been performed to improve the stability and accuracy of this system, as follows:

1) A black colored board was placed above the strip in the bottom surface inspection area to provide a color contrast that improved detection of the strip edge.
2) Bottom surface edge inspection accuracy was improved by eliminating side guide disturbance through adjustment of software settings.
3) Non-synchronous inspection of top surface and bottom surface was adjusted through modification of the Level 1 incoming signal.
4) Water-related pseudo defects were eliminated by adjusting the angle of the side water spray after F6.
5) Camera and lighting glass are cleaned each shift and the electronics box is checked every 3 months for damage and cleanliness.
6) System backups are performed at least monthly, or earlier if required.

2.2 Material Classification

As a result of differing chemical compositions and production process parameters, the hot roll strip surface of different steel grades has differing grey values and distribution characteristics. According to the steel grade and the grey value, product at the Shougang Qian’an HSM has been divided into 5 categories: cold roll application strip, carbon steel, pipeline steel, silicon steel, and embossed pattern strip. Parsytec inspection sensitivity is set according to the product category, and the surface defect photos are then stored according to their respective product category. Fig.2 shows an example of the grey value of cold roll application strip. Fig.3 shows the unique periodical inspection record for embossed pattern strip.

Fig.2: Typical Grey Value of “Cold Roll Application Strip” Product
2.3 Sensitivity Adjustment

There are three steps for properly adjusting sensitivity. Firstly, the grey value should be set according to strip edge inspection. Secondly, sensitivity should be set according to the 5 product categories and the surface quality grading requirement. And finally, sensitivity should then be adjusted for inspecting the strip edge defects. In October, 2009, with proper sensitivity adjustments, detection of the tongue-shaped crack on the edges of pipeline steel was achieved with high accuracy.

2.4 Defect Comparison to Create and Optimize the Parsytec Classifier

Before collecting defect photos in the Classifier Building Environment (CBE), the engineer responsible for optimizing the Parsytec system should have knowledge of the various strip surface defects, and recognize the difference between the detected images and real defects. Each week, at least ten coils are selected for recoil inspection to compare actual defects with the recorded Parsytec images. As required, laboratory analysis is also incorporated to accurately characterize defect identities. All defects detected either by Parsytec or by eye, are compared and any classifications deemed to be inaccurate will be corrected.

After a suitable number of defect photos were collected, the classifier was established and its optimization is being maintained through continued recoil inspection comparison analyses.

Table 1 illustrates the comparison of a Parsytec image with the corresponding actual defect image used to construct the Parsytec classifier.
Table 1: Comparison of Parsytec System Detected Defect Photo and Recoil Inspection Photo

<table>
<thead>
<tr>
<th>No.</th>
<th>Slab ID</th>
<th>Steel Grade</th>
<th>Location of defect</th>
<th>System Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>33422</td>
<td>092049442202</td>
<td>SDX51D</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>From Head</td>
<td>From DS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of Coil</td>
<td>352</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parsytec System Detected Image: Real Defect Image:

The defect has been found, Yes or No: Yes Classification is right or not: Right

2.5 Application of Defect Alarm

After the Parsytec system has been optimized with high level detection and classification ratios, a defect alarm function can be incorporated. The Shougang Qian’an Steel Company HSM is now utilizing the defect alarm system to alert for roll marks, scratches, large slivers, and other heavy defects.

2.6 Online Ranking of Surface Quality using QES & Parsytec Systems

A process to rank strip surface quality into four groups (ranging from non-surface critical to automotive surface critical) has been established using the Qian’an QES and Parsytec systems. The preconditions for assigning an accurate surface quality ranking are high-level Parsytec defect detection and classification rates, and reasonable ranking rules within the QES system. Thus far, QES ranking rules for cold roll application strip have been created based upon the incidence of four main defects: scale, slivers, roll mark/scratch, and inclusions. For each coil, the frequency and severity of each of these defects, as detected
by Parsytec, will determine the assigned surface quality ranking.

## 2.7 Quality Control Using the Parsytec System

An optimized Parsytec system can be used to provide assistance to other information-based tools, such as quality control. Fig.6 shows the Shougang Qian’an HSM quality information flow. With the Parsytec system, a closed loop of quality control has been established.

![Quality Information Flow and Quality Control](image)

Fig.6: Quality Information Flow and Quality Control

## 3. Surface Defect Research Using the Parsytec System

With the improvement of Parsytec system, it has act as a very important role in surface defect research. Due to defect inspection with high accuracy and timely, quality research team can react quickly. The much more important is that Parsytec system can also give the defect character of distribution and periodicity. Considering with other influenced parameters such as the chemical composition, Process of continuous casting, quality of slabs, hot rolling machine and process, many kinds of the difficult surface defects have been resolved. For example, surface crack of pipeline steel, tongue-shaped crack of cold roll application strip, transverse cracking of wheel steel, edge sliver of IF steel etc. Following are two examples of the usefulness of the Parsytec system for surface defect research.

### 3.1 First Slab Surface Quality Research

It is well known, because of an unsteady casting state, coils produced from first slabs almost always have problems with inclusion and sliver defects. To improve the quality of first slabs prior to hot rolling, a scarfing machine can be used to remove the surface layer. During this process, the distribution and the depth of inclusions and other defects can be studied.

Data from the Parsytec system has helped with these studies through its ability to identify and count each type of defect on a given coil. Fig.7 shows the most common surface defects from first slabs at Shougang Qian’an: edge slivers, random slivers, and slag inclusions. Fig.8 shows results from the Parsytec system of the typical defect count distribution for a first-slab coil. As shown, the number of defects within 100m of the head end of these coils is much higher than in the remainder of the coil (at Qian’an, the head end of the coil corresponds to the lead end of the slab).
3.2 IF Steel Edge Sliver Research

When IF steels were first being hot rolled by Shougang Qian’an, edge sliver defects were common on greater than 30% of produced coils. The Parsytec system was instrumental in the investigation to identify the root cause of these slivers. Parsytec data showed this defect was exclusively occurring on the operator top surface and with higher frequency toward the tail ends of coils. Fig. 9 shows the typical image of an edge sliver on IF steel.

By incorporating microstructure analysis of the defect and hot rolling process parameters with the defect distribution provided by Parsytec, it was found that these slivers correlated with abnormal edge temperature distribution which affected the phase transformation and precipitation behavior. Subsequent process parameter adjustments have since eliminated the occurrence of IF steel edge slivers.

Fig. 9: Image of Edge Sliver on IF Steel
4. Results

1) The prerequisites for high level detection and classification ratios of Parsytec online inspection system are regular maintenance and persistent optimization of hardware and software.

2) The defect classification ratio can be improved significantly by:
   
i. Grouping steel categories by their grey value.
   
ii. Proper defect identification through regular comparison of Parsytec images with manual recoil inspection and laboratory analysis
   
iii. Effective classifier construction and continual optimization.

3) The Parsytec system can improve the efficiency of surface defect root cause analyses.