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Development of the Cross-Linked Integrated Information System

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Quality is one of the most important issues for both producers and customers. With the constant demand of strict quality control and efficient inspection, there are a number of automatic inspection systems installed in the distributed production lines. Although we have many inspection systems from upstream to downstream production lines, when defects occurred in a downstream line, it was difficult to locate the origin of the defects since these systems were isolated. In order to solve numerous cross-process quality analysis problems, a cross-linked integrated information system for inspection information was developed by China Steel Corporation (CSC) to locate the origin of defects to correct the problem. The system has three main functions, such as single coil integrating information query, by rolling sequence quality analysis and dynamic analysis. The range of data covers host data, quality statistical data of production lines, and various kinds of automatic surface inspection system (ASIS) data and images. This makes the quality analysis of coils from the upstream process lines to the downstream ones much easier and more efficient. There were several successful applications achieved by using this system. With this system, the quality management skill of CSC was improved tremendously.

Keywords：Cross-process, Information integration, Inspection application, Quality analysis

1. INTRODUCTION

For a sequence of production lines the quality level of each production line should meet the requirement. Otherwise, the final product could not fulfill the quality required. To confirm that the quality level meet the requirement, monitoring sensors and inspecting systems were developed and installed in the production lines(1-5).

Under the pressure of severe market competition, the quality improvement is constantly being pursued. To locate the bottlenecks of quality improvement, as much as possible process information and a handy managing platform is eagerly expected. For the purposes of solving numerous cross-process quality analysis problems and improving the data management skill, a cross-linked integrated information system for inspection information was developed by China Steel Corporation (CSC).

This information system involves steelmaking, hot rolling and cold rolling. The range of data covers host data, quality statistical data of production lines, and various kinds of inspection data. This system provides single coil integrating information query, by rolling sequence quality analysis and dynamic analysis tools, that user can choose the desired analysis variables and conditions, according to different requirement. This system also provides a so clear tracking procedure that the data can be analyzed by every staff engineer without disturbances. This makes the quality analysis of coils from the upstream process lines to the downstream ones much easier and more efficient. This paper focuses on the recent development of this system and successful applications.

2. SYSTEM ARCHITECTURE

In order to build up a system with the capability of gathering sufficient information and allowing several simultaneous queries, the nowadays widely used web-based platform style was adopted. The web-based platform contains two main components that are database server and web server(6). The cross-linked integrated information system automatically gathers the data from host computer, statistical process computer and inspection system computer through intranet. Then by using various kinds of data transfer interfaces to decompose the corresponding format of data, and saved them organizationally in the system database consequently.

With the intelligence of experienced quality analyzers, numerous applications were developed. By using these applications several cross-process and cross-system quality analysis issues became feasible and promoted the analysis domain up to higher level. Figure 1 shows the cross-linked integrated information system (CLIIS) architecture. At present, there are three main functions in the cross-linked integrated information system, such as single coil integrating information query, rolling related sequence quality analysis and dynamic analysis. Every authorized staff engineer can use a web browser to connect the system website.

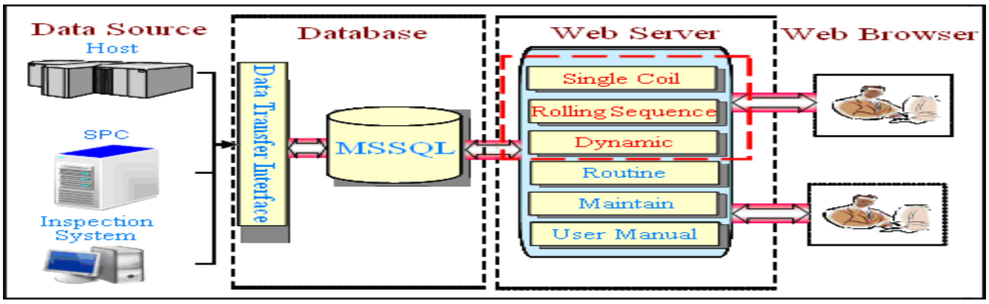


Fig.1. The architecture of the cross-linked integrated information system.

3. INTEGRATION SYSTEM ANALYSIS PLATFORM

There are four elementary parts to support the wealth of information, query efficientency, manipulation handling and security preserved cross-linked integrated information system (CLIIS). These four elementary parts are of data transfer module, data base, authority management and application platform, and they will be introduced as follows:

3.1 Data Transfer Interface

Since the data of the integration system covers various data sources. Each data source has its own data format. To gather all of this different data and make it available to being queried by only one type of search command format, their format must be unified. To execute the data format unification, there is a data transferring program to handle this work. As the integration system receives a batch of data, the program checks the format of this data batch. If the format of the entire batch is self consistent, then the system conducts the data format transfer and logs them in to the database. The corresponding flow chart of the data transferring program is shown in Figure 2.

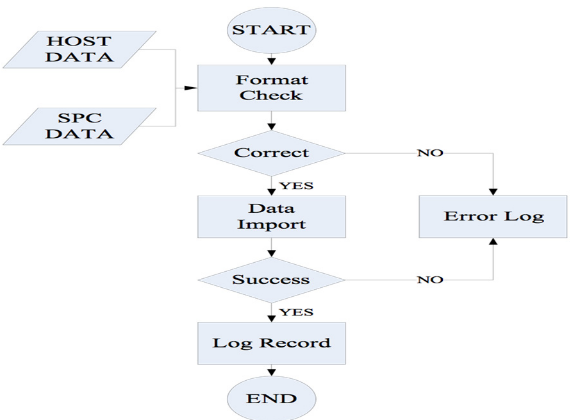


Fig.2. Data transferring program flow chart.

3.2 Database

To make the quality analysis as complete as possible, the data collected should be plenty enough for various applications. One application maybe customer related, and the other one maybe the malfunction of some rolling mill related issue. All of this data is subject to manipulation by different departments. Therefore, the range of the integration system covers the slab information data, each line coil data, the machine test data, order scheduling data, customer's complaint loss data and rolling process information data etc.

As to the automatic surface inspection systems, the data related includes two types. One is of defect description type text data, and the other one is of the image type. Since the data size of an image is very large, so in the defect analysis, the system directly reads and uses the data stored in the automatic surface inspection system (ASIS) through the internet.

3.3 Login Authority Management

Due to security concerns, there is a restriction on the system users. That is the user should be an employee of the China Steel Group and also a registered member.

The login permission management process is illustrated in Figure 3. First of all, the user has to apply for an account. Once it has been approved, the new user is registered in the permissions list. When the user switches on their computer and tries to use the CLIIS

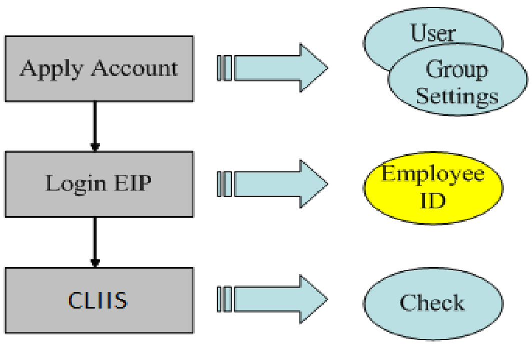


Fig.3. Login permission management process flow chart.

system, the user has to use his employee identification number and password to login to the company network explorer system (EIP), and then log on to the CLIIS system. As the user clicks the CLIIS system, the user will be asked to key in their user ID and password. Besides this, there is another permissions limitation for special functions applications. For instance, a long time interval quality information query is allowed only for some users, since it will take a long time to get the result and that will reduce the efficiency of other queries.

3.4 Web-based Platform

Within the information explosion and sharing era, the most common medium is the web browser. Inevitably, the CLIIS quality analysis platform was developed in a web-based structure.

The CLIIS quality analysis platform was developed by using the Microsoft Windows Server operating system, IIS Web server and Microsoft SQL Server Database. The user interface and application programs were coded in ASP.NET and C#.NET languages. C#.NET is a visual-based programming language, and the outlook seen on the UI screen during the programming phase is almost the same as the one shown on the screen when the program is under execution. Besides, C#.NET takes the advantage of the object oriented design concept that makes the program code and object separate.

There are three main functions in the CLIIS system, such as single coil integrating information query, by rolling sequence quality analysis and dynamic analysis, all of which will be introduced in detail in the next section.

4. SYSTEM FUNCTIONS

With many steel grades and production lines, it is quite impossible to conduct a vast and cross-process quality analysis without using the aid of computers and an automatic information integration facility. The design of the cross-linked integrated information system (CLIIS) is based on the needs of quality analyzers. To make the work of analysis not only easy and accessible, but all of the information, analysis variables and determination operators, were organized as a menu, that could be selected in any combination as desired by the user.

4.1 Single Coil Integrating Information Query

The main functions of single coil integrating information query are the process and ASIS defects analysis of a single coil produced by any production line[7-9]. For the convenience of operation, various kinds of modules were developed, such as width analysis, thickness analysis, mechanical property analysis and profile analysis related. Figure 4 shows an example of single coil integrated information function to analyze the hot rolled data. Figure 5 shows an example of ASIS defect analysis. And Figure 6 shows the example of the defects comparison study of a single coil. These defect distribution patterns were created by different ASISs of adjacent production lines.

4.2 By Rolling Sequence Quality Analysis

In the integrated sequential production lines steel

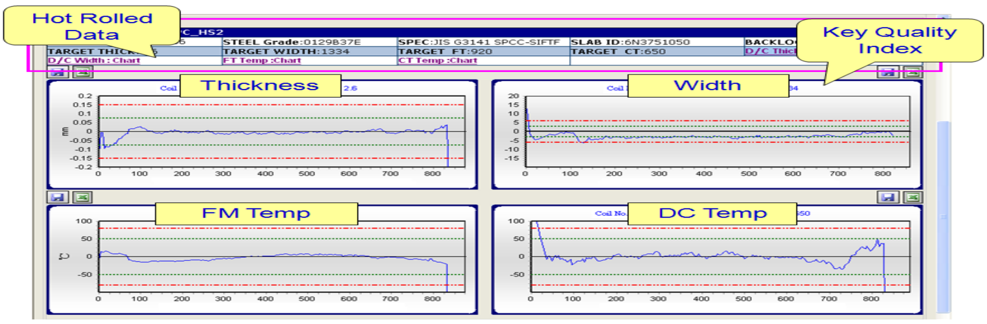


Fig.4. Example of single coil integrated information function to analysis the hot rolled data

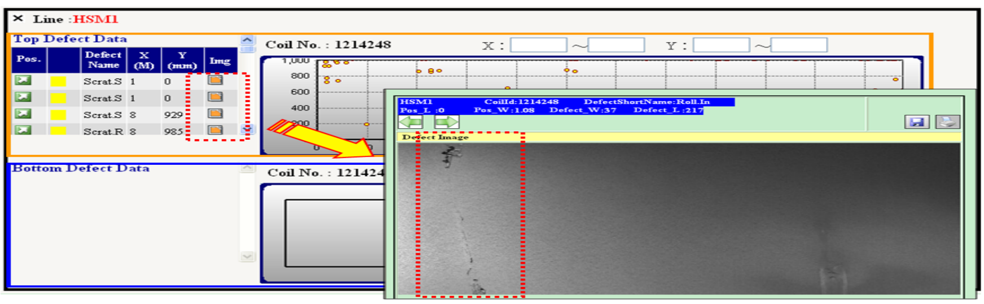


Fig.5. Example of ASIS defect analysis.

work, the types of production defect are various and the causing mechanisms may be complex. However, most of them are closely related to the rolling process. Hence, it is strongly expected to have a sequential rolling defects lookup and comparison platform for quick and accurate trouble shooting. The functions of by rolling sequence quality analysis were established in two branches, corresponding to the quality control factors analysis and ASIS defect images comparison.

Figure 7 shows the application example of rolling sequence related quality analysis. The main function of rolling sequence quality analysis is of organizing the quality control factor variation records of the related upstream and downstream production lines and index the abnormal evidence for trouble shooting. The operation method is for just specifying the production line which is related to the study case, and the system will automatically display the corresponding control factor variation records of the adjacent production lines for analysis. It is also possible to select a cross production line for a comparative analysis.

As to defect images, since the type of data format is very different from that of quality control factors, the way of managing the rolling sequence quality analysis is rather different. It is related with the ASIS. Besides, many surface type defects are quite closely related with the process of casting, especially the mold level variation. Therefore, this part of the analysis for the records of casting level variation can be queried for sequential ASIS defects analysis. Figure 8 shows an example of sequential ASIS defects and mold-level variation analysis.

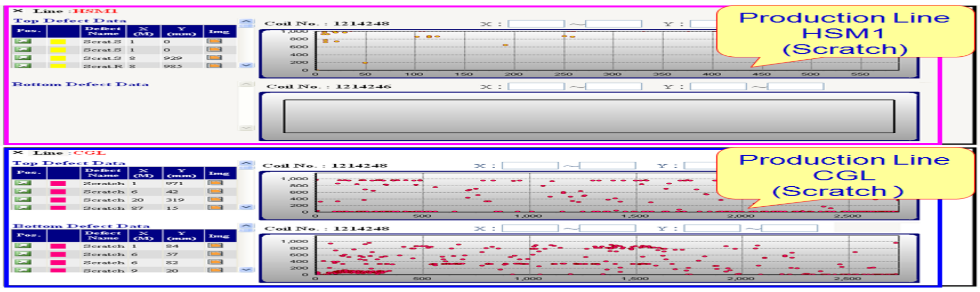


Fig.6. Example of single coil defects comparison study.

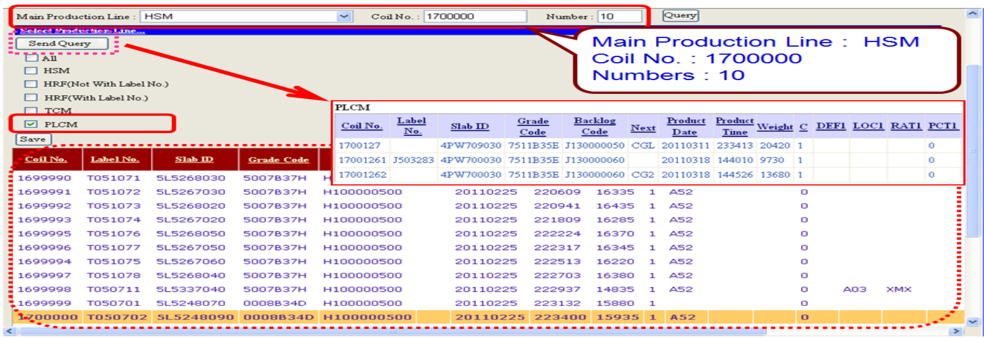


Fig.7. Application example of rolling sequence related quality analysis.

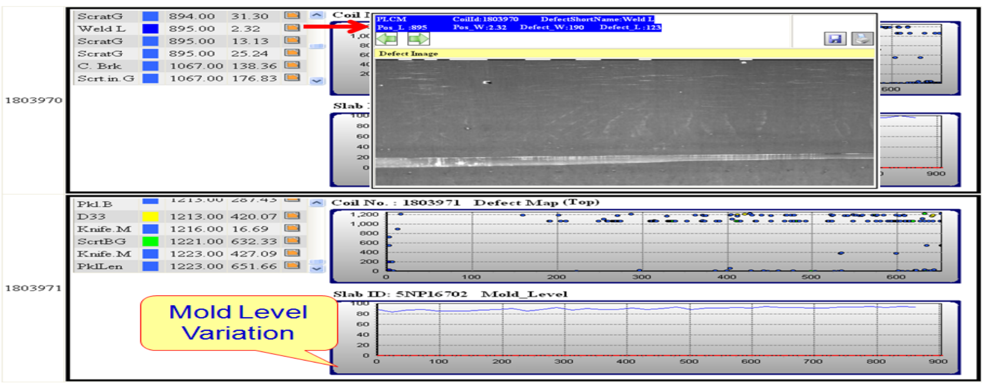


Fig.8. Example of sequential ASIS defects and mold-level variation analysis.

5. SYSTEM APPLICATIONS

The cross-linked integrated information system (CLIIS) is an important tool for quality analysis and problem-solving. There were several successful applications achieved by using this system, such as strip profile unqualified causing mechanism clarification, new product physical property analysis, steelmaking shell defects and hot-rolled scratch defects development tracking, etc. The benefits of substantial improvements not only can be attained, but also can significantly enhance the efficiency of the process improvement. The applications were summarized as follows:

5.1 Strip Geometric Quality Analysis

No.2 hot strip mill (#2HSM) down coiling web width gauge detected four coils with necking at the 125 ~ 130 m measured from the head. By checking the #2HSM finish mill width trend figures, it shows that the width trend was within the tolerance. But the necking defects were found through checking the down coiling width trend figures. To confirm the necking defects, the coils were examined in the next hot-rolled finishing line. The results showed that the corresponding batch of coils which were detected by down coiling width gauges did have the necking defects. The application of the CLIIS system conducting the overlay analysis was demonstrated in Figure 9. And then doing further analysis, it showed that the #1 down coiling (DC1) width gauge detected the first segment of necking, and the width measured by #2 down coiling (DC2) width gauge was normal. Finally, the mechanism for causing the necking defects was determined as a malfunction of the coiler. It was found that the inner wrapping layers were a few more and the wrapper roll opening was a little bit late, resulting in opened tension loss. Consequently, the mandrel's hard acceleration caused heavy web tension so by over necking occurred. After taking the measure to limit the maximum number of inner wrapping layers and control the wrapper roll opening time and duration, the neck defects were eliminated.

5.2 New Product Physical Property Analysis

During the new steel grade API 5L X52M PSL2 development period, the experimental product passed the impact test (-40° C), i.e. the impact value was consistent with the design goal, but part of the coil's tough off was lower than the expected values. In order to resolve the causes of the problem, a metallographic observation was conducted, first. From the observation of the fracture surfaces of the samples, showed that the brittle section was in the half thickness zone of the specimen, and the brittle fracture was caused by the center segregation of a continuous ribbon wave formed by iron and MnS. Through experience and professional judgment, the affecting factors maybe due to the inadequate setting of the HSM finishing, coiling temperatures, casting speed, mold level or other factors.

Using the CLIIS system to do the overlay analysis, it was found that the coils with lower rough off were made from the slabs suffering from unstable casting speed. To prove this factor, the slabs taken for the next trial were selected from the middle portion of the second casting. And the coils made from these slabs through the hot strip mill showed their quality with the required rough off ratio. By this study, the successful trial ratio increased from 84% up to 100%. The demonstration of this analysis application is shown in Figure 10. In this figure two coils made from the slabs with unstable casting speed are circled.

5.3 Defects Development Tracking

This case happened on the CGL production line. There were 343 tons of coils found with long wide white folding marks on the strips. All these coils were retreat. Examining the inspection results of the ASIS of the corresponding CGL production line, it showed that the defects distributed almost from the front to the end and in the central portion of the top surface. Again, through the processing variables dynamic analysis, the defect type metallographic analysis, and the upstream and downstream ASIS defects pattern comparison, it showed that all the defective coils had the same steelmaking furnace number. With this information, the remaining slabs of the same furnace number were examined. It showed

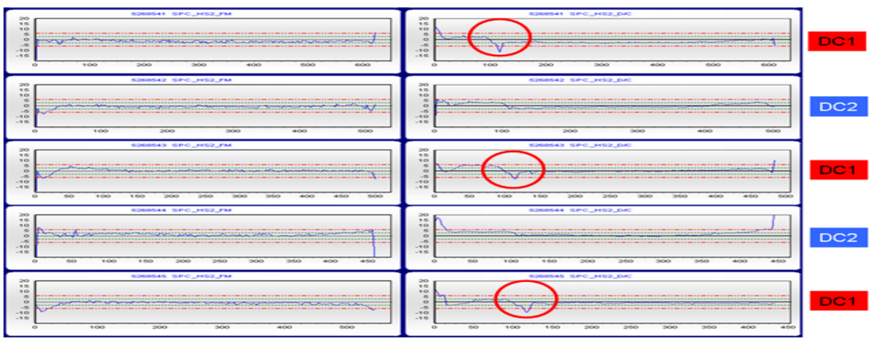


Fig.9. The comparison result of finish mill and down coiler width gauge measurements.

that there was a rather deep scarfing mark in the corresponding position of every slab. One of the results of this defect tracking study is shown in Figure 11. By this evidence and the adjustment of the scarfing nozzles, there was no such defect found on the subsequent coils.

5.4 Cross-Plant Quality Analysis

This case happened on the #1CGL production line in CSC. There was a large number of steel line marks and hot-rolled scratch defects on the production of computer chassis materials. Using the CLIIS system to search for this time period, found that the defect code and location of the picked steel coil was not regular, and the hot-rolled steel coils were from CSC and DSC. Further analysis shows that the slab came from DSC as shown in Figure 12. Through connecting the DSC information, it was found that the problem embryo mainly takes the L/D exchange material, the exchange front piece, the opening casting embryo and the first casting second block, will this information repay the DSC. With metallographic analysis, that confirm this defect is a steel-making alumina intercalate (Al_2O_3) as shown in Figure 13. This is an improved case study of cross-plant / cross-process quality analysis so that users can quickly clarify problems and make the most effective judgment and solution.

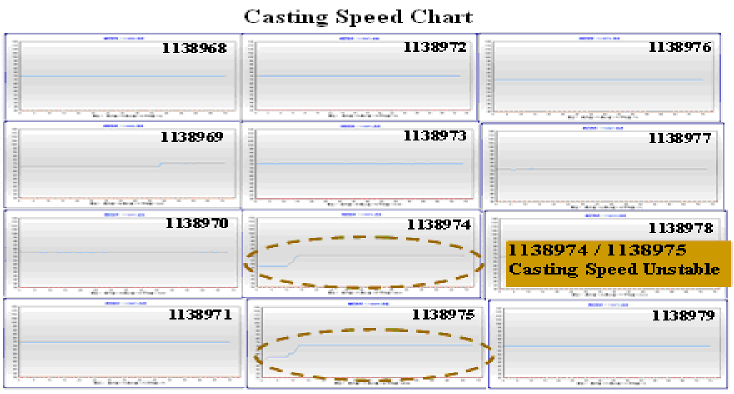


Fig.10. Casting speed charts comparison study.

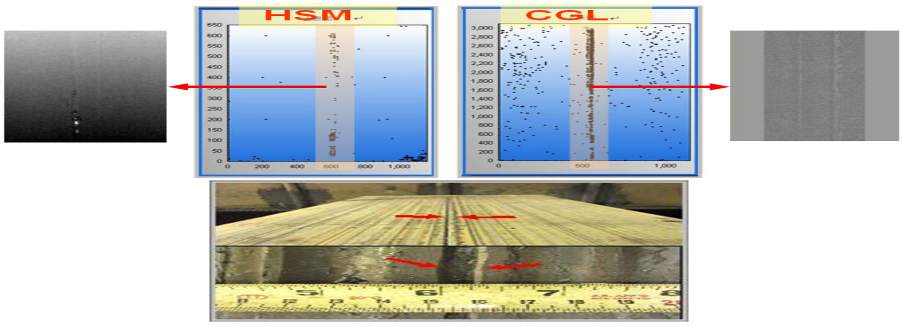
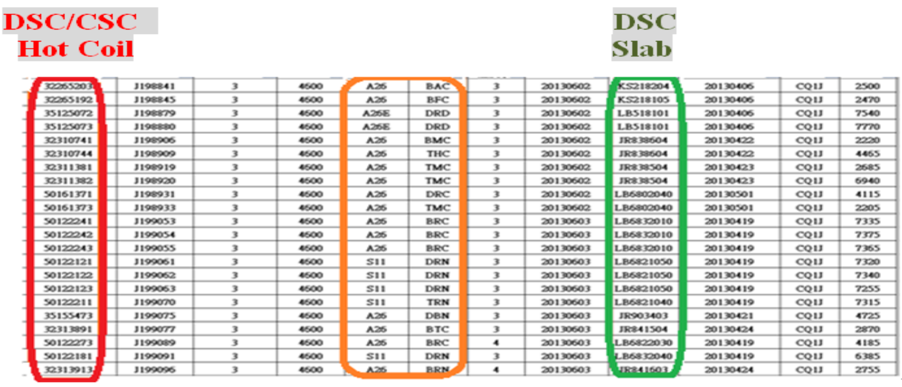
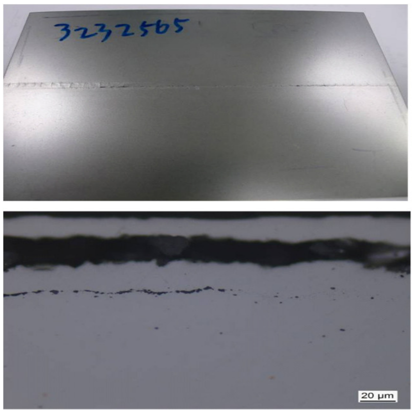


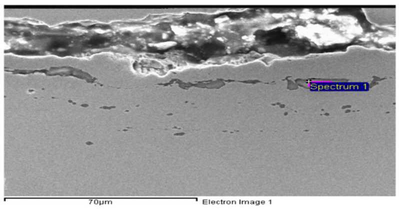
Fig.11. ASIS detected defects analysis.



32265203	J198841	3	4600	A26	BAC	3	20130602	KS218204	20130406	CQ1J	2500
32265192	J198845	3	4600	A26	BFC	3	20130602	KS218105	20130406	CQ1J	2470
35125072	J198879	3	4600	A26E	DRD	3	20130602	LB518101	20130406	CQ1J	7540
35125073	J198880	3	4600	A26E	DRD	3	20130602	LB518101	20130406	CQ1J	7770
32310741	J198906	3	4600	A26	BMC	3	20130602	JR838604	20130422	CQ1J	2220
32310744	J198909	3	4600	A26	THC	3	20130602	JR838604	20130422	CQ1J	4465
32311381	J198919	3	4600	A26	TMC	3	20130602	JR838504	20130423	CQ1J	2685
32311382	J198920	3	4600	A26	TMC	3	20130602	JR838504	20130423	CQ1J	6940
50161371	J198931	3	4600	A26	DRC	3	20130602	LB6802040	20130501	CQ1J	4115
50161373	J198933	3	4600	A26	TMC	3	20130602	LB6802040	20130501	CQ1J	2205
50122241	J199053	3	4600	A26	BRC	3	20130603	LB6832010	20130419	CQ1J	7335
50122242	J199054	3	4600	A26	BRC	3	20130603	LB6832010	20130419	CQ1J	7375
50122243	J199055	3	4600	A26	BRC	3	20130603	LB6832010	20130419	CQ1J	7365
50122121	J199061	3	4600	S11	DRN	3	20130603	LB6821050	20130419	CQ1J	7320
50122122	J199062	3	4600	S11	DRN	3	20130603	LB6821050	20130419	CQ1J	7340
50122123	J199063	3	4600	S11	DRN	3	20130603	LB6821050	20130419	CQ1J	7255
50122211	J199070	3	4600	S11	TRN	3	20130603	LB6821040	20130419	CQ1J	7315
35155473	J199075	3	4600	A26	DBN	3	20130603	JR903403	20130421	CQ1J	4725
32313891	J199077	3	4600	A26	BTC	3	20130603	JR841504	20130424	CQ1J	2870
50122273	J199089	3	4600	A26	BRC	4	20130603	LB6822030	20130419	CQ1J	4185
50122181	J199091	3	4600	S11	DRN	3	20130603	LB6832040	20130419	CQ1J	6385
32313913	J199096	3	4600	A26	BRN	4	20130603	JR841603	20130424	CQ1J	2755

Fig.12. Cross-plant / cross-process defects analysis.





Element	Weight%	Atomic%
O K	41.68	56.98
Mg K	0.70	0.63
Al K	44.95	36.44
Ca K	5.49	3.00
Ti K	2.14	0.98
Fe K	5.03	1.97
Totals	100.00	

Fig.13. Defects metallographic analysis.

6. CONCLUSIONS

The final quality approved steel products, were made through the steelmaking, hot rolling, cold rolling and cold-rolled coating lines. The study of the defect evolution needs the process information supplied by the upstream and downstream lines. To make the study easier and more efficient, it is necessary to organize the efforts of the R&D, QA and other department units and work together to establish a cross-linked integrated information system. The development of the system not only improved the overall operating efficiency but also increases the quality analysis capabilities.

The cross-linked integrated information system contains steelmaking, hot rolling and cold rolling areas. The range of data covers host data, quality statistical data of production lines, and various kinds of inspection data. This system provides single coil integrating information query, by rolling sequence quality analysis and dynamic analysis with the measures of optional analysis variables and conditions selection according the case requirement. This system also provides such a good tracking procedure that the data can be analyzed by every staff engineer easily. This makes the quality analysis of coils from the upstream process lines to the downstream ones much easier and more efficient. By using this system it makes the old individual quality analysis reach the wide upstream and downstream cross-process quality management, and accelerates the analysis process to ensure product quality and to reduce costs. With this system, the quality management skill of CSC was improved tremendously.

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