THE QUALITY RESULTS OF SLABS AT SEgregation AREA

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Abstract

The discussed issue is solved in ArcelorMittal Ostrava a.s. The VŠB - Technical University of Ostrava is participated on this issue under a grant project of TIP program. The grant project with ID FR-TI1/432 „New advanced computational methods for quality control in production of high quality steels“ is financially supported by the Ministry of Industry and Trade of Czech Republic. The aim of the project is development and implementation of methods for analysis of macro structure of metallographic samples leading to facilitate monitoring of production and to increase quality of production and technological practices. The article describes possibilities of slab sample inspection and introduces new methods for quality inspection in the middle part (segregation). In the present article, new results of the solved project, especially results from segregation area evaluation are given.

Key words: Steel, Slab, Quality, Segregation, Model

1. INTRODUCTION

The above cited grant project monitors the center slab quality of samples. The attention is engaged in development of new methods for visual quality evaluation of the center part of macroscopic slab samples (cross-sections, etched) and development of mathematical methods for automated recognition of quality (segregation) with statistical evaluations of results.

2. DESCRIPTION OF THE SLAB CASTER AND THE SAMPLING

These solved issues (described in the introduction) are related to the production of slabs on the CCM No. 2 (Continuous Casting Machine) in Steel Plant ArcelorMittal Ostrava a.s. [1]. This production is based on a CCM with the bow radius of 5 m. The supplier of CCM is Siemens - VAI. The maximum of metallurgical length is approximately 22 m. After modernization of CCM it is possible to cast with casting speed up to 2,75 m/min. The chamber consists of a bending segment, 3 bow segments, 2 straightening segments and 5 horizontal segments. Besides foot rollers there are used water-air nozzles at 6 metallurgical cooling zones. The static soft reduction is set in the CCM cooling chamber.

Slab samples (cross-sections) are taken by a burning machine. Each sample is divided into 3 smaller parts (in case of wide slabs of approx. 1500 mm, the sample is divided into 4 parts). After cooling off, each sample is identified by a number of heat with a symbol of sample part: „L“ left, „C“ central (middle), „P“ right. Thus, processed and identified slab samples are transported to the mechanical workroom, where these slabs are prepared (cutting and milling) for etching in the metallographic laboratory. Etching the slab samples is normally performed by the device Macroetcher made by Steltech® Structural Ltd using an electrolyte. The electrolyte contains: 1,0-2,0 N HCl solution (it means 6,5 % HCl). Moreover, in order to highlight the place of segregation, manual etching of slab samples is carried out in the metallographic laboratory. The reason of highlighting the place of segregation is due to evaluation of the samples within the grant project and due to development of new methods for classification of the centre slab quality.
3. POSSIBILITIES OF SLAB SAMPLES CLASSIFICATION

3.1 Established procedures for visual quality classification of slab samples

A catalogue of defects and a methodology for the slab quality classification was developed as part of commissioning of CCM No. 2 [2, 3]. This catalogue includes among others descriptions, causes and preventions of defects and possibilities of removing these defects. An example of a picture from the catalogue of defects is shown in Figure 1.

According to the methodology, the studied defect is classified in the cross-section of the slab sample, where defect parameters are measured (for example length and number of defects in a given place). Results of the classification are recorded in a protocol of the metallographic laboratory. Subsequently, the quality levels are calculated for the given defect or for the given group of defects. Quality levels assume values from „0“ to „5“, where the level „0“ means that the sample has no defect of the given type.

Another methodology was also applied for visual metallographic inspection of slab samples. For example, a methodology for evaluation of corner cracks and surface (subsurface) bubbles have been introduced.

3.2 Implement procedures for centre slab quality (segregation) classification

The newly implement procedure for quality classification of slab samples is related to the central part of the slab – the final place of solidification. Specifically, the centerline segregation is assessed and classified. The classification is based on counting dark particles, respectively segments, which are induced by etching of the slab sample. Ammonium persulphate is used for etching, because it has shorter etching time without causing the macrostructure, but with induction of central segregation. Subsequently, these particles are evaluated by size and frequency. As a result, quality classes are predetermined. Currently, clear black (dark) particles with diameter 1 mm or more are marked. Discrete and continuous occurrence of particles is recognized. Depending on particles type and number of particles in the classified part, the quality class from 1 to 4 is determined. The quality class „1“ means the best quality, whereas the quality class „4“ means the worst sample quality, respectively. The quality classes „1“ and „2“ are acceptable. The evaluation methodology has been specified and further development of the methodology is expected under the grant project.
4. AUTOMATIC RECOGNITION OF SEGREGATION

4.1 The method developed at VŠB-Technical University of Ostrava

Segregation modeling represents a complex task. Beckermann [4] provided review with more than 150 references including basics physical models, coupled microstructure - macro segmentation models and direct numerical simulations. The system for automatic recognition of center quality of metallographic samples has been developed by the co-investigator of the research project from the Department of Applied Mathematics, FEI VŠB-TU Ostrava [5, 6, 7]. The recognition system is based on a robust search algorithm, in which small objects from the metal sample are being automatically detected. The recognition system is designed as a separate model, which is connected with the model of technology and data quality (TQ model), which has been developed at the Research dept., ArcelorMittal Ostrava a.s.

The automated assessment of center quality of a metallographic sample works as follows [6]:

- Segmentation of the image sample. In this step, the image of the metal sample is separated from the background of the sample. The segmentation algorithm is based on thresholding.

- Localization of the area of interest with darker central objects. This is implemented by detecting image rows with local minima in brightness, because the central objects are darker than the rest of sample, see Figure 2a. A probability distribution of the examined disorders was set depending on the observation of samples. Consequently, this probabilistic distribution is being used in filtering so-called false-positive matches. The detected area of interest in the sample centre is seen in Figure 2b.

- Localization and selection of objects in the region of interest. We already know the region with central defects from the previous step. These detected defects are being compared with the probability of occurrence of the defect and are being successively highlighted, see Figure 3.

- The localized defects are being filtered: Dots with insignificant size are identified as noise. The remaining significant dots are counted and measured. Especially, their size, position and area are being estimated and stored into a database.

A demonstration of developed software for quality evaluation of two selected metallographic samples is shown in Figure 3. Rating the quality of the center was carried out automatically without any user intervention. The sample "P" denotes the right side of the slab sample, whereas the sample "CP" refers to the central portion of the slab close to the right side. Pattern "P" contains 30 detected central objects. The minimum and maximum of the detected particle size is 0.12 and 1.76 mm, respectively. On the other hand,
the sample "CP" contains 57 detected particles. The minimum and maximum size is 0.10 and 3.62 mm, respectively. In both samples, large number of detected objects is smaller in width than 1 mm, see Figure 4. These small detected objects are not included for classification according to the methodology. The histogram shows intuitively that the "P" sample may have a higher quality class than the "CP" sample, because the "CP" sample contains larger central objects. However, the quality class of the sample depends on properties of detected central dots (their number and size) in the predetermined evaluated segment. A distribution of countable detected samples in a typical segment window is shown in Table 1.

![Automated detection of central objects](image)

**Fig. 3** Automated detection of central objects for „P“-sample (up) and „CP“-sample (down). Detected central objects are highlighted in red.

![Histogram of width of central objects](image)

**Fig. 4** Histogram of width of central objects in mm extracted from „P“ sample (up) and „CP“ sample (down).

The sample "P" in the window segment includes up to 3 objects having size between 1-3 mm. Because the number of detected dots is less than the predetermined limit and larger objects are not being detected, "P" sample is rated as Class Quality "1" (i.e. best quality). On the contrary, an object having size 3-5 mm was found in the window segment of sample "CP". According to the established methodology, this part of the sample is rated as Class Quality "2".

The machine-based central quality assessment provides in both cases the same results as an expert evaluation by a specialist from the metallographic laboratory. Moreover, ongoing testing, calibration and further improvement of the search algorithm have been passed.

**Table 1** Extracted countable particles in the worst window section

<table>
<thead>
<tr>
<th>Sample</th>
<th>Objects 1 - 3 mm</th>
<th>Objects 3 - 5 mm</th>
<th>Objects &gt; 5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
4.2 The method developed at ArcelorMittal Ostrava a.s.

Development of automated recognition of center quality of samples was also launched on the contractor’s project in ArcelorMittal Ostrava, plc. The recognition approach is similar to that of VŠB-TU Ostrava. First, properties of objects and expected areas are specified. This specification includes search of inner border of the sample slab, retrieval of the center line and specification of area of interest. Subsequently, central objects are being sought. Central objects are determined by histogram analysis, either in whole or in part, due to the elimination of glare and unstable directional lighting. By specifying the upper and lower limits of the threshold a filter to retrieve objects in the image is determined. These specified values are important for the quality of subsequent classification of the central segregation, in which random and uninteresting noise particles are automatically eliminated, whereas particles probably related to the central segregation are analyzed in detail. When the evaluated parameters are being set correctly (not too little or too much sensitive, depending upon the sensitivity of the segmentation filter), then we can achieve a very close resemblance between human classification and machine perception of the object, see Figure 5. Handwritten notes of a human expert and automated notes describing the particle size given the computer code are listed in the white box. The computer code gives also additional properties of extracted objects (e.g. size and area of dots).

![Sample classification by a specialist from the metallurgical laboratory (up) and the computer-based automated classification (down).](image)

5. RESULTS OF QUALITY ASSESSMENT

The described project was launched in 2009. A classification of segregations of selected slabs according to established methodologies started in the first year of the project. The software system includes classification results of 52 slab samples produced in 2009 (168 sub-samples), for example results of microalloyed steel grades for production of spiral welded pipes mainly by the API standards. TQ model with its sub model provides in the ArcelorMittal Ostrava a.s. company tools for displaying classified results and its parameters, archiving photos and coupling both qualitative and production parameters.

The aim of the project is to monitor and improve the production process of the slab CCM No. 2 with regard to the required quality of the center - the occurrence of segregation. According to [8], one of the major influences on the quality of the center is the CCM curve geometry, especially at higher casting speeds and larger slab widths. For these reasons, it is very important to ensure the comparability of results and quality of slabs with specific technological data. As a result, analyses of slabs production from 2009 showed that all sub-sample slabs, except one, were rated Class "1" (in total, 148 sub-sample slabs) or Class "2" (19 sub-sample slabs). In order words, these sub-sample slabs meet quality requirements according to the established methodology. Only one sub-slab sample was classified as Class "3". According to [8], wider slabs with approx. 1 400 – 1 500 mm width are prone to meet a lower-class quality.
6. CONCLUSIONS

In the grant project, we continued to develop two methods for machine assessment of the center slab quality in terms of segregation. One of the methods has been developed by the project co-investigator from the VŠB-Technical University of Ostrava, whereas the other method has been developed by the project investigator from the ArcelorMittal Ostrava a.s. company. Moreover, we have created a database of real photographs of metallographic samples and a database of digitally processed images, including human and computer-based classification of the center slab quality. Developed software has been tested and verified according to results of the expert classification. Achievements of machine and expert quality classification of slab center part will be statistically evaluated and paired with manufacturing parameters that are already stored in the database. The quality of analyzed slab samples produced in 2009 can be considered as very good in the term of central segregation, because only one of all 168 collected samples has been classified by the unsatisfactory class “3”.

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REFERENCES


