SOFTWARE FOR THE EVALUATION OF SEGREGATION IN WIRE ROD

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Abstract

This article presents a method for software assessing the level of axial segregation in wire rod. This so-called axial segregation is routinely determined visually as dark spots on the etched cross-section of wire, which classifies comparison to a etalon. The result is a class of characterizing the degree of segregation in the axial wire. The disadvantage of the visual evaluation is considerable subjectivity in evaluating particularly borderline levels of segregation and mere only categorial variable characterizing the degree of segregation.

Software evaluation eliminates these drawbacks. The evaluation algorithm still works in the same way and the output is a quantitative variable, which can be further processed statistically. Measurement is faster, more accurate and more objective. The paper gives an example of a software evaluation of the level of segregation in the rolled wire before and after modernization of wire rod mill in Trinec Ironworks, Inc.

Keywords: Segregation, wire rod, automated inspection, image processing

1. INTRODUCTION

An important requirement for reliable production of high-carbon steel wire is mastering axial segregation of injurious elements in the continuously cast billets. The practise confirms the negative effect of increased segregation on the limit deformation and thus the formability during wire drawing [1]. There are many articles dealing with segregation formation in technical bibliography [2, 3, 4, 5]. The degree of axial segregation is currently determined visually (the assessment of the size and shape of segregation dark areas) on the polished and etched samples of wire. Final evaluation is thus influenced by the human factor.

The task of the automatic classification system is to reduce errors to a minimum and getting same results for a long time. As compared to visual evaluation using a microscope, software evaluation is faster, more accurate, independent on the human factor with the outputs well process-able using statistical methods.

2. SOFTWARE FOR THE EVALUATION OF SEGREGATION

Software for the evaluation of segregation is intended for an automatic determination of axial segregation in steel wires. This software was tested in the metallographic laboratory of wire cord producer, where the trial was conducted as conventional visual method and using newly developed software for the evaluation of segregation. The results confirmed that the software is capable to conduct assessments of segregation as well or better than visual assessment influenced by the human factor.

Software for the evaluation of segregation can be installed on a desktop PC without specific performance requirements and is designed primarily for 32-bit Windows NT. The PC is connected to a standard office scanner with a resolution of at least 1200 dpi (**Fig. 1**). Samples of wires are pressed into bakelite discs of diameter 40 mm and height 17 mm (**Fig. 2**), the disc may contain 4, 6 or 12 wires. The wires are polished and etched in the etching agent before assessing.

The samples prepared in this way are placed on the scanner (maximum four discs simultaneously) and evaluation is performed. Evaluation of segregation is fully automated with possibility of manual correction of result.

Fig. 1 Personal computer + scanner

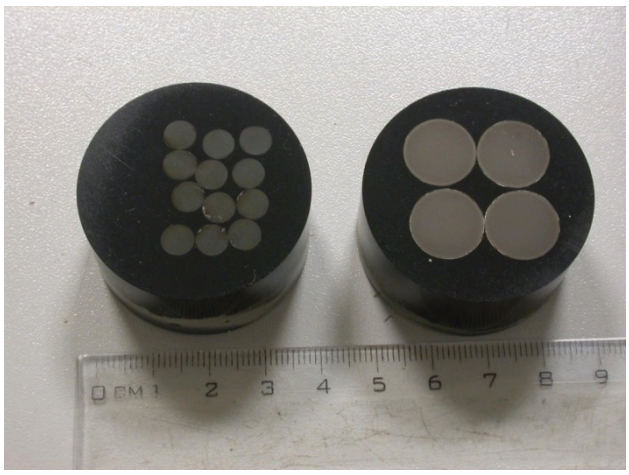

Fig. 2 Wire samples prepared for evaluation

Outputs of the software are:

1) **class of segregation** (GN, UL A, UL B, ZL A, ZL B, …) - categorial parameter describing degree of axial segregation (agreeable with output of former visual evaluation). Subtypes A and B distinguish segregation spot with and without ring of negative segregation.

2) **numerical index**, characterizing degree of axial segregation (numerical variable with an accuracy of two decimal places, without distinguishing subtypes A and B). Numerical index corresponds with segregation classes according to **Fig. 3**.

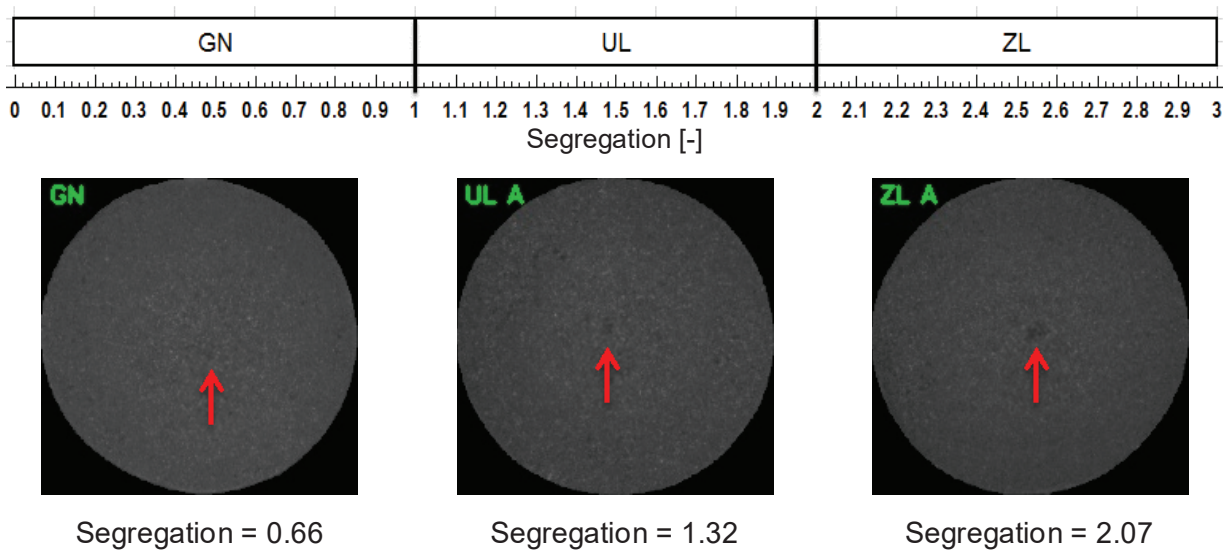

Fig. 3 Examples of three evaluated wires

The main advantages of software evaluation are:

1) elimination of human factor, influencing segregation evaluement (the main disadvantage of former visual evaluation is considerable subjectivity in evaluating particularly borderline levels of segregation)
2) software measurement is faster, more accurate and more objective, output of software is a quantitative variable, which can be further processed statistically

3. MEASURING PRINCIPLE

The level of segregation is determined for all input images like on the following **Fig. 4**. During the analyses it was found out that the scanned image has low dispersion of values of brightness. This dispersion has only units of the brightness. This fact makes the classification of segregation more difficult because the information is devalued by noise and surface reflectivity of material. For this reason it was chosen the following process. The first step is to analyze parts of wire area. It was statistically found out that the area of every wire contains a several parts.

a) Area of potential appearance segregation

b) Active area of the wire

c) Area without any useful information

The area of potential appearance of segregation is part of the wire where is found precipitated carbon. The radius of this area has been found by experiments for 30 percent of the wire radius (0,3R). Active area of the wire is a part of wire with important statistic information about a distribution of pixels values in wires. For this reason this part is the referential one. Its size is 60 percent of the radius (0.6R).

The area without any useful information is the border part of the wire. In this area there is a distortion that comes with scanning the clamp. After the separation of area to three parts, the classification of segregation can be started.

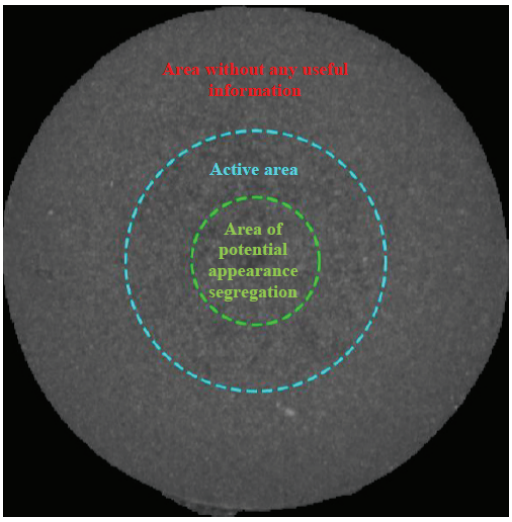

Fig. 4 Three parts of the wire

The process is shown on the diagram in **Fig. 5**.

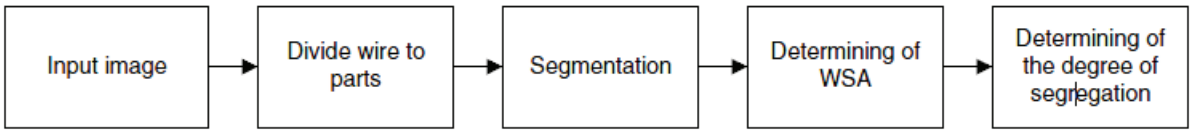

Fig. 5 Flowchart of segregation measurement

The principle of segregation evaluation with the aid of image analysis, calculation of parameter WSA etc. authors of the software describe in detail in their published articles [6, 7].

4. PRACTICAL APPLICATION

The output of the software is the quantitative variable - the level of segregation, determined with an accuracy of two decimal places. It is much easier to work with such kind of variable during statistical assessment of the effect of various process parameters on the level of segregation.

An example of some practical utilization of software numerical output is below. The aim of the analyse was to compare the degree of segregation in high carbon wire and steel cord, produced before and after modernization of wire rod mill in Trinec Ironworks, Inc. Analysis was performed in the statistical software Statgraphics Centurion XVI. Usual significance level $\alpha = 0.05$ in testing was considered.

To test the effect of categorical variable "modernization_KDT" (containing two categories of "before" and "after" that distinguish wires manufactured before and after the modernization of the wire rod mill) on the numeric level of segregation, an analysis of variance (ANOVA) was performed. Analysis of variance tests the null

hypothesis (mean values of segregation before and after modernization KDT are identical) against the alternative hypothesis (mean values of segregation are different). Two basic assumptions of the ANOVA were verified before performing the analysis - normality and equality of variances of both choices [8]. The result is shown in **Table 1**, in graphical form in **Figs. 6, 7**.

Table 1 ANOVA Table for segregation by modernization_KDT

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	15.1687	1	15.1687	61.84	0.0000
Within groups	850.663	3468	0.245289		
Total (Corr.)	865.832	3469			

The final p-value of analysis of variance <0.05 confirms, that the average values of segregation for wires produced before and after the modernization of wire rod mill varies.

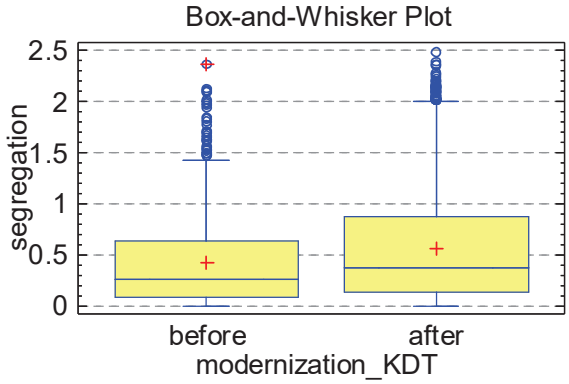

Fig. 6 Box plots - segregation

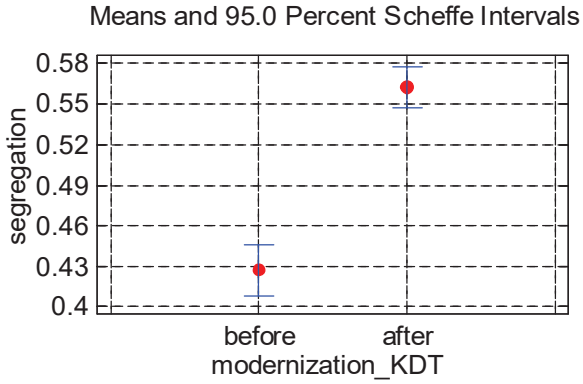

Fig. 7 Averages with conf. interval - segregation

5. CONCLUSION

In this article a visual measurement system intended for an automatic evaluation of segregation in steel wires as a feedback quality control is presented. This system is based on an image processing which represents a non-destructive field in measurement area.

Current visual measurement of segregation level is accomplished by a human inspector who represents inexact and subjective evaluation. On the other hand, the automatic software classification system is getting same results for a long time. The main advantages of software evaluation are elimination of human factor, accuracy, objectivity, and proper output - quantitative variable, which can be further processed statistically.

An example of some practical utilization of software numerical output was presented. The aim of the analyse was to compare the degree of segregation in high carbon wire and steel cord, produced before and after modernization of wire rod mill in Trinec Ironworks, Inc. It was confirmed, that the software gives reliable results.

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