Defects Detection of Profile and Rail Surface with Image Processing Techniques

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Abstract

In the manufacturing sector and engineering, the system need for image processing with high performance capability is further increased every day. Image processing functions are used in many areas of medical and industry for product inspection, classification and also estimation of weather and agricultural productivity. Thus saving time and money in the development process and the introduction of new products in shorter period of time are achieved. During the production phase, fast detection of faulty or defective products will prevent defective parts to enter the market. In the hot rolling process, some defects such as cracks, shells and pits may be encountered. During metal forming process such as rail and profile, defects are checked by destructive or non-destructive inspection methods. Destructive inspection is not widely used because it creates damage on the material. Visual inspection and Eddy current commonly used as non-destructive methods. These methods are not useful because they are time consuming and having high error rates. Image processing techniques applied by computer on steel microstructure, mechanical behavior and surface structure, have been a subject of interest for last few years. In this study, a new algorithm is developed by using Watershed method to detect the surface defects which occur after the hot rolling process of profile and rail. This image pre-processing algorithm is applied to gray-level image obtained by a CMOS camera. At this stage, defective and non-defective image is separated and then defects areas are identified.

Key words: Image Processing, Watershed, Rail and Profile, Rolling Processing

1. Introduction

Hot rolling process (Figure 1) is an essential step in production of profile and rail. Detection of surface defects which affect the quality in the production process is an importance issue. In general, the detection of defects in the metal industry can be performed using destructive and non-destructive inspection methods. The destructive inspection method may create unwanted damage on the product surface. The non-destructive inspection method is widely used because of not creating damage on surface as the destructive inspection method. Due to the effect of high temperature, detection of surface defects in the hot rolling process is more difficult than cold rolling process. Thus, the steps of defect detection may be limited and slow in the hot rolling process [1].

The non-destructive inspection method ensures an examination of product surface without causing damage. Also using human in the hot rolling process directly for this purposes reveal a significant danger. In addition, the visual inspection method is the one of nondestructive testing methods, during the implementation of defect detection human factor is an important actor.

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Therefore, detection of surface defects should be performed by considering these factors. In this study, computer-aided detection system is aimed defect detection, in order to eliminate the human-induced deficiencies and errors.

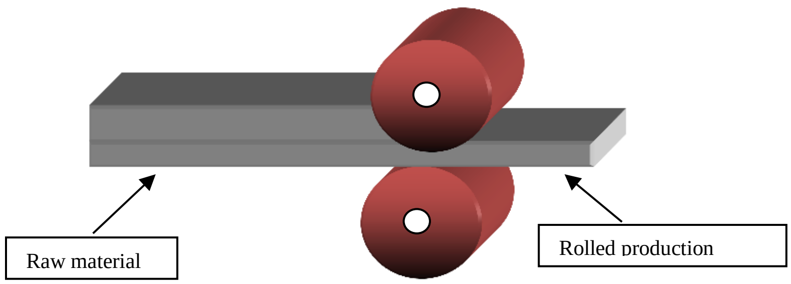

Figure 1.Rolling Process

During the hot rolling process, different sizes scurfs, pits, water droplets and color difference on surfaces may occur. Therefore, traditional defect detection algorithms are not applicable on hot-rolled products. New algorithms have been developed for defect detection of hot rolled strips [2].

AT company is working about surface detection in today [3]. The previous studies about defect detection on hot rolling operation are limited. Xi Xi and Yang Chaolin performed a study about detection of defects on hot roll strips [2]. In real time defect detection on surface of hot rolling matterials was made by Hongbin Jia, Yi Lu Murphey, Jianjun Shi, Tzyy-Shuh Chang by using Support Vector Machine [4]. After hot rolling the parallel CPU application was made by Guifang Wu, Hoonsung Kwakand, Seyoung Jang, Ke Xu ve JinwuXu [1]. The first study for the detection of defects formed during cold rolling process was made by TANG Bo, KONG Jian-yi, WANG Xing-dong Chen Li [5]. A smart Surface defect detection application using artificial neural networks was made by Xiao Deng, Xiaojuan Ye Jinsheng Fang, Chun Li and Lei Wang [6]. Also a study on feature recognition method for defects formed during the hot rolling process was made by Guifang Wu, Haichao Zhang, Xiuming Sun, Jinwu Xuand ve Ke Xu [7]. In addition to these studies, the detection of defects on the surfaces of semi-finished slab was made by Bındınganavl R. Suresh, Richard A. and Tod S. Levitt Fundakowski [8]. In the studies, it is seen that the detection of defects in materials is a very important and necessary stage. In this study, using a different method, watershed algorithm, gray images are separated into color regions and from these defect regions are detected.

In this study, the system is used for defect detection on surface of rail and profile that is an important product group. In this study, profile and rail's surface images (image frames) are taken by a camera as real-time. Watershed image processing algorithm on OpenCV image processing library is used for defect detection. For image detection FFT and Hough transform algorithms are other algorithms which can be used. Watershed algorithm is preferred because of producing more accurate results on gray images comparing to Hough transform and FFT algorithm. In following studies, this developed algorithm and system will be considered on parallel system for fast processing and immediate alerting operator with appropriate message.

2. Image Acquisition System

Image acquisition of hot rolling production is performed by the system in figure 2. The camera system was positioned on cooling line of rolled products. CMOS camera takes images according to reflected laser light source. The camera has a speed of 500 fps (frame per second) and a high resolution feature [3]. Profiles may have dimensions up to 560 mm wide. The rails can be produced in different lengths up to 72 m in rolling mill of Karabuk Inc. Material flow speed changes from 2.4 m / s to 7 m / s in the rolling mill.

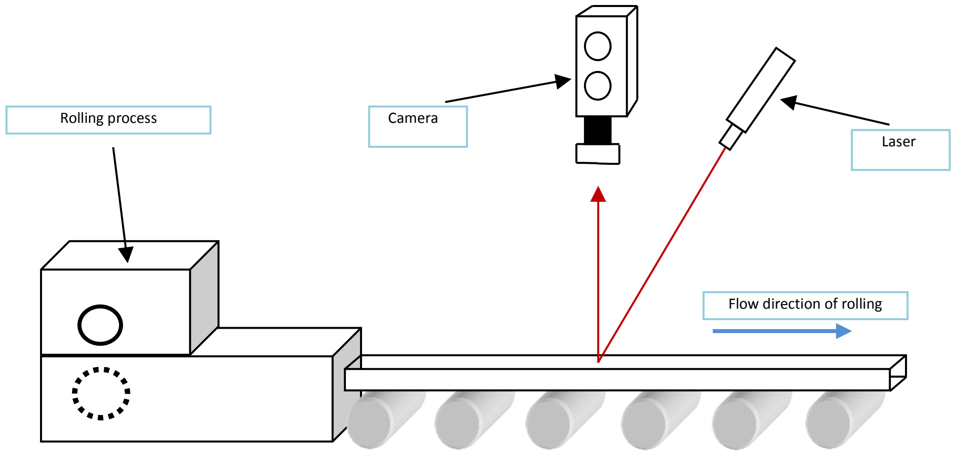

Figure 2. Obtaining Surface Image of Rolled Product

3. Image Processing Algorithm

Image processing methods include many operations such as image acquisition, digitization, segmentation, improvement, classification, recording and recalling [2,4]. The stage shown in figure 3 as dashed lines indicates defect detection by watershed algorithm. This is one of the most important process steps.

Defect detection of the defective areas on the images should be performed immediately after the rolling operation as a first action. Then cleaning unwanted pixelation of defective area is done. Image separation as classification of defective or non-defective image is performed after the time of image processing operations.

Using computer-aided system in processing the rail and profile surface images will be quite beneficial. It is observed that the accurate results have been achieved when Watershed image algorithm is used for processing. As shown in the figure, in the first step, images obtained is transferred to the system. In the second step, the defective areas are determined with Watershed algorithm. In the third stage, values of unwanted pixels are cleared. Finaly by determining whether or not the image is defective, later separation is performed.

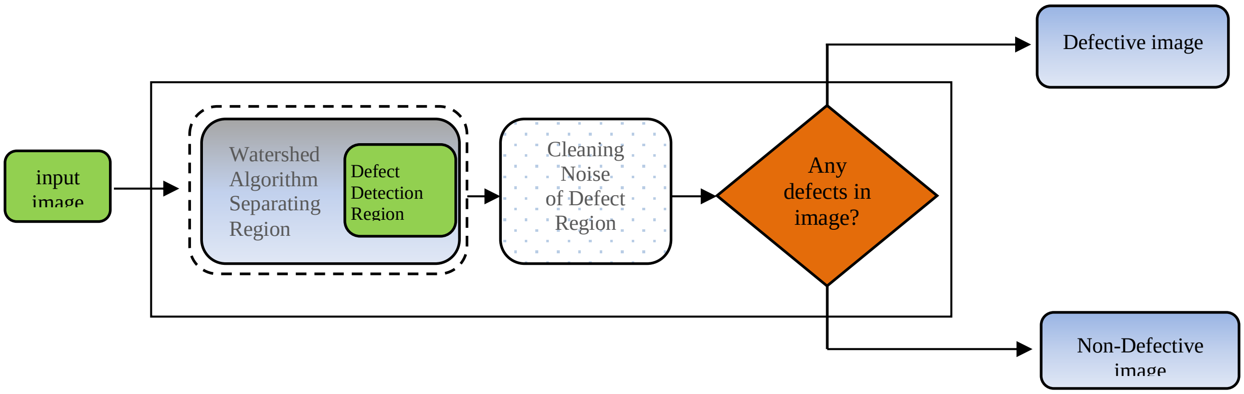

Figure 3. Image processing steps

In figure 4, the calculation of different watershed lines in image processing is shown. Some regions having different pixel values on images can be separated with borders. Watershed has effect on the whole image but the priority is at the neighboring pixels [9]. For calculating areas of Watershed regions there are many different methods [10,11]. In these methods, sum of pixel values in the allocated areas or number of pixels having same value horizontally and vertically are used to calculate the area size. Different image gray level values may be defined for separating the regions individually. But same RGB color values are given to the same gray-valued pixels. In Figure 4, watershed algorithm implementation is shown according to different gray level values (gray RGB). A-B-C-D-E different zones are divided according to the gray value. The regions which have gray values different than defined ones are specified with RGB = 0 (black) color value .

```
if
RGB(value)<=20  ----->Region A
Else if
RGB(value)=< 40 -----> Region B
Else if
RGB(value)=< 50 -----> Region C
Else if
RGB(value)=< 70 -----> Region D
Else (Others)
RGB(....)=0  -----> Region E
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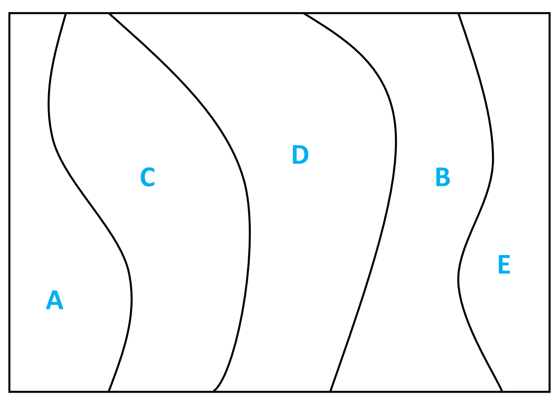

Figure 4. Region detection with WaterShed algorithm

Each region on image are specified with different colors. Figure 5 shows the defective area on rail images. Watershed algorithm identifies defects by finding irregular transitions between regions having different colors. Algorithm was applied to the images obtained from rail products. Images captured by the CMOS camera are gray color images with 384x197 resolution and "Tif" image format. Watershed algorithm achieves better results on images having different color values. In the next stage, the uneven distribution regions having different colors are separated.

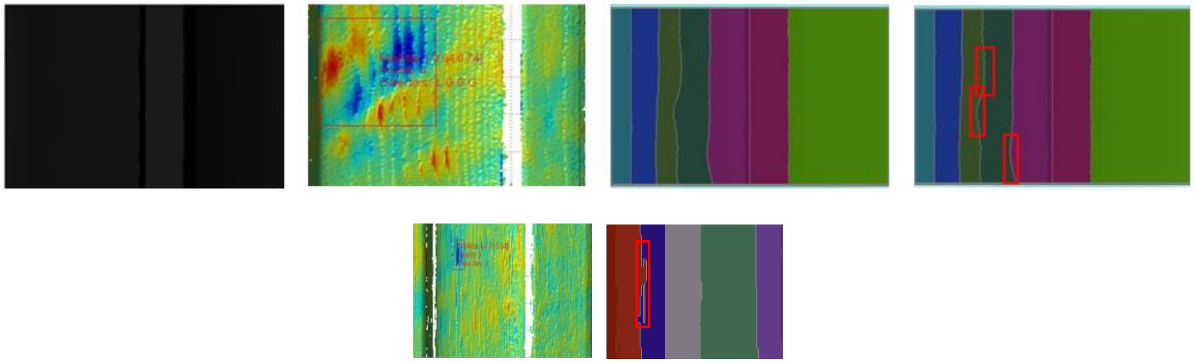

Figure 5. Examples of rail images having defects

When Watershed algorithm is applied on defective images, it is observed that a certain level of contribution is done. These regions represent the defective areas. In this study, it is proved that regional defects but non-point defects can be detected. Number of images varies according to rolled product size. About 500 images are obtained for profile and rail products with 72 meters length. Speed of 7 meters per second can be reachable in production line. There may not be defective areas on each rail and profile. This study was applied on about random image and defective areas of five images were detected.

4. Results

Computer-aided image processing enables to carry out quickly of a significant workload with the help of computer. On this study a large number of rail and profile surface images obtained with the help of CMOS on camera. Defective areas were determined with image processing techniques on the computer. Detecting defects, which may occur on the surface of rail and profile, in the production stage may lead quickly reaching a solution to find out the source of the problem. Solving the problems quickly by finding the cause of defects provides a major contribution to the production stage in terms of cost and time.

In this study it is aimed to overcome the shortcomings of visual inspection methods of non-destructive inspection methods and eliminates dangerous situations that people face during inspection of defects on hot rolling. Besides of being safe system, being fast and applicable for different product groups are important advantages of this system. Defects on hot rolling mills are significant problems. Detecting defects in a short time will prevent manufacturer from the financial loss. High performance can be expected by implementing the system with parallel processing [3,5]. Simultaneously processing of many images is important for the rapid defect detection. In future studies, processing images and results will be evaluated with parallel methods.

Watershed algorithm is successfully used for detection of defects on surface of rail and the profile. Potentially defective regions have been separated on gray-level images with WaterShed algorithm by separating image into areas with different colors. Defective regions have been identified with high accuracy in the tested images. After this stage, the images will be identified as defected and non-defected. By applying classification methods on the defective images, defect types will be determined.

Thanks

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