DIGITAL IMAGE PROCESSING METHODS FOR ROLLING MILL AUTOMATION PROCESSES

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Abstract

The paper deals with digital image processing methods, related to rolling mill. Image processing is a method, which is used to harvest useful data from digital images. It is no so common to use this term with rolling mill, but contrary is the case. The present state of rolling mill uses an operator to guide the billets to the mill. This is an exhausting job, focusing on concentration. In the past, there were many attempts to automate this task, but without success. The problem is to determine exact position of the billet and then its proper guidance to the center of the mill. Modern trends in the development of automation in the metallurgical industry are characterized by the widespread use of information technology. Today, automated control systems are used in all modern companies in the metallurgical industry and the tendency of their involvement is increasing. The use of such systems makes it possible to ensure the continuous operation of the equipment and to minimize unplanned downtime. The main goal of the article is to show the use of digital image processing methods for rolling automation processes.

Keywords: Rolling, digital image processing, automatization

1. INTRODUCTION

Automation leads to improved quality of manufactured products due to process stability, increased labor productivity and minimization of the human factor in production. The article deals with the description of the main technological steps in the rolling process and contains a proposal for the automation of pre-roll handling processes. It will involve the use of computer vision technology using a system of line lasers, digital cameras, and algorithms for digital image processing. The system will be used to manipulate the rolled bars between the individual stands and between the rolling calibers within the rolling mill stands.

The modern metallurgical plant with a full metallurgical cycle combines three main productions, namely the blast furnace, the steelworks, and the rolling mill. The rolling mill usually includes several independent workshops that produce various products according to the current range. Cast iron obtained in blast furnaces is processed in converters, open-hearth furnace, or electric steel furnaces. The supply of liquid iron, which ensures the continuous operation of steel mills, is stored in heated warehouses. The technological process of production of rolled products consists of two stages: rolling of an ingot into a semi-finished product and rolling of a semi-finished product into a finished product.

2. TECHNOLOGICAL PROCESSES IN ROLLING MILL

One of the main metal forming processes in the metallurgical industry is rolling. Rolling mill play a major role in completing metal processing in the metallurgical industry. The rolling mill is a set of machines and units designed for plastic deformation of metal in rolls, and its further processing and transportation. It is a complex consisting of many mechanisms connected by one technological line for metal forming between rotating pair of rolls. The main mechanisms of rolling mills are the rolling stands, which are designed to process metal and give it the desired cross-section and shape of the finished product. In the broader sense it is a system, or series of machines that performs not only rolling but also auxiliary operations. The auxiliary equipment are designed for the transporting of the original billet from the warehouse to the heating furnaces and rolling stands, the transfer of rolled material from one caliber to another, tilting, cutting into pieces, marking, straightening, packaging, transfer of finished products to the warehouse, etc.

Rolling mills are divided according to the purpose, number, and location of stands and number of rolls. It should be noted that the production process of rolled products consists in the plastic deformation of steel by exposure to rotating rolls. The billet is fed to the rolling stand, the deformation zone of which is fitted with rolls, passing through the space defined between them, where it obtains the required shape and dimensions by means of pressure influences. [1-3]

3. ROLLING MILL MECHANISMS AND PROBLEM DEFINITION

The construction, dimensions and weight of the rolling stands depend on the purpose and specialization of the rolling mill, the conditions of the metal rolling process and the number of working rolls in the stand itself. There are many types of rolling mills, and their classification methods are not unified. It can be classified in several ways, based on the temperature of rolling, rolling mill product, roll configuration, stand arrangements, etc.

The starting material of rolling are continuous cast billets of various shapes, sizes, and steel grades. The technological process of rolling is a complex of successive thermomechanical operations performed on the relevant rolling mill equipment to obtain a semi-finished or finished product. The prepared starting material is heated in heating furnaces to reduce the flow stress of the metal, increase its plasticity, and improve the physical, mechanical, and physicochemical properties. After discharging from the furnace and at the beginning of rolling, the temperature of the metal heating is checked by an optical pyrometer, a photoelectric element, or other devices. At the same time, the uniformity of the continuous cast billet heating is checked over the entire height, both visually and by its behavior when rolling. An unevenly heated continuous cast billet bends during rolling due to uneven deformation. The heated metal is transported to the rolling mill using roller conveyors after it falls out of the furnace. The advantage of pusher furnaces is that pushing is the easiest and cheapest method of transporting metal through the furnace. Roller conveyors are designed for transporting metal to the rolling stands, filing metal in the rolls and transfer it to other equipment and mechanisms. All other roller conveyors are called transport.

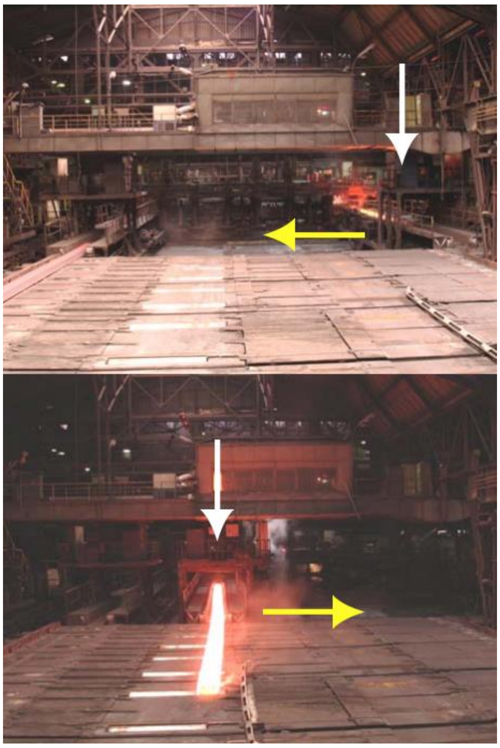

Figure 1 The transfer of rolled material [10]

When rolling, it is necessary to move the billet between the individual stands and between the rolling calibers within the rolling stand. The movement of the metal is ensured by two handling units (cars) installed on the input and output side of the stands. The loading of material into the caliber of the working rolls is performed by a manipulator on the rails, which is operated by the operator from the control room located in the upper part. Improper introduction of material into the caliber of the work rolls can lead to damage of the rolling mill or rolls or manipulator, which can cause production downtime and consequent losses.

Due to the human factor, manual operation of handling trucks is inaccurate and can lead to poor production consequences. There is also some time set aside for the entire rolling process (4-5 minutes), otherwise the material will cool. Therefore, if the operators do not have time to finish rolling in time, this leads to cooling of the billet and a change in its properties, which is unsuitable for further rolling. The automation of a given process, i.e., the transfer of rolled material between the individual stands and between the rolling calibers within the rolling stand (**Figure 1**), can significantly eliminates the risk of the human factor. [4]

4. DIGITAL IMAGE PROCESSING IN HEAVY INDUSTRY ENVIRONMENT

Automation of rolling mill production depends on exact billet position knowledge. This is a crucial task, with no easy solution. One of the possibilities is to use digital image processing. The task is found out positions of the billet and the position send to automation system. There are many small difficulties, which complicate relatively easy task. The first issue is a hot billet. There is necessity to take images from distance because the heating energy in form of infrared radiation is very intensive and can severely damage to camera. Temperature is above 1000 °C and IR component of light is high enough to excite not only right pixels, but also nearby areas and cause "fuzzy" image. The solution is to place digital camera at least 3 m from the heat up surface and to use lenses with partial IR filter. The red-hot surface can be the advantage in some cases but emits far more light energy than the surroundings. Then contrast can be so high, that the edges of billet could be easily defined. The above mentioned must be combined with exposure time, the parameter of digital image camera. The shorter the time, the darker the image. The difference can be seen in figures (**Figure 2**) and (**Figure 3**). The original image is unusable for subsequent processing, but the second image with suppressed brightness is perfect. As can be seen on (**Figure 3**), the background of the image is naturally dark, because of low exposure time. The billet is so bright, that the darkening is not concern. [5-8]

Figure 2 Original image of the billet 1/100 ISO 1600 [own study]

Figure 3 Image with IR filter and exposure time set to 1/250 with ISO 100 [own study]

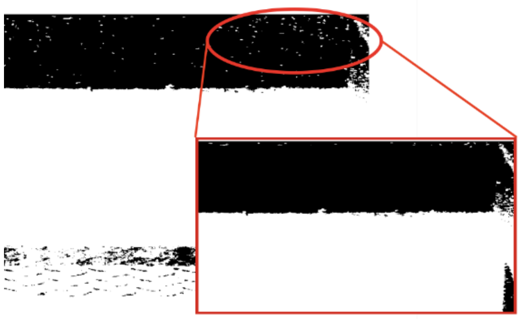

Figure 4 Binarized image with wrong and proper setup of the light threshold [own study]

The next step is to binarize the image. The binarization process is conversion from color (grey scale) image to black and white image. The difference is that color image consist of 3 matrixes, where each cell could have a value from 0 to 255. Black and white image has only one matrix and each cell (pixel) could have only two values, 0 or 1. This type of image could be used to advanced processing. The binarization is not so complicated, but the wrong settings for initial variables of the algorithm could destroy the image's data. There must be set up a threshold, which defines which pixels (matrix cells) will gather 0 and which 1. There is not any universal answer on how to setup this variable. It depends on overall image structure, on level of contrast, on maximum brightness of region of interest and so on. The example is presented on figure (**Figure 4**). The wrong selection of light threshold leads to appear many unwanted artefacts which complicate succeeding processing. Increasing light threshold will remove the artefacts, as is presented on (**Figure 4**) on the right bottom. The isolated artefacts can be removed by another algorithm, but there is a risk of removing some valuable areas with data we want to extract. [6,7]

With clear view of billet edge, it is possible to calculate its mean value, respectively probability of edge occurrence. The probability is in place because the edge is defined by white pixels neighboring the blacks. The mean value moves us from probability to real coordinates.

The final operation is calculation of regression line. The regression line defines the borders of the billet and serves as a starting point for center calculation and movement direction of the billet. The picture (**Figure 5**) shows calculated lines, which become from the numerical algorithm, which seeking both borders of the billet and do linear regression calculation. The numerical form of linear regression equation is presented in (**1**). [6,9]

$$a\sum_{i=1}^{n} x_i^2 + b\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} x_i \; y_i$$
$$a\sum_{i=1}^{n} x_i + bn = \sum_{i=1}^{n} y_i \qquad (1)$$

The regression lines are presented by red color and perfectly trace billet border, even though it is rough, because of binarization of the image and due to imperfections of digital camera optical system. The results can be verified with (**Figure 2**), which acts as an input data for analytic algorithm. Now can be easily calculated center of the billet and movement direction. These parameters can be used by operator to revise position of the moving billet before it enter the mill, or by automation system, to automatically steer the billet to the mill.

Figure 5 Regression lines automatically calculated from billet border [own study]

5. CONCLUSION

The use of digital image processing methods can facilitate and optimize the production process and quality control for rolling automation processes. By using computer vision technology using a system of line lasers, digital cameras, and algorithms, it is easier to obtain the position of the block and its position relative to the center of the rolling mill. The support of the camera system will be based on edge detection using own algorithms, which will ensure accurate and fast detection of the rolled material before entering the rolling mill. The feasibility study shows that automation of the process can significantly reduce the risk of the human factor. In addition, it leads to effective control and management of corporate resources and restrictions on work in dangerous areas.

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