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IFAC-PapersOnLine 49-20 (2016) 108–113

# Vision-Based Material Tracking in Heavy-Plate Rolling

**Florian Schausberger** * **Andreas Steinboeck** * **Andreas Kugi** *
**Martin Jochum** ** **Daniel Wild** ** **Thomas Kiefer** **

* *Automation and Control Institute, TU Wien, Vienna, Austria (e-mail: {schausberger, steinboeck, kugi}@acin.tuwien.ac.at)*
** *AG der Dillinger Hüttenwerke, Dillingen, Germany (e-mail: {martin.jochum, daniel.wild, thomas.kiefer}@dillinger.biz)*

**Abstract:** Knowledge of the position and the material conditions, e.g. the temperature, of the plates during hot rolling is important for process control. In fact, a precise material tracking system may help to prevent problems during the production process. This paper deals with the tracking of the rotation of heavy plates before and after the lateral expansion phase. The presented approach estimates the orientation and the position of the plate moving on the roller table. Images captured by a thermographic camera are utilized to identify the edges of the plate within the field of view. The detected edges are fed into an optimization-based estimation of the angular and translational position of the plate. Measurements of a plate from an industrial rolling mill demonstrate that the proposed method is robust against disturbances from the harsh environment nearby the mill stand.



*Keywords:* Hot rolling, material tracking, image processing, thermographic imaging, edge detection, unconstrained optimization

## 1. INTRODUCTION

The considered rolling mill of AG der Dillinger Hüttenwerke, Germany, is outlined in Fig. 1. The slabs are first reheated in one of the furnaces. During the heating process, a scale layer builds up, which is removed in a descaling unit before the actual rolling steps at the roughing mill. After the beginning of the rolling process, the product is called plate. Following the lateral expansion to the desired width at the roughing mill, the plate is rolled in longitudinal direction to the desired plate thickness and length at the finishing mill. In the following cooling section, a specific reduction of the plate temperature may be enforced to obtain the desired mechanical properties of the plate material. Then, the plate is leveled to reduce residual stresses.

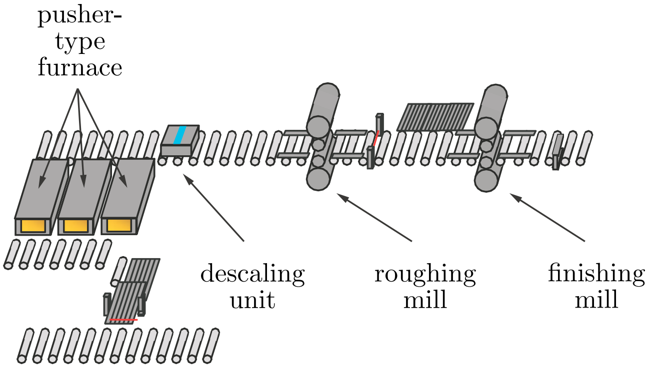


Fig. 1. Processing line of AG der Dillinger Hüttenwerke, Germany.

The temperature of the plate undergoes large changes during the production process. Since the temperature evolution is significant for the properties of the final product, it has to be carefully considered when planning the roll pass schedule. A large-area roller table is located between the roughing mill and the finishing mill. It is used to store plates until they have reached the necessary temperature for the subsequent processing at the finishing mill. The cooling time of a specific plate on the large-area roller table depends on the processed type of steel and the performed metallurgic treatments. Several plates with varying material properties and dimensions are simultaneously processed in this production line. Because different cooling times may be needed, the processing order of the plates can change during the production. Clearly, a precise tracking of the plate position is necessary to distinguish between the plates.

A vision-based material tracking approach in heavy plate rolling was proposed by Tratnig et al. (2007). They used 4 visible light cameras with overlapping fields of view to track the position of the plates between a descaler and a rolling mill. Vision-based systems are also used for material tracking during the rolling pass itself, see, e.g., (González et al., 2001; Montague et al., 2005; Carruthers-Watt et al., 2010; Schausberger et al., 2015).

Contrary, this paper deals with a special part of the whole material tracking problem. After the heating and the descaling of the slabs, they are first rolled in width direction to their desired plate width. In the subsequent rolling passes, the plate is rolled in longitudinal direction to its final plate length. Before and after the lateral expansion, the slabs or plates have to be rotated with


10.1016/j.ifacol.2016.10.105

respect to their vertical axis, i.e., at least 2 rotations of the plate are necessary. The rotation in front of the mill stand is performed by means of a roller table with tapered rolls. Here, the tapering of the rolls is alternately arranged (cf. Fig. 2). This special type of roller table has two roller pairs which can be individually rotated.

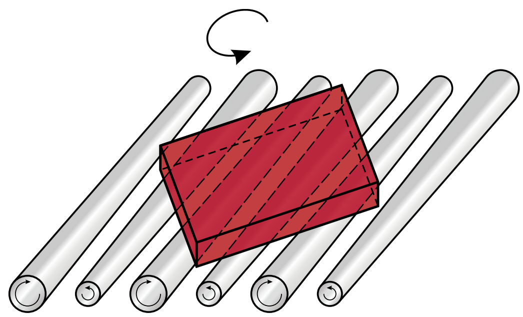

Fig. 2. Roller table with tapered rolls and rotating plate.

The rotation of the plate is currently controlled by the mill stand operator. However, feedback control could help to reduce the time needed for the rotation of the plate and hence may yield considerable time savings during the rolling process. A simple feedforward control of the plate rotation is not possible due to the slip between the plate and the rolls of the roller table. Hence, feedback control should be applied to control the rotation of the plate which essentially builds up on the knowledge of the angular position of the plate. In this work, a method to estimate the angular position is presented.

The paper is organized as follows: An infrared camera mounted at the ceiling of the rolling-mill building captures images of the plate lying on the roller table. Within the infrared bitmaps, a threshold based edge detection is performed which is discussed in Section 2. The detected edges are then used in Section 3 in an optimization-based approach to estimate the plate movement. Measurements of a plate taken from the standard production process are presented in Section 4 to prove the feasibility of the proposed method. Section 5 contains a short summary and gives an outlook on further research activities.

A more detailed description of the calculation steps of the presented material tracking approach is given in Tab. 1.

## 2. EDGE DETECTION

The first step of the presented material tracking approach is the detection of the plate edges within the images captured by an infrared 2D-CCD camera. Compared to standard cameras for visible light, infrared cameras are superior for the considered application due to the following properties:

- Objects can be captured through a cloud of steam.
- The thermal contrast between the plate and its environment is high and therefore no illumination is needed.
- There is no disturbance of the images due to other light sources, e.g. sunlight.

The first property is beneficial for the subsequent edge detection because the plate may be surrounded by a cloud of steam due to the cooling water sprayed onto the

Table 1. Calculation steps of the material tracking approach and their results.

| Step | Result |
|---|---|
| image capturing | monochrome bitmap of radiation intensity |
| edge pixel detection in rows and columns | edge pixels in vertical and horizontal direction |
| clustering of edge pixels | 4 clusters of edge pixels representing the 4 plate edges |
| fitting of a polynomial to each cluster of the initial plate configuration | 4 polynomials representing the plate edges of the initial configuration |
| solving of the optimization problem for the actual configuration | position and orientation of the plate |

plate during the rolling process. Furthermore, the high thermal contrast (cf. Fig. 3) enables a simple threshold-based edge detection. Clearly, visible light cameras are suffering from disturbing light sources which may entail erroneously detected edges, see, e.g., (Montague et al., 2005). However, disturbing radiation sources are seldom in the measured infrared range of thermographic cameras. Additionally, the measured temperature distribution of the surface of the plate can be used for process monitoring and process control.

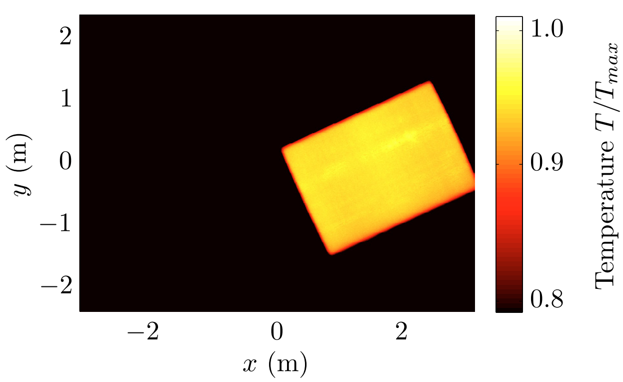


Fig. 3. Thermographic bitmap of a rotating heavy plate.

The camera is mounted 25 m above the pass level of the roller table. Mounting the camera at the ceiling of the rolling-mill building isolates the camera from vibrations, steam, and dust induced during the rolling pass and hence renders an air flushing of the lens of the camera unnecessary. The industrial camera captures 30 frames/s with an image resolution of 659×494 pixels. Using a 25 mm lens, a spatial resolution of approximately 1 cm/pixel is achieved. The origin of a fixed global coordinate frame $(x, y, z)$ is located at the center of the field of view (FOV).

The camera is connected via Gigabit Ethernet to a PC and addressed using the so called pylon API. The pylon API is based on the GenICam standard and allows an interface-independent control of the camera in the respective software application. Furthermore, the pylon API allows to change a large number of parameters of the camera. An important parameter is the exposure time which has to be properly chosen to get high contrast images. The camera