Cobble reduction in Rotary Entry System using Image Analytics

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Abstract

New Bar Mill (NBM), Tata Steel uses hot rolling process to convert billets into rebars. One billet can produce several thousand meters of rebars which have to be cut into sizes along length as required by customers. The rebars are first cut into multiple of customer length at divide shear and the fed into Rotary Entry System (RES) which then feeds it into cooling bed rake from where they are cut into final customer length. RES at NBM is seventy-eight-meter length and consists of thirteen segments connected using couplings with drive at head end and channels on periphery through which the bar passes. The rebars enter RES at speeds of above thirty-six meters per second and their speed must be reduced by pinch rolls before RES while passing through the channels. The channels then rotate and then the bar falls on cooling bed rake. RES of each line consists of four channel which at ninety degrees apart. During every cycle RES rotates four times each by ninety degrees. Deviation in rotation can cause the bar to knock inside RES or failure causing mis-rolls or cobble.

RES is the entry point to produce the rods in NBM. RES home position is monitored by a striker and proximity sensor for home position confirmation per cycle. Hence a need was arising to give visibility of RES home position to operators. RES cross markers are perpendicular to each other and rotates clockwise and anti-clockwise. After each rotation, a rod will insert in rod channel from hot steel billet. RES is playing a vital role to produce a proper bar from billet. After each rotation, the cross marker should align with a white top marker of RES. If it is not aligned with the white marker, rod will not be inserted properly in rod channel and it will create cobble, which will stop the production. Image processing technique was used to identify deviations of RES rotation to home position, if there is continuous deviation, angle data is being captured to show user the trend of deviation for user to take proactive action to prevent cobble.

Introduction

Tata Steel Limited (TSL) Hot rolling process carried out at NBM consists of reheating of billets to above recrystallization temperature followed by reduction of cross section in rolling mill and subsequent in line heat treatment and sizing of product length to customer length. The overall flow process depicted in figure 1. The rolling process is carried out in mill stands grouped as roughing followed by intermediate stands and then finishing mill. The mill stands in NBM consists of No-Housing type stands with two rolls rotating at same speed in opposite direction. The gap in between the rolls is lower than the input stock, hence the material while being rolled reduces in thickness and increases in length. This leads to decrease in cross sectional area and increase in velocity of outgoing stock from a stand as compared to incoming stock. So, in a tandem rolling mill the cross-sectional area of stock gradually reduces and speed increases while going downstream in rolling line. In a continuous mill matching speed of adjacent mill stands to achieve a constant mass flow through the mill is very important as otherwise high tension can stretch reduce the cross section of the bar making shape control very difficult. After passing through all the stands, rebars passes through intermediated mill and at Power Slitter divided into two and further passed through no twist mill and then through water boxes and with help of breaking pinch role speed is

slowed down for entering into RES. RES plays very important role in the hot rolling process flow, as it's continuous process with faction of seconds gap between two consecutive billets. In case of any obstruction in the process will lead to delay in production and many times lead to cobble. RES is positioned at the end of the process flow just before cooling bed for accumulating the rebars on the cooling bed.

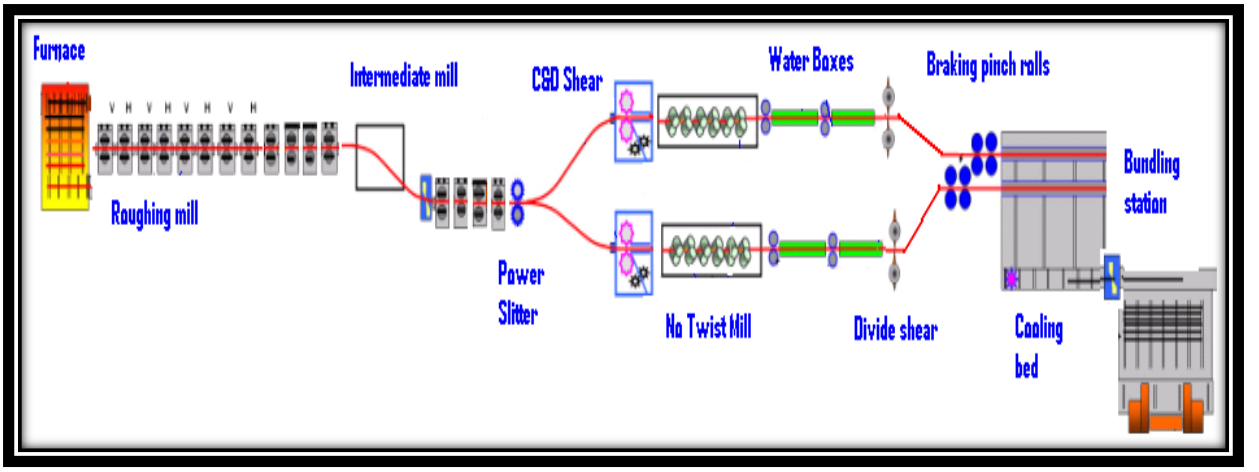

Figure1: Overall Mill Process Flow

Literature Search

Extensive research has been conducted to explore various methods for automated data capturing and the architecture to be followed for deployment of image processing algorithm (Porob, et al., 2107). For detecting the object from the background Circular Hough Transform algorithm used and same can be applied in finding RES objects (R. Hussin, 2012). The detection of circular and elliptic shapes is a common task in computer vision and image recognition. Some methods rely on converting gray-scale images to binary ones using edge detection techniques and calculating numerical shape descriptors. (J., 1997) studied some simple shape descriptors. One of them, known as elliptic variance, is especially useful for detecting ellipses.

Low level edge detection operators do not guarantee continuous boundaries of objects. This makes many image analysis tasks difficult, especially for noisy images. The aim of contour grouping algorithms is to connect edges that are supposed to be sub-parts of the same object. Contour grouping techniques were concentrated mainly on detecting salient curves ((S, 1991); (Zhu Q., 1996). Their improvements favor closed (W., 1996) shapes rather than long and smooth ones.

Detecting circles is an important part of object recognition in image processing and computer vision, the adaptive method explained in (Lestriandoko & Sadikin, 2020) to detect circle shapes in digital image. The method of estimating five arc parameters is robust in presence of moderate amount of noise as explained by (Kierkegaard, 1992).

Proposed Solution

NBM consists of 16 mill stands 2 NTM finishing blocks and 4 RES for aligning rebars into cooling bed. RES is the entry point to produce the rebars in NBM. The RES looks like a circular disc with a cross marker (see Figure. 2). This RES cross markers are perpendicular to each other. The RES rotates clockwise and anti-clockwise. After each rotation, a rebar will insert in rebar channel from hot steel billet. Therefore, RES is playing a vital role to produce a proper bar from steel billet. After each rotation, the cross marker should align with a white marker which is marked on top part of RES. If it is not aligned with the white marker, then the rebar will not be inserted properly in rebar channel and it will create cobble situation which will stop the production.

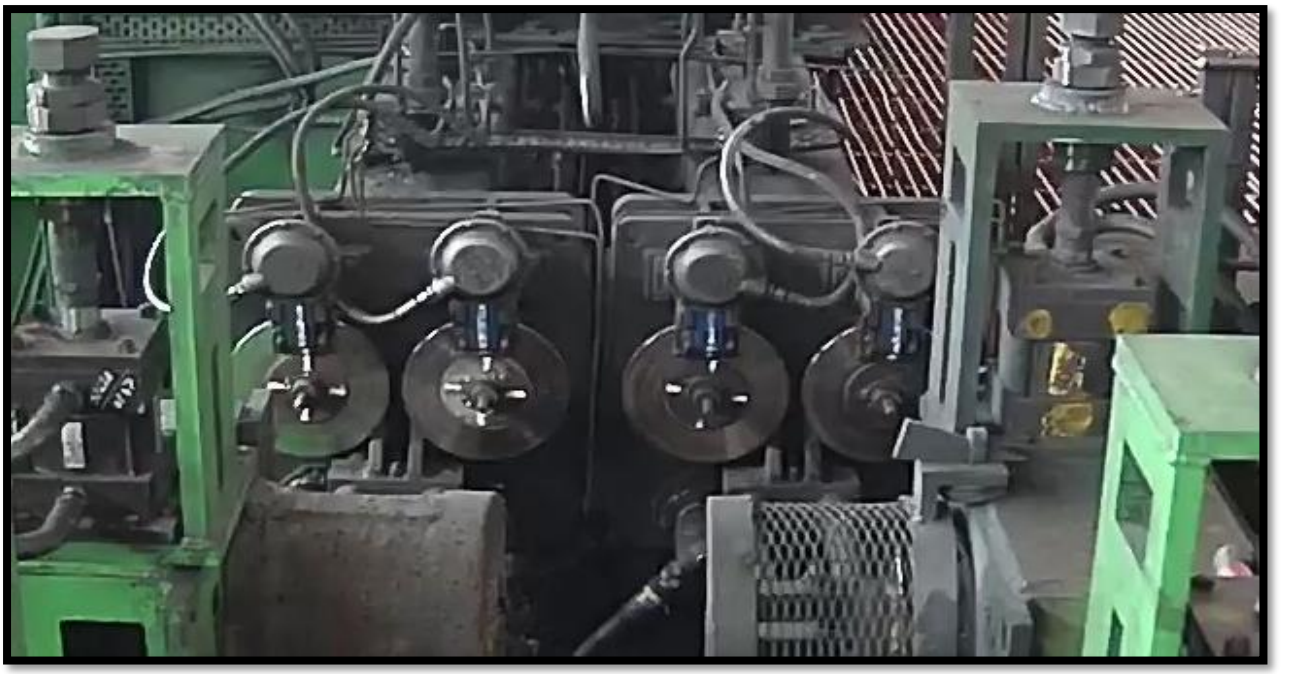

Figure 2: Rotary Entry System (RES)

In present situation, operation team monitor the RES rotation manually. The client does not have the rotation information for each rotation event. Therefore, client want to monitor the RES rotation for each second and try to store the rotation information in Database (DB). So that, they can analyse these data and take proactive action to avoid any delay in the rebar production process to prevent the cobble situations.

To achieve the above-mentioned information, we proposed a Computer Vision based solution to monitor the RES through CCTV camera.

Firstly, we converted video into frames with help of python language and taking live camera feeds. After capturing the frame from IP camera. We got each frame in Red Green Bud(RGB) format and convert to grey format (see Figure. 3). After converting the frame to gray scale, RES region extracted from the converted image to extract angle information.

(a) (b)

Figure:- 3 (a) Origianl image (b) Converted gray image

In the RES circular moving object there are four white markers and one perpendicular marker on static object on the upper side as in figure 4. Each RES looks like circular object. To locate circular object, we use Hough Transform and get the statistics of 100 frame to get the all observations for each RES and extracting white marker information after every rotation.

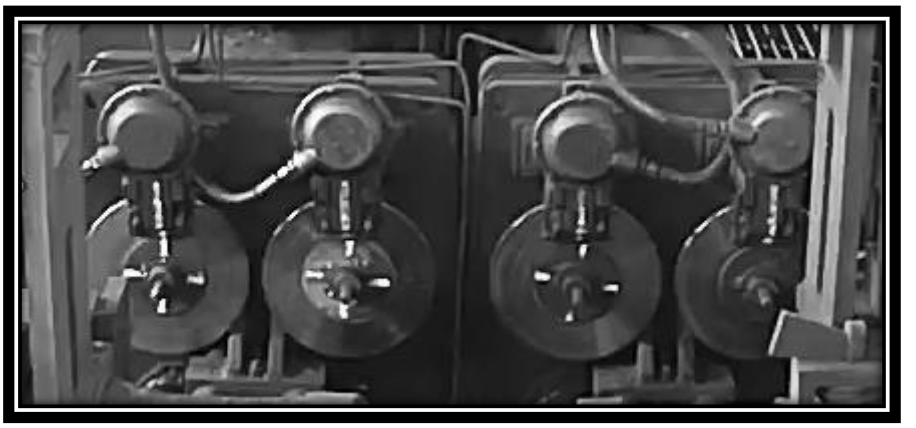

Figure 4: Croped image of all RES

After getting the crop region of all RES, we apply range bound intensity-based classification on top of crop region to detect all RES indicator. After classification, we got some candidate keys, which are, may be RES indicator. For confirmation, we implement region approximation and morphological operation for better finding of the indicators (see figure 5).

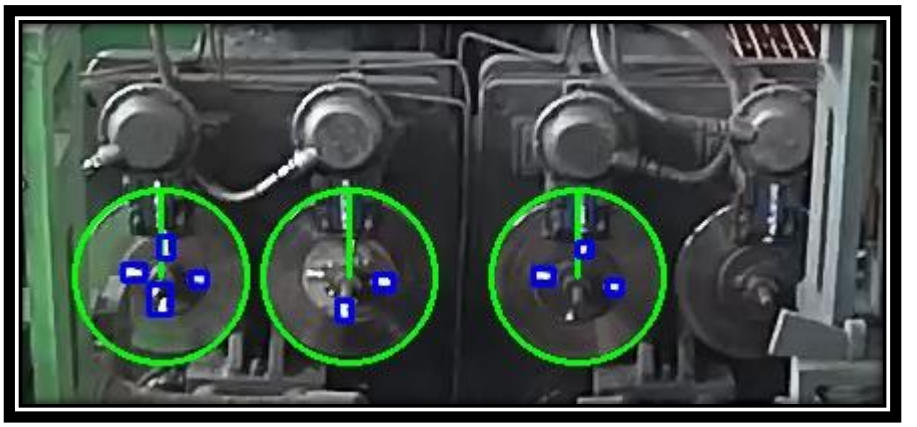

Figure 5: After indication localization

After getting all RES indication, we try to find out the upper most indication (mark as red colour in fig. 5) along with the centre of gravity of that indication.

Now we calculate the angle between the centre of gravity of the top most indicator and the perpendicular line of circle from the centre of the circle, which was the desired output of our project (see in figure 6).

Then we store this derived angle information for each frame into the database. Deployed this development as a live solution, where live camera feed is taken, and angle information is extracted and stored in database. Dashboard is developed for usage of the solution, where live angle trend can be observed with live processed video for user to take proactive action for cobble avoidance, see figure 7.

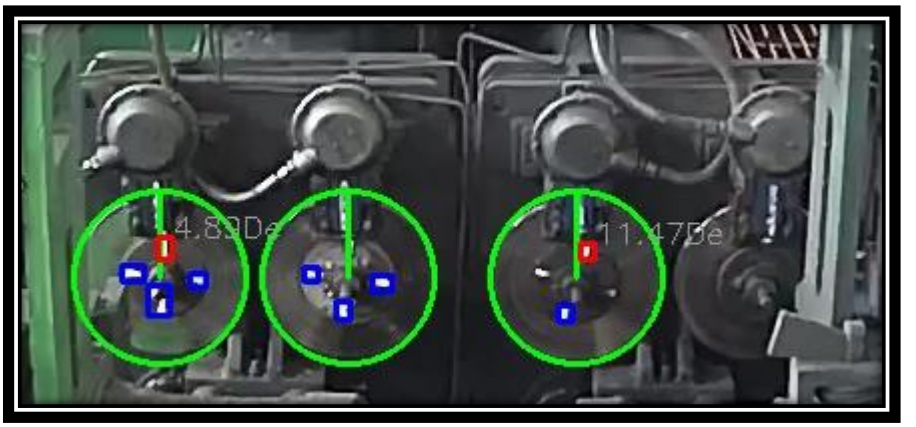

Figure 6: Final output after angle finding

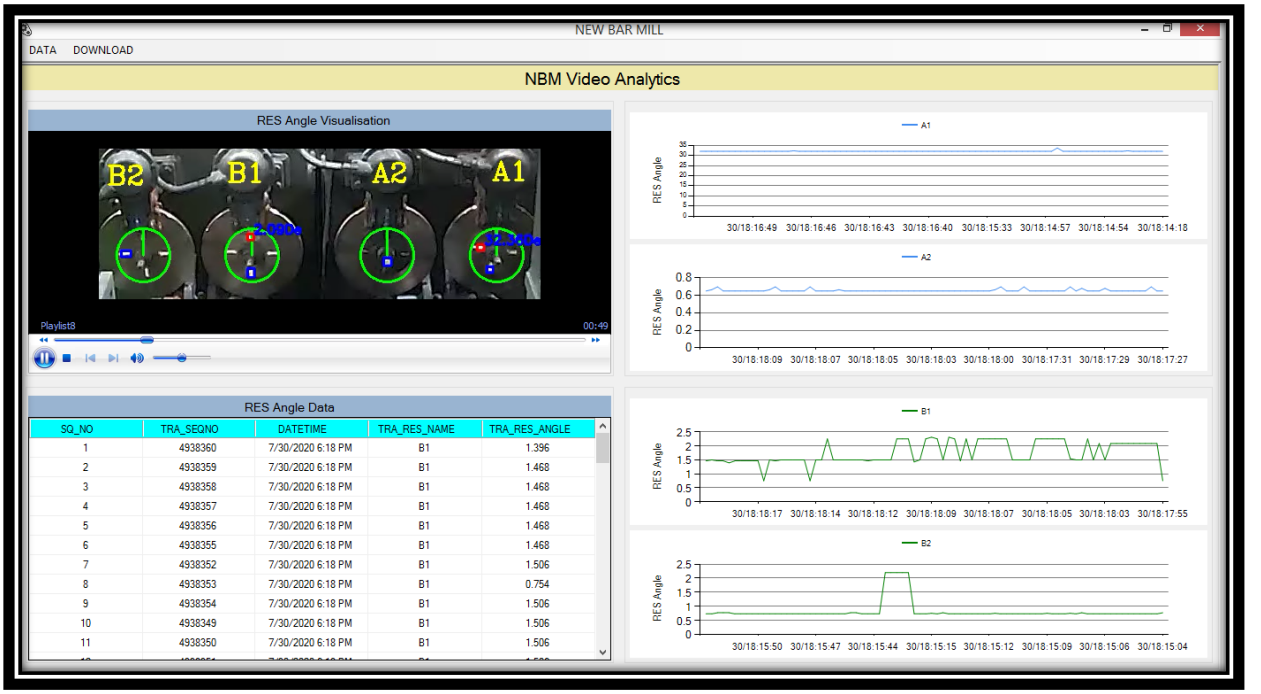

Fig 7: Processed Output Video with real time trend of deviations from home position