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Model-based sticker detection in continuous casting

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Many innovations are currently initiated by scientific community in the field of dynamic system diagnosis. Arcelormittal Maizières R&D adapted and evaluated some advanced diagnosis tools for the detection of abnormal events and operating mode changing in steel processes. The developed approach is illustrated and applied to the sticker detection in continuous casting process, where the prevention of breakouts in slabs is a crucial challenge. Results show that it is possible to reduce relatively, the time delay for sticker detection and the false alarms rate without reducing the sticker detection rate. The evaluation of the proposed system on industrial data is encouraging and promising. This adaptable software solution could contribute significantly to improve the supervision and the productivity of the process with low or no investment.

AVAILABLE MEASUREMENTS ON THE MODL

The proposed diagnosis system uses on-line thermal measurements and casting speed. As we can see on figure 1, thermocouples are generally placed on two rows and some columns.

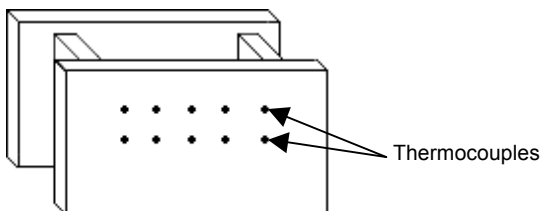


Figure 1: Continuous casting mold

Analysis of industrial data shows that the measurements from lower thermocouples in continuous casting mold are strongly linked to the former values of the lower thermocouple

measurements, the upper thermocouple measurements and the casting speed. This behaviour is reformulated as a model and used to build the proposed detection system.

DESCRIPTION OF THE DETECTION SYSTEM

The detection system receives as inputs the upper and lower thermocouple measurements and the casting speed. The output is an alarm signal of abnormal behaviour occurrence. For each thermocouple column and at each step of time, the software estimates the lower thermocouples temperatures based on the following model:

$$\hat{T}_{inf}(k) = \alpha T_{inf}(k - \tau_1) + \beta T_{sup}(k - \tau_2) + \gamma T_{sup}(k - \tau_2) v_c(k)$$

where k represents the current time instant, $T_{inf}(k)$ and $T_{sup}(k)$ the lower and upper thermocouple measurements. These estimations give an image of the temperatures behaviour in normal condition. The two constants τ_1 and τ_2 are obtained by correlation analysis on industrial data. Parameters α , β and γ are estimated on-line. Then the estimated value of lower thermocouple is compared to the measured one in order to generate a residual signal. The generated signal is compared to a threshold to give the alarm signal in case of abnormal behaviour like a sticker. The principle of the method is resumed on figure 2.

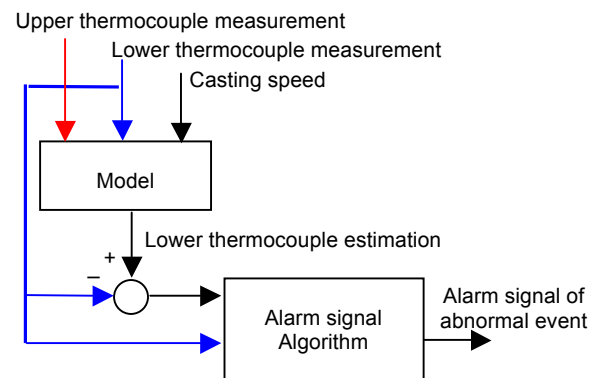


Figure 2: Principle of the method

The evaluation of the proposed approach is tested on industrial data of continuous casting process. At that stage, only steady state operating mode is evaluated in this context.

Figure 3 shows a columns of thermocouples some minutes before the sticker occurrence and the typical thermal (linked) pattern (during the few last seconds).

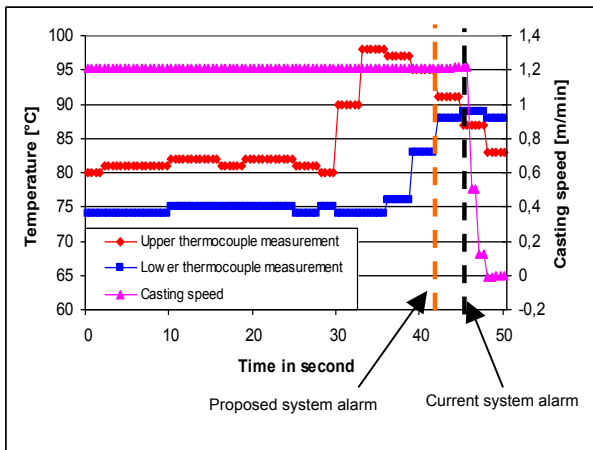


Figure 3: Sticker alarm case

Figure 4 shows a situation for which many false alarms have been generated by the current diagnosis system. As shown, the casting speed was reduced because of these false alarms (in this case, the feedback of the plant shows these false alarms are due to partially clogged nozzle). The proposed system doesn't generate any false alarm in this case unlike the current system.

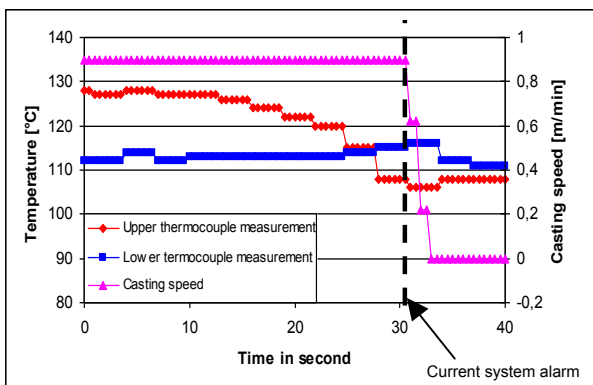


Figure 4: False alarm case

Figure 5 illustrates the gain due to the new system, using 4 months industrial data. The proposed method generates about 65% less false alarms than the current system. The detection of sticker events is performed few seconds faster using the developed system. In this evaluation, one sticker event was not detected before current system because of casting stop. This special case needs further analysis to improve the results and ensure quick detection.

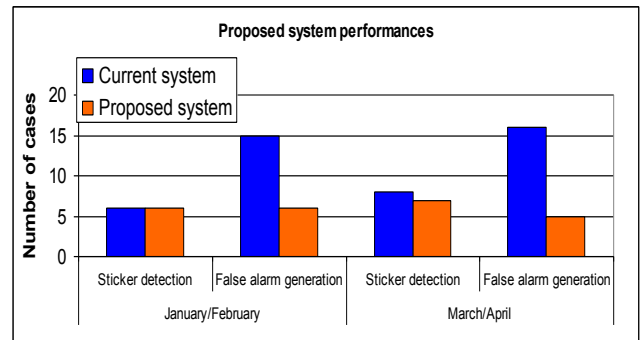


Figure 5: Evaluation of system performances

BENEFITS OF THE SYSTEM

The developed system is a software solution for sticker detection based on advanced tools from automatic control community. This solution could be easily adapted for different plants. The developed approach reduces false alarms which cause mostly casting speed reduction and product downgrading. It can be a solution to prevent breakout while reducing false alarm costs.

CONCLUSION AND PERSPECTIVES

These first results are very encouraging. The detection of stickers is performed with reduced false alarm rate. The developed solution will be evaluated on more data to recover all possible situations.

Further on-line evaluation of system performances will be performed for industrial condition in order to confirm the obtained results and prevent breakout properly.

However the proposed diagnosis approach needs further developments in order to be adapted to transients to detect stickers during casting speed variations, casting start and nozzle change.