

Fuzzy control strategy for secondary cooling of continuous steel casting

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Abstract. The purpose of this paper is to create an original fuzzy solution on the existing structure of the control system of continuous casting that eliminates fissures in the poured material from the secondary cooling of steel. For this purpose a system was conceived with three fuzzy database decision rules, which by analyzing a series of measurements taken from the process produces adjustments in the rate of flow of the cooling water and the speed of casting and determine the degree of risk of the wire. In the specialized literature on the national plan and the world, there is no intelligent correction in the rate of flow of the cooling water and the speed of casting in the secondary cooling of steel. The database of rules was made using information collected directly from the installation process of continuous casting of the Arcelor Mittal Hunedoara.

1. Introduction

A fuzzy solution is proposed that placed on the existing structure of the management system of continuous casting will reduce fissures in the secondary cooling by generating necessary value adjustments to change the water flow and the velocity of the casting.

There are no current systems in the world that can eliminate cracks if they are detected in the secondary cooling steel. Basically, the database rules were designed for this purpose and they contain measures to mitigate the risk of a fissure.

This principle is original, as the structure of the proposed system. The proposed structure can be applied to any continuous casting plant.

The method of continuous casting consists of introducing the liquid metal with a determined temperature in a shape which has the walls cooled with water named crystallizer, and the evacuation is on the other side where the solidified steel is obtained [1], [2].

A crucial component of the continuous casting installation is the secondary cooling zone. The secondary cooling zone has the role to continue the wire cooling after it has emerged from the crystallizer and to assure the total solidification of the semi-product. It is considered “the heart” of continuous casting and has the benefit of ensuring a better quality of the material. The material surface shape has to ensure a homogeneous cooling and a uniform repartition of the water on the materials surface [3], [4].



2. Design of fuzzy controllers

Fuzzy logic can process vague variables whose values can vary continuously in any numerical range defined by taking decisions depending on the position indicator in the numerical range and predefined rules [5], [6].

Applicability of fuzzy logic is varied, in metallurgical domains fuzzy systems are more commonly used.

For the issue in question a database was built that consists of information gathered from technologist experts. This database was supplemented with information from the mathematical model of solidification process [7].

The fuzzy system receives from the process the following values, depending on the area in which the blank is situated:

- Casting speed v
- Cooling water flow q
- Steel temperature T

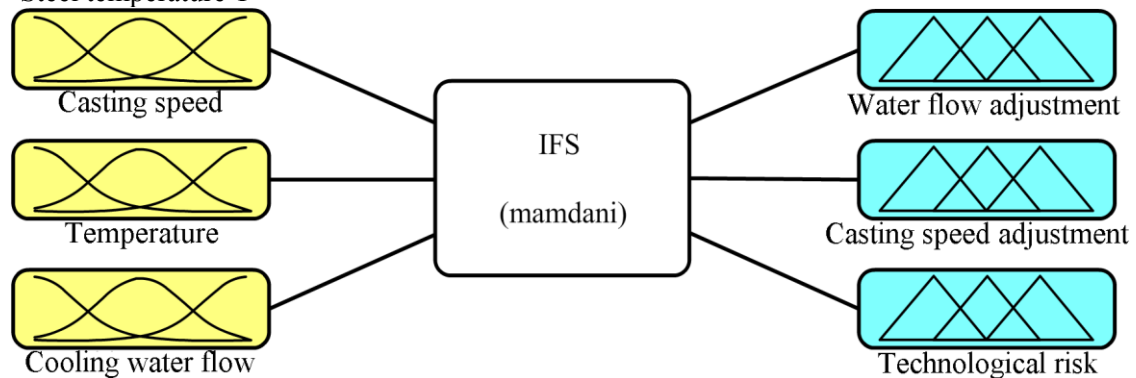


Figure 1. Block diagram of IFS

Laying the foundation of rules required an analysis of all possible outcomes. To this end, a number of expert technologists with extensive experience in the operation of the casting machines were consulted.

Also, for each case was carried out an analysis of the phenomenon of solidification of the crust. In Figure 1 is depicted the block diagram of the intelligent fuzzy system (IFS) [6], [7].

3. IFS projection

IFS actual design was achieved using Matlab toolbox fuzzy. The systems produces 3 outputs namely: water flow adjustment, casting speed adjustment and technological risk. Given the characteristics of the process and that the process is linear were adopted triangular membership functions for both input and output presented in Figure 2.

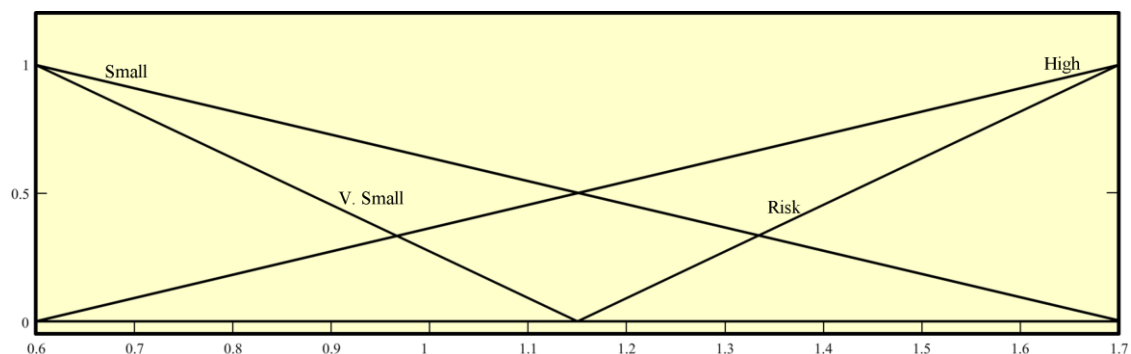
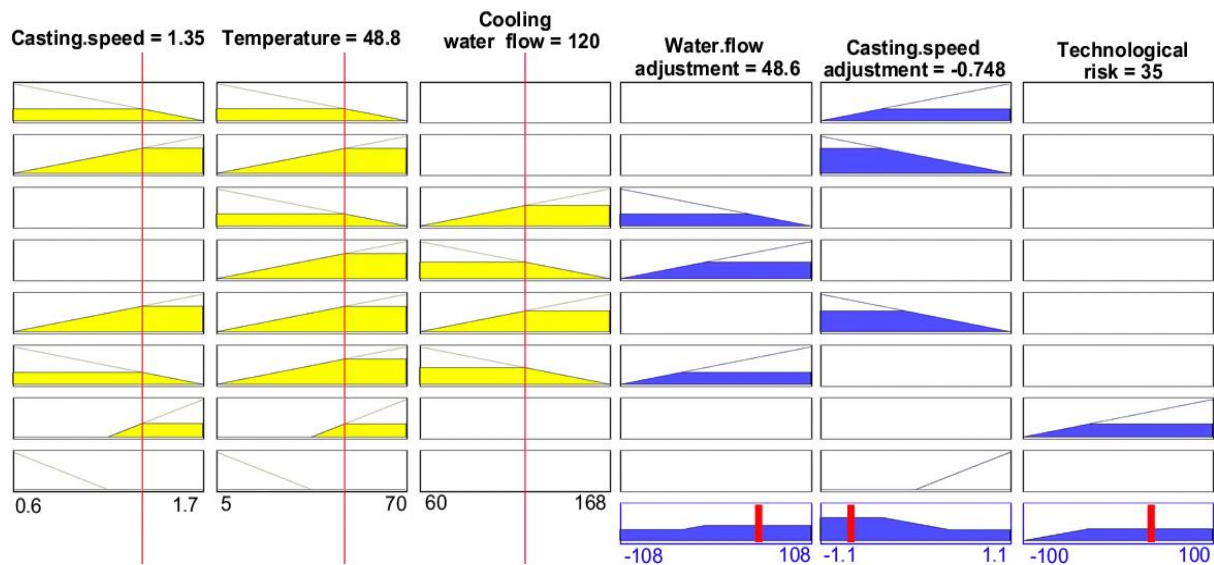
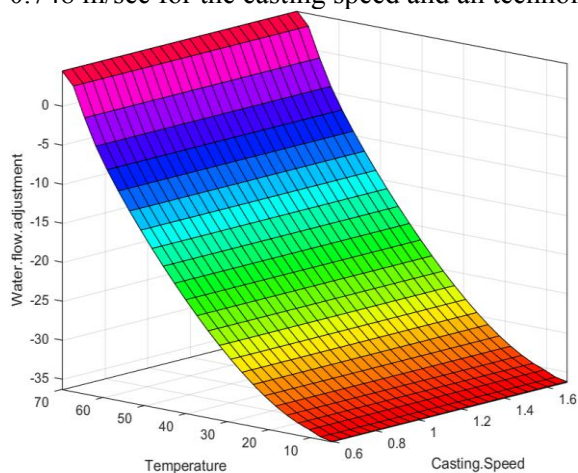
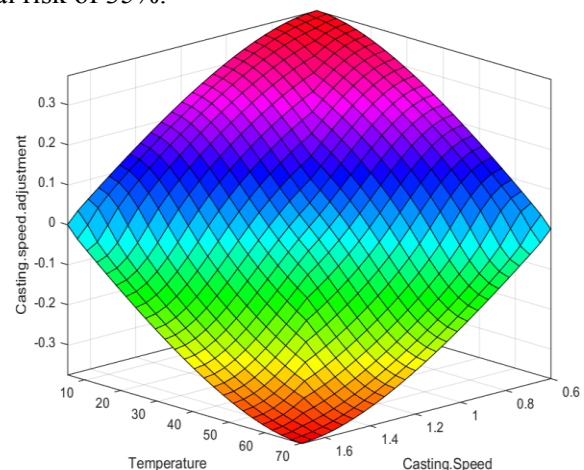
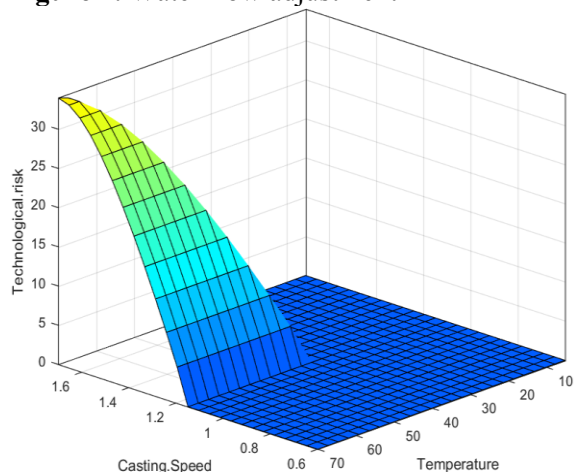


Figure 2. Membership functions

**Figure 3.** Rule table of IFS

The parameters used for creating the graphs below where: Casting speed 1.35m/sec, temperature difference 48.8 °C and water flow 120 l/s and the generated adjustments +48.6 l/s in the water flow, - 0.748 m/sec for the casting speed and an technological risk of 35%.

**Figure 4.** Water flow adjustment**Figure 5.** Casting speed adjustment**Figure 6.** Technological risk

The starting parameters chosen for the graphical representation determined a risk of 35% for crust cracks formation. The parameters were adjusted by the fuzzy rules in such way that after 12 steps the risk dropped down to 0% and was maintained at 0% for the rest of the process. The cooling is made using some valves which adjust the water flow depending on initial measure. The goal of fuzzy system is to improve the classical adjustment system.

4. Conclusions

Analyzing simulation results shows that regardless of the values of the generated input, IFS develops the necessary corrections casting speed and primary cooling water flow, which confirms the validity of system operation. It is considered that, in terms of quality, use fuzzy decision system is an effective, practical and easy to implement, in order to analyze complex phenomena and nonlinear.

The goal of fuzzy system is to improve this classical adjustment system, the introduction of some adaptive components in the adjustment loops and some overall predictions over the continuous casting machine.

This paperwork introduces a new and original concept of the structure of a control system for the continuous casting.

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