Fuzzy decision system with a single variable parameter used in the intelligent control of the processes

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Abstract. Based on the results obtained from the fuzzy systems presented in other published articles, a simplified fuzzy system was made, which was considered as the main factor the temperature difference. In this paper, another type of fuzzy system (single input and two outputs) has been developed and tested using the fuzzy toolbox in Matlab for viewing the resulting graphs and comparing them with the graphs resulting from the other types systems has come to the conclusion that the optimal solution is this fuzzy system with one input and two outputs.

1. Introduction

Secondary cooling zone is one of the most important components of the continuous steel casting installation. The secondary cooling zone will continue the wire cooling after it has emerged from the mold and to assure the full solidification of the product. It is considered to be a very important part of a continuous casting and has the role of ensuring the quality of the material, the material surface shape and has to ensure a homogeneous cooling and a uniform repartition of the water on the materials surface [1-3].

A fuzzy system that will be placed on the existing structure of the control system of continuous casting will reduce cracks in the secondary cooling by generating necessary value adjustments to change the water flow and the velocity of the casting [3]. There are no current systems in In the world bibliography not appears systems that can eliminate cracks if they are detected in the secondary cooling steel. The rules database was designed specifically for this purpose and it contains measures to be taken to mitigate the risk of a crack [4], [5].

A very important 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 crystallizing and to assure the total solidification of the product. It is considered “the heart” of a continuous casting and has the role of ensuring the quality of the material, the material surface shape and has to ensure a homogeneous cooling and a uniform repartition of the water on the materials surface [6-9].

In [7] Tirian proposed three fuzzy system on three cooling zones, with more inputs and more outputs. Starting from here in the paper is proposed a complex system with five inputs and five outputs optimized to the very efficient solution with one input and two outputs.

2. Structure of the system with more inputs and outputs

The secondary cooling system is realized from three subareas such as: area one or foot roller area located on the mold exit, area two and area three, these areas are controlled separately. Usually the sprayed water flow decrease from the mold in the direction of the cast. The sprayed water flows must be bigger in the superior side of the casting machine (area 0 and area1), for realizing the increasing of the products crust and thus improve the resistance crust according to the effort. Lowering the cooling intensity in the casting direction must prevent that the surfaces temperature became too low in the straightening points [10], [11]. The fuzzy system also take's in consideration the distance between the rings and the length of the curved wire.

The system presented in [7] with 3 individual fuzzy systems can be put into practice, but we would need 3 SIEMENS programmable PLCs, one for each area, which would involve relatively large costs, which is why proposes a solution with a single fuzzy system with 5 inputs and 5 outputs as can be seen in Figure 1.

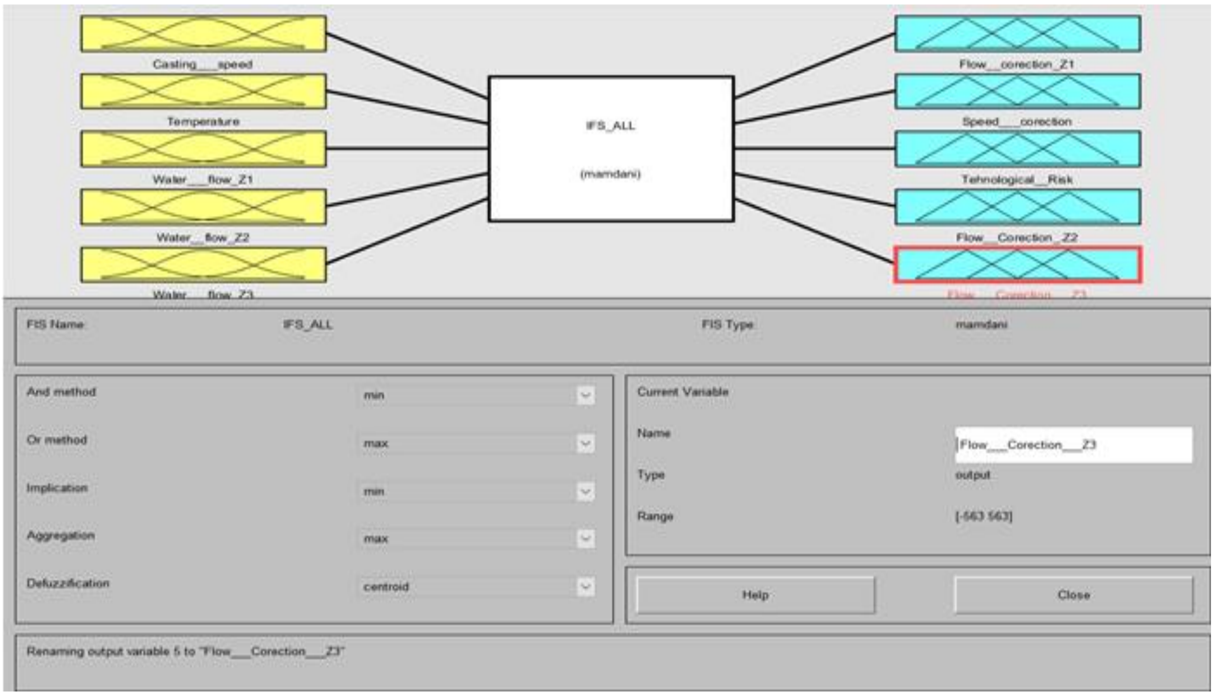

Figure 1. IFS with five inputs and five outputs

The system has been optimized from a number of 5 inputs and 5 outputs, we can only use the temperature reading and introduce the initial starting values of the casting, so we need 5 inputs and 5 outputs using the total water flow rate that can be assigned to the 3 areas according to the calculation formula: 24% of total water flow in zone 1, 34% for 2 and 42% in zone 3 [6].

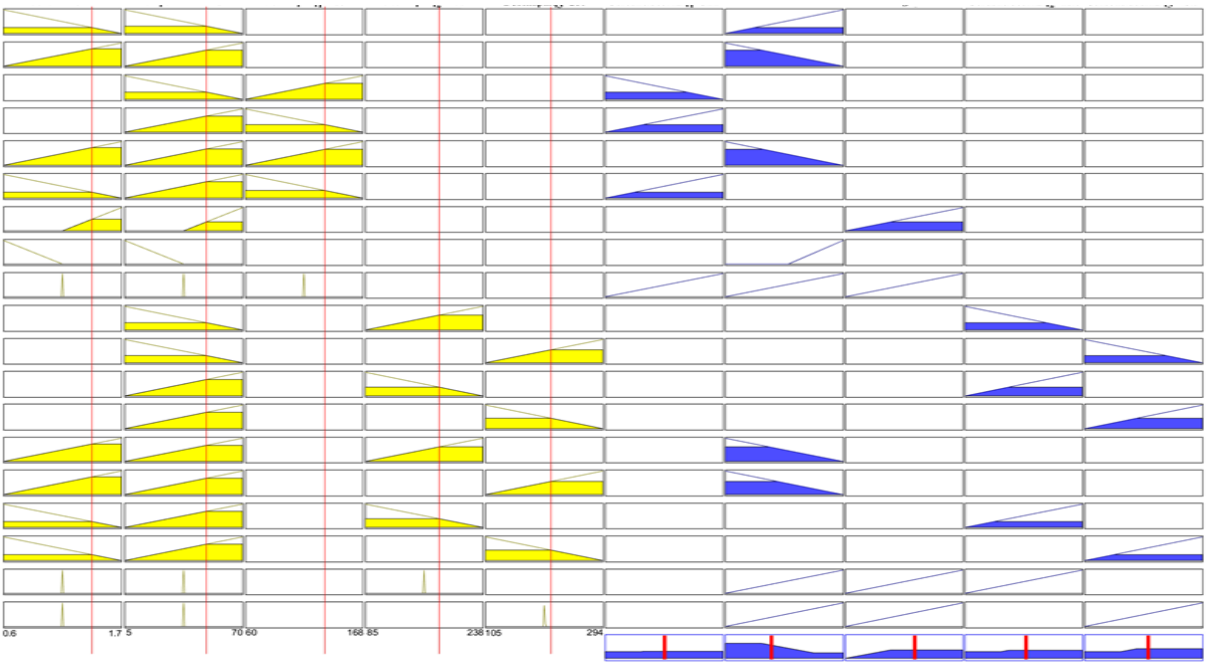

Figure 2. Viewer rules

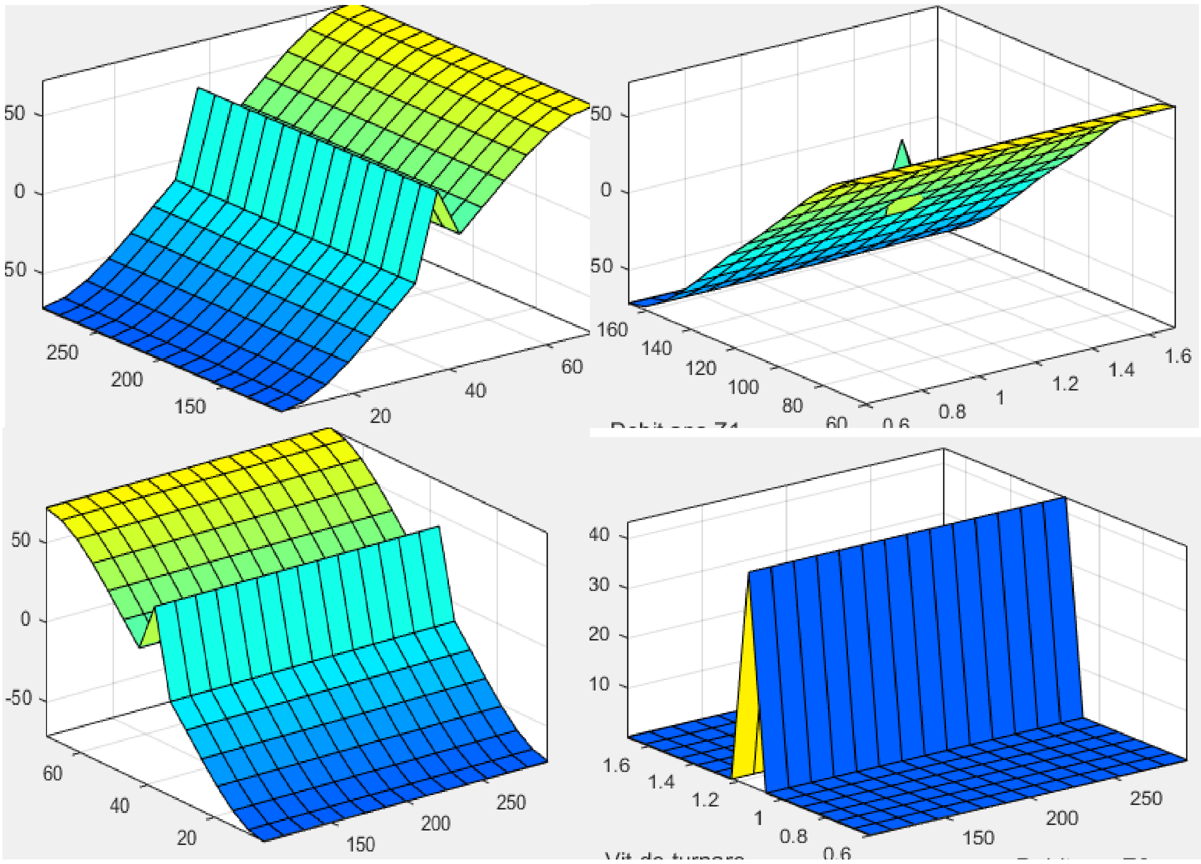

Figure 3. Surfaces viewer

3. Structure of the system with one input and two outputs

Based on the results obtained from the fuzzy systems presented in [5], [7], together with the specialists from S.C. Arcelor Mittal S.A. a simplified Fuzzy system was made at which the temperature difference was considered as the main factor.

In this regard, another type of fuzzy system (single input and two outputs) [7] was developed and tested using the Fuzzy toolbox of Matlab [12] to view the resulting graphs and compare them to the graphs resulting from the other types systems has come to the conclusion that the optimal solution is this Fuzzy system with one input and two outputs.

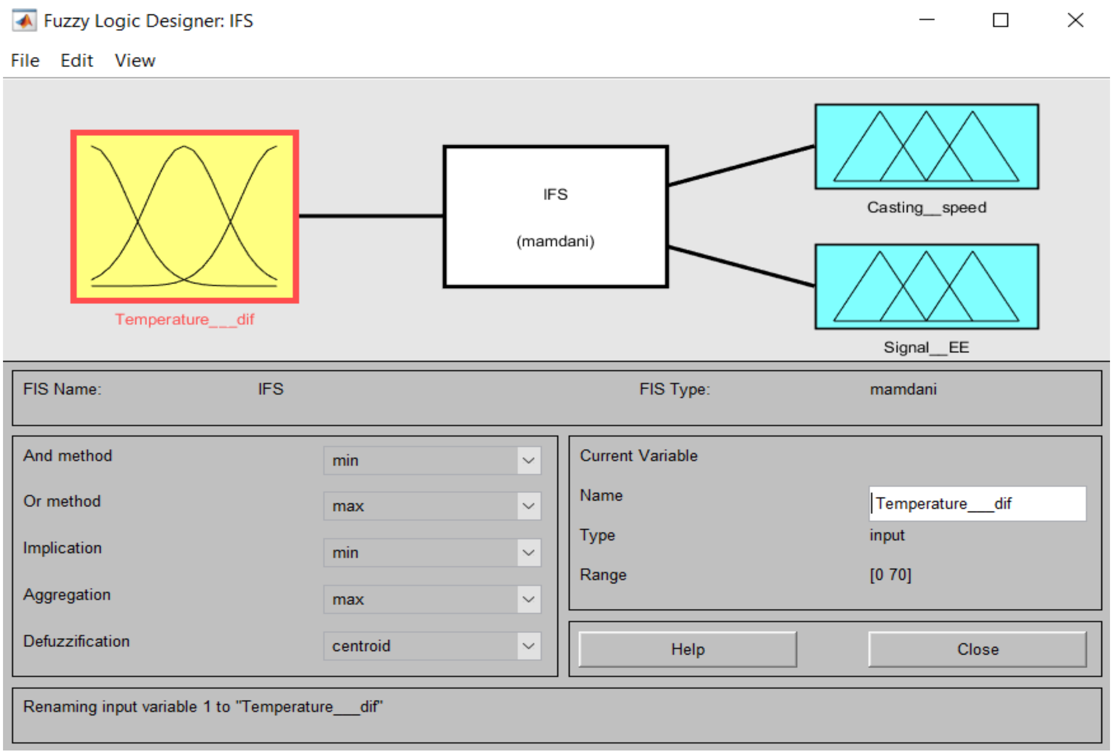

Figure 4. IFS with one parameter

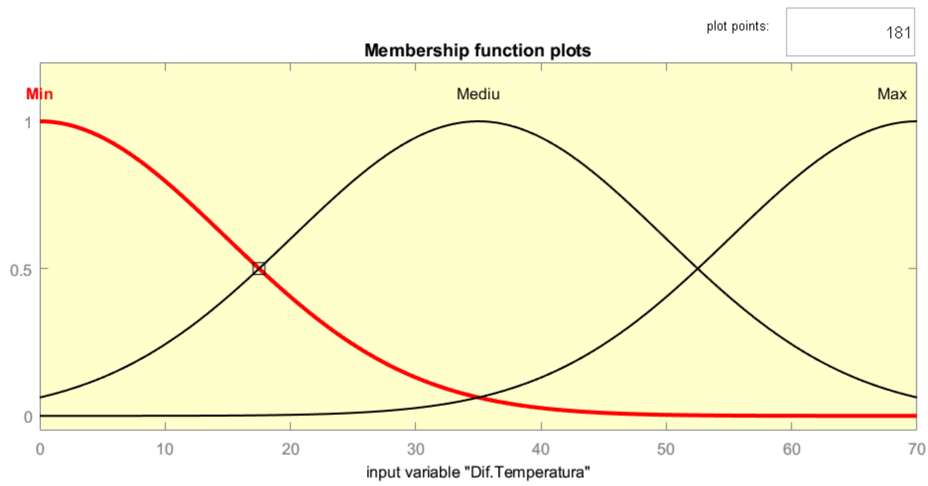

Figure 5. Membership functions “Temperature_dif”

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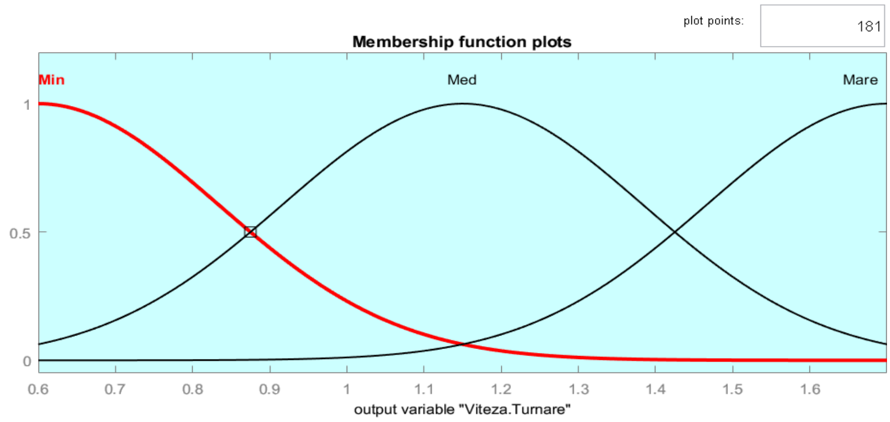

Figure 6. Membership functions "Casting_speed"

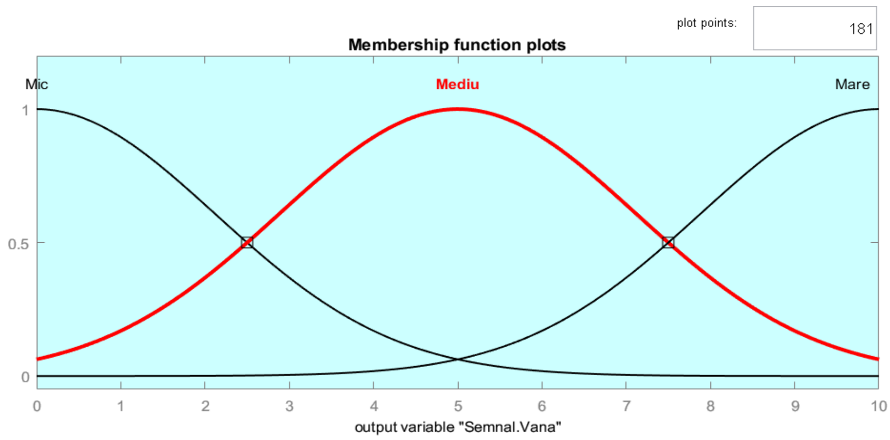

Figure 7. Membership functions "Signal_EE"

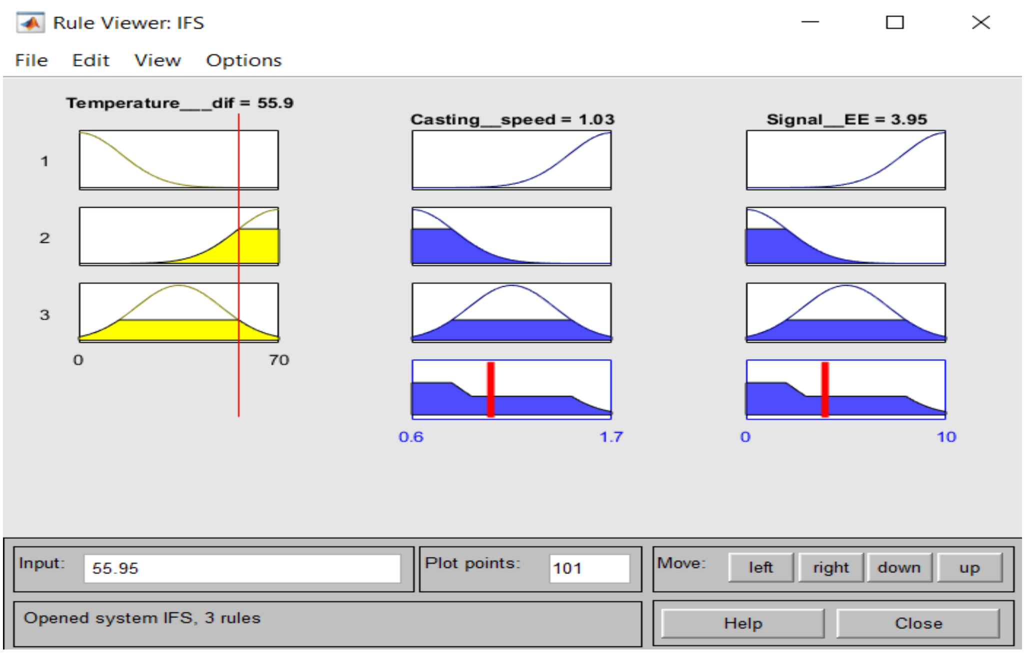

Figure 8. IFS rules

The inference used is Mamdani max-min and the rule inference table is shown in Figure 9. The values at any time for the inputs (temperature difference = 55.9) and the correction values performed by IFS (casting speed = 1.03, Signal_EE = 3.95).

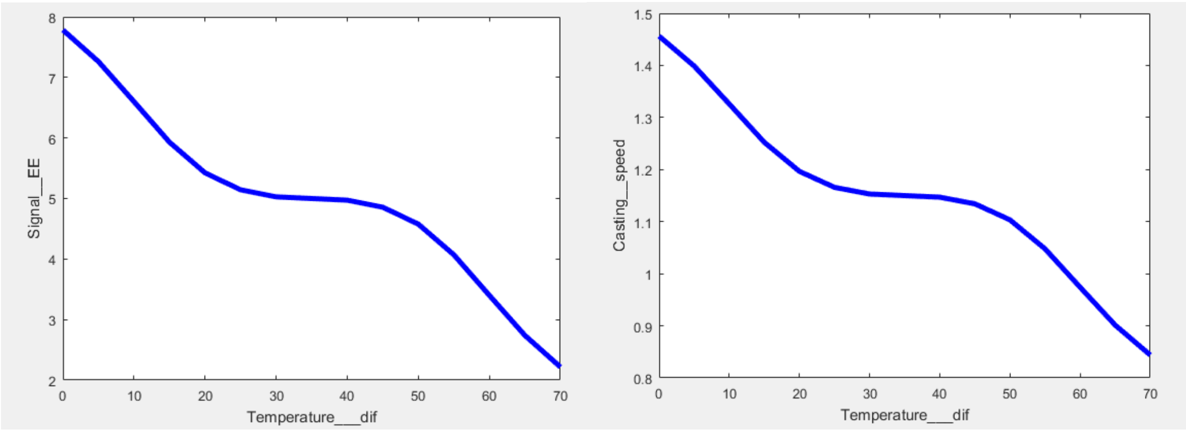

Figure 9. Control surface

4. Conclusions

Based on the research carried out and presented in this paper, we can conclude that: an fuzzy solution has been proposed on the existing structure of the continuous casting system which eliminates cracks in the casting material in the secondary cooling zone; the schema of a fuzzy decision system was designed, analyzing a series of quantities taken from the process producing changes in the cooling water flow and the casting speed; the basing of the rules was done using the experience of human operators and information gathered directly from the process to the continuous casting installation from A.M.-HD; verification and confirmation of the bases of rules and of the designed IFS was done by simulation in Simulink; from the analysis of the simulation results, it is noted that regardless of the values generated at the input, the IFS elaborates the necessary corrections for the casting speed and the primary cooling water flow, which confirms the validity of the system operation; from a qualitative point of view, the use of the fuzzy decision system is an efficient, practical and easy to implement method for the analysis of complex and non-linear phenomena.

References

[1] Ardelean E, Ardelean M, Socalici A and Heput T 2007 Simulation of continuous cast steel product solidification, *Revista de Metalurgia* **43**(3) 181-187
[2] Bouhouch S, Lahreche M, Moussaoui A and Bast J 2007 Quality Monitoring Using Principal Component Analysis and Fuzzy Logic. Application in Continuous Casting Process, *American Journal of Applied Science* **4**(9) 637-644
[3] O'Conner T and Dantzig J 1994 Modeling the Thin Slab Continuous Casting Mold*, Metallurgical and Materials Transactions* **25B**(4) 443-457
[4] Tirian G O, Gheorghiu C A, Hepuţ T and Chioncel C 2016 Control system of water flow and casting speed in continuous steel casting, *IOP Conf. Ser.: Mater. Sci. Eng.* **200** 012047
[5] Tirian G O, Gheorghiu C A, Hepuţ T and Rob R 2016 Fuzzy control strategy for secondary cooling of continuous steel casting, *IOP Conf. Ser.: Mater. Sci. Eng.* **200** 012046
[6] Tirian G O, Gheorghiu C A, Hepuţ T and Chioncel C 2017 Cooling water flow control realized with systems based on fuzzy mechanism, *IOP Conf. Ser.: Mater. Sci. Eng.* **294** 012063
[7] Tirian G O and Chioncel C P 2018 Fuzzy logic controllers for high performance in secondary cooling, *Annals of Faculty of Engineering* **XXV**(2) 143-154
[8] Tirian G O and Gheorghiu C A 2017 Cooling water flow control realized with PLC, *Annals of*

Faculty of Engineering **XV**(3) 155-158

[9] Lee C C 1990 Fuzzy logic in control systems: Fuzzy logic controller, *IEEE Trans. Systems, Man & Cybernetics* **20**(2) 404-435

[10] Cioată V G, Kiss I, Alexa V and Raţiu S A 2017 The optimization of the position and the magnitude of the clamping forces in machining fixtures, *IOP Conf. Ser.: Mater. Sci. Eng.* **200** 012015

[11] Cioată V G 2008 *Determining the machining error due to workpiece-fixture system deformation using the finite element method*, Annals of DAAAM & Proceedings of the 19th International DAAAM Symposium, Trnava, Slovakia, October 22-25, pp 253-255

[12] Singh J and Ganesh A 2008 Design and Analysis of GA based Neural/Fuzzy Optimum Adaptive Control, *Transactions on Systems and Control* **5**(3)