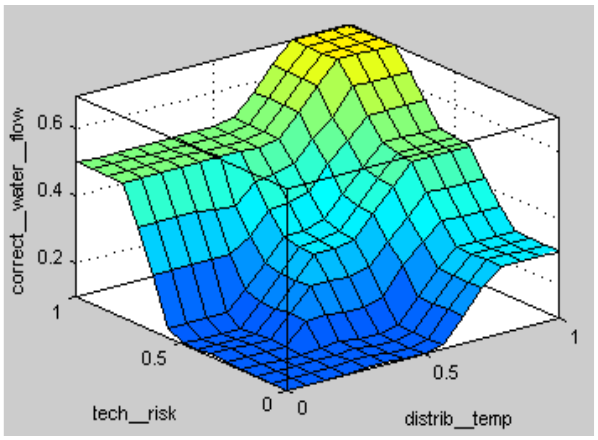


Fig.6 Control surface
Correct _water _flow=f (distrib _temp, tech _risk) at water _flow=const. and casting _speed=const.

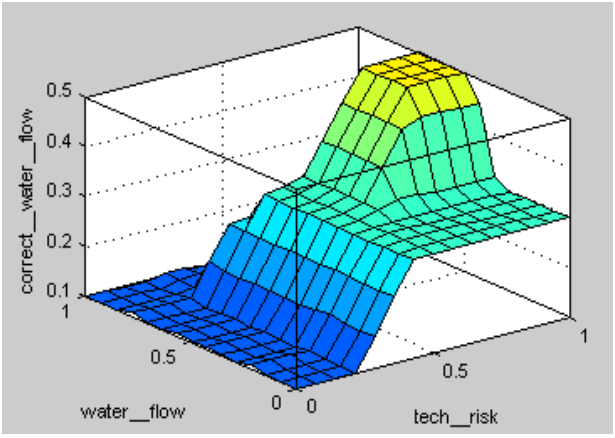


Fig.7 Control surface
Correct _water _flow=f (tech _risk, water _flow) at casting _speed=const. and distrib _temp=const.

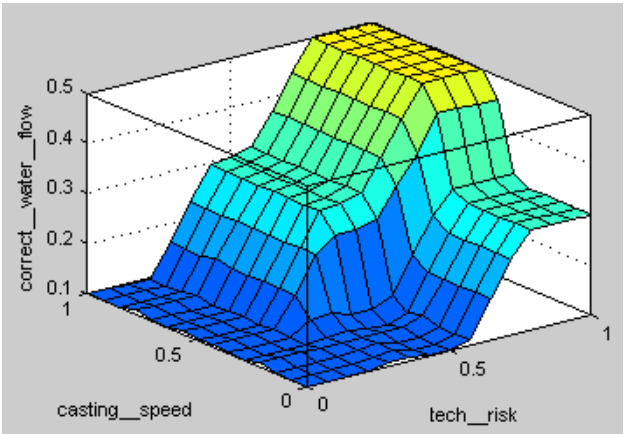


Fig.8 Control surface
Correct _water _flow=f (tech _risk, casting _speed) at water _flow=const. and distrib _temp =const.

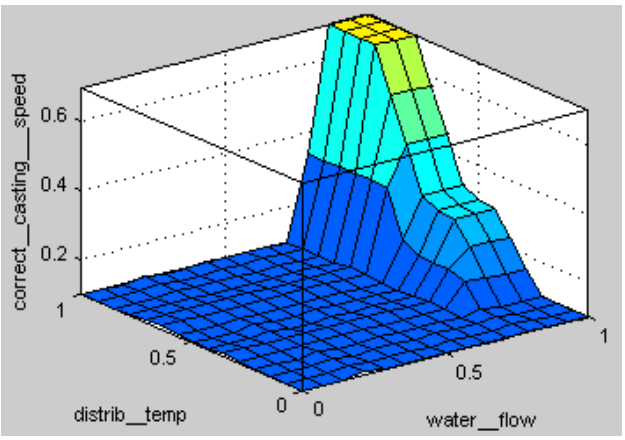


Fig.9 Control surface
Correct _casting _speed=f (water _flow, distrib _temp) at casting _speed=const. and tech _risk =const.

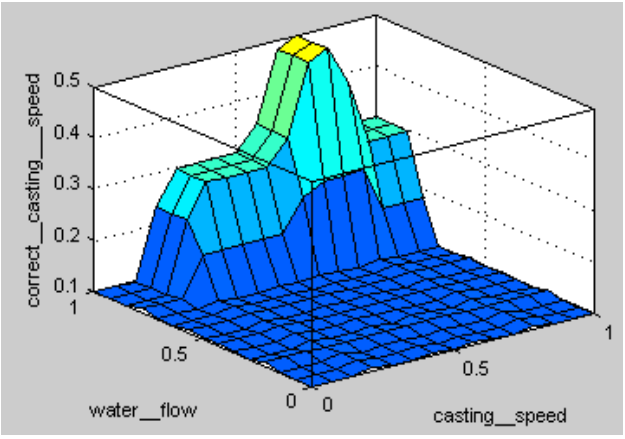


Fig.10 Control surface
Correct _casting _speed=f (casting _speed, water _flow) at distrib _temp=const. and tech _risk =const.

3.2 Design of fuzzy controller FC1

In figure 11 we describe the block diagram of the fuzzy controller FC1.

Input information's

1) water _ flow (water flow in crystallizing apparatus, [l/min])

Number of states: 5

States	Real domain [l/min]	Standardized values domain
Very small	900 ÷ 940	0÷0,2
Small	940 ÷ 980	0,2÷0,4
Medium	980 ÷ 1020	0,4÷0,6
Big	1020 ÷ 1060	0,6÷0,8
Very big	1060 ÷ 1100	0,8÷1

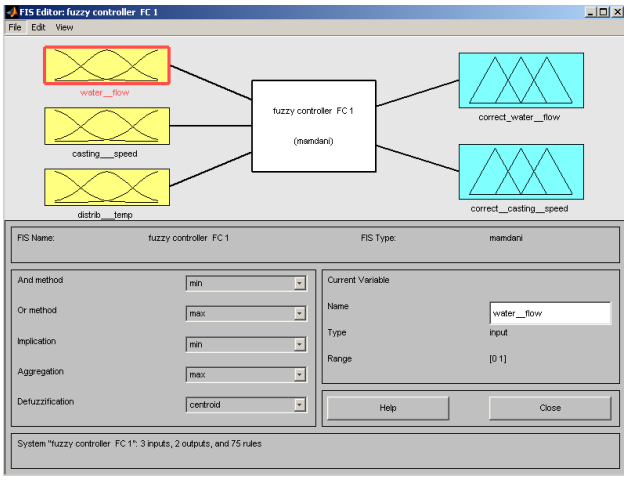


Fig. 11 Block diagram of the fuzzy controller FC1

2) casting _speed (casting_speed, [m/min])

Number of states: 5

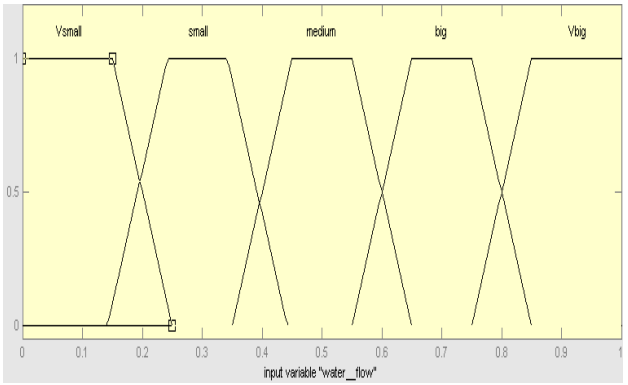
States	Real domain [m/min]	Standardized values domain
Very small	0,7 ÷ 0,8	0÷0,2
Small	0,8 ÷ 0,9	0,2÷0,4
Medium	0,9 ÷ 1,0	0,4÷0,6
Big	1,0 ÷ 1,1	0,6÷0,8
Very big	1,1 ÷ 1,2	0,8÷1

3) distributor _ temperature (steel temperature in crystallizing apparatus [°C])

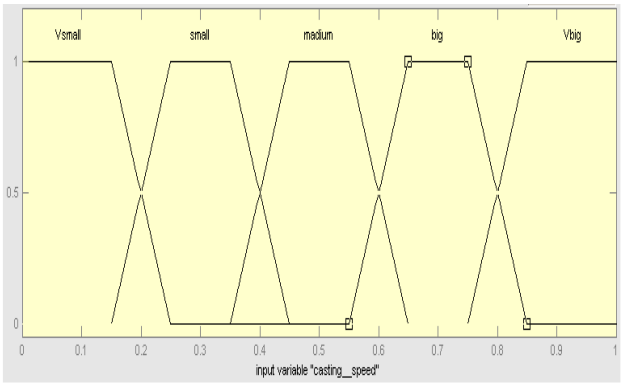
Number of states: 3

States	Real domain [^{0}C]	Standardized values domain
Small	1540 ÷ 1550	0÷0,33
Medium	1550 ÷ 1560	0,33÷0,66
Big	1560 ÷ 1570	0,66÷1

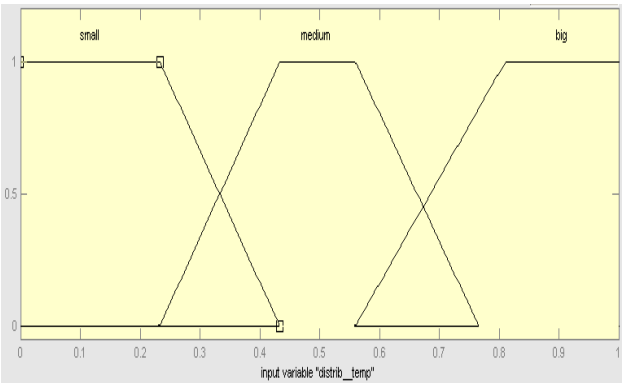
In figures g, h and i we describe the membership functions for the input sizes.



g) Membership function „water _flow”



h) Membership function „casting _speed”



i) Membership function „distrib _temp”

Output information's

1)correct_water_flow (water flow corection [l/min])

Number of states: 5

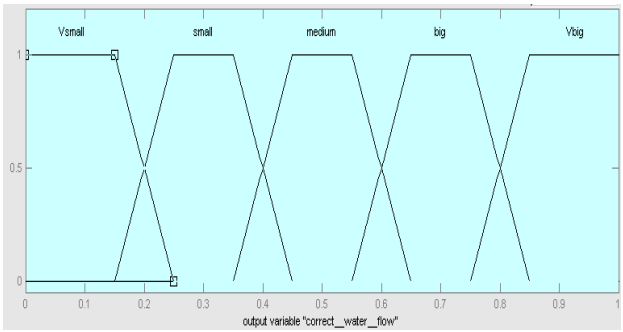
States	Real domain [%]	Standardized values domain
Very small	0÷-4	0÷0,2
Small	-4÷-8	0,2÷0,4
Medium	-8÷-12	0,4÷0,6
Big	-12÷-16	0,6÷0,8
Very big	-16÷-20	0,8÷1

2) correct_casting_speed(casting speed correction [m/min])

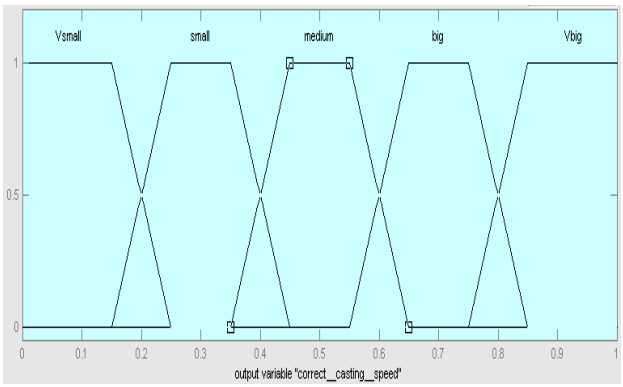
Number of states: 5

States	Real domain [%]	Standardized values domain
Very small	0÷-4	0÷0,2
Small	-4÷-8	0,2÷0,4
Medium	-8÷-12	0,4÷0,6
Big	-12÷-16	0,6÷0,8
Very big	-16÷-20	0,8÷1

In figures j and k we describe the membership functions for the output sizes.



j) Membership function „correct _ water _flow”



k) Membership function „ correct _ casting _ speed”

Table of inference for some of the rules is given below:

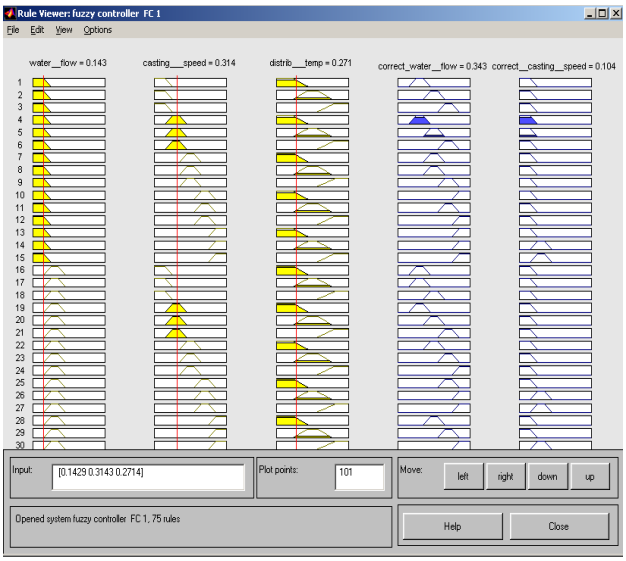


Fig. 12 Table of inference for FC1

Control surfaces obtained by simulations according to the block diagram from the figure 11 are listed below:

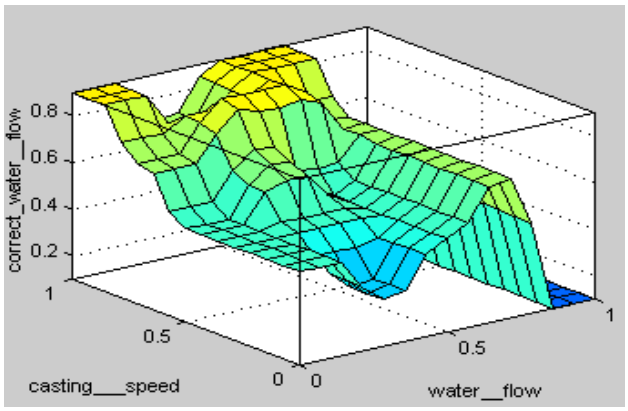


Fig.13 Control surface
Correct_water_flow=f (water_flow, casting_speed)
distrib _temp=const.

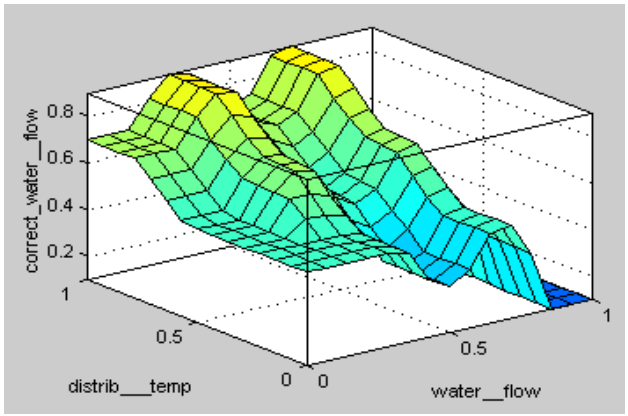


Fig.14 Control surface
Correct_water_flow=f (water_flow, distrib _temp)
casting _speed=const.

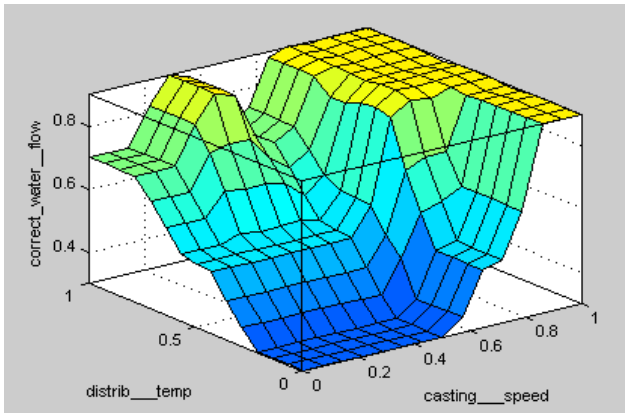


Fig.15 Control surface
Correct_water_flow=f (casting_speed, distrib_temp)
water_flow=const.

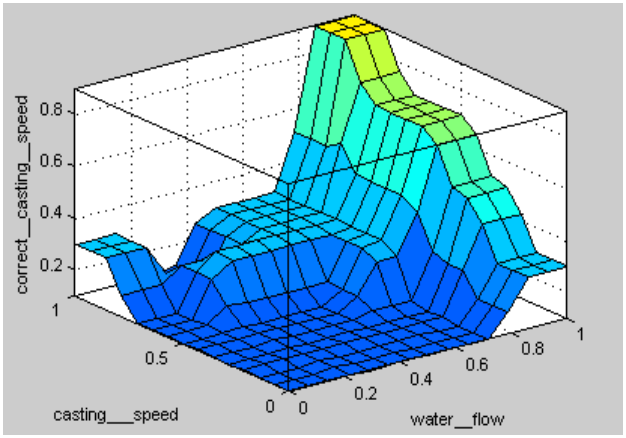


Fig.16 Control surface
Correct_casting_speed=f (water_flow, casting_speed) distrib _temp=const.

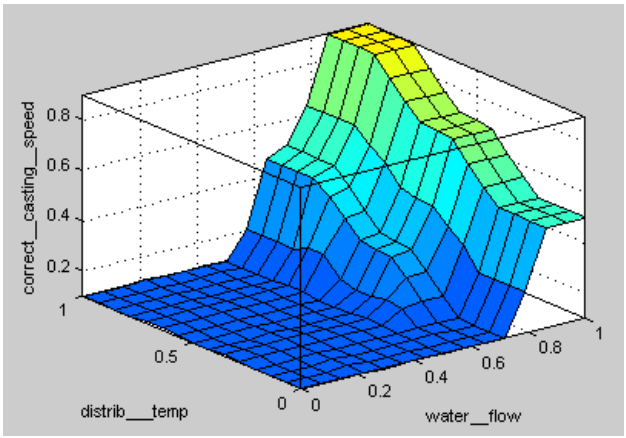


Fig.17 Control surface
Correct_casting_speed=f (water_flow, distrib_temp) casting_speed=const.

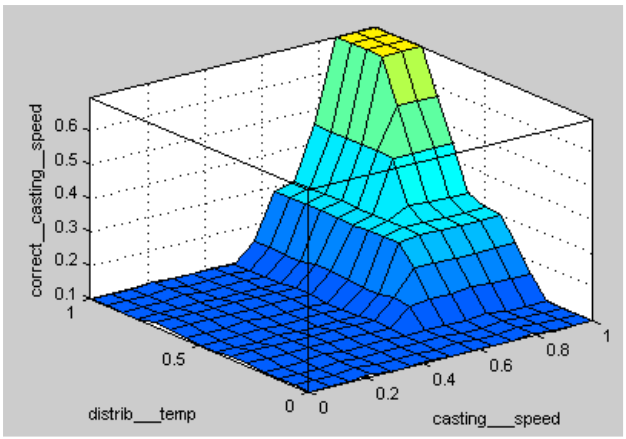


Fig.18 Control surface
Correct_casting_speed=f(casting_speed, distrib_temp) water_flow=const.

4 Conclusions

This paperwork describes a modern control method we should use during the continuous casting. This method is based on the fuzzy logic, in order to avoid any crack inside the crystallizing apparatus. This method contains two fuzzy controllers FC0 and FC1 which, based on a set of rules established with the help of the mathematical model to the crust solidification process of the semi-product inside the crystallizing apparatus and uses the experience of human experts, requires changes of the casting speed value and the primary cooling water flow.

When we have designed the pattern, we considered other important features: it should anticipate any crack, which allows us to take some measures in order to diminish the number of cracks inside the crystallizing apparatus, without decreasing the productivity of the equipment; once the primary cracks have been detected by the neuronal network, another controller consider this situation and take the most appropriate measures in order to avoid the temporarily decrease of the productivity; the pattern should be as flexible as possible, in order to adjust to any equipment we already use. This is possible if we change the set of rules, and does not imply any additional costs.

Although, the pattern has not yet been practically used, a part of the set of rules has been implemented and tested for an industrial equipment. It has uphold that the data is correct.

We consider that any costs could be paid off within a year, by elliminating casting waste.

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