Aspects Regarding the Fuzzy Logic in the Process Control From the Sintering Plants

CORINA MARIA DINIŞ  CORINA DANIELA CUNŢAN  ANGELA IAGĂR
GABRIEL NICOLAE POPA  STELA RUSU ANGHEL
Department of Electrotechnical Engineering and Industrial Informatics
Politechnica University Timișoara
Revoluției Str., no 5, Hunedoara, 331128
ROMANIA
corina.dinis@fih.upt.ro  http://www.fih.upt.ro

Abstract: - This work presents, for the last two phases of the agglomerate’s manufacturing process, the diagrams of some expert systems based on Fuzzy logic, by which is achieved the control of these processes. These expert systems based on Fuzzy logic allow the automatic control optimization of non-linear processes of agglomerating charge elaboration. Also, are presented the three fuzzy controllers which were designed with Fuzzy Shell FLOP from the WinFACT 7 development environment. Two of the controllers are used for the process control on the sintering machine, and the third one for the process control on the agglomerate’s cooling machine.

Key-Words: - Sintering process, Fuzzy controller, Fuzzy logic, Expert System, Belt speed, Sintering machine, Cooling machine, Speed correction, Simulation

1 Introduction

The major cast-iron producing countries are using iron ores previously prepared as agglomerate, meant to ensure the achievement of some charges with high iron content and homogeneous from chemical and grading viewpoint.

From the processes with special influence on preparation, in this work are analyzed: sintering and cooling. Cooling of the agglomerate is made on two linear coolers, one for each sintering machine. The cooling air is supplied by 5 fans with 200000 m³/h air flow, blown by each fan. At the entrance on the cooler, the agglomerate has a temperature of 700-800°C and leaves the cooler with 80-100°C, fact which allows it to be transported by some special rubber belts [ ].

Nowadays, processes from an iron ore sintering plants are conducted through analogical adjustment loops without taking into account a series of factors that influence these processes, such as:
- Technical endowment with modern sensors and transducers;
- Conceiving of a hierarchical automation strategy;
- Technical endowment with modern processing equipment (microcontrollers, PLC, industrial micro-computers);
- Completion of the automation strategy with an expert system based on fuzzy logic.

All these are leading to: energetic consumptions much over the world level, raw material losses; inadequate quality of the agglomerate; reduced productivity; improper operation regimes for equipments, with repercussions on their efficiency and life-time.

Improving of the current situation can be achieved by using of expert systems based on Fuzzy logic. Their need is imposed by the fact that the processes can not be accurately mathematically modeled and a lot of parameters (charge’s humidity, materials’ physical-chemical properties, sintering vertical speed, cooling speed, agglomerate’s temperature on the cooling belt) are changing in time in a way that can not be previously acknowledged. The fuzzy-sets theory allows a formalization of imprecision, by means of an adequate treatment of linguistic variables. Expert systems with fuzzy logic become useful and efficient for solving of some high-complexity problems, but also for simpler control problems, that contain a high uncertainty degree.

Nowadays, fuzzy logic is suitable to be used for conceiving of controllers for hard-modelable processes. There are proposed two expert systems based on Fuzzy logic: one for the process control on the sintering machine (fig.1) and the other for the process control on the agglomerate’s cooling machine (fig.2).
2 Using of Fuzzy Logic for Simulation and Control of the Sintering Process

The version proposed for modernizing the process control on the sintering machine is based on the fuzzy logic model. In this respect, in fig. 5 is noticed that are used two fuzzy controllers that achieve the speed correction of the agglomerating band depending on certain parameters read along the sintering process. In fig. 3 is presenting the block diagram of the Fuzzy controller 1 and in fig. 4 the block diagram of the Fuzzy controller 2. The parameters read along the sintering process are: T20, T21, T22 – temperatures in the last three suction chambers of the sintering belt; T_{cond} - temperature in the gas collecting pipe; T11 – temperature in the suction chamber 11.

The first controller makes the speed correction of the sintering belt depending on the temperature from the suction chamber 11, the temperature from the gas collecting pipe and the parameter $\Delta = \frac{d_{21} - d_{22}}{d_{20} - d_{21}} = PantaD$ where: $d_{21}$ – depression from the vacuum chamber 21; $d_{20}$ – depression from the vacuum (suction) chamber 20;

The second regulator makes the second speed correction depending on the temperatures from the last three suction chambers. For a height of the agglomerating layer of $H_{layer} = 400$ mm the prescribed speed of the sintering belt lays within $v = (2 \div 2.5)$ m/min. Designing of the two Fuzzy controllers is made with the Fuzzy Shell FLOP program and is based on the following conditions:

The average temperature $T_{11}$ prescribed for the vacuum chamber lays within $(55 \pm 5) ^{\circ}$C and, depending on this, the belt’s speed is corrected as follows:

- If $T_{11}$ is lower than the prescribed temperature, the correction is $\Delta v = -0.1 m/ min$;

![Diagram](image_url)
Fig. 2 Expert system for the cooling process control based on Fuzzy logic

- If $T_{11}$ lays within the prescribed temperature range $\Delta v = 0 \text{ m/min}$;
- If $T_{11}$ is higher than the prescribed temperature, the correction is $\Delta v = + 0.1 \text{ m/min}$.

The prescribed average temperature of the gas from the collecting pipe lays within $(105 \pm 15){}^\circ\text{C}$:

- If the gas temperature from the collecting pipe is lower than the prescribed one, the speed correction is $\Delta v = -0.1 \text{ m/min}$;
- If the gas temperature from the collecting pipe lays within the prescribed range $\Delta v = 0 \text{ m/min}$;
- If the gas temperature from the collecting pipe is higher than the prescribed one, the speed correction is $\Delta v = + 0.1 \text{ m/min}$.

The relative depression $\Delta$ is calculated by the formula $\Delta = \frac{d_{21} - d_{22}}{d_{20} - d_{21}}$.

Depending on the prescribed values of the depressions from the three vacuum chambers $d_{20} = 650 \text{ mm water col.}$; $d_{21} = 600 \text{ mm water col.}$; $d_{22} = 500 \text{ mm water col.}$, are made the following corrections:

- If $\Delta > 2$, the speed correction is $\Delta v = + 0.1 \text{ m/min}$;
- If $\Delta \in (1.5 \div 2)$, the speed correction is $\Delta v = 0 \text{ m/min}$;
- If $\Delta < 1.5$ the speed correction is $\Delta v = -0.1 \text{ m/min}$.

When setting the rules basis for the second fuzzy controller, are taken into account the following conditions:

- If $T_{20} < T_{21}$ and $T_{20} > T_{22}$, the speed correction is $\Delta v = + 0.1 \text{ m/min}$;
- If $T_{20} < T_{21}$ and $T_{20} = T_{22}$, the speed correction is $\Delta v = 0 \text{ m/min}$;
- If $T_{20} < T_{21}$ and $T_{20} < T_{22}$, the speed correction is $\Delta v = -0.1 \text{ m/min}$.

Fig. 3 Block diagram of the Fuzzy Controller 1
3 Using of Fuzzy Logic for Simulating and Control of the Agglomerate’s Cooling Process

Modernization of the agglomerate’s cooling process control can be achieved using an expert system based on fuzzy logic. As important measures for the agglomerate’s cooling process were taken in consideration: the belt’s running speed and the air flow blown by the ventilators mounted beneath the belt. At the process control on the agglomerate’s cooling machine was used a fuzzy controller that achieves the speed correction of the cooling belt and the start/stop of the spare ventilator by opening the dumper-plate depending on the parameters sampled along the cooling belt (fig.5). From the 4 temperature thermocouples mounted above the cooling belt (fig.2) for the fuzzy control will be used the first two from the cooling belt’s beginning and the last one mounted towards the belt’s end.

The agglomerate’s cooling on the cooling machine is made by air blowing, using the ventilators existent beneath the belt. The designed Fuzzy Controller has as input measures: temperature T1 measured by thermocouple 1f1, temperature T2 measured by thermocouple 1f2, temperature T3 measured by thermocouple 1f4 (fig.2) and as output measures: speed correction of the cooling belt and the air flow blown by the ventilators.

In fig.7 is presented the block diagram of the agglomerate’s cooling process control with a Fuzzy controller, which was designed using Fuzzy Shell FLOP from the development environment WinFACT 7 and in fig.6 is presented the block diagram of the Fuzzy Controller. Designing of the Fuzzy Controller is based on the following conditions:

- The prescribed average temperature measured with the thermocouple 1 lays within 275°C ± 25°C.
  - If the temperature is within the prescribed range, will operate the three base ventilators, each at 3/4 from capacity (450 000 m³/h);
  - If the temperature is higher than the prescribed range, will operate the three base ventilators, each at 3/4 from capacity and starts in operation also the spare ventilator (525 000 m³/h);
- The prescribed average temperature measured with the thermocouple 2 lays within 225°C ± 25°C.
  - If the temperature is within the prescribed range, will operate the three base ventilators, each at 3/4 from capacity (450 000 m³/h);
  - If the temperature is higher than the prescribed range, will operate the three base ventilators, each at 3/4 from capacity and starts in operation also the spare ventilator (525 000 m³/h);
  - If both temperatures measured by the thermocouples 1 and 2 exceed the prescribed ranges, then will operate the three base ventilators at 3/4 from capacity and starts in operation also the spare ventilator at 3/4 from capacity (600 000 m³/h).
- The prescribed average temperature measured with the thermocouple 4 lays within 50°C ± 10°C.
  - If the temperature is lower than the prescribed range, the speed correction Δv = +0.2 m / min;
  - If the temperature lays within the prescribed range, the speed correction Δv = 0 m / min;
  - If the temperature is higher than the prescribed range, the speed correction Δv = -0.2 m / min;
4 Simulation Results

For exemplification, is presented the Fuzzy Controller 2 designed for the process control on the sintering machine and the Fuzzy Controller designed for the agglomerate’s cooling process control.

In fig. 8, 9, 10, are presented the membership functions of the input measures T20, T21, T22 and fig. 14 presents the membership functions of the output measures Correction Speed (at the Fuzzy Controller 2). The rules basis of the Fuzzy Controller 2 is described in fig. 15.

A part from the adjustment surfaces and the static characteristics obtained further the simulation with Fuzzy Shell FLOP from the development environment WinFACT 7 of Fuzzy Controller 2 are presented in fig. 11, 12, 13, 16, 17.

For the Fuzzy Controller designed for the cooling process, in fig. 18, 19, 20 we have described the membership functions of the input measures T1, T2 and T3 and in fig. 21, 22 the membership functions of the output measures: Correction Speed and Airflow Blown.
The rules basis is described in fig. 23 and fig. 24, 25 presents two of the adjustment surfaces obtained for the fuzzy controller from cooling.

In fig. 26 and 27 we have two of the static characteristics obtained for this controller.

One can notice that there are obtained non-linear characteristics for the designed Fuzzy controllers, their non-linearity being influenced by selecting the rules, the membership functions and the inference methods.

For all the designed Fuzzy controllers the selected implication is of Mamdani type, the rules aggregation is made with the max-min connectives and defuzzification is made by the center of gravity method.

6 Conclusion

In the last period are used increasingly expert systems based on fuzzy logic, which are capable to simulate the judgements and the behavior of a human expert. Researches upon the behavior of the “human expert” have emphasized the fact that specific to him is a strongly non-linear behavior, accompanied by anticipation, delay, integration and prediction effects and even adapting to the concrete operation conditions.

Specification of the linguistic characterization for process’ undergoing, as well as the experience-based interpretation of the process from the sintering machine and the agglomerate’s cooling machine, represent the parameters by which the controller’s properties can be modified.

As consequence, the designed fuzzy algorithms has lead to non-linear controllers which, taking into account a great number of variables for the adjusted parameters, will obtain a precision clearly superior to the current situation.

References: