OPTIMIZING THE COMBUSTIBLE CONSUMPTION USING THE IoT CONCEPT FOR FOUNDRY FURNACES

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The command-and-control technology of industrial aggregates developed through the SCADA concept has started, due to the evolution of the digitization process which has moved in the cloud. The advantage IoT technologies offers the possibility to reduce and improve production costs by online monitoring of technological processes. The paper presents a case study on the implementation of this technology in heat casting furnaces using the IoT concept. The technical-economic advantages are generated by two important aspects: reducing errors due to the existence of a centralized management system, with a high-performance infrastructure and decreasing the maintenance cost due to the economies of scale offered by such a solution.

Keywords: SCADA, optimizing, gas consumption, IoT.

1. Introduction

The SCADA technology used in the materials industry to monitor and control processes adapts with the industrial revolution 4.0 to the new directions that involve the transfer of monitoring using cloud technology [1].

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Considering these trends, numerous suppliers of automation equipment have started to release acquisition boards or Programmable Logical Conrolers (PLC) with communication facilities through WiFi modules.

The article presents a case study for monitoring the operation and control of thermal aggregates using the IoT concept in aluminium foundries. In the materials industry, energy sources are mainly used to carry out the processes of melting, drying and heating, where temperature control is essential in order to obtain the finished product. In the current conditions regarding the evolution of energy prices, cost optimization with this becomes a essential condition for the production and processing of metallic materials [2].

In order to optimize consumption and costs, especially with the energy consumed in the materials industry, it was passed, now at the beginning of the 90's, together with the development of the SCADA concept, and its implementation on a large scale allowed the monitoring of the behavior of the furnace during the elaboration process in order to improve the quality of cast products.

The recent development of communication technologies, as well as the reduction of costs with high-speed connection, led to the development of the digitization process through the implementation of computer applications that allow data storage and accessing them from the cloud. Through the cloud concept, a major change is implemented in the way users in the industrial field have access to computing resources, process command and control, storage, applications or other IT services.

2. Description of the method

In the framework of the technical work used, it involves the remote control from the cloud of the heating process from a metallurgical furnace. To achieve this, development equipment whose purchase costs are relatively low and allow the modernization of some SMEs in order to adapt them to the new trends in the world economy, namely the industrial revolution 4.0, were used in the implementation of the presented method.

In the monitoring and control process (Fig.1), we use 2 controllers (ESP8266) realized by Arduino an acquisition board (namely a Nodemcu v.3), an thermocouple (k-typ,e with max6675 converter) that allows the measurement of temperatures up to 1024 degrees C.

In Fig. 2 is presented the acquisition board Nodemcu v3, which has incorporated a micro-chipset (esp8266) for Wi-Fi communication. This board allows, by connecting to the local network, the transmission of the data necessary to follow the technological process via the Internet.

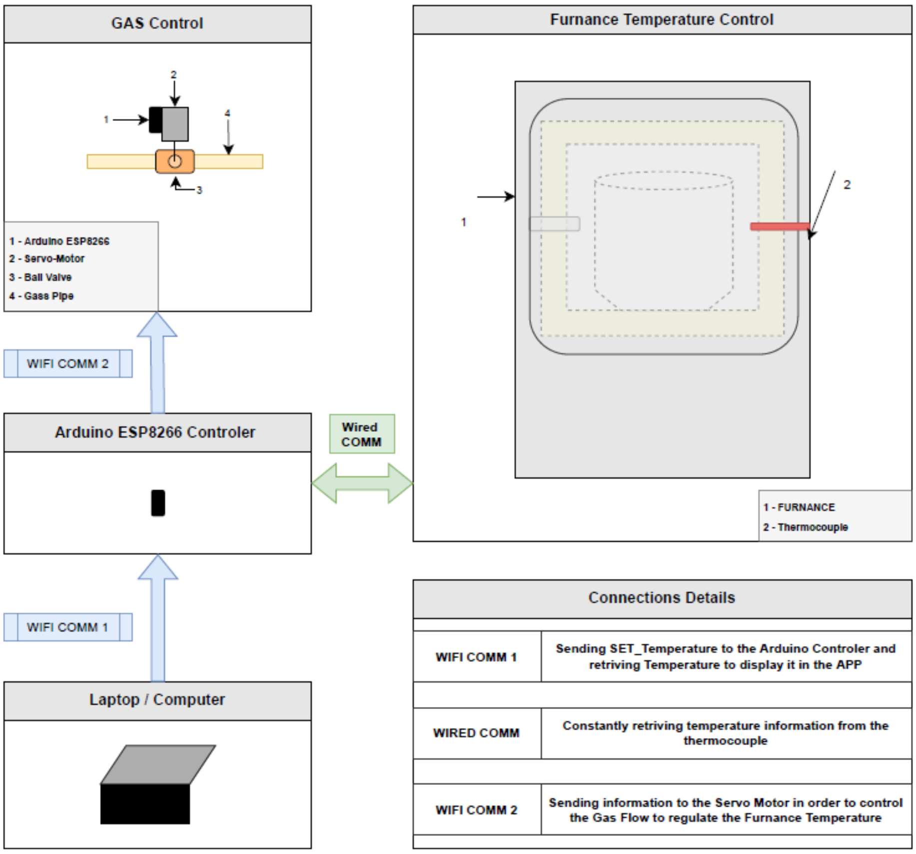

Fig. 1. SCADA communication scheme in the cloud

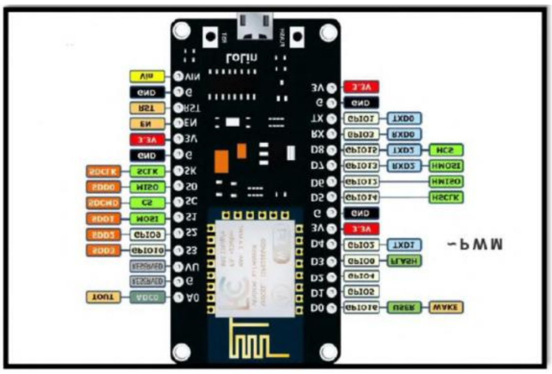

Fig. 2. Nodemcu V3 WIFI acquisition board

In order to achieve remote communication via the Internet using the cloud computing concept, an application was developed using the PHP language as a support and runs on the server side at the address www.cuptoaresmart.ro. The data taken from the process are transmitted through a program developed in Arduino Ide from the Nodemcu acquisition board to the PHP script that stores the monitored parameters in real time in a database created in MySql and running in cloud.

To design the IoT temperature monitoring device, (Fig. 3) shows the scheme designed using the ThinkerCAD platform. Using the system designed in Fig. 3, the software was later created in Arduino IDE that allows monitoring the temperature in a casting furnace.

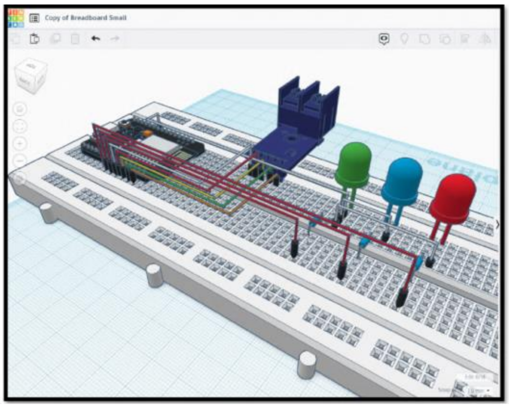

Fig. 3. Design of the control system using the ThinkerCAD application

A casting furnace with an energy output of 50 kwh, heated with gas, was used for the melting process to test the solution. To improve the thermal efficiency and to reduce the processing process and therefore the consumption, the automation solution designed in Fig. 3 was implemented. In order to be able to optimize production costs, in our experiment we used a mathematical modeling of gas consumption based on the first principle of thermodynamics, namely the conservation of energy according to relation (1).

$$Qi = Qc \tag{1}$$

where: *Qi* is the total heat introduced into the furnace [kJ/h]

Qc total heat consumed in the oven [kJ/h].

To optimize gas consumption, it was necessary to use an ESP8266 board to communicate with the Nodemcu v3 board. With this solution, the temperature in the oven is taken with the help of the Nodemcu board and transmitted to the php script running in the cloud, and the command and control part of the gas consumption is carried out by means of the ESP8266 board.

The advantage of moving the SCADA concept to the cloud lies in the fact that it allows the reduction of maintenance costs of the automation solution as well as the possibility of ensuring efficient management of small companies of the IMM type.

Taking into account the trends within the EU to reduce pollution, the presented solution focuses on the efficiency of gas consumption.

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Fig. 4 shows a snapshot with the monitoring synopsis of the aluminum melting process. The user only sets the casting temperature on a smart device connected to the Internet and by pressing the start button the technological process begins. The adjustment of gas consumption is done automatically based on the logical scheme in Fig. 5. [3]

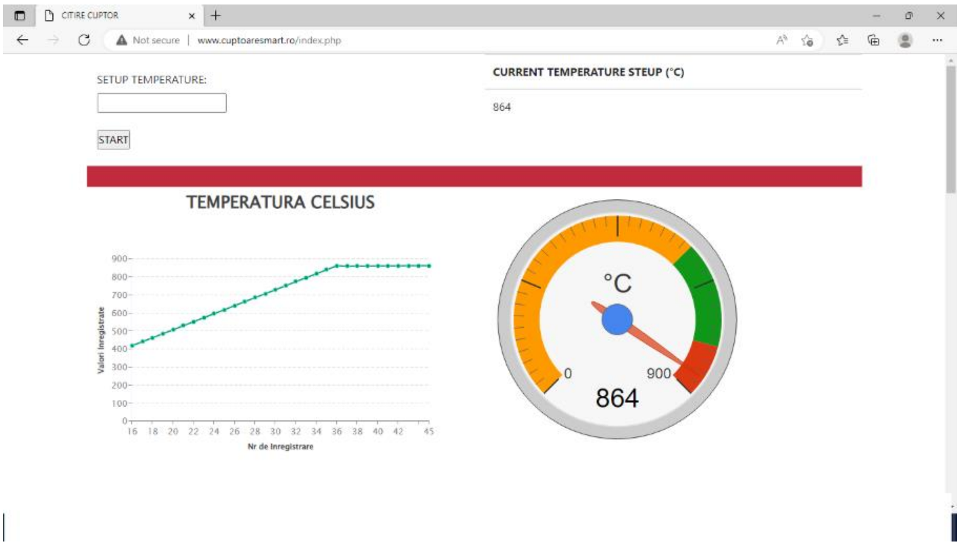

Fig. 4. Synopsis for monitoring the casting process (www.cuptoaresmart.ro)

In Fig. 5 is used a series of notations that have the following meanings: pci is the calorific value of the gas, cp the specific heat of the gas at a certain temperature, cpa the specific heat of the air at a certain temperature, cp the temperatures at different temperatures of the material, Q useful heat, Qarse heat of the burnt gases, Qorif lost through the holes, Qper-through the walls, Qvault-vault, Qvatra-vatra.

In the case of furnaces heated with gas, the realization of the heat balance starting from relation (1) requires solving the following equation:

$$Qcb+ Qfcb+ Qfa+ Qfm+ Qaux+Qfz \; Qu+Qaux+Qpz+Qacz+Qpga+Qpga(exf)+ Qpr+ Qar+Qnep \qquad (2).$$

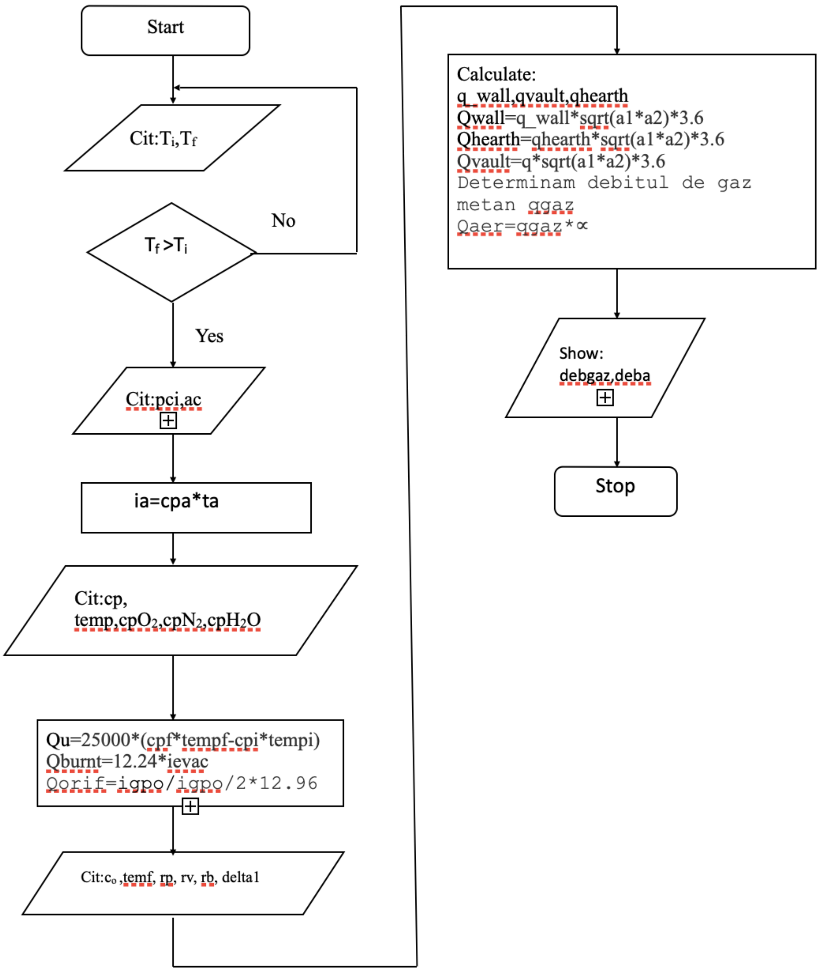

Fig. 5. Logical scheme for calculating gas consumption

The terms used in relation (2) for the heat input are Qcb, representing the chemical heat of the gas, and those symbolized by Qf - the physical heat of the gas, respectively of the combustion air, of the heated material, of the auxiliary materials, of the furnace masonry, respectively at Qu- heat consumed in a useful way and those symbolized by Qp- heat lost through the masonry, heat accumulated in the masonry, heat carried by the exhaust gases, the exfiltrated ones, the heat lost by radiation in the surrounding space and the accidental ones.[4]

Based on the solution presented in this article, an aluminum alloy from the 7xxx series was obtained following the process of using IoT technology, which from the analysis of the microstructure shown in Fig. 6, it can be concluded that the casting process led to obtaining a material with a homogeneous grain.

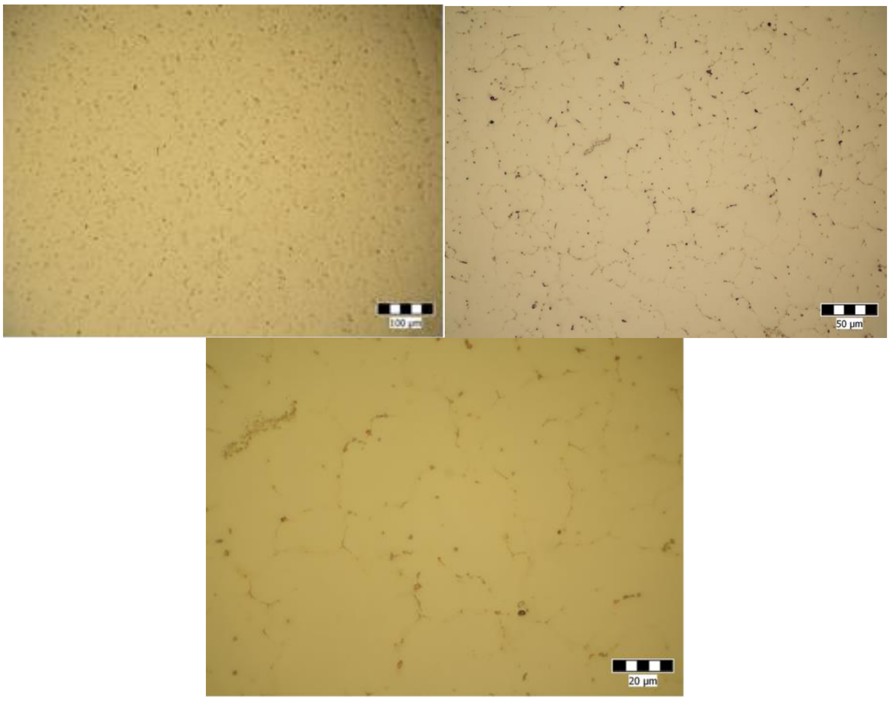

Fig 6. Optical microscope cast alloy

The solution presented by us, as opposed to the classic automation solution, i.e. intelligent automation, by adjusting the parameters that characterize the controller online. The effect is the reduction of gas consumption, due to the linearization of temperature maintenance by using command and control cycles of the millisecond level. These cycles run in real time the mathematical model shown in Fig. 5, thus leading to optimization of the gas/air mixture with which the casting furnace is supplied [5].

In our experiment we found that to process the amount of AA7xxxx material by the standard method the hourly consumption is 5.4 cubic meters. Introducing the millisecond frequency calculation of gas consumption leads to a reduction compared to the standard variant to a consumption of 5.1 cubic meters.

The main advantage identified in the case of this solution is the fact that the identified solution can be applied to SMEs, without any conditionalities given by the field of activity, the investment value not being prohibitive [6,7].

3. Conclusions

The advantage of realizing this proposed solution consists in the management of gas consumption, the price of which is increasing, and the reduction of the degree of pollution, leading, following the analysis of the cost elements involved in the technological process, to a reduction of approximately 6.5% of the specific costs.

Reducing gas consumption from 5.4 cubic metres/hour to 5.1 cubic metres/hour results in a saving of 0.3 cubic metres of gas/hour, i.e. 0.36 euro/hour. This saving is all the more important given the current strong upward trend in fuel prices. The use of the PHP language as a support in the implementation of this program to reduce consumption and store data taken through IoT technology offers the possibility of implementation in a computer system for the management of a technological flow without taking into account certain costs with the implementation platform determining at the same time reduction of costs with fixed assets.

The implementation of the presented concept is also a step in the development of technological processes in the casting field in accordance with the solutions proposed by the 4.0 concept. This case study being received and implemented by more and more Romanian and European industrial companies.

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