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ISSN 0543-5846
METABK 60(1-2) 93-96 (2021)
UDC – UDK 669.14.018:621.747:536.5:620.1.08=111

PROPOSAL OF A NEW SOLUTION FOR MOLD TEMPERATURE MONITORING

Received – Prispjelo: 2020-07-17
Accepted – Prihvaćeno: 2020-09-30
Preliminary Note – Prethodno priopćenje

The paper deals with the proposal of a new solution for monitoring the mold temperature. The mold is used for the production of thermosetting products by pressing technology. At present, the mold temperature is measured separately at sixteen locations of the mold. This measurement is lengthy and laborious, causing production downtime. At the same time, measurement is physically problematic since the mold has a temperature in the range of 130 to 150 °C. The controller must manually record all measured data in the record and re-write the record to the computer. The new solution is to measure four control points at once. The controller will measure these points and the measured data will be sent online to the system. This method will clearly speed up the measurement process.

Keywords: steel, mold, temperature, measurement, process

INTRODUCTION

The basic prerequisite for successful production of a molding is a mold the shape of which is suitable for the molding to be produced. The parameters of a mold clamped onto the press should be optimized and the mold should be filled with a suitable polymeric material. The molds consist of high precision functional and auxiliary parts. The mold must ensure that the production of moldings from polymeric material can be repeated many times over. Therefore, certain requirements are placed on the mold in terms of its strength, toughness, stability, durability and good heat conductivity [1-3].

Tool steel, structural carbon steel and alloy steel are most often used in manufacturing the mold and its parts. Choosing the type of steel most suitable for the individual mold components is a relatively complicated matter [4,5].

The crucial criterion for choosing the type of steel is useful properties of the same, accommodating the functions and working conditions of the individual mold components. The mold designer must select not only the appropriate type of steel but also its heat treatment process. Heat treatment of steel is sometimes a critical factor affecting the life of the mold [6,7].

In the manufacturing industry, various types of machines and equipment fail during operation or show a certain error rate, a deviation from the required default value. Manufacturing products by the application of pressing technology is still one of the best methods of how to process thermosetting materials. Hundreds of board pieces are processed in presses each day, with the focus on molding quality, as the quality is much desired by customers. That is why attention is paid to the timely identification of problems, their analysis and subsequent elimination of deficiencies [8].

A heating temperature of the molds that is constant over time is expected of the molding device. If the temperature is set incorrectly and fluctuating, the granulate inside the mold degrades rapidly. Under higher temperatures the moldings are excessively hardened and lower temperatures result in a material with greater porosity [9].

CURRENT PRACTICE OF MONITO-RING THE MOLD TEMPERATURE

Currently, the temperature of the molds is monitored in two ways. The first type of monitoring is performed by a pressing device, which signals a default heating temperature of the heating plates. This is shown on the display located in the control part of the pressing device. The recorded values are obtained from four sensors placed in the heating plates.

Inside the board, there are heating coils that heat the mold itself. The sensor records the total temperature of the heating plate, not that of its specific parts. Therefore, a second separate measurement is performed using a magnetic thermocouple.

Prior to the monitoring, the measuring points at which the temperature will be measured are determined first. These are specific areas of the mold (Figure 1).

The measuring points are designed to achieve the most accurate result with regard to the location of the heating coils inside the heating plates. A thermocouple is placed inside the mold at the respective measuring

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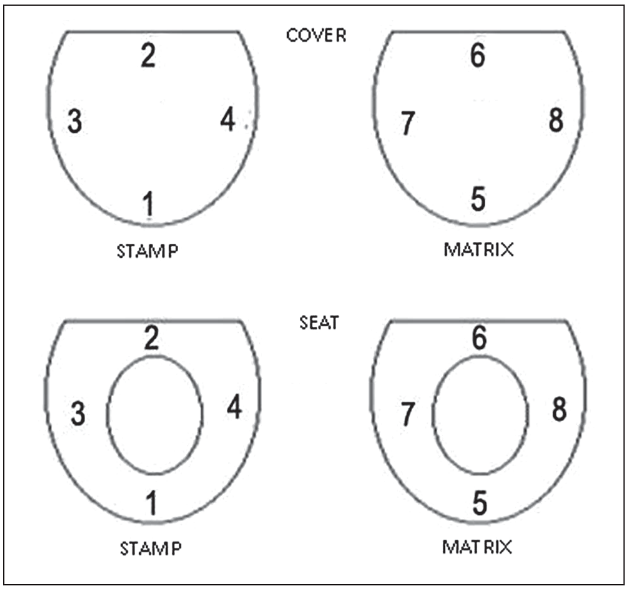

Figure 1 Measuring points in the inner part of the mold

point. The value is immediately shown on the display of the EBRO TTX120 digital thermometer, but it takes a few seconds for the value to stabilize.

Disadvantages of the current monitoring method

The monitoring performed by the pressing device, an integral part of which are sensors built into the heating plates, is not sufficient because it monitors the total temperature of the plate regardless of the state in which the individual heating coils are at. With the quality of the molding in mind, it is necessary the appropriate temperature, corresponding to that of the production process, is ensured throughout the mold. A K-type contact magnetic thermocouple is used to monitor the mold temperature. The mold consists of two parts, a matrix and a die. There are 8 measuring points in total to be monitored. Since there is a mold for both the seat and the cover on the press, the final number of measurements is 16.

Such measuring is time consuming for the worker performing the measurement, as each measuring point must be monitored and read separately, and the recorded value must be written down in the log. Logs recorded in paper form need to be archived, which takes up space in the long run. In terms of safety, heightened attention must be paid by the person performing the measurement, as he moves in the vicinity of the heated molds, since to take each subsequent measurement, he has to apply the measuring sensor to the respective part of the mold.

HOW TO MONITOR THE MOLD TEMPERATURE IN AN INNOVATIVE WAY

The most advantageous method for monitoring the temperature of thermoset processing molds is employing magnetic thermocouples, which cannot be replaced by the contact method in this type of measurement, a fact that has also been found in separate measurements using a thermal imager and a pyrometer. Therefore, an innovative, easy-to-use monitoring device has been designed, universally applicable to all mold types, with the ability to measure the entire part of the mold, and with the output values recorded in a table in electronic form. The measuring device consists of both hardware and software.

The basic hardware component is the structure of a measuring jig in the shape of a cross (Figure 2). Components from National Instruments are used to collect and process sensor data. A measuring card with a USB bus will be used. Bus signals are sent to the device with the installed LabView software.

The evaluated data, recorded in the table, are displayed in the program's graphical environment. A simulation is created in the LabView software environment to monitor and record the temperature of four thermocouples. During the measurement, the simulated signals are replaced by thermocouple input signals. The resulting monitoring values are displayed in a LabView control panel table with the possibility to record data in an external file.

Hardware

This part consists of the structure of the measuring jig and the respective components, which together form the measuring device. The components are designed to be mutually compatible. The hardware base is a cross-shaped structure, in which the magnetic temperature sensors are systematically distributed according to the mold's measuring points. These sensors are mounted in grooves so that they can be moved to measure all mold types. After adjusting the sensor positions according to

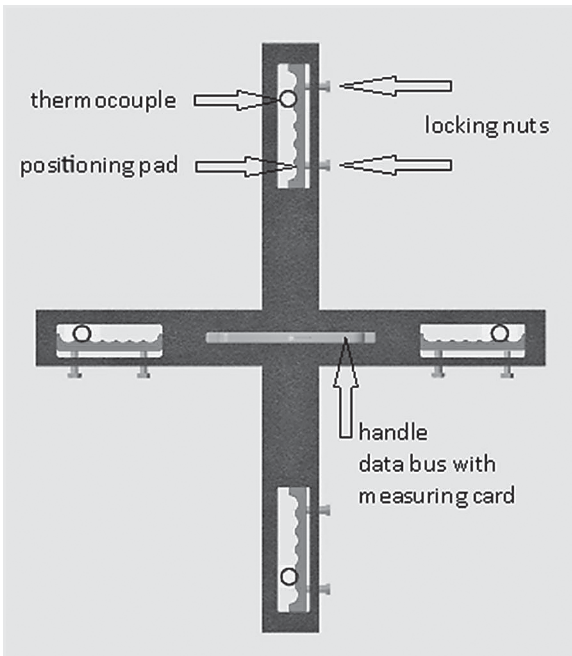

Figure 2 Measuring jig

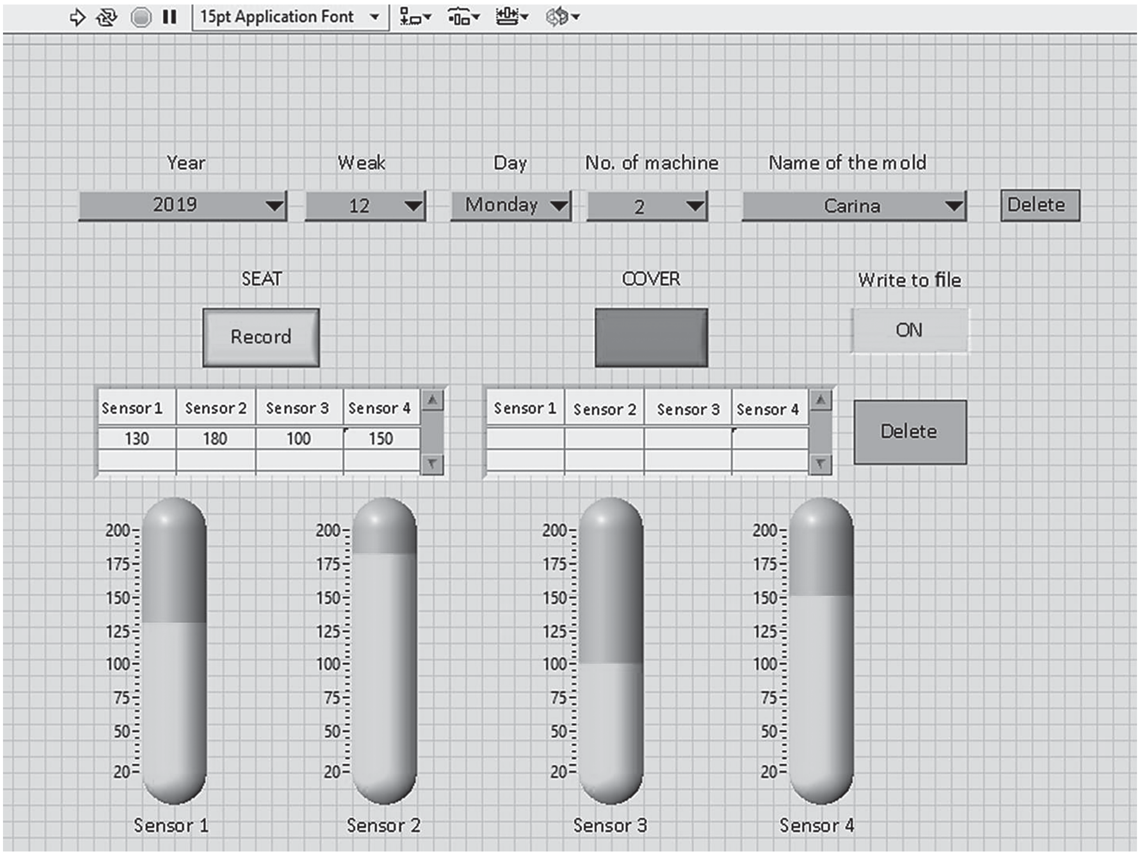

Figure 3 Front panel of the monitoring environment

the respective mold type, tightening the screws prevents the sensors from moving. The screws are located in the groove areas on the side of the measuring jig. In the process of their tightening the pressure pad, which secures the sensor against movement, is pushed. The data bus with a measuring card, to which temperature sensors are connected, is placed in the space of the handle used for transmission.

The sensors are connected to the module using a terminal block. The measuring card converts the detected analog signal from the sensors to a digital signal and travels to the cDAQ bus. The technical data of the measuring card are displayed in Table 1.

Table 1 **Technical data of measuring card [10]**

Number of channels	4
ADC resolution / bit	24
Sampling frequency / S/s	14
Voltage measurement range / mV	± 80
Conversion time / ms	70
Connection	Terminal block
Protection	IP40

Table 2 **Technical data sDAQ 9191 [10]**

Input size / samples	127
Resolution / bit	32
Timing / ns	12.5
Connection	WIFI 802.11
Network protocol	TCP / IP
Power suply	5V 500 mA

Data collection (cDAQ) takes place through Wi-Fi communication via either the IEEE 802.11 or the Ethernet wireless network. The cDAQ bus technical data are given in Table 2. Best suited for easy practical use for the purpose of measurement is a tablet. It must have the Windows operating system.

It is equipped with a protective case against damage, to be used in production. In the design of the monitoring device, this component performs the function of displaying results, so it must be reliable, fast and trouble-free.

Software

LabVIEW software was used to monitor the mold temperature. It is a graphical programming environment based on graphical programming developed by National Instruments [10].

First of all, it is necessary to choose the appearance of the front panel, i.e. the user interface. Attention must be paid to clarity and simple operation. The front panel consists of indicators and controls. We can set up the visual environment according to our own requirements. What the environment will look like, how many controls it will have, the display elements, all of that can be selected from a number of options and relatively quickly and easily. Figure 3 shows the final front panel of the monitoring environment.

After inserting all the elements to the front panel, their respective terminals were created in the block diagram. Using the (Ctrl + E) buttons, we can switch over to the block diagram.

Steps of creating a block diagram:

– It insert elements implementing the writing function of measurement data to a file into the block diagram. By right-clicking the mouse, the Functions function from the Programming palette is displayed. Proceed to selecting the group with File I / 0 write functions, and the Write to Measurement File element inside this group. Click and drag, to place it in the area of the block diagram.
– Use this procedure to insert the simulated signal function into the diagram: Functions - Express - Input - Simulate Signal and the signal selection function: Functions - Express - Sig Manip - Select Signals.
– Next, the terminals are connected using a wiring tool. The mouse cursor changes to a coil as you approach the connection pin. By left clicking on the pin, start dragging the connection to the target pin of the terminal, where the connection is finished by clicking the left button again.

The same procedure as in the front panel – Properties - applies to setting the properties of the elements' function in the block diagram. The properties change according to the program variables. By changing the Write to Measurement function properties, we set the destination location of the file. File name and format.

CONCLUSION

High-quality production of thermoset moldings requires correct setting of the mold temperature. To be able to do so, regular monitoring of the mold and recording of its data for subsequent corrective action is advised. There are two ways of addressing simultaneous monitoring. Mold temperature monitoring from a pressing device and walk-through measurements with a hand-held thermocouple thermometer. The graphical interface located on the press in the control section shows the status of the current temperatures, but the data displayed represent the total temperature of the heating plate, not the status of the heating elements. Such monitoring is not sufficient. Individual monitoring examines the actual state of the mold temperature in its parts featuring the heating elements. The most ideal is the contact method, which yields the most accurate measurement results, but monitoring specific mold locations on the press and recording measurement data in a log takes a lot of time and can be affected by an accidental operator error during the reading. The innovative monitoring device presented introduces a method of universal mold temperature measurement, evaluation the data measured and recording them in the form of an electronic report.

Acknowledgement

This research has been elaborated in the framework of the projects VEGA no. 1/0026/19.

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Note: The responsible for English language is Lucia Gibľáková from Iluminata Linguistics, Slovakia