Program for the Recording Temperature Characteristic in the Furnace

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Abstract: This paper represents the program, which is used to record the temperature field homogeneity in the furnace, using measuring and acquisition system Agilent 34970. This program is made in Metrology Laboratories Orao a.d. in Bijeljina and was originally used to record the homogeneity of temperature field in vacuum furnaces. These furnaces installed in Orao a.d. Bijeljina are intended for heat treatment process of various spare parts for aircraft engines. It is very important to have good homogeneity of the temperature field in the furnace, in order to avoid spoilage in the production of spare parts and thus the great financial losses. Now, the program is used for recording temperature field homogeneity in many companies in the Republic of Srpska, Federation of Bosnia and Herzegovina, Serbia, Montenegro and Croatia. Beside of furnaces, this program is used to record homogeneity of temperature fields in sterilizers, refrigerators, freezers and other areas where temperature field homogeneity is important in manufacturing process technology. After finishing each test, we have received very useful information about the temperature distribution in working volume and discovered critical points, which was necessary to eliminate. Based on these data, some corrective measures are taken in order to ensure better homogeneity of temperature field of the furnace. In case that is not possible to make corrections on the furnace, then, based on temperature field homogeneity report, it is possible to determine optimal furnace working volume in which heat treatment of spare parts for aircraft engines is done. The aim of this is to minimize scrap material during heat treatment in the furnace.

Key words: Program, temperature, characteristics, measurement, report.

1. Introduction

Metrological laboratory Orao a.d. from Bijeljina performs calibration of measuring equipment in the Republic of Srpska, the Federation of Bosnia and Herzegovina, Serbia, Montenegro and Croatia. It has 25 standards for physical quantities, and is accredited laboratory by BATA (BiH Accreditation Institute) according to standard EN ISO/IEC 17025/2006 in terms of qualifications to perform the calibration in the fields: electrical quantities, time and frequency, dimensional size, mechanical size, the size of the fluid, temperature and humidity. Metrological Laboratory performs calibration of temperature sensor, temperature indicators/temperature controls, which are located on furnaces, sterilizers, refrigerators, freezers and other areas where temperature field homogeneity

is important in manufacturing process technology. Beside that, temperature homogeneity survey of furnaces is done by Metrological Laboratory.

Industrial furnaces are used for heat treatment of materials. Inside the furnace there is a heating chamber, in which parts can be placed in order to be heat treated. Heating chamber is usually built of steel casing, around which are fireclay bricks, surrounded by insulation material. As an integral part of the heating chamber are heating elements (heaters), which are usually individually replaceable. Control of the temperature in the furnace is carried out with the temperature controller, and there are one or more temerature sensors (usually a thermocouple), inside the working volume of the furnace. Measuring the temperature using a single temperature sensor in the working volume of the furnace may be one of the reasons for occurrence of uneven distribution of temperature within the working volume of the furnace,

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which results in uneven heating of the parts, which are heat treated. This leads to rejects in production. Also, beside the furnace temperature indicator there is temperature recorder, which is used to record the temperature during the entire period of the thermal treatment of parts in the furnace [3, 4].

Survey temperature shall be the three values of temperature of the furnace operating range, but it can be more or less the temperature values according to users requirements. Thermocouple K-type or N-Type are used for temperature recording in the range from 300 °C to 1,100 °C. Thermocouples are arranged as shown in Fig. 1. For the temperature survay in the range from -100 °C to 300 °C (in case of recording temperature in refrigerators, bathrooms, sterilizers) the Pt100 resistance thermometers are used. Depending on the size of the working volume of furnace we can use 6 or 9 thermocouples.

After being positioned within the volume of the furnace, thermocouples are connected to the measurement and data acquisition system Agilent 34970 using compensating cable K-type or N-type. Measurement data acquisition system continuously measures the temperature at each temperature sensor, and using computer, collected data are downloaded and written in Excel. These measured values are automatically displayed on the graph.

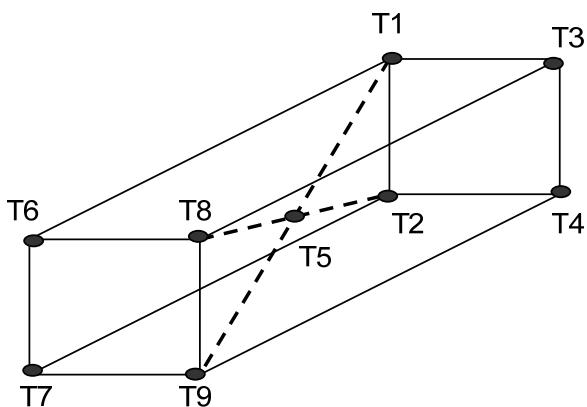Checking the uniformity of furnace temperature field is, usualy carried out in an empty furnace. After

Fig. 1   The arrangement of thermocouples within the furnace volume.

the stabilization of set temperature, measuring is carried out and a record of each transducer with the temperature every 10 to 60 seconds for a period of at least thirty minutes. But it is necessary to see at least five cycles of temperature change.

2. Program Operating

The use of computers in metrology gave a new quality of the measurement process, which is reflected in the next [2].

(1) Metrology opportunities are expanded because the automated measurement using computers allows us to run measurements that previously were not possible to do, because it was hard to execute within a short time interval a large number of measurements on a large number of measuring points.

(2) The quality of the measurement is increased by reducing the total measurement uncertainty with respect to the following:

(a) Influence of the subjective factor in measurement is reduced to a minimum, by excluding possible big error when reading, writing and processing measurement results.

(b) Almost complete identity of the measurement method can be achieved, which significantly improves repeatability of the measurement, and thereby reduces the random component of measurement uncertainty, with multiple repeat measurements.

(c) As a rule, the number of measurement points, and the number of repeated measurements by one measuring point are increased in relation to the traditional measurements, which also reduces the random component of uncertainty in measurement.

(d) The automatic correction is enabled, so, in that way it can be possible to reduce the number of systematic errors, and with it the systematic component of the uncertainty of measurement.

(e) It is possible to perform measurement procedure outside working hours, when the interference of all kinds are reduced, but especially at night when there is a time for the optimal measurement conditions.

(3) Measurement costs are reduced.

(4) Automation of calibration is enabled, which leads to acceleration and higher quality of calibration of referens standard and conventional measuring devices. Also, it is possible to calibrate programmable standards and measuring devices.

(5) Measuring method and procedure for processing the measurement results are not separated, but, moreover, they are carried out simultaneously, with the ability to show measurement results immediately or later by analizing the record.

Furnace temperature uniformity survey in metrology laboratories Orao a.d. is performed using measurement and data acquisition system Agilent 34970. Acquisition System Agilent 34970 consists of the following components:

- control unit with display;
- HP-IB card to communicate with the computer;
- USB / GPIB interface, type: Agilent 82357;
- RS232 interface;
- three 34902A replacement cards with 16 measuring channels for measuring voltage, resistance, temperature using thermocouples with automatic compensation of the cold junction or resistance thermometers (two-wire or four-wire);
- digital multimeter (6 1/2 digit).

Measuring data acquisition systems are remotely controlled with computer. Communication between the measurement and data acquisition system and the PC is made with the USB/GPIB interface Agilent 82357 or RS232 port. USB/GPIB interface is connected to the computer USB port at one end, and to the data acquisition and control-unit Agilent 34970 HP-IB port on the other end.

User program controls operation of acquisition system and it is run on a personal computer. The program determines the type of measurements to be performed and their time schedule, form and time interval of measurement data obtained from measuring instruments. Also the program determines the type of mathematical operations that will be performed on collected data before their alphanumeric or graphic representation. Utility programs are written in a programming package VEE Pro 6.0. VEE Pro is a line programming language primarily intended for software connecting your computer to Hewlett Packard (later Agilent and Keysight Technologies today), measuring instruments, and programmable measuring instruments of other world famous manufacturers. Using the programming language VEE Pro we can connect programmable instruments and devices to a computer through the following interfaces: GPIB, Serial, GPIO, USB/GPIB, LAN.

Software package VEE Pro 6.0. is object-oriented [2]. The program is assembled of finished blocks. Each block represents a sequence of commands, which constitute a single entity (e.g. IF, FOR, UNTIL BREAK loop, mathematical functions, counters, graphics, displays, buttons, etc.). The developer adapts these finished blocks to its program and connects them into a single unit. Software package Agilent VEE Pro allows the user to do measurement using some finished tools, but at the same time it provides the ability for the user to create their own programs. This VEE Pro 6.0 feature provides simple and effective use of the acquisition system possibilities of Agilent 34970. We had used this opportunity and made more programs that allow the computer to communicate with instrumentation and data acquisition systems Agilent 34970. We made programs for many types of temperature sensor (thermocouple K, R, N, and J type, Pt100 resistance thermometers), as well as the programs with a combination of more sensors. Continuous recording of measured values of temperature or voltage, and a graphical representation of these values is done using Microsoft Excel. Fig. 2 shows a part of the program written in a programming package VEE Pro 6.0. which is used for measuring with the data acquisition unit Agilent 34970.

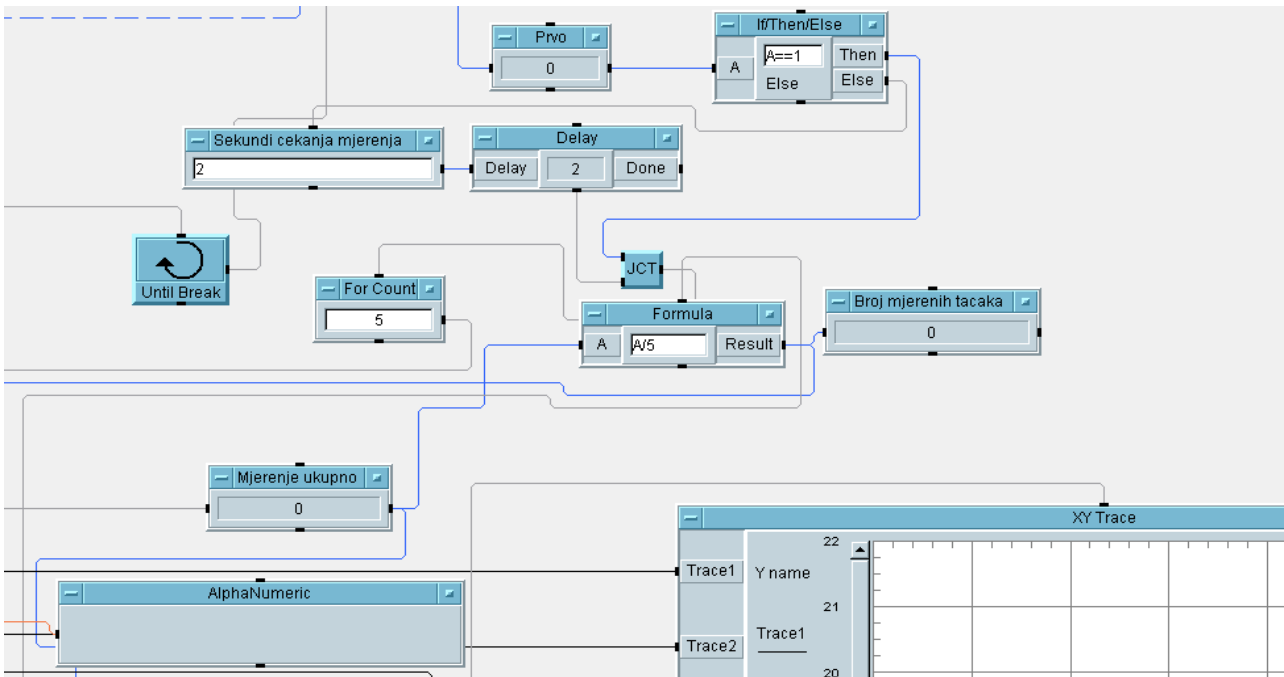Fig. 3 shows the screen layout of the main program for recording furnace temperature field homogeneity,

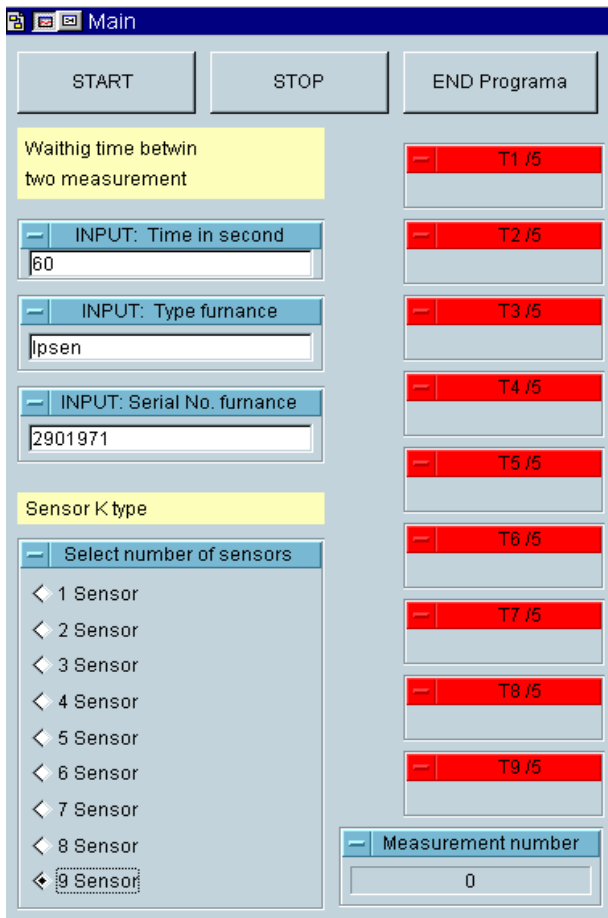**Fig. 2   Programing in VEE Pro.**

Fig. 3   The appearance of the main window.

using thermocouples K type. The operator can choose 1 to 9 thermocouples in order to perform recording. Also, the operator selects the time between the two measurement cycles. One cycle represents the measurement time of measuring the temperature of the all 9 thermocouples and data acquisition system this can execute in one second. Recording homogeneity of temperature fields in the furnace generally could last for several hours, so theoretically we could gain thousands or tens of thousands of measurements from each sensor temperature. This is not a problem for the data acquisition system, but it is for the operator because he, later, has to deal with the large number of obtained data, of which a large number repeats. By monitoring the results obtained by temperature measurement in furnaces, we have found that it is quite enough to make the measurement every 10 to 60 seconds, not every second.

In order to further reduce measurement uncertainty, we programmed the processing of the measured values so that it always shows the temperature averaged over the past five measurements. Display for showing the average value over the past five

temperature measurements is made using a shift register. Shift register is ready made programming block that exists in the software package VEE Pro 6.0. This register can remember, at any time, the last five (or whatever it is programmed) measurement results, which come to its input. On this register output there is average of the five values that are currently in the register. This register exists for each temperature sensor used for measuring. So, output data from this program, which are sent to Excel, are the mean value over the past five measurements for each signal to be measured. Fig. 4 shows the appearance of the Excel document, which presents the results of measurements of the temperature field homogeneity in some furnace. Every column represents the results of the measurements by single temperature sensor and a single measuring cycle is entered in one row. For each measurement cycle, there is a written information about measurement starting time. The time is computer system time. Measurement results for each measurement cycle are automatically displayed on the

Excel chart. To be able to distinguish between the results of measurements of multiple sensor, each sensor measurement results are displayed in a different color. When finished recording the temperature field homogeneity on the site, analysis of the results and the test report are performed subsequently in the laboratory.

Fig. 5 shows a set of diagrams, with the processed results of the recording of homogeneity of temperature with 9 thermocuples K-type in a vacuum furnace on temperature around 600 °C.

Subsequent processing of the measurement results is necessary, because it is very easy to see the diagram, which part of the furnace is the hottest or coldest. It is, also possible to see the differences between each individual sensor temperature and set temperature. In this way we can discover points where the temperature is much higher or much lower than expected. This is a very important information, and based on it, we can conlude if the temperature homogeneity meets customer requirements or relevant standards requirements
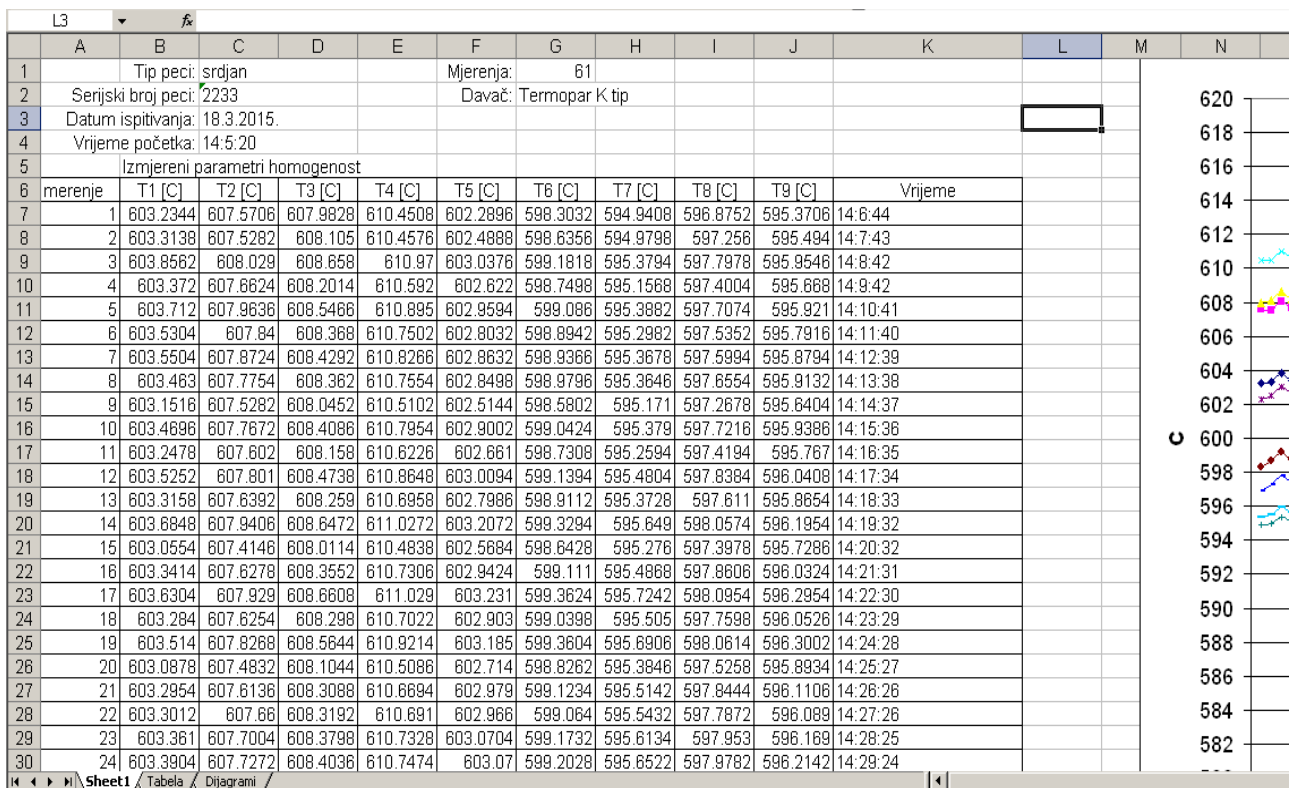

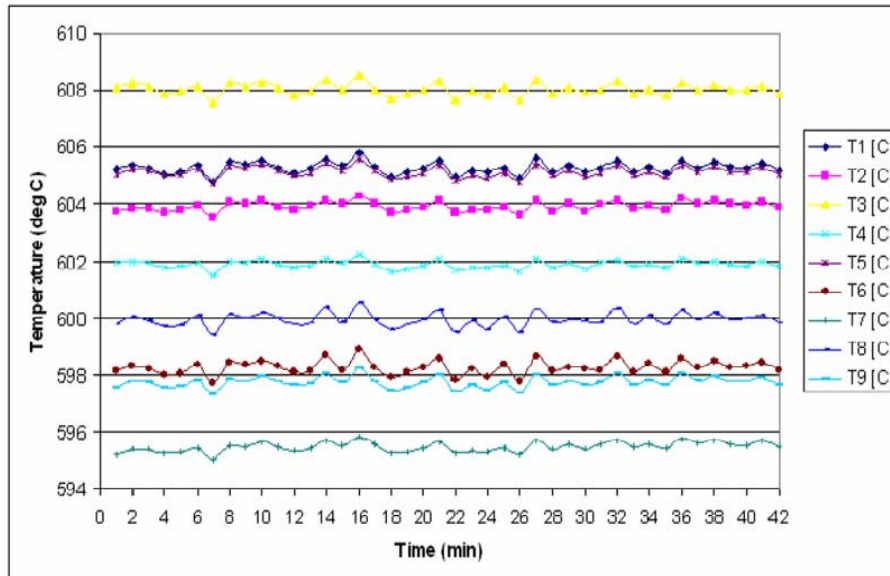**Fig. 4   Excel document with the measurement results.**

Fig. 5   The diagram layout of the temperature field in the furnace.

in whole furnace working volume or only in some part of furnace working volume. Based on these data, we can take some corrective measures on the furnace, in order to ensure the necessary homogeneity of the temperature field. Some of these corrective measures are:

  • replacement of the furnace heater ;
  • replacement of temperature sensor, indicator and temperature regulator in the furnace;
  • replacing insulation material on the furnace;
  • repair of insulation around the furnace door;
  • installation of the fan in the furnace, etc.

After the corrective measures on the furnace have been done, usually we repeat recording of temperature field homogeneity in the furnace, in order to determine whether corrections gave improvements. If it is not possible to make corrections to the furnace, then report of temperature field homogeneity can be used as a basis for determining the optimum volume in which components are placed in order to be heat treated in a furnace.

3. Conclusions

The importance of this program is primarily in the fact that the metrology laboratories Orao a.d. replaced the old instrument for recording temperature field homogeneity in the furnaces with this program and data acquisition unit Agilent 34970. The old instrument was multi-channel temperature meter and a printer. Measured values on all chanal were written in the form of dots on the paper. It was the instrument whose accuracy class satisfies requirements of the temperature field homogeneity shooting, but it was extremely difficult to process and analyze data, particularly when 9 temperature sensors were used for temperature measurement. The biggest advantage of using data acquisition systems for recording homogeneity of temperature fields in the furnace is post processing and analysis of data and the ability to view and print obtained results in various forms. Also, it is easier to create test reports. Test reports are made according to international standards, but the content of test report is not the subject of this paper.

The main contribution of using measurement and data acquisition system for recording temperature homogeneity in the furnace can be expressed as follows:

(1) High-speed measurement

Increase of measurement speed was achieved thanks to a much higher computer performance speed compared with the man as the operator. Operator who reads and writes the measurements results obtained

with nine temperature sensor needs much more time than when computer does. Because of higher measurement speed total measuring time is shortened, and thus reducing the cost of testing.

(2) The smaller measurement uncertainty

The influence of the subjective factor in measurement is reduced to a minimum, by excluding possible big errors in reading, writing or the processing of the measurement results. By averaging the measurement results measurement uncertainty type A is significantly reduced, which comes from measurement results repetition.

(3) Flexibility of the expression and presentation of the results of measurement

Temperatures from all temperature sensors are displayed on one screen, which is much clearer than the observation of individual instruments. All values measured by data acquisition system can be immediately printed on the printer and stored in the Excel document.

Thus, after completion of the test, the stored values can later be processed, analyzed, and printed.

This program, with very little change, could be used for other various measurements of temperature, when the temperature measurement is performed simultaneously with multiple sensors.

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