MULTICHANNEL MICROPROCESSOR CONTROLLER FOR DATA COLLECTION FROM THERMOCOUPLES

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Development of 9-channel microprocessor controller of the system of welding thermal cycle recording with digital interface for communication with PC of Ethernet-100Base-TX is presented. CAT and WRT type thermocouples are used as temperature sensors. Application of Internet-protocol of data exchange with PC of TELNET type allows designing automated system for research performance in the field of multipass welding at minimum cost.

Keywords: *multipass arc welding, thermocouple, microprocessor controller, Internet, TELNET, sigma-delta ADC*

Performance of experimental studies of mechanical properties of welds in critical structures involves application of expensive welding equipment and consumption of considerable material resources, such as welded samples metal, electrode wire, shielding gas, as well as power. Therefore, one of the main objectives at experiment performance is ensuring reliable recording of maximum possible scope of information to obtain the most complete idea of the nature of structural changes in the HAZ metal of the item being welded. Of considerable interest is the information on dynamics of variation of spatial temperature field in the welded item during performance of mutlipass arc welding. The most widely accepted in welding are contact methods of temperature measurement using chromel-alumel (CAT) and tungsten-rhenium (WRT) (VR5/VR20) thermocouples which allow measuring temperature in the item up to 1300 (CAT) and 2500 °C (WRT), respectively, with ±1 °C error.

At present use of corporate Internet network is an effective method of creating computerized systems for research performance. During applied research in the field of arc welding using Internet

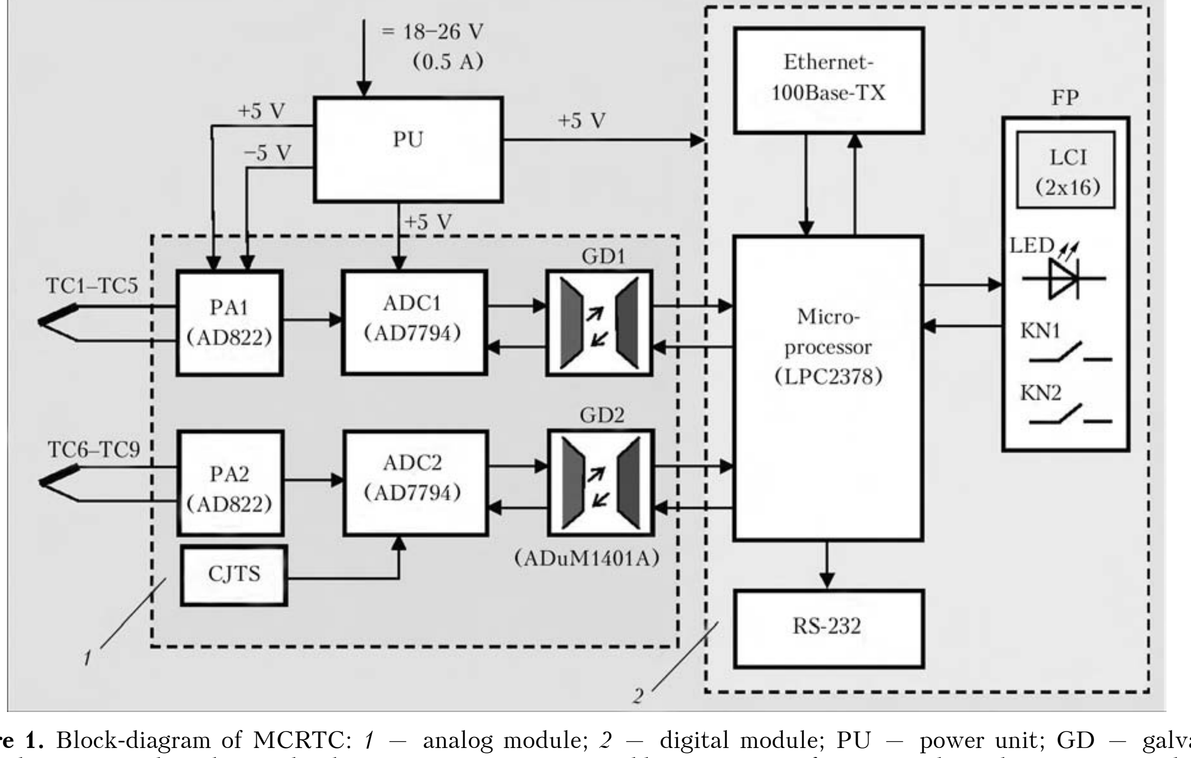


Figure 1. Block-diagram of MCRTC: *1* — analog module; *2* — digital module; PU — power unit; GD — galvanic decoupling; LCI — liquid-crystal indicator; KN1, KN2 — control buttons; FP — front control panel; PA — preamplifier; LED — light-emitting diode; TC — thermocouples; CJTS — sensor of «cold junction» temperature

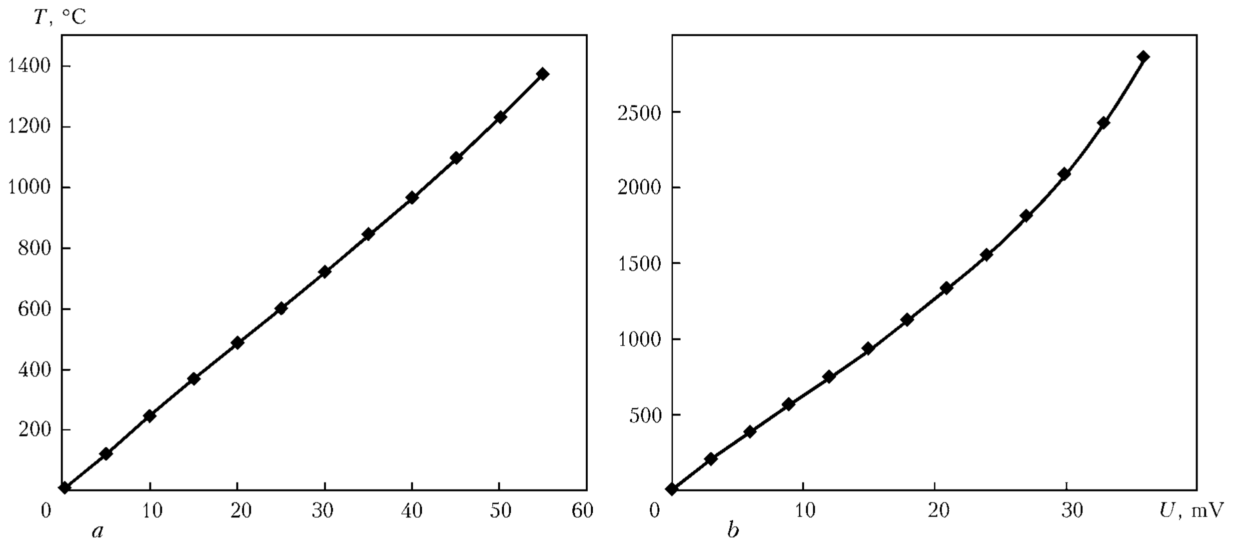


Figure 2. MCRTC metrological characteristics: *a* — mode of thermocouple of CAT type; *b* — mode of thermocouple of WRT type (A1)

technologies it is possible to solve the problems of both galvanic decoupling and reliable data exchange between the controllers and PC. Ethernet-100Base-TX bus is usually used as physical interface, and Internet-protocols of TCP/IP and TELNET type ensure reliable connection and error-free data transmission. In connection with the fact that batch-produced thermocouple controllers with Internet connection are not available now, PWI developed a microprocessor controller, designed for recording thermal cycles of multipass welding [1] (further on referred to as MCRTC) which ensures digitizing signals from 9 thermocouples and issuing the results to PC by TELNET protocol with real-time labels (Figure 1).

MCRTC is designed as an analog and digital modules, connected to each other through galvanically decoupled interface of SPI type. Digital module uses 32-bit microprocessor LPC2378 (NXP Company). Analog module is realized on the basis of OA microcircuits of AD822 type and

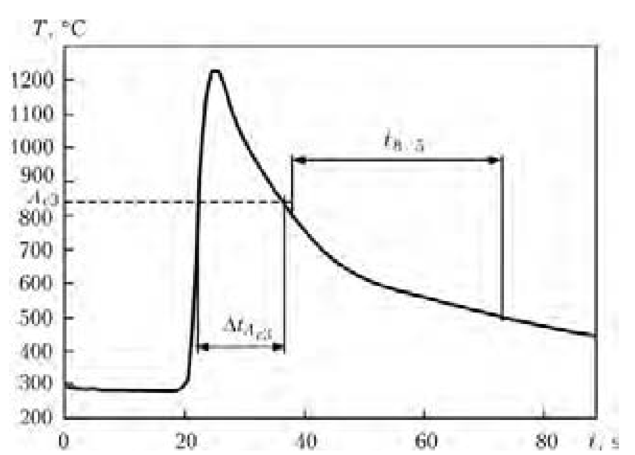


Figure 3. Recorded thermal cycle of multipass welding (fragment): $\Delta t_{A_{c3}}$ = 15 s; $t_{8/5}$ = 37 s

24-bit sigma-delta ADC of AD7794 type (Analog Devices Company). «Cold junction» temperature is measured by thermistor B57861S with 10 kOhm resistance (EPCOS Company). Range of measured temperatures for thermocouples of CAT type is equal to 0–1300 °C, and for thermocouples of VR5/VR20 type it is 0–2500 °C. Sampling rate is 3 Hz for all the channels.

Application of galvanically decoupled interface of Ethernet-100Base-TX type allows placing MCRTC in the immediate vicinity of the object of studies, and removing the PC to up to 100 m distance, that will shorten the length of thermocouple wires to 1 m, and minimize the level of electromagnetic noise and interference.

Information exchange with the computer is performed through network protocol of TELNET type, which ensures storing the data received from the controller into the file specified by the user. MCRTC operation is controlled using three special commands: TIME — current time setting; TP — thermocouple type selection, and MEAS — sending thermocouple readings to the computer.

Calculation of thermocouple readings (in Celsius degrees) is performed by the known method based on the read value of thermocouple emf using calibration charts [2] and allowing for cold junction temperature. To assess the controller metrological characteristics, constant voltage was applied to its inputs through a resistance divider from a galvanic power source. Voltage at controller input was monitored by digital voltmeter MASTECH MS8218 (measurement pitch of 0.001 mV). After program displacement compensation at shorted inputs, metrological characteristics of all the measurement channels practically coincided. Differences of obtained «voltage-temperature» characteristics (Figure 2) from graduation charts [2] did not go beyond the limits of error ±0.2 °C.

Figure 3 shows a fragment of thermal cycle obtained in an experiment with multipass welding of V-shaped groove by short sections, using the developed controller and subsequent data processing by MS Excel program. A thermocouple of CAT type with 0.6 mm wire diameter was used in the experiment, which was caulked in on the surface on an item from low-carbon steel at 5 mm distance from the groove edge. From Figure 3 it is not difficult to assess the time of metal staying above point A_{c3} (15 s), and time $t_{8/5}$ of cooling from the temperature of 800 to 500 °C (37 s). Maximum temperature in the controlled zone was 1240 °C.

Developed microprocessor controller used for identification of mathematical model of the heat source in MIG/MAG welding, as well as during investigations of structural transformations in steel in multipass welding, demonstrated a high stability to welding interference and reliability of data transmission in PC.

1. Dolinenko, V.V., Skuba, T.G., Vashchenko, O.Yu. (2012) Microprocessor controller for registration of thermal cycles of multipass arc welding. In: *Abstr. of 11th Int. Conf. on Instrument Engineering: State-of-the-Art and Prospects* (24–25 April 2012, Kiev). Kiev: NTUU KPI, 223.
2. *GOST R 8.585–2001*: Nominal static characteristics. Instead of GOST R 50431–92, MI 2559–99. Introd. 21.11.2001.

NEWS

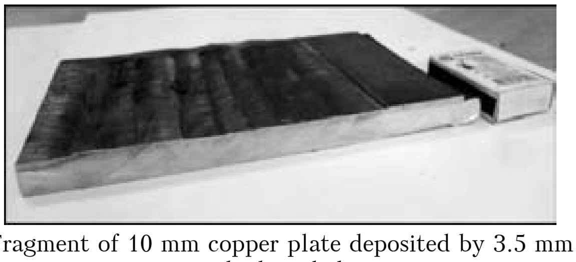
DEPOSITION OF NICKEL COATINGS ON COPPER PLATES OF MOLDS OF MCCB USING FRICTION STIR SURFACING METHOD

Intensive wear-out of the internal surfaces of the molds takes place in a process of continuous casting of steel that makes extremely high demands to quality of surfaces of the copper plates. Copper plates with the nickel coating have the highest working capacity. This results in increased wear resistance of the copper plates in 3–4 times.

Process of coating using FSS method

Technology for deposition of nickel on the copper plates of machines for continuous casting of billets using friction stir surfacing (FSS) based on friction stir welding method was developed at the E.O. Paton Electric Welding Institute of the NAS of Ukraine.

Welding is performed by a face of rotating tool having an extended pin which moves in a weld metal in welding direction. Plastification of the metal takes place in the metal-to-tool friction along the butt of surfaces being welded that results in its stir and formation of weld.



Fragment of 10 mm copper plate deposited by 3.5 mm thick nickel

Material of the surfacing tool should be high-temperature and heat-resistant that allows working at 1000–1200 °C temperatures. Shape of the tool has an important role at that. Thus, the best results were obtained in application of a tool with conical pin.

Working tools were manufactured from ultra-hard materials, i.e. tungsten-cobalt hard alloys with microadditions of refractory compounds and cubic boron nitride, and they had complex configuration.

Lap slot weld is formed in a tool movement. Successive overwelding of such welds with overlaying allows nickel surfacing on the copper plate.