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SYSTEMS FOR VISUALIZATION OF WELDING PROCESSES IN REAL-TIME MODE USING NOISE-PROOF CHANNEL FOR TRANSFER OF SECONDARY ELECTRON EMISSION SIGNAL

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Noise-proof digital systems were developed for processing, transfer and input into computer of a secondary electron emission signal with visualization of welding processes in real-time mode. The equipment was developed for conversion, transfer and processing of the secondary electron emission signal, namely block of processing, conversion and transfer of the secondary electron emission signal; block of input and decoding of the digital electron secondary emission signal; block of processing, conversion and transfer of the secondary electron emission signal via Ethernet. Video monitoring systems using the equipment for conversion and transfer of the signal and equipment for conversion and information transfer into computer were developed and tested. Software was designed. The investigations of developed video monitoring system were carried out, their comparative analysis with video monitoring system RASTR, widely used in the units for electron beam welding, were performed. 6 Figures.

Keywords: *electron beam welding, interference immunity, electron beam, secondary electron emission, video monitoring, image*

EBW is widely used in industry for producing the parts of critical designation, first of all, in aerospace and power branches due to vacuum protection of molten metal from gas saturation, small welding deformations and possibility to achieve high weld depth-to-width ratio. Image of a weld and butt of the edges can be received simultaneously with welding processes using electron beam in a mode of low current scanning of metal surface.

Computer technologies allow accurate guiding of electron beam in the butt, but only at sufficiently high ratio, desirably more than 20 dB, of useful and noise signals of the secondary electron emission (SEE). Usually, this ratio makes from 12 to 14 dB.

Parasitic noises are formed in a cable transmitting analog signal of the SEE from preamplifier to device of information input into computer. A noise signal is imposed on useful one, at that it has wide amplitude and frequency spectrum. It is extremely difficult to select and eliminate the noise signal, therefore, it is necessary to minimize its effect on the useful signal.

It is possible to eliminate or significantly reduce the effect of noises on the SEE signal by means of its conversion into digital form and transfer by noise-proof digital channel.

Currently, the units for EBW widely use RASTR video monitoring system designed for displaying the welding processes in real-time mode on a screen. RASTR block-diagram is shown in Figure 1.

Scanning field, created by focused electron beam of EB gun (EBG), is formed in a control and scan block. Scan control signals are fed to a deflection system (DS) of EBG. Electron scanning beam is directed on the surface of examined object. A flow of electrons, reflected from examined area, comes to a secondary electron probe (SEP), in which an electric

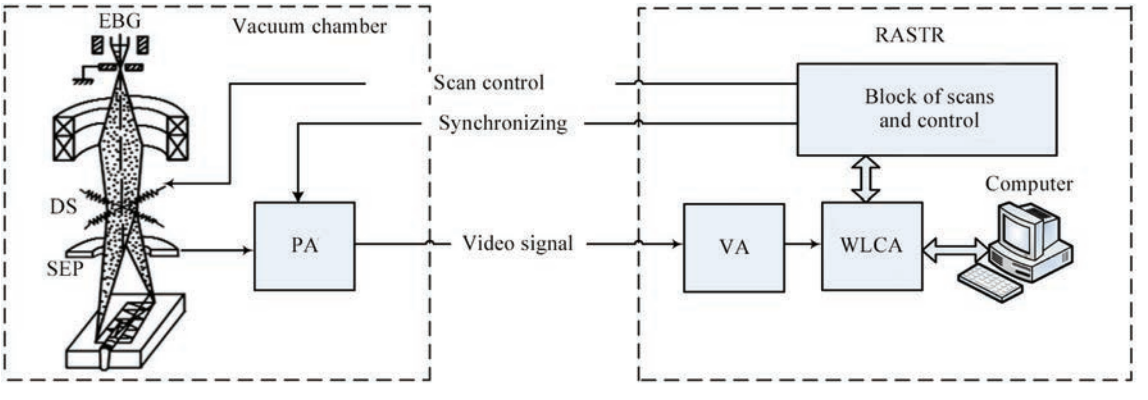

Figure 1. Block-diagram of video monitoring system RASTR (see designations in the text)

signal of the SEE is formed. This signal is transferred to a preamplifier (PA), located in vacuum chamber. The signal from the preamplifier is fed to a video-amplifier (VA) of RASTR system. After VA the signal comes to WLCA block, in which an analogue signal of the SEE is converted into digital code. The data from WLCA block come to control computer. In the computer received information is processed by a program and video image of welding process is formed in real-time mode.

Analogue signal of the SEE in RASTR system is transmitted from PA to VA using long coaxial cable. The PA is located in a unit vacuum chamber, the VA is in a control cabinet out of the vacuum chamber. The coaxial cable is laid in the cable channels close to power and signal cables of a drive control system, high-voltage cable of the EBG and cables of the executive and control devices. The electric motors of drives are regulated by alternating current, waveform of which is different from sine one. This current develops high-frequency electromagnetic interferences in a wide spectrum of frequencies and amplitudes.

Interferences are overlaid on useful signal of the SEE. Effect of the interferences results in distortion of image of welding processes and depression of performance of a system for automatic butt tracking.

Application of a digital channel for information transfer is proposed as an efficient method preventing the effect of interferences on a signal of the SEE. An analogue signal of the SEE in the direct vicinity from the PA should be converted into digital code and obtained information is transmitted through noise-proof digital channel.

Systems for processing, transfer and signal input into computer was developed for realizing the given task by the PWI specialists together with International Center «Institute of Applied Optics» of the NAS of Ukraine.

The following equipment was developed:

- block of processing, conversion and transfer of signal (BPS), in which an analogue signal of the SEE is converted into digital code;
- block of input and decoding of digital signal (BDS), in which information on signal of the secondary electron emission is converted from digital code to analogue signal;
- block of processing, conversion and transfer of signal via Ethernet (BPSE), in which an analogue signal of the SEE is converted into digital code and in accordance with TCP/IP protocol is transferred into computer via Ethernet.

Systems for imagining the welding processes in real-time mode were developed by PWI specialists using equipment indicated above:

- video monitoring system using the equipment for conversion and transfer of signal (ECTS), and
- video monitoring system using the equipment for conversion and information transfer into computer (EITC).

Software allowing processing the information on SEE signal and forming an image of welding process in real-time mode was developed for EITC. Investigations of the video monitoring system were carried out and their comparative analysis with RASTR visual system was performed.

Description of the developed systems is given below.

Block-diagram of video monitoring system using ECTS is presented in Figure 2.

Scanning field, developed by focused electron beam of the EBG, is formed in a block of control and scans of RASTR system. Scan control signals are fed to deflection system of the EBG. Scanning beam of electrons is directed on a surface of examined object. A flow of electrons, reflected from examined surface, is fed to SEP, in which an electric signal is formed. This signal is transferred to BPS of ECTS system. In BPS a signal of the SEE is amplified, synchronized with control signals and converted into digital code. Data are transferred by wire noise-proof cable outside the vacuum chamber to a control cabinet, where BDS is located. BDS converts the signal into analogue signal, which is transmitted to VA of RASTR system, where an image of examined object is formed in real-time mode.

In ECTS system the signal of the SEE is transferred in a digital form through wire shielded twisted pair cable.

Information transfer in the digital form provides for high interference immunity of a transferred signal.

Block-diagram of system of video monitoring using EITC is given in Figure 3.

Scanning field, developed by focused electron beam of the EBG, is formed in a block of control and scans. Scan control signals are fed to DS of EBG. Scanning beam of electrons is directed on a surface of examined object. A flow of electrons, reflected from examined surface, is fed to SEP, in which an electric signal is formed. This signal is transferred to BPSE. In BPSE the signal of the secondary electron emission is amplified, synchronized with control signals and transformed into digital code. Obtained data in digital form are transferred outside the unit vacuum chamber. The information comes to Ethernet port of computer for program processing. Image of the examined object is displayed on the screen in real-time mode.

Data are transferred in a digital form through wire Ethernet cable in accordance with network protocol TCP/IP, that provides for high interference immunity of a transferred signal.

Experimental results and discussion. Operation efficiency of the video monitoring systems ECTS and

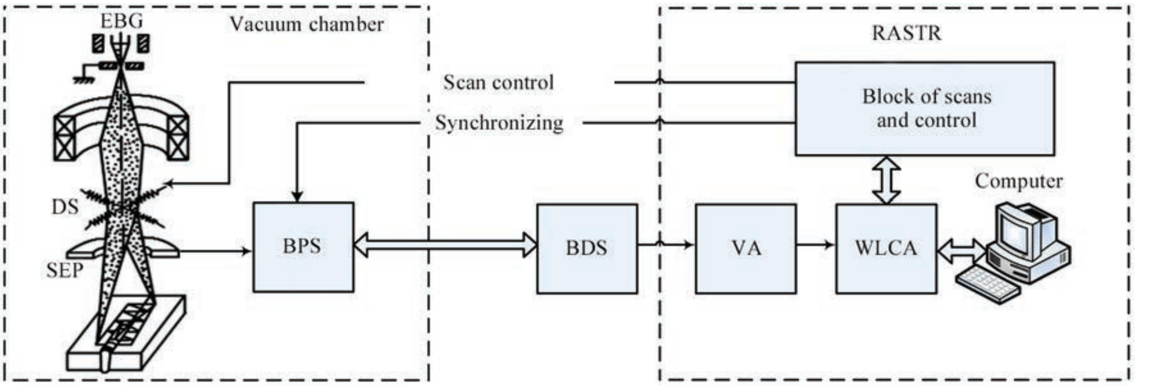

Figure 2. Block-diagram of EITC system (see designations in the text)

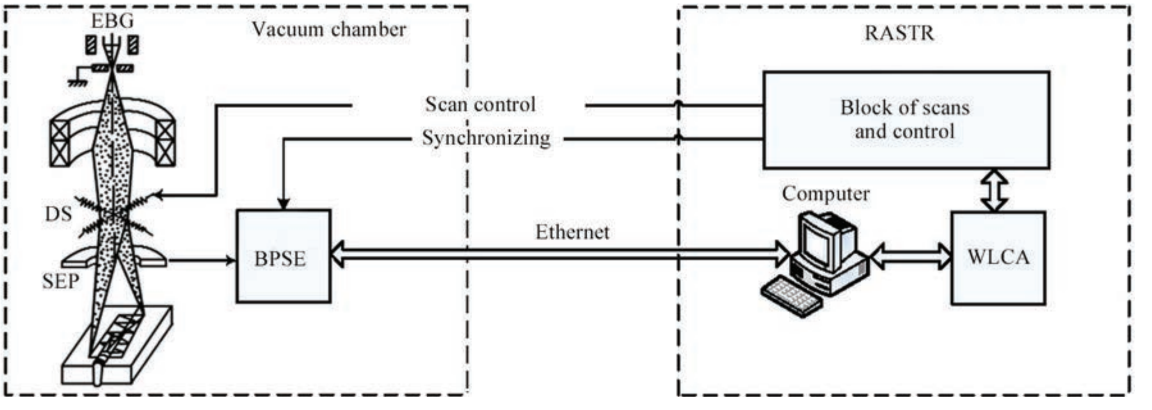

Figure 3. Block-diagram of EITC system (see designations in the text)

EITC was evaluated using a method of comparative analysis with the video monitoring system RASTR.

Quality of imagining of welds and reference objects as well as presence of interferences caused by process equipment was compared.

Tests were carried out on a test bench and industrial unit for EBW.

Investigation of video monitoring system using test bench. A test bench is developed based on EBW small-size unit of SV-112 type.

Quality of image of the investigated objects was tested visually.

Images, received using different imagining systems, are given in Figure 4. Quality of the image made by RASTR system is acceptable for performance of process works on EBW equipment.

The image made by ECTS system is acceptable for performance of welding and process works, but is inferior in image quality of the objects made by RASTR system. It is necessary to note lower image detailing, that is caused by loss of information at double transformation of a signal of the SEE from analogue to digital and back.

The principle difference of ECTS system from RASTR system lies in the method of transfer of the SEE signal from secondary electron probe to information imagining block. Information in ECTS is transferred in digital form, that provides for interference immunity of data transfer. This makes an advantage of ECTS system.

Images in Figure 4, *c*, *f* were made by EITC imagining system. It is necessary to note higher image quality of examined objects, better detailing in comparisons with image made using RASTR system. Information on SEE signal in EITC system is transferred in a digital form, that provides for interference immunity of data transfer. Effect of the interferences on the SEE signal is minimum. It makes an advantage of EITC system in comparison with RASTR system.

An advantage of EITC system in comparison with ECTS system is an absence of multiple conversion of

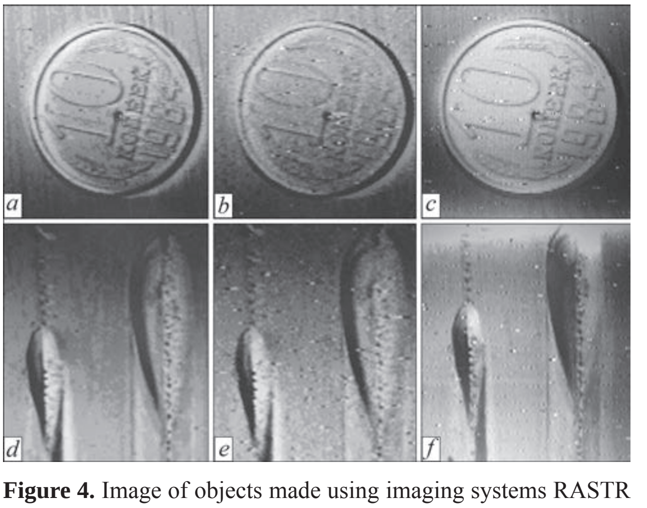

Figure 4. Image of objects made using imaging systems RASTR (*a*, *d*), ECTS (*b*, *e*) and EITC (*c*, *f*)

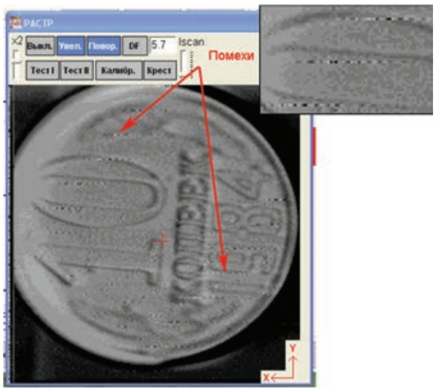

Figure 5. Interferences on investigated object image form by RASTR system

Figure 6. Image made using ECTS system

signal, which results in information loss and, as a consequently, deterioration of quality of object imaging.

However, application of EITC system in existing EBW units with preinstalled RASTR system will provoke change of hardware and software parts of the equipment, that is not always acceptable.

Application of ECTS system for modernizing does not require introduction of changes in hardware part of the equipment. This is an advantage of ECTS system in comparison with EITC system. Preferred application of EITC in comparison with RASTR and ECTS is obvious in newly developed equipment as well as in units requiring substantial modernizing.

Investigation of video monitoring system using EBW commercial unit. Investigation of the system was carried out on commercial unit of KL-181 type. Effect of the industrial interferences on image quality was investigated as a result.

Figure 5 shows an image of tested object formed by RASTR system on KL-181 unit. The interferences in form of horizontal bands displaced in diagonal can be observed on the image. The interferences were caused by an effect of drive control signals on analogue signal of the SEE.

Optimum location of the cables inside the unit is used in practice for interference control. It allows reducing of effect interferences, but does not eliminate them. Transfer of signals of the SEE in a digital form allowed significant improvement of the interference immunity. Figure 6 shows an image of tested object made using ECTS system.

The image has no interferences in form of diagonal bands, that verifies necessity of application of digital noise-proof channels for transfer of a signal of the SEE.

Conclusions

1. Signal of the SEE for elimination of the interferences is proposed to convert from analogue form to digital one and transfer through noise-proof digital channel. A signal converter shall be located in the direct vicinity to the secondary electron probe.

2. New equipment was developed for conversion, transfer and processing of the signals of the SEE, namely block of processing, conversion and transfer of the secondary electron emission signal; block of input and decoding of the digital electron SEE signal; and block of processing, conversion and transfer of the SEE signal via Ethernet channel.

3. The systems were developed for imagining the welding processes in real-time mode using noise-proof digital channel for transfer of the SEE signal, namely video monitoring system using the equipment for conversion and transfer of the signal; video monitoring system using the equipment for conversion and information transfer into computer.

4. Software was developed for a video monitoring system using the equipment for conversion and information transfer into computer.

5. Investigations of the developed video monitoring systems ECTS and EITC, and their comparative analysis with widely used in present time imagining system RASTR were carried out. Video monitoring systems are applicable for further operation. They provide for high interference immunity of transfer the SEE signal, acceptable quality of imagining of objects and welding processes in real-time mode.

6. ECTS system is designed for modernizing the EBW units having installed RASTR video monitoring systems. EITC system is designed for application with newly developed EBW equipment as well as for substantial modernization of the equipment with RASTR video monitoring system.

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