THE LENS EFFECT IN THE SECONDARY EMISSION BASED SYSTEMS OF JOINT SEARCHING IN EBW*

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Abstract

The results of the developed scan lines generator for the magnetic correctors system are presented. Get the dependency between various types of scan lines and distribution of the allocated energy in the electron beam welding facility. The lens effect in the secondary emission based system of joint searching, using 3-fragment linear scan line is received. The accuracy of the joint searching system (the error of the positioning system) is 0.05 mm, the lens effect can decrease this value several times. The requirements for the creation full calibrated system of joint searching are listed.

INTRODUCTION

Electron beam technologies based on using beam source (electron gun) with accelerating voltage about some decades kilovolts and power from several watts to several decades kilowatts. The joint search system is very important part of the electron beam welding facility, it allows scan the surface of the target and sees the map of scanning area with asperities of the surface, in particular, the system allows see the joint.

Basically, the principle of functioning the joint search system is reflection and reemission the part of electrons, which interact with the target surface. The back current is measured by the isolated electrode. Different areas of the surface have different reflection coefficient, so we can see the different current values depending on the surface traits. In practice, we need the beam reflecting system with a reading of values from sensors.

EXPERIMENTAL SETUP

The experiments were conducted in the Budker Institute of Nuclear Physics (Siberian Branch of the Russian Academy of Science). The experimental setup has the vacuum chamber, the electron gun (up to 60 kV) with current ability up to 750 mA [1], two-coordinate reflection system based on cos(theta) coils, magnetic amplifiers (bipolar current sources up to 1.5 amperes), electrode, amplifier, and processing block of the joint search system.

Processing block include several channels of digital-analog converter which form the signal for magnetic system, one channel of analog-digital converter, which measure the value from the sensor, FPGA based device for synchronous communication between DAC and ADC, and the single-board computer, which provides the network access for staff of the facility, and realizes the interface to change settings of scanning (by changing internal values in FPGA). Figure 1 shows the main equipment of joint searching system, and interaction point with the rest of facility equipment.

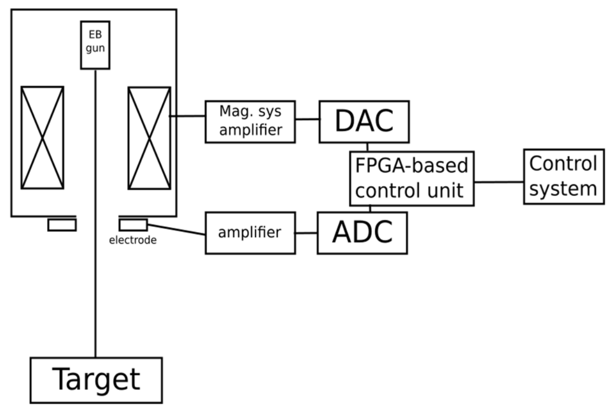

Figure 1: Scheme of the joint searing system.

THE SCANNING PROCEDURE

Despite the scanning system has two coordinates, usually for practice purpose we need only one of them. The beam intersects the joint each period of scanning, and the target movement system moves the detail along the joint. As a result, we can see the position error for all length of the joint. The dual scan uses when we need to get the frame of the scanning area. The experimental setup allows creating this type of scan.

We can illustrate the signal formed by the scanning system. In the simplest case, this signal is sawtooth. Usually, we use a sawtooth-like signal with positive and negative ramps (triangle wave). Using of the one-side sawtooth signal may give us negative effects with quality and appearance of the seam (in the case, when we weld the details with scan), so we use symmetric types of scan.

The scanning system forms the map of the surface, and the size of the map corresponds to the size of the scanning area. We can change the amplitude of the scan, depending on the view, which we want to see. It is possible, to get the ratio between scan amplitude and width of the scanning area. Due to the incline of the beam, the ratio will be changing for each new vertical position of the target. This problem can be solved by using 2 magnetic correctors, one above the other, with the birefringence of the beam. This moment we have the second pair of magnetic correctors but haven't made hardware and software modifications in the control system to get this opportunity. So we fix the distance between the beam gun and target in order to get

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repeatability of experiments (approximately 100 mm from the end of the gun).

The quality of the plotted map depends on the noises level in reflected beam current, the geometry of the collector electrode, and the amplification factor. Besides, we can use programming methods to increase the quality of the image. One of them is filtering methods applying to the big set of data measured by special function in automatic mode. The user interface allows seeing the map in real time, with noises. It is very useful for a primary setting of the target position.

THE LENS EFFECT

The architecture of the joint searching system allows setting any data sequence to form the signal for the magnetic system. We develop the 3-stage linear signal, with the ability to set different incline and different size of each stage. Two parameters set the form of signal, and the program generates it automatically. The most interesting form shown on the Fig. 2. The beam moved with small velocity on the central part of the scan line and has high velocity at the edges of the scan line. The same time, the surface map shows the signal evenly in time, so the central part of the scan line has a bigger segment in the surface map. We named this "the lens effect".

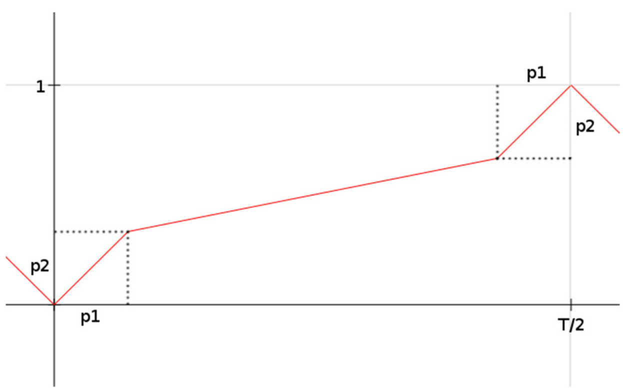

Figure 2: Three-stage linear signal.

The parameters of this digital lens could be adjusted by the scan line generator. The shape could be transformed in various waves with different lens effect (from triangle wave to straight line or square wave).

The shape of the signal influences to power distribution in the welding application. The form with lens effect in the central part of the scanning area increases energy release in the joint. Thus the depth of the seam is increasing and we can improve welding quality and weld with less beam current.

ACHIEVABLE ACCURACY

This section describes the boundaries and restrictions of the joint search system and says about accuracy, which we can reach on the facility. First, the beam has it's own size, the lens of magnetic optic system of the beam could reduce the size of the cross-section of the beam, but the minimum size is limited by gun geometry, beam quality and influence of space charge of the beam. Gun of BINP EBW facility has beam minimum size about 0.5 mm (with current used for scanning).

Second, the control signal is formed by 14 bit DAC. The amplitude of the beam trace with using maximum range of the DAC is 2 cm (could be increased by using another model of DAC). One LSB corresponds to 1.25 um of beam trace; this is the extreme achievable value of minimal beam movement. For scan shape, we use an array of forming a line with 500 values. The length of the trace segment between two neighboring values with maximum scan amplitude is 40 um. By reducing the amplitude or by using the mode with lens effect we can increase the resolution.

Besides the spatial properties, there are temporal characteristics of the scanning system. The frequency of the scan is limited by Foucault currents and capabilities of the DAC. Practically, we can achieve 1 kHz frequency of the scan.

CONCLUSION

We developed the joint search system based on secondary emission effect. Possibility to set any form of scan line allows getting the scanning system with lens effect. The minimum size the system can show, limited by the beam size, on the electron beam welding facility this value is about a one-tenth millimeter.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Yu. I. Semenov, P. V. Logatchev *et al.*, “60 keV 30 kW electron beam facility for electron beam technology”, in *Proc. EPAC’08*, Genoa, Italy, Dec. 2008, paper TUPP161.