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CONTROL OF THE WELD POOL FORMATION DURING ELECTRON BEAM WELDING DISSIMILAR MATERIALS

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Abstarct. The nature of the heat source in a weld pool is non-stationary and the dynamic processes occurring in both the welding pool and the plasma cavity play a dominant role in the formation of the welding seam during electron beam welding of dissimilar metals. The possibilities to control and study the energy transfer mechanism from an electron beam to a metal target, weld pool and keyhole of formation during electron beam welding using CCD techniques is demonstrated.

Keywords: welding-electron beam, control – CCD, equipment

1. INTRODUCTION

Electron beam welding of materials has a number of decisive advantages over conventional techniques. The focused electron beam is one of the highest power density sources and thus high processing speeds are possible and narrow welds with a narrow heat affected zone can be produced accurately[1,2].
Electron beam welding is a very useful process for joining a wide range of dissimilar metal combinations. An important problem during electron beam welding dissimilar metal is electron beam deflection and its control over the quality of the welding seam.

Depending on the power density distribution of the electron beam, welding speed and materials properties, a number of different physical processes such as heat conduction, phase transition, fluid dynamics, evaporation kinetics, and plasma dynamics are involved determining the processing results. When welding with an electron beam at high intensities a focused beam leads to molten material being evaporated with a capillary in the melt (plasma cavity) also formed; in literature the capillary is called a keyhole [3-8]. The greatest problem from the practice point of view is provided by the keyhole because in the electron beam radiation is absorbed efficiently.

During the electron beam welding of dissimilar materials when a electron beam is used to produced deep weld in thick plate, the beam axis must be in the same plane as a the joint faces and aligned with the joint. However in practice we found deflection of electron beam. This can be due to the residual magnetism of weldments and thermoelectric magnetic fields as results of temperature gradients in dissimilar metals or electric currents on the wall of the vacuum chamber [2].

This paper describes experimental investigations in monitoring the welding pool and keyhole behaviors during electron beam welding carbon St 45 with tool steel P18 using a charged coupled device (CCD) camera. Develop the practice for reduce of influence of beam deflection on the quality of weld seam.

2. EXPERIMENTAL METHOD

The experimental arrangement used in the present work is shown on **Fig.1.**

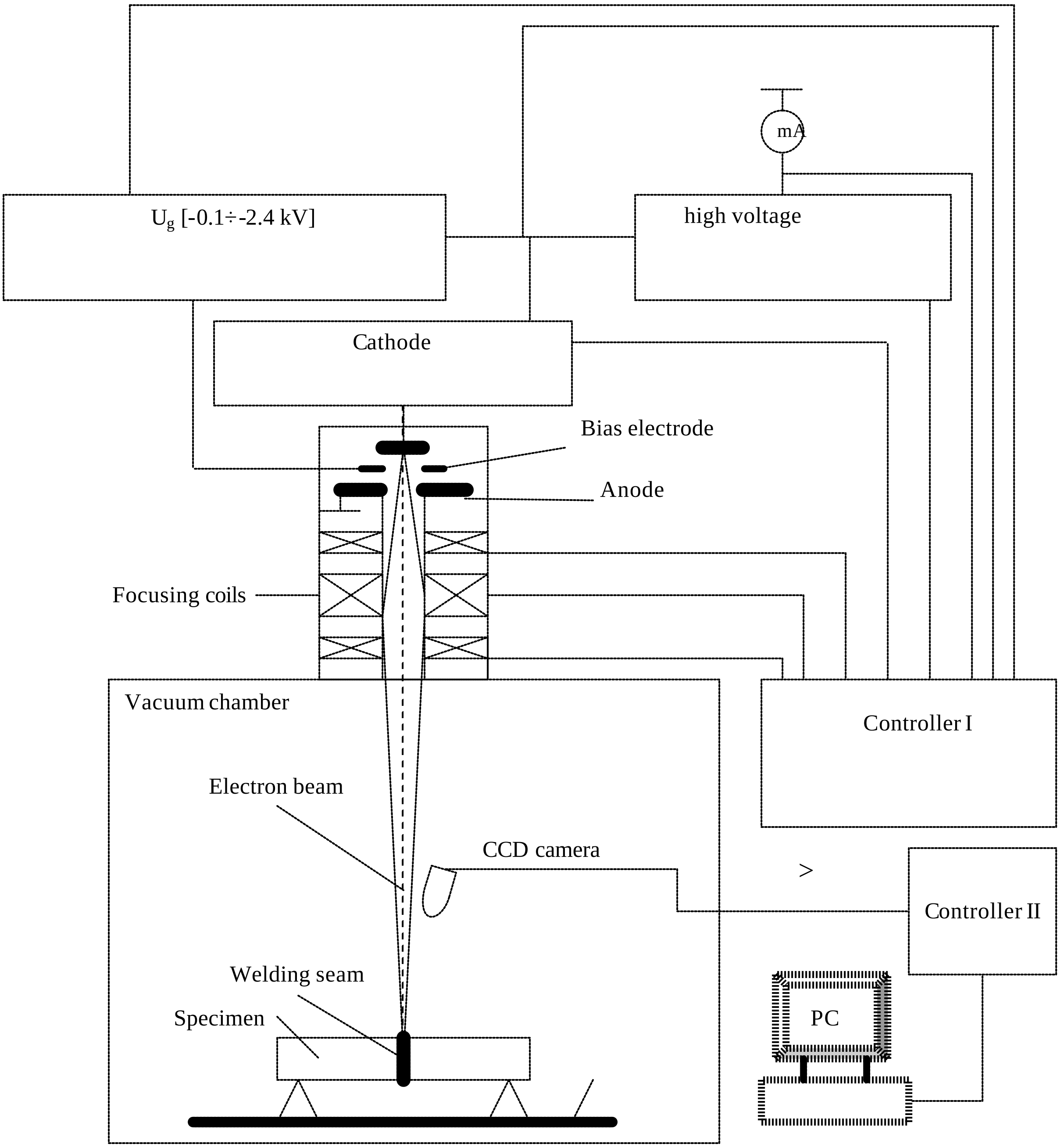

Figure 1. Experimental arrangement.

An electron beam formed in an electron optical system interacts with a moving metal target and a welding seam is created. The CCD camera is used for observation of the molten pool, keyhole, metal vapor and plasma above the surface of the welded specimen.

The main equipment used to registration the liquid metal and keyhole picture was a Santa Barbara Instrument Group's CCD camera model ST-8 – **Fig.2**. The active region of the CCD is KAF1600 chip with 13.8×9.2 sqr.mm and 1530×1020 sqr.pixels 9×9 mkm each.

The original software of the CCD camera allows rebinning of the image, so the original pictures taken during the experiment were 765×510 pixels each. The exposure times were 10 s (chosen after some experiments), so a neutral wedge was used to lower the illumination. The CCD was cooled to 10?C by a thermoelectric cooler– see Tabl.1 for technical parameters of the camera.

Standard procedures, included in the firm software were used to subtract the dark current and the primary reduction of the images. If/when needed the specialised procedure from the ESO (European South Observatory) MIDAS software package to improve the quality of the picture is used.

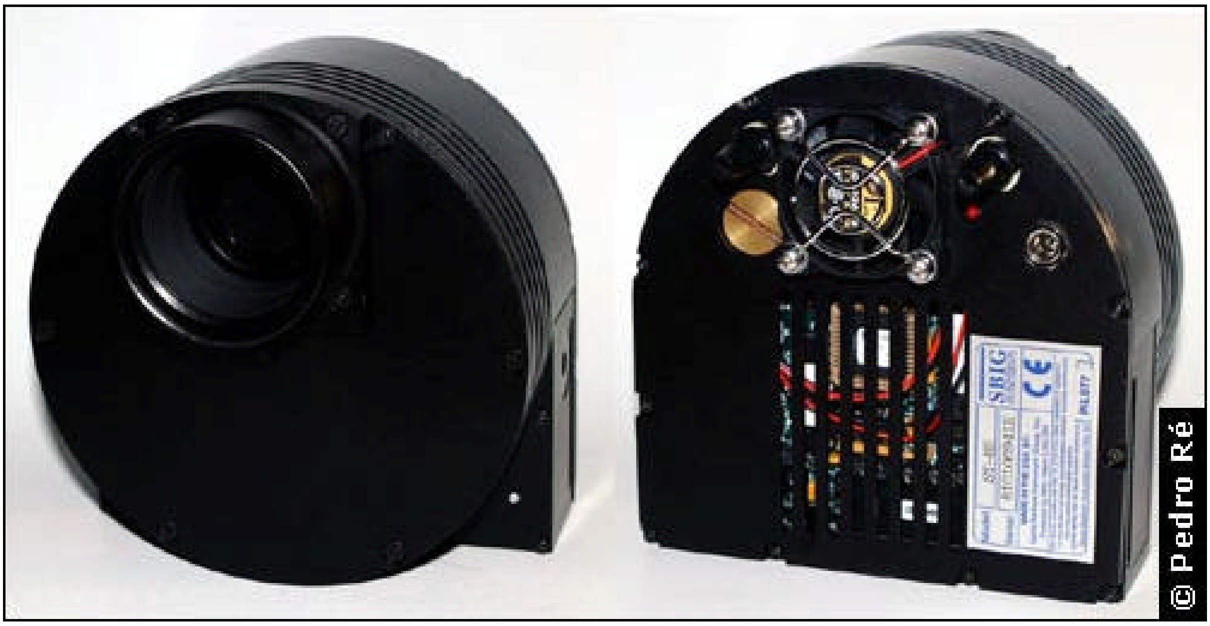

Figure 2. CCD camera ST-8 – common view.

Table 1: Model ST-8E CCD Specifications

CCD	**Kodak KAF-1602E + TI TC-211**
Pixel Array	**1530 x 1020 pixels, 13.8 x 9.2 mm**
Total Pixels	**1,500,000**
Pixel Size	**9 x 9 microns**
Full Well Capacity ABG	**~50,000 e-**
Full Well Capacity NABG	**~100,000 e-**
Dark Current	**1e^-/pixel/sec at 0° C**
Antiblooming	**Standard (Non-ABG as option)**

Readout Specifications

Shutter	**Electromechanical**
Exposure	**0.11 to 3600 seconds, 10ms resolution**
Correlated Double Sampling	**Yes**
A/D Converter	**16 bits**
A/D Gain	**2.3e^-/ADU**
Read Noise	**15e^- RMS**
Binning Modes	**1 x 1, 2 x 2, 3 x 3**
Pixel Digitization Rate	**30 kHz**
Full Frame Acquisition	**under 60 seconds**

All experiments were made using Leybold Heraeus 300/15-60 equipment – **Fig.3**, with specimens made from carbon St 45 with tool steel P18. The electron beam technological parameters were: acceleration voltage U = 60 kV, beam current I = 20-100 mA, welding speed V = 0. 5-2.5 mm/s, current of focused lens If = 400-517 mA.

Figure 3. Common view of the electron beam welding Leybold Heraeus.

3. PRELIMINARY RESULTS

The weld pool images obtained with the CCD camera is present in **Fig.4** and cross-section of welding seam in **Fig.5**.

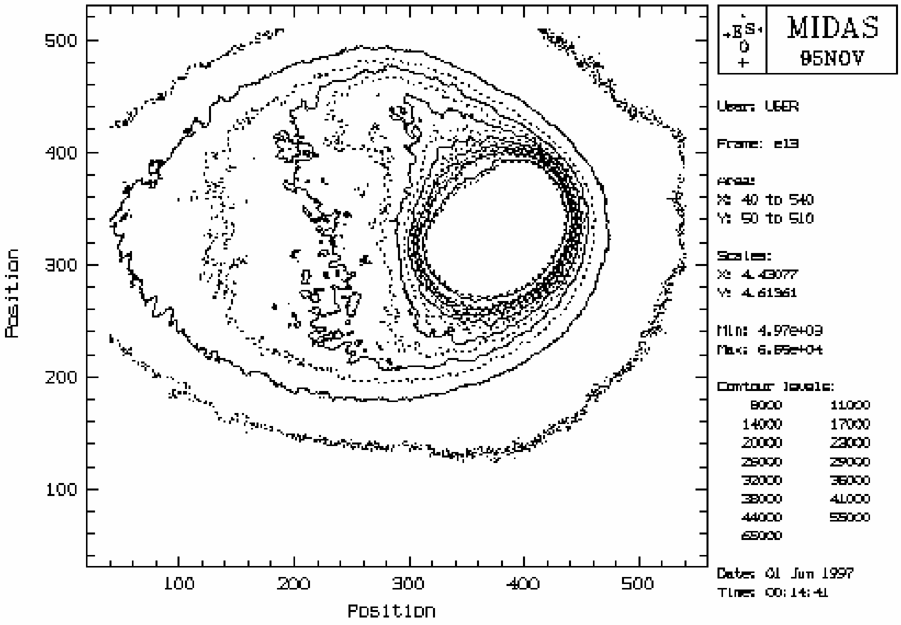

Figure 4. Weld pool image registered from a CCD camera: P = 3.6 kW, lf = 512 mA, l = 60 mA.

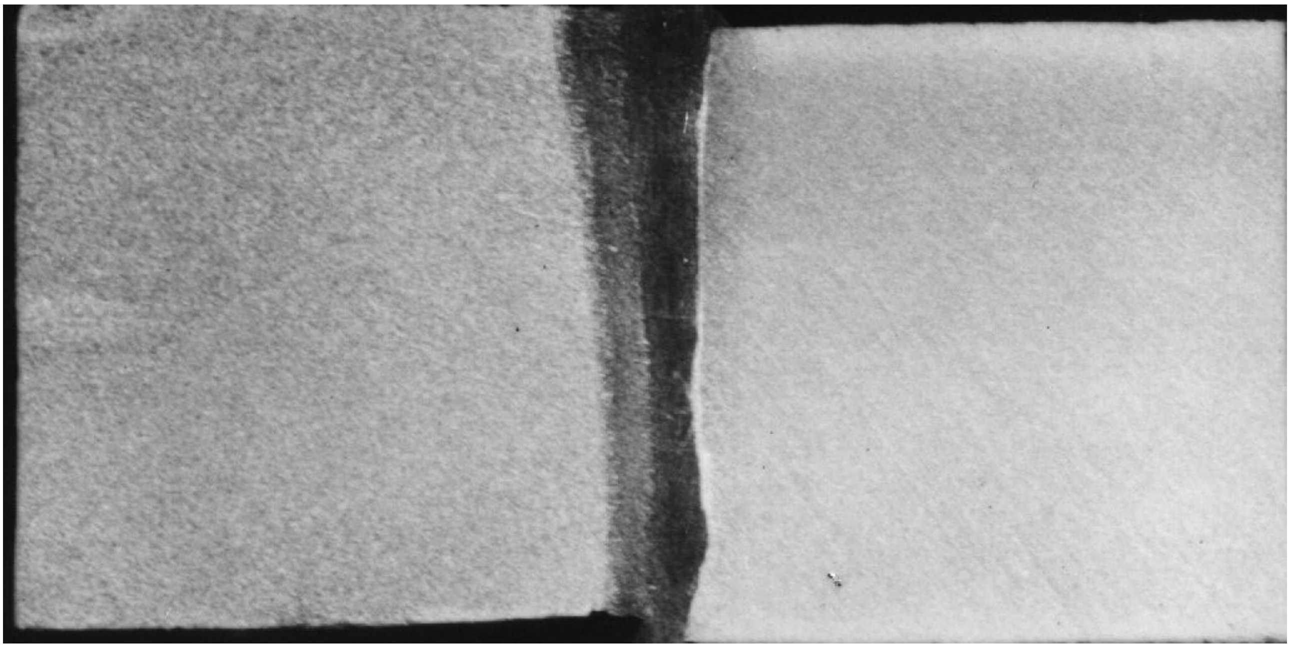

Figure 5. Cross-section of welding seam carbon St 45 with tool steel P18

The shapes of the welding pool and of the keyhole are apparently asymmetrical as results different themophisical parameters of welded materials. The front side of the welding pool has a few layers of liquid metal compared with the back side of the pool. The dimensions of the cavity are more varying with time than the same characteristics of the welding pool. The processes of dissipation and focusing of an electron beam in evaporated metal must be taken into account too, because they influence directly the changes in the beam power density in the keyhole.
Evaporation starts when the surface temperature reaches a value dependent on the target material. The vapor pressure and temperature of rice leads to the keyhole formation. The metal evaporated from the front side of the keyhole, together with the portion of backscattered electrons, at reaching the rear side of the welding pool extract the local pressures on the back liquid metal walls of the plasma cavity.

4. CONCLUSIONS

As a result of the carried out research work, it is obvious that the CCD camera has been possible to be used for high degree precision to follow the behavior of the weld pool and keyhole during electron beam welding dissimilar materials. The nature of the heat source is non-stationary and the dynamic processes taking place in both the welding pool and the plasma cavity play a dominant role in the formation of the welded seam.

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REFERENCES

1. Rykalin, N., Uglov, A., Zuev, I. and Kokora, A., Laser and Electron Beam Treatment of Materials. Mashinostroeni, Moscow, 1985, p.495.
2. Pan Jiluan, 2003. Arc welding control. Nanchang University, China
3. Tong, H. and Gied, W., Welding J., 1970, 6,p.259.
4. Tsukamoto, S. and Irie, H., Transaction of JWRI, 1993, 1, p.18.
5. Mitkevich, E. and Lokshin, A., Automatic Welding, 1980, 9, p.26.
6. Petrov, P., Georgiev, Ch. and Ivanov, R., Int. J. for the Joinin` of Materials, 1996, 4, p.152.
7. Hiramoto, S., Ohmine, M. and Sakamoto, M., Transaction of JWS, 1992, 1, p.33.
8. Petrov, P., Georgiev, Ch. and Petrov, G., Vacuum, 1998, 51, No.3, p.339-343.