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To study on Spiking Phenomena in Electron Beam Welding

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Abstract

Electron beam welding (EBW) is a fusion welding process in which a beam of high velocity electrons is applied to two materials to be joined. The work pieces melt and flow together as the kinetic energy of the electrons is transformed into heat upon impact. Melting process and spiking phenomenon have been investigated in electron beam welding. X- rays generated as a consequence of beam-metal interaction were measured at some specific sites of 3 mm in length along penetration using Xe-proportional counter simultaneously with taking high speed photography of the molten metal flow to clarify a melting process. A spike is a sudden increase in penetration beyond what might be called the average penetration line. Many spikes have voids in their lower portions because molten metal does not fill in completely. Also, in some cases the molten metal will fill a spike but will not fuse to the sides of the hole, producing a condition similar to a cold shut in a casting. These cold shuts seriously reduce the strength of the weld at the root. The results obtained were as follows.1) Spiking phenomenon was most likely to occur when the electron beam was focused on the root portion of penetration. 2) Melting process and spiking phenomenon were dominated by the periodical flow of the molten metal. 3) Soon after the periodical ejection of the molten metal, the beam cavity was clear of the molten metal and the electron beam was free to drill the bottom causing the spite. 4) it is effective in monitoring spiking phenomenon to detect electrons emitted from interacting point using a probe biased 6V with respect to the specimen. This paper provides a technical overview of the unique features of the electron beam welding process including several applications. Weld cross sections of production parts will be shown to demonstrate obtainable weld shapes. Solutions to specific weld challenges using the EB process will be shown. In addition, an overview of today's welding equipment and a brief look at future developments will be presented.
Keywords- Electron Beam Welding, Welding Phenomena, Melting Process, Welding Defect, Spike, X-ray

I. INTRODUCTION

The electron beam welding process is used in a variety of industries. Applications range from fully automated, high productivity and low cost automotive in-line part production to single part batch processes in the high-cost aircraft engine industry at the other end of the industrial spectrum. For those manufacturers and many others not specifically mentioned here, welding processes have to meet the increasingly stringent standards that have become more prevalent over the years. In this regard, welding process is well-positioned to provide industries with the highest quality welds and machine designs that have proven to be adaptable to specific welding tasks and production environments. Electron beam welding was developed by the German physicist Karl-Heinz Steigerwald, who was at the time working on various electron beam applications. Steigerwald conceived and developed the first practical electron beam welding machine, which began operation in 1958. American inventor James T. Russell has also been credited with designing and building the first electron-beam welder. In order to use an electron beam for welding purposes, it must be focused at or near the work piece surface. Due to imperfect electron optics during focusing, the beam current distribution distorts gradually as the degree of focusing is increased.

It can be readily appreciated that a beam which focuses to an elongated spot would have different fusion zone features depending on the direction of the weld pass. It can also be expected that smaller and more concentrated beams will produce larger depth to width ratios. It might then be concluded that the best welding beam is a small and highly concentrated one—that is, one of high power concentration. However, it has been observed that this is the condition which is conducive to the formation of welding defects such as porosity, cold shuts, or spiking. A spike is a sudden increase in penetration beyond what might be called the average penetration line. Many spikes have voids in their lower portions because molten metal does not fill in completely. Also, in some cases the molten metal will fill a spike but will not fuse to the sides of the hole, producing a condition similar to a cold shut in a casting. These cold shuts seriously reduce the strength of the weld at the root. They are quite difficult to find by radiography but can usually be detected by ultrasonic inspection. It has been suggested that spiking is inherent in the hole boring mode of electron beam welding and cannot be eliminated by any parameter adjustment on commercially available machines without sacrificing penetration. Spiking, rippling and humping seriously reduce the strength of welds. The effects of beam focusing, volatile alloying element concentration and welding velocity on spiking, coarse rippling and humping in keyhole mode electron-beam welding are examined through scale analysis. Although these defects have been studied in the past, the mechanisms for their formation are not fully understood. This work relates the average amplitudes of spikes to fusion zone depth for the welding of Al 6061, SS 304 and carbon steel, and Al 5083. The scale analysis introduces welding and melting efficiencies and an appropriate power distribution to account for the focusing effects, and the energy which is reflected and escapes through the keyhole opening to the surroundings. The frequency of humping and spiking can also be predicted from the scale analysis. The analysis also reveals the interrelation between coarse rippling and humping. The data and the mechanistic findings reported in this study are useful for understanding and preventing spiking and humping during keyhole mode electron and laser beam welding.

This point is, however, contradicted by extensive experimental evidence showing essentially, stable beam penetration. A detailed physical model of the Paper presented at the AWS 59th Annual Meeting held in New Orleans, Louisiana, during April 3-7, 1978.D. A. SCHAUER is with the Nuclear Explosives Division, Mechanical Engineering Department, Livermore Laboratory, University of California, Livermore, California; W. H. CIEDT is Associate Dean—Graduate Study, College of Engineering, University of Cali-fornia, Davis, California.

Electron Beam interaction with the material being welded is lacking. However, the most reasonable current interpretation is that the metal vapor pressure maintains an open cavity surrounded by liquid metal which periodically flows into the cavity due to the liquid hydrostatic head as the surface tension of the liquid metal tends to constrict the cavity. It has been estimated that in order to achieve significant cavity penetration, the surface temperature at the base of the cavity must be such that the local vapor pressure is greater than the sum of the constriction forces due to surface tension and the hydrostatic head.

For a 1.25 mm (0.049 in.) diameter electron beam cavity in aluminum with a base radius of curvature of 0.62 mm (0.024 in.) the required vapor pressure is about 27 torr (3600 Pa) which corresponds to a surface temperature of about 1900 C (3452 F). - If the cavity dynamics depend on the vapor pres-sure, then an increase in temperature of only a few hundred degrees could produce a high local pressure that might also lead to momentarily deeper penetration (spiking phenomena). Analytical models of the electron beam weld process or thermocouples' allow temperatures to be determined in the vicinity of the weld region. However, none of these analytical or experimental methods allow accurate calculation of temperatures at the surface of the molten metal which would allow one to determine the vapor pressure.

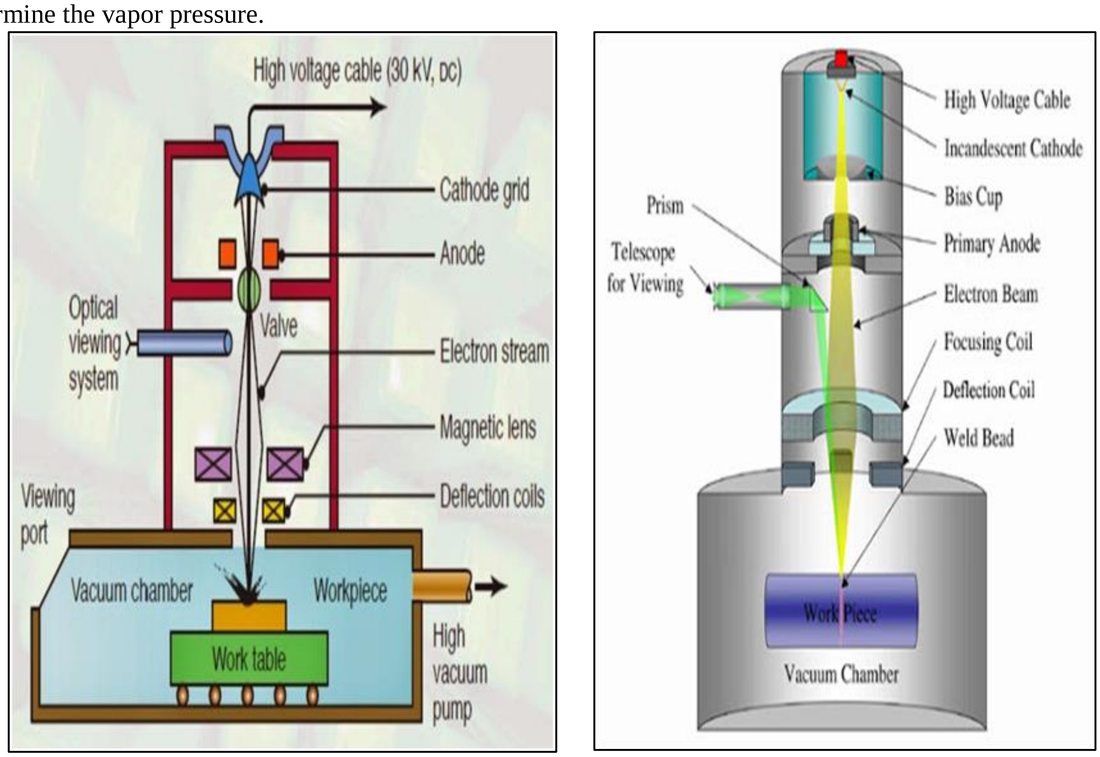

Fig. 1: Electron Beam Equipment

Therefore, an experimental program was initiated to deter-mine the local molten metal temperature in the weld cavity. The method developed and results obtained are described in the literature.

II. WORKING PRINCIPLE

It works on the principle that when a high velocity beam of electron that has Kinetic energy strikes the two metal pieces, the kinetic energy of the electron transformed into heat. The intensity of heat produced is so much that it melts the two metal pieces and fuse them together to form a strong weld.

III. METHODOLOGY

In an electron beam welder, electrons are "boiled off" as current passes through a filament which is in a vacuum enclosure. An electrostatic field, generated by a negatively charged filament and bias cup and a positively charged anode, accelerates the electrons to about 50% to 80% of the speed of light and shapes them into a beam. Due to the physical nature of the electrons – charged particles with an extremely low mass – their direction of travel can be easily influenced by electromagnetic fields. Electron beam welders use this characteristic to electromagnetically focus and very precisely deflect the beam at speeds up to 10 kHz. Recent machine developments make it possible even to go up to 200 kHz. With today's CNC controls, the beam focus as well as the beam deflection are part of the weld schedule and can be variably programmed along with other process parameters.

When fast moving electrons hit a metal surface they are decelerated which transforms the kinetic energy of each individual electron in the beam into thermal energy in the component. This transformation is stable in the high 90% range for all metals regardless of whether the electrons hit the surface at a perpendicular or a shallow angle. As a practical matter, this physical behavior makes the process very robust and reliable!

When electrons in a focused beam hit a metal surface, the high energy density instantly vaporizes the material, generating a so-called key hole (Figure 2). A characteristic of this phenomenon is that it allows the unique capability for deep, narrow welds with very small heat affected zones (HAZ) and minimized thermal distortions of welded assemblies(figure -3)

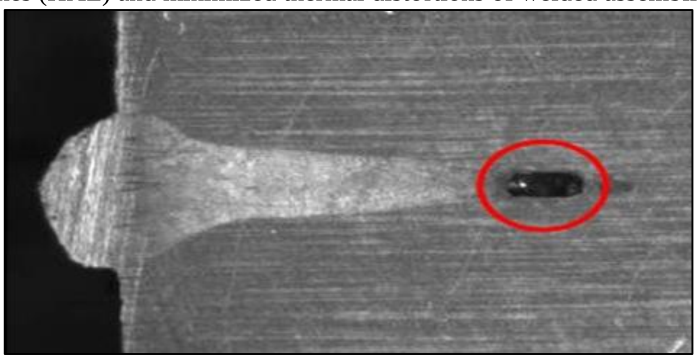

Fig. 2: Key-Hole

Fig. 3: Deep Section Weld

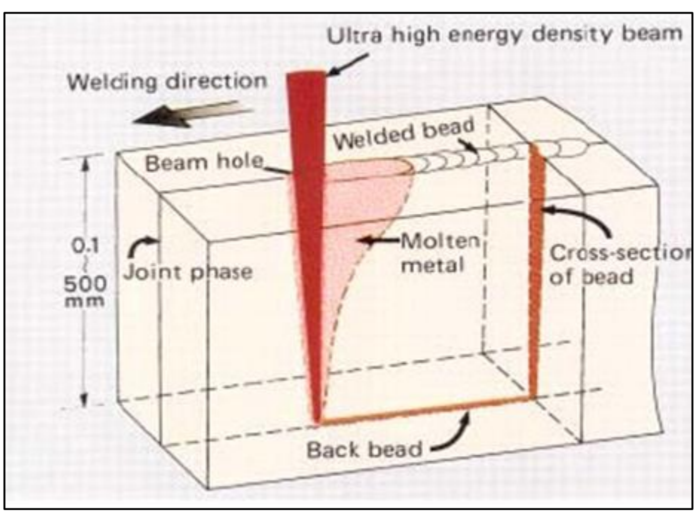

Fig. 4: Spiking in Deep Section Weld

A. Aluminum and its Alloys

Aluminium-based materials, because of their low specific density and good thermal conductivity, are finding an ever-widening range of applications in our daily lives, particularly in lightweight constructions. For this material, electron beam welding is a very suitable process because the high melting oxide film that interferes with other processes is easily destroyed by the momentum of the electrons. Etching the work piece surface in the weld area before welding reduces the oxide layer and thus improves the flow behavior and weld quality with reduced porosity. Furthermore, with electron beam welding no problems arise from reflection of the beam resulting in reduced energy input. It is possible to achieve welding depths of 200 mm and more with very good aspect ratios.

B. EB Process Parameter

The output parameter of EBW, such as the depth of penetration, thickness of the thermal affected area, productivity, working time, surface precision etc. depend on input parameter [1]. A few important EB welding parameters are listed below.

- Vacuum parameter: vacuum in EB gun, vacuum in working chamber.
- Work piece material parameter: melting temperature and thermal conductivity of work piece.
- Electron beam parameter: electron beam diameter, electron beam power, beam current, beam current intensity, acceleration voltage.
- Beam focus parameter: form, amplitude and frequency of oscillation, focalization current, focal point and beam oscillation, focal distance.

IV. CONCLUSION

This paper provides a technical overview of the unique features of the electron beam welding process including several applications. Weld cross sections of production parts will be shown to demonstrate obtainable weld shapes. Solutions to specific weld challenges using the EB process will be shown. In addition, an overview of today’s welding equipment and a brief look at future developments will be presented. From the results-driven, the spiking is decreased when the welding speed increases being higher voltage and current. So here we can conclude that to reduce spiking, higher welding speeds should be given irrespective of the electron beam power which reduces the depth of the penetration. Increasing welding speed causes to decrease the formation of spikes which yields to the high strength of the material.

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