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ARTICLE

Influence of Multi-Beam Electron Beam Welding Technique on the Deformation of Ti6Al4V Alloy Sheet

Fan Jikang, Zhang Wei, Qi Bojin, Liu Fangjun

Beihang University, Beijing 100191, China

Abstract: Multi-beam electron beam welding (EBW) is a new technique that allows more than two electron beams running simultaneously for welding and it is considered a promising method to reduce welding stress and deformation. In order to reduce the deformation of Ti6Al4V alloy sheets, a novel multi-beam EBW method was proposed in this research, including two additional electron beams to post-heat the weld, besides one main electron beam to melt metals. Experiments were conducted on Ti6Al4V alloy sheets using this multi-beam technique. Results show that compared with the conventional EBW, the multi-beam EBW can improve the welding thermal cycle and effectively reduce the welding deformation by adjusting the position and energy distribution of two additional electron beams.

Key words: multi-beam; welding deformation; electron beam welding; Ti6Al4V alloy

The low density, high specific strength, excellent high-temperature strength and good corrosion resistance of titanium alloys have led to a diversified range of applications in the aerospace, medical, automotive and nuclear industries[1-3]. Ti6Al4V alloy is one of the most commonly used titanium alloys due to its excellent combination of above properties and it can be welded by several common fusion-welding processes such as electron beam welding (EBW), gas tungsten arc welding (GTAW) and laser beam welding (LBW). Among these welding processes, high vacuum EBW is a preferred technique. Firstly, as EBW is performed in vacuum, it can effectively prevent the titanium alloy from contamination of atmosphere gases. Secondly, EBW is capable of producing deep and narrow welds due to its high energy density and ‘keyhole’ effect. Moreover, EBW is a welding process with high heating and cooling rate and therefore can produce welds with minimal distortion[4].

Multi-beam EBW is a new technique that allows more than two electron beams running simultaneously for welding and it is considered a promising method to reduce welding stress and deformation. In EBW, the electrons accelerated by high voltage have very high energy density, but they have almost no mass and are inertia free. Therefore they can be deflected by magnetic fields almost without time delay. Fig.1 shows the producing mechanism of multiple beams. Generally a set of deflecting coil is fixed under the focusing coil. When the focused electrons pass through the magnetic field produced by deflecting coils, they will have a specific deflection in very short time, so electrons can be divided into multiple beams visually[5]. With the high-frequency magnetic deflection system equipped in modern EBW machines, the multi-beam EBW technique becomes possible and the energy input and focus position of different beams could be adjusted flexibly, which allows to freely control the welding thermal process and in this way influence the welding deformation.

The multiple beams can be modulated to various forms, among which the following two modes shown in Fig.2 are most common. First, electron beams can be modulated to generate multiple molten pools simultaneously to increase processing efficiency and reduce welding stress (Fig.2a); second, electron beams can be modulated to one main welding beam used to generate molten pool and several additional beams used to preheat or post-heat the workpiece (Fig.2b). In recent years, the multi-beam technique is developed and

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Corresponding author: Zhang Wei, Ph. D., School of Mechanical Engineering and Automation, Beihang University, Beijing 100191, P. R. China, Tel: 0086-10-82338416, E-mail: zhangweibh@buaa.edu.cn

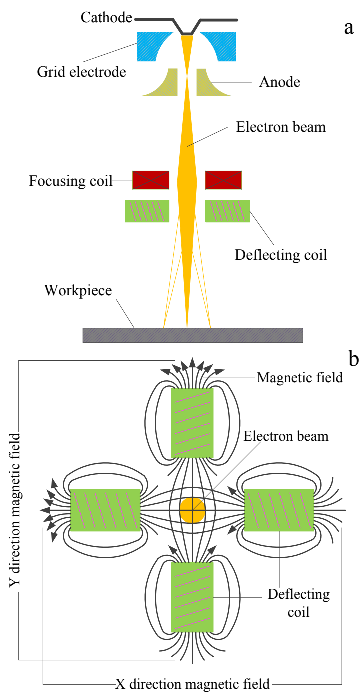

Fig.1 Producing mechanism of multiple electron beams in EBW: (a) configuration of electronic gun in EBW machine and (b) the deflecting system of EBW machine

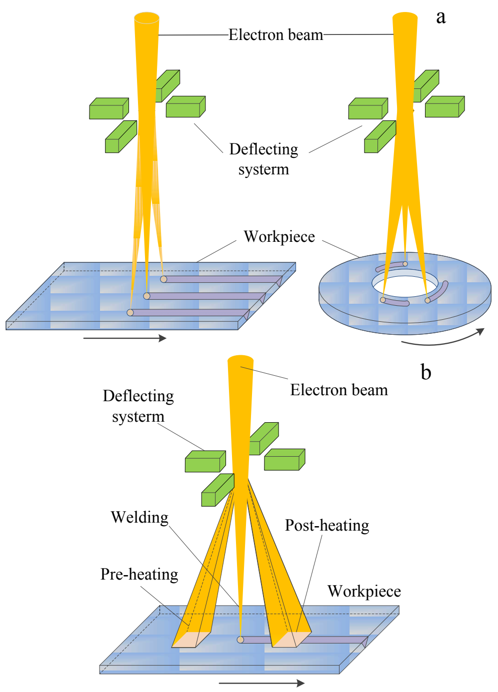

Fig.2 Two common forms of the multi-beam EBW technique: (a) electron beams used to generate multiple molten pools and (b) one main beam used to generate molten pool and several beams used to preheating and post-heating

applied in many industries[6] and has been investigated by several researchers. C. J. Rosen found that the application of multi-beam technique for EBW local post-heat treatment provides an effective tool for reducing of residual stresses when welding thin sheet materials[7]. Sergii Krasnorutskyi developed multi-beam techniques by creating a series of weld pools simultaneously in order to produce high-quality welds on duplex stainless steel[8]. Claußwelded automobile gear boxes with three weld pools and diesel particle filters with 60 beam spots using the fast deflection and multi-beam technique[9]. Von Dobeneck D found that multiple beams can significantly reduce porosity by extending the cooling cycle[10]. Haiyan Zhao investigated the generation and the processes of multi-beams in EBW by both the numerical simulation methods and experiments, and the result shows that the residual stress of EBW could be minimized by the multiple beam technique[5]. However, as we know, the influence of multi-beam technique on the deformation of titanium alloy has not been researched.

Welding deformation is one of the most important problems in welding fabrication and how to reduce the welding deformation becomes an important research topic. In this research, for reducing the deformation of Ti6Al4V alloy sheet, a novel multi-beam EBW method was proposed including two additional electron beams to post-heat the weld, besides one main electron beam to melt metals. Experiments were conducted using this three-beam technique on Ti6Al4V alloy sheet by changing the position and energy distribution of two additional electron beams. After experiments, workpieces with less deformation were successfully welded, which proved multi-beam EBW can effectively reduce the welding deformation of Ti6Al4V alloy sheet.

1 Experiment

The 1 mm thick Ti6Al4V alloy sheets were chosen as the base metal and the chemical composition is given in Table 1. The dimension of sheets is 300 mm × 100 mm. Before welding, they were cleaned with acid solution and then swabbed with ethanol in order to remove the surface metal oxides as well as other tarnishes.

In this research, the multi-beam technique was realized by one KS15 high-voltage vacuum EBW machine produced by PTR Corporation. The machine can precisely control the deflection position, the scanning pattern and the energy input of multiple beams and its deflecting holding time can correct to 1 us. The novel multi-beam EBW method is shown in Fig.3, which includes a focused main electron beam in ahead and two additional electron beams in the wings. Before conducting multi-beam experiments, repeated experiments were carried out to find the suitable parameters for welding 1 mm thick Ti6Al4V titanium alloy sheet with the conventional EBW. Parameter shown in Table 2 is acquired and the welded workpiece is shown in Fig.4. In the subsequent multi-beam EBW experiments, the welding parameters in Table 2 always remain the same.