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Investigation of the Electron Beam Positioning Accuracy at Electron Beam Welding

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Abstract

Electron beam welding (EBW) became widely spread in the branches of mechanical engineering connected with manufacturing of aviation and aerospace equipment. At present time much attention is paid to increasing the quality of essential and highly-loaded components obtained by means of EBW. This requirement is closely connected with butt positioning accuracy of the manipulator output members included into an automatic electron beam production complex (AEBPC). The control algorithm of a manipulator output member positioning process is given in the paper for path following based on the developed mathematical model of accounting the kinematic and dynamical characteristics of manipulators included into an automatic electron beam production complex (AEBPC). The feature of the model is accounting the electron beam (EB) deviation from the ideal position based on manipulators errors. Inclusion of the simulation results into the control model of electron beam welding process will allow increasing the quality of weld joints.

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Keywords: positioning accuracy; error; control; transfer function; manipulator; electron beam welding.

1. Introduction

The feature of the EBW is that the welding process and, consequently, the process of electron beam (EB) butt positioning is hard to observe visually [1, 2]. That is why the task of inspection over the output member position of a welding manipulator and a workpiece manipulator during the EBW is actual. It becomes especially important when the butt visualization is practically impossible, for example, in the process of welding inside a deep glass or from the internal surface of the weld component with application of intrachamber electron beam gun (EBG).

High welding speed (up to 30mm/s), precision of the EBW process and limited capacity of visual inspection make it difficult for an operator to control both the welding process and the EB positioning process. A mathematical model was proposed for the positioning process based on accounting the errors of electromechanical part of the AEBPC in order to decrease "yaw" during the butt monitoring [3].

It should be noted that the existing automatic devices of beam butt positioning do not completely satisfy the modern requirements of accuracy and reliability of targeting the beam to the butt [3]. It occurs because of errors of electromechanical complex. That is why the task of research and development of new EB butt positioning models and creating on their basis the automation of inspection and systems of butt monitoring is actual.

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2. Analysis of butt positioning process of manipulator output member during EBW

The word «positioning» means passing the butt by the electron beam at path points with given accuracy. Accuracy of the path depends on kinematic and dynamical characteristics of welding gun (EBG) and component for which the value of total error is significant [4, 5]. That is why it is also necessary to take into account their mutual position and kinematic features in the process of performing the operating functions (Fig. 1).

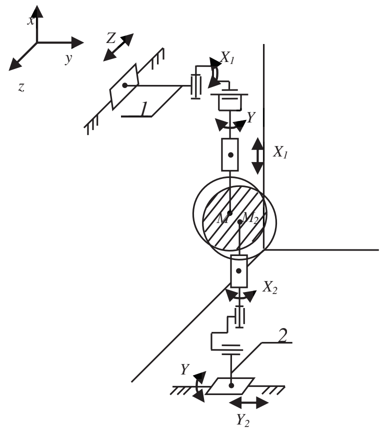

Fig. 1. Kinematic scheme of production equipment of AEBPC: 1 – welding gun manipulator; 2 – device for workpiece displacement; 3 – accuracy area; M1 – center of EB heating spot; M2 – center of welding joint at some point.

Location accuracy of EB focal heating spot at the butt of the weld components is determined by radius-vector which is an accuracy sphere radius of the manipulator output member [6-8]. It is necessary to ensure coincidence of the points M_1 and M_2 according to the condition.

$$\Delta r \leq \Delta r_{given} \tag{1}$$

where Δr is the allowable manipulator error; Δrgiven is the maximum given error of path following.

Geometrical locus satisfying to (1) can be found on the base of determination of an accuracy sphere having radius Δr_{given} and center at the point M (Fig. 1). If end points M of output members of all manipulators do not belong to the received area of the accuracy sphere the value of which is determined by kinematic and inertial manipulator characteristics, then the position of the output member is corrected taking into account the value of total error of electromechanical complex of AEBPC. Analysis of the obtained research results of kinematic and dynamical components of manipulator errors allowed refining the arising deviations of end-effectors end points from the given position during positioning of manipulators output members with account of acting forces, speeds and accelerations [9].

A generalized mathematical model of positioning the manipulator output member is proposed on the base of carried out analysis of factors influencing the accuracy of path following by the manipulator output member; it is described in the form:

$$F = \begin{cases} \Delta r(\Delta q, \delta_\Sigma, J_\Sigma, \Delta q', I_D, v, m) \\ f_{T.P.}(K_1, K_2, K_3, K_4) \end{cases} \tag{2}$$

where Δr is the total manipulator error; Δq is the error of control system and motor; δ_Σ and J_Σ are the kinematic error and dead stroke of the motion transformer correspondingly; Δq' is the error caused by the mechanism compliance; I_D is the dynamical invariant; v is the speed of manipulator output member; m is the mass of manipulator's end-effector; $f_{T.P.}$ are parameters of technological process; $K_1 \ldots K_4$ are criteria of ensuring butt positioning accuracy of EB during EBW [10]. The degree of these 0factors influence on the output member positioning accuracy is different and depends on characteristics of AEBPC equipment, its operational modes and parameters of EBW [11].

The total error of the manipulator Δr is determined as:

$$\Delta r = \Delta q + \delta_\Sigma + J_\Sigma + \Delta q' + \Delta_{dyn} \tag{3}$$