Design and application of robot welding station for BTE

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Abstract. The battery tray enclosure (BTE) is an important part of new energy vehicles, and has high requirements on quality, strength and heat dissipation. Considering the function of the BTE, the characteristics of the welding process and the specialty of the tooling system, a BTE robot welding workstation was developed by integrating the fusion welding technology, weld seam tracking technology, sensor technology and machine electrical integration engineering technology. The one-time fully automatic welding of the frame tray improves the working environment, reduces labor intensity and the welding skill requirements, and avoids poor quality such as less welding, leakage welding, and poor consistency due to manual welding.

1. Introduction

With the rapid development of the automotive industry, energy issues are becoming more and more urgent. More and more car companies are beginning to develop new energy projects. It is hoped that the development of new energy vehicles will gradually alleviate the energy crisis, reduce greenhouse gas emissions, and reduce dependence on conventional energy sources. It conforms to the concept of energy saving, emission reduction and green environmental protection for modern society [1] [2] [3] [4]. At present, new energy vehicles have become an important trend for the transformation of the automobile industry, and car batteries are the power source for energy vehicles. BTEs are important components for storing automobile batteries [5]. The charging and discharging of the power battery will always exist. The performance of the power battery is related to the temperature. In order to prolong the battery life and obtain a large power, the battery needs to be used within the specified temperature range, and the battery tray is the important part of cooling device. This puts higher requirements on the welding quality of the BTE.

The BTE is shown in Figure 1, which is assembled by welding 10 parts. At present, most of the welding of the battery tray frame is still produced by manual argon arc welding. This has problems such as poor working environment, high labor intensity, low production efficiency, and it is unable to meet the needs of mass production. In addition, the welding quality has high requirements on the skills of the workers, and is greatly affected by the mood, experience and techniques of the welding workers.

With the continuous maturation of robot technology, the industrialization of robots has been more and more widely used, which has liberated people from high risk and repeatability posts [6] [7]. This paper firstly studied the structural characteristics and production process of a BTE, designed a battery pallet enclosure pneumatic tooling fixture, developed a three-axis double-station positioner, and integrated the development of robot welding station. Welding trajectory and interference simulation were carried out, and the BTE products were welded. It is proven that the BTE welding workstation can meet the needs of automated welding of battery tailing trays.
2. Overall plan

2.1. Design
There are many considerations in the design of the BTE robot welding workstation. It needs to be based on the factory production schedule, the construction site foundation setting, the existing working conditions, the welding object structure and the process characteristics.

This paper first evaluates the battery tray welding time, clamping time, station switching time, etc., calculates the welding cycle, combined with the production shift to calculate the production capacity, and determines the number of workstation construction according to the production program requirements; Secondly, based on the structural characteristics and functional characteristics of the BTE, the Fronius TPS4000CMT welding power source was selected, the positioning clamping method was analyzed, and the design schemes of the positioning point, clamping point, support point and tooling fixture were determined. Then, according to the structural nature and weight of the tooling sub-system, the corresponding three-axis double-station positioner is designed. The welding range of the BTE and motion of the positioner is analyzed, and the robot system is selected with the corresponding arm and load. Finally, the robot workstation is simulated and the welding trajectory is verified to avoid the welding interference. The workstation is supplemented with equipment such as error-proof and fool-proof system, smoke exhausting device, clearing wire cutting machine to form a complete system function of the BTE robot welding station.

2.2. Process layout
The welding station is mainly composed of KUKA KR60-3 robot, Fronius TPS4000CMT welding power supply, 3-axis double-station positioner, Nederman FilterMax C25, welding fixture, weld seam tracking system, error-proof and fool-proof system. In order to ensure the reliable use of the BTE welding station, the operation is convenient and more gonomic, the process layout and layout size of the system are shown in Figures 2 and 3 respectively.
2.3. Process flow
The process flow of the robot welding station is shown in Figure 4, which is divided into three stages: pre-weld preparation, welding and finishing.

In the pre-weld preparation stage, the workstation operator assembles and fixes the battery tray enclosure parts according to the specified clamping process, and then performs robot teaching programming.

During the welding phase, robot welding and workpiece clamping are performed simultaneously. When the PLC control system reaches the two-hand button box preparation signal, that is, after the operator completes the workpiece clamping and leaves the working area, the positioner transfers the assembled BTE from the clamping station to the welding station, and the robot start welding. At the
same time, the welding station is also switched to the clamping station, and the operator performs the clamping of the next product.

At the completion stage, the PLC control system receives the welding completion signal when the welding of a BTE is completed; Then, the rotation of the positioner converts the welded BTE back to the clamping station. The operator removes the BTE and places it in the area to be inspected, and then performs the clamping of the new workpiece. This cycle eliminates robot wait times, maximizes robot utilization, and increases productivity.

Figure 4. Workflow of the welding station.

3. Subsystem design

3.1. Fixture sub-system
The fixture sub-system consists of a base plate, support units, positioning units and clamping units. Considering the rigidity requirements, the base plate is designed with a 25mm thick Q235 steel plate. The support unit, the positioning unit and the clamping unit all adopt the design idea of “installation module + adjustment module” combination, and compensate the manufacturing error and assembly error of the fixture by adjusting the number of gaskets. The support unit and the clamping unit are designed to be close to the weld joint without affecting the welding, so as to reduce the influence of the welding deformation on the welding quality. The clamping unit adopts pneumatic clamping method to select SMC brand pneumatic components. In combination with the requirements of the clamping force, 40 clamping cylinders and 63 clamping cylinders are respectively selected. According to the usage mode, some cylinders are automatically clamped and some cylinders are manually clamped. In addition, the positioning units in the same direction of the BTE components are designed on the same side for easy access.

3.2. Positioner subsystem
In order to maximize the use of welding robots and improve welding efficiency, a 3-axis dual-station R-type positioner is designed with three degrees of rotational freedom. One of the rotational degrees of freedom uses the weiss rotary indexing table. The CR700C model is selected according to the load, and it is used to switch between the welding station and the clamping station. When the robot performs a welding operation on the welding station, the workstation operator can simultaneously perform the upper and lower parts at the clamping station. The other two degrees of freedom are KUKA original
seventh-axis servo motor, and the MGU3900-219 model is selected according to the moment of inertia. It is used for the linkage of the fixture with the robot welding, so that the robot can carry the welding torch in a proper posture to ensure the welding quality. The overall installation diagram of the positioner, fixture and workpiece is shown in Figure 5.

Figure 5. Positioner, fixture, and workpiece installation diagram.

3.3. Weld seam tracking sub-system
The weld tracking system can realize the weld trajectory tracking function. The POWER-TRAC laser vision system is a non-contact weld/workpiece positioning and real-time weld tracking system which is generally used in high performance automated welding processes. Workpiece machining and assembly errors are important factors in welding defects, reduced productivity, and industrial automation weld downtime. The POWER-TRAC laser vision system solves these problems by precisely positioning the torch.

This system includes POWER-CAM laser sensor and Power-Box control unit, Ethernet communication interface, advanced connector processing software module, TRAC-3D track generation module. The POWER-CAM laser sensor provides a 3D field of view based on the principle of laser triangulation and integrates a 2D colour video camera for process monitoring and remote programming. These two technologies provide high-accuracy geometric measurements of 3D laser triangulation and flexible 2D video capture.

The dimensional data acquired by the POWER-TRAC laser vision system is provided in real time to the robot to correct the teaching trajectory, enabling it to perform welding in harsh welding environments.
3.4. Error-proof and fool-proof sub-system
The error-proof and fool-proof sub-system is an important part of the BTE welding workstation, and it is the premise and guarantee of automatic welding. It mainly includes welding room, safety grating, workpiece detection sensor and so on.

The welding room is the physical protection of the welding work area of the BTE welding station. The first is to prevent the loss caused by the illegal entry of non-workers or staff members; the second is to prevent the adverse effects of welding arc and smoke on the working environment of the workshop and the staff.

Safety gratings are used to detect whether a worker has entered the main equipment for work area inspection. When it is judged that the worker enters the work area, a detection signal is generated and fed back to the integrated control system, so that the positioner stops rotating and protects personal safety.

The workpiece inspection sensor is designed to detect whether the workstation operator installs all the parts when clamping the workpiece, whether the parts are clamped in the right place, whether the parts are reversed or wrong. The applications based on workpiece inspection sensors can reduce operator requirements, increase productivity and product yield.

4. Welding test
In order to verify the welding effectiveness of the BTE robot welding station, this paper developed a prototype of the system. The BTE is welded, and the welds are regularly displayed in fish-scales shape. The welding sample has beautiful appearance, excellent quality, and the welding efficiency is improved by 320%. At the same time, the welding process rarely causes splashing, and has high promotion and practical value. The workstation is shown in Figure 7, and the workpiece welding quality is shown in Figure 8.
5. Conclusion
Through the development of the BTE welding workstation, the traditional manual operation of the battery enclosure tray was changed, and the automatic welding of the BTE was realized. The welding skill requirement for the operator is reduced, the influence of human factors on the welding quality is eliminated, the production efficiency is improved, and the working environment and labor intensity of the operator are improved. This is due to the fact that the robotic welding station has the following features compared to conventional manual work.

- Robot welding can smoothly control the attitude of the welding torch, accurately perform welding trajectory, high welding speed, improve welding quality and efficiency;
- The repeating motion of the robot is high, and it is not affected by emotions and human factors, and the welding consistency is good;
- The weld seam tracking sub-system can assist the robot to realize the correction tracking function of the welding path of the BTE to ensure the welding quality;
- The error-proof and fool-proof system detects the workpiece clamping state and welding state in real time and reduces installation errors.

References
[1] Wan Z, Sperling D, Wang Y S.(2015) China’s electric car frustrations. J. Transport Research Part D:Transport and Environment., 34:116-121.
[2] Yuan X L, Liu X, Zuo J. (2015) The development of new energy vehicles for a sustainable future: A review. J. Renewable and sustainable Energy Reviews., 42:198-305.

[3] Delucchi M A, Yang C, Burke A F, Ogden J M, Kurani K, Kessler J, Sperling D. (2014) An assessment of electric vehicles: technology, infrastructure requirements, greenhouse-gas emissions, petroleum use, material use, lifetime cost, consumer acceptance and policy initiatives. J. Philos. Trans. R. Soc. A., 372(2006):20120325-20120325.

[4] Wang H, Kimble C. (2011) Leapfrogging to electric vehicles: patterns and scenarios for China’s automobiles industry. J. International Journal of Automotive Technology Management., 11(4):312-325.

[5] Xiao Yan. Research on the Market Diffusion of New Energy Vehicles in China under the Background of Low-carbon Transportation [D]. WuHan: China University of Geosciences, 2016

[6] Shuai Yang, Huijin Zheng, Juanjuan Su, Lu Gan. (2017)Robot Welding System for TypicalShip Plate Structures. J. Marine Technology, 3:72-75.

[7] Yanli Liu, Jinliang Gao, Yong Chen, Baodong Zhang, Hongwei Li, Wei Fan. (2013) Research on Welding-robot Technics of Outer Diesel Oil Box. J. New Technology & New Process., 1:80-82.