Research on Welding Process Simulation Training Technology Based on Virtual Manufacturing

Ying WANG[1], Fei DI*[1,2], Jing Ying LI[1], Jin Jun WU[2] and Jun Yi LIU[2,3]

[1]China Productivity Center for Machinery Co.Ltd, Beijing, 100044, China
[2]China Academy of Machinery Science and Technology Group, Beijing, 100044, China
[3] Machinery Technology Development Co. Ltd., Beijing, 100044, China

*Corresponding author's e-mail address:dylan0136@163.com

Abstract. With the development of virtual manufacturing technology, computer virtual welding has become an important means of basic manufacturing processes. It not only connects information systems with actual manufacturing processes, but also greatly improves traditional manufacturing efficiency. This paper proposes a welding process simulation training system based on virtual reality (VR) interactive technology, which simulates multiple welding process scenarios for training personnel. The welding process simulation training system is applied to the field of large and thick plates for offshore wind power foundation single pipe piles. The welding process simulation training process based on virtual manufacturing is deeply explored to shorten the welding training cycle and improve the learning efficiency of training personnel.

Keywords: Virtual manufacturing, Welding process, Simulation training, Single pipe pile thick plate

1 Introduction

Since the 21st century, computer technology has undergone rapid development. As a new technology, virtual simulation technology has been widely used in inspection, maintenance, manufacturing, and other aspects. Virtual manufacturing technology [1] is a subdivision and extension of virtual simulation technology in the manufacturing field, including design, prototyping, processing, assembly, inspection, planning, training, and simulation [2]. It converts manufacturing knowledge into actual manufacturing processes through three-dimensional computer graphics simulation, in order to more accurately evaluate and control production processes. This technology is also widely used in the welding and manufacturing of large and thick plates. In the face of increasingly complex and harsh manufacturing environments, remote welding robots have now replaced humans to achieve complex welding tasks [3]. Due to the strong technical nature of the welding process operation, the special working environment, and the production of irritating gases during the manufacturing process, as well as the expensive investment in time and infrastructure to cultivate skilled welders, using virtual manufacturing technology to achieve welding has a better operating space for welders,

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thereby avoiding the use of welding rods and welding guns in harsh production environments. Through the research of computer virtual manufacturing technology, this paper applies it to welding process, combines virtual manufacturing with actual production, and takes the welding training of offshore wind turbine tower as an example to develop a welding process simulation training system.

2 Computer Virtual Manufacturing Welding Technology

With the continuous improvement and development of virtual reality technology, virtual simulation and process planning techniques are gradually realized and applied. Computer-aided manufacturing welding (CAW) technology, too, has gradually been able to effectively help design welded structures and joints, develop reasonable welding process plans, and manage the welding process using computer management software to improve production efficiency and quality. Kristian Arntz et al[4] used a computer-aided manufacturing system to meet the processing needs for special laser process deposition welding, and provide solutions for the process chain of complex manufacturing and repair tasks for small quantities of high-value parts. While virtual simulation is mainly divided into Virtual Reality (VR), which is immersed in a virtual world to interact with virtual objects to achieve operations, and Augmented Reality (AR), which combines the real world with virtual objects to interact with operations. Currently, virtual reality technology is mostly used in the training of welders' welding skills. Chan et al[5] have proposed a virtual welding system based on VR and AR technologies that can assist in guiding operators through visual and haptic sensations to use and improve their welding skills. Isham et al[6] proposed a virtual reality welding kit for welding training using multiple marker image methods as interaction method, the system also evaluates the user's acceptance of the new interaction. In terms of human-machine collaborative welding research, Wang et al[7] constructed a virtual welding environment based on HTC VIVE, established a mapping model between arc voltage, length and welding current, and achieved better welding results based on weld tracking algorithms by combining the advantages of human-machine collaboration. Olena et al.[8] analyzed the solution for welder simulation training using VR and AR technology, and found that the simulator can establish a neural fuzzy system in addition to training, thereby designing automated and robotic welding systems. Liu et al.[9] proposed an augmented reality welder training system to assist unskilled workers in training, and proposed a predictive control algorithm to derive analytical solutions to determine the optimal welding speed.

Based on the above research status, this paper builds a virtual welding training system architecture as shown in Figure 1, which establishes the macro and micro levels of simulation of the virtual welding process, respectively.

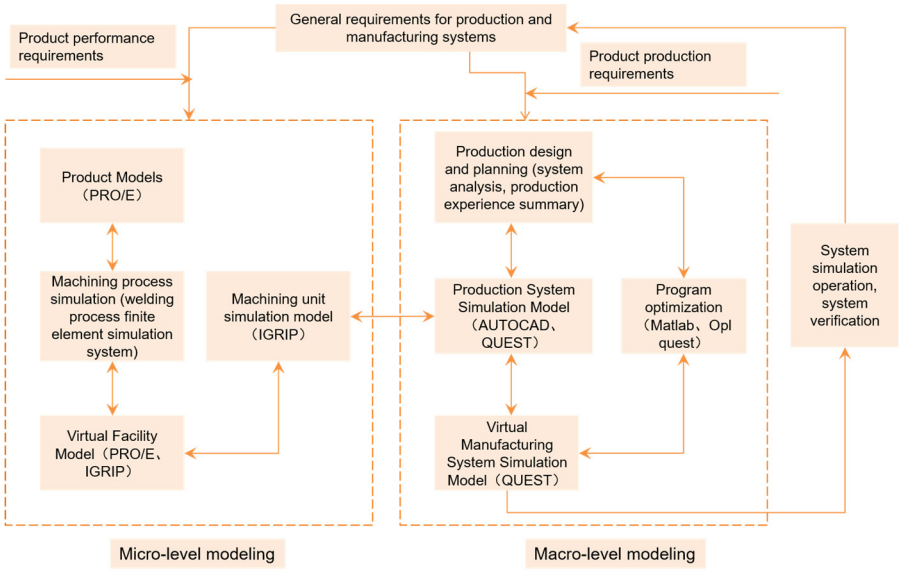

Fig. 1. Virtual welding training system architecture.

The virtual welding training system established aims to provide environmental protection, energy saving, and general skills training and evaluation services. It adopts distributed simulation technology, virtual reality technology, microcomputer measurement and control technology, sound simulation technology, and computer image real-time generation technology, providing users with a more realistic practical experience. Through the simulation master control system, position tracking system, acoustic effect display system, and evaluation system, it is possible to achieve accurate control of the welding gun during the welding drill process, including position, speed, angle, and operation information, so that virtual welds can be generated without using a real welding machine to improve welding quality. There are mature virtual welding environment construction systems, such as HTC VIVE VR system [7] and Onew360 system[10], which can organically combine simulation operation equipment, real-time 3D technology, and WM-VR rendering engine to make welding drills more realistic. Operators can clearly observe the generation, flow, and cooling process of welding arcs, and can also hear accurate welding sounds, making the operator's experience more realistic.

Welding technology is a complex processing process that involves many aspects such as heat transfer, metallurgy, high-temperature arc physics, and mechanics. It is an important research direction in the field of material processing, and the welding process needs to be completed in a very short time. Therefore, in order to improve the welding quality, it is necessary to establish an accurate physical model to simulate and simulate the welding process, in order to achieve the best welding effect. By combining computer technology with the welding process, it is possible to effectively analyze residual stress and thermal stress reactions and have an impact on structural components, thereby achieving precise control and ultimately achieving automation and

controllability of the welding process. The overall architecture of the welding process simulation system is shown in Figure 2.

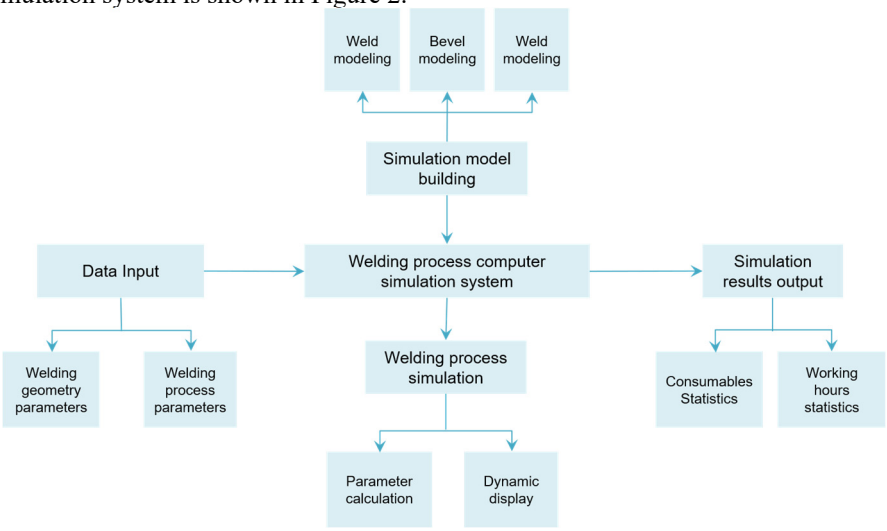

Fig. 2. Overall architecture diagram of welding process simulation training system.

3 Application of training system in welding process of single pipe pile for offshore wind power foundation

3.1 Application objectives

With the proposed goal of carbon reduction and the rapid development model of wind power, offshore wind power has developed more rapidly. However, for the welding of large and thick plates of single pile pipes in offshore wind power foundations, multiple welding operations are required, which makes it difficult to ensure the consistency and stability of welding quality, and the welding operation space is relatively small. The welding environment is located in the port area, and the welding quality is heavily dependent on highly skilled welding workers. Therefore, it is necessary to train relevant professional technicians. To meet current needs, reduce training costs and shorten training duration. To this end, a set of virtual manufacturing simulation welding software has been developed for large and thick plates with different diameters, which is composed of four parts: hardware, software, document management, and backup. The hardware part includes equipment such as helmets, welding guns, test pieces, external displays, and hosts. The software part includes virtual manufacturing welding training software, and the document management mainly includes technical documents and user manuals. This system can assist technicians in mastering the welding skills of large and thick plates with different diameters, thereby completing engineering projects more effectively. Through simulation exercises, it is possible to effectively reduce the loss of materials such as steel and welding materials, while accurately evaluating the accuracy

and stability of actions, thereby saving training costs and improving training effectiveness.

3.2 System function

The virtual manufacturing simulation welding training software for large and thick plates consists of four parts: welding helmet, welding specimen, welding gun, external display, and operation guide, as shown in Figure 3. By using large and thick plate simulation welding software, the trainer can obtain a three-dimensional welding environment, and can manipulate the simulation welding gun by controlling three-dimensional positioning technology, thereby achieving accurate control of each step in the welding process. In addition, the software can also automatically adjust the distance between the welding gun and the test piece according to the operation of the trainer, thereby generating a variety of different welding arcs and weld pool states, to improve the training effect of the trainer. By presenting the above information, we can create a real virtual reality world that allows people to interact with machines. All jobs must have complete welding facilities, including a set of the latest electric welding tongs, gas shielded welding guns, and various welding tool assemblies. This simulation training method uses three levels of training methods, including elementary, intermediate, and advanced.

Fig. 3. Virtual Manufacturing Simulation Welding Training Software System for Heavy Plate.

Through the three basic features of "immersion-interaction-conception", the simulation welding software for large and thick plates of single pipe piles can create a virtual environment, allowing participants to have a sense of immersion in the welding scene

through vision, hearing, and interaction. At the same time, operators can interact through multidimensional information.

By using the simulation welding software for large and thick plates of single pipe piles, trainers can learn the best welding posture, including welding speed, distance and angle between the welding gun and the workpiece, under the guidance of software voice and process. By continuously adjusting the welding posture accuracy, weldment quality, and welding stability of the trainees during the training, not only can the trainees experience the actual welding process from the welding environment, but also can be familiar with the operation essentials during the process. In addition, it can also provide a clean and quiet training environment for training personnel, so that the training personnel can better grasp the welding technology and achieve the best welding effect.

3.3 Equipment situation

Before safe operation of welders for large and thick plates used in offshore wind power, it is necessary to be familiar with the welding materials used, construction techniques, welding scenarios, welding guns used, protectors used, and relevant basic information such as power supply, current, and voltage. In addition, it is also important to understand the safety hazards that may arise during the welding process of large and thick plates with different diameters. In addition, it is possible to simulate the welding situation under various parameters based on the welding scene, experience the operation techniques and feedback obtained by pressing, and also simulate the realistic experience effect brought by the strong interference environment of arc, strong light, and splash during the welding process, achieving multi angle and all position welding drills.

Using a virtual reality head-mounted displays (VR-HMD) to present a virtual environment, its display device parameters are shown in Table 1, and it supports the Vive VR wireless control handle and precise SteamVR2.0 positioning technology. It will be able to simultaneously use up to four Base Stations, doubling and expanding the activity space to 10 square meters to achieve rapid welding of objects. Support real-time monitoring and repeated playback of the welding process of the trainer, enabling the trainer to quickly understand the problem in response to deficiencies. The system provides teaching for students through voice prompts, tactile feedback, and text explanations. The software provides welding scenarios for large and thick plates with different diameters. Trainers can achieve multi-scenario switching training by selecting different weldment materials, welding guns, welding rods, etc.

Table 1. VR-HMD Device Parameters.

No.	Equipment parameters	Parameter value
1	Use space	1.8m×1.5m×2.0m
2	Resolution ratio	2880×1600
3	Field of view angle	110°
4	Frame rate	90 Hz
5	Weight	550g

During the welding training process for large and thick plates, due to their special welding characteristics, in addition to the above welding scenario settings, it is also necessary to adjust the welding current, voltage, and other related parameters, and adjust the position and posture of the welding gun according to the operating space. During the operation process, gray welds will appear in the virtual scene based on specific welding conditions, and there will also be cooling scenarios for welds.

3.4 Operational process

To ensure the accuracy of the training, it is necessary to set up a number of simulated test pieces that can be used to weld large thick plates of monopile piles of different diameter sizes. The preparation before operation also includes teaching the types of welding positions for large thick plates of monopile pipes. Since the welding of large thick plates of monopile pipes is a pipe weld, there are generally three welding positions such as horizontal fixed position, vertical fixed position and inclined position. Unlike the type of welding position of plate welds, pipe welds contain pipe plate welds, fillet welds, and bevel welds [5] welding positions.

By using a simulated welding external display, the operator can view the stereo visual image of the simulated welding helmet worn in real time, thus achieving a synchronized and consistent effect. In addition, you can also use the simulation welding software, which can be automated in the above-mentioned simulation welding hardware. The operation process of the specific virtual manufacturing welding process training system is shown in Figure 4, which contains six main steps, namely, starting the system, entering the training program, formal training sessions, training upgrades, multi-scene simulation training, and post-training services.

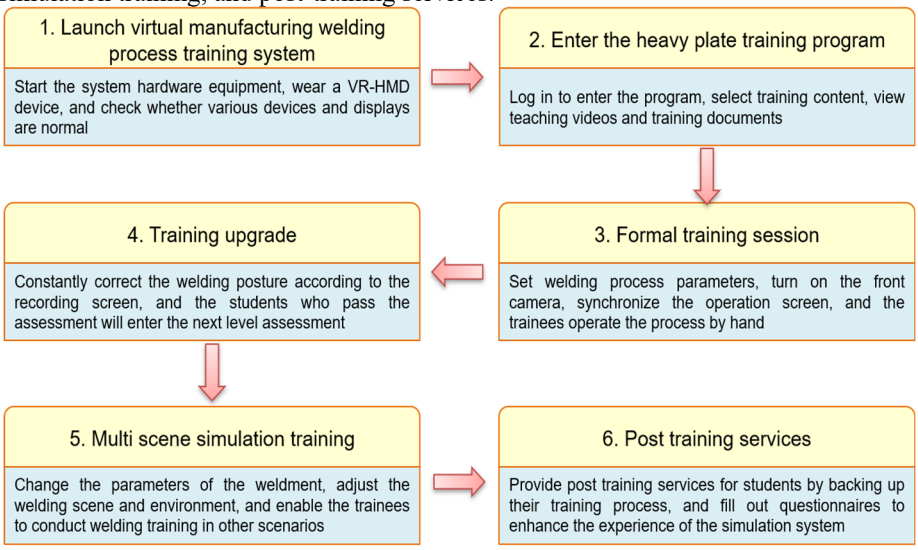

Fig. 4. Operation process of virtual manufacturing welding process training system.

Step 1: Start the virtual manufacturing software system. In this process, you need to start the system hardware equipment, wear VR-HMD equipment, and check whether all the equipment and display, sound and other aspects are normal.

Step 2: Enter the training program. Login to the trainee account, enter the virtual training program, select the content that needs to be trained, and first watch the instructional videos and training documents to understand the content of the training.

Step 3: Formal training session. Set the welding process parameters, turn on the front camera, synchronize the operation screen of trainees, and trainees follow the specific operation process to practice by hand. In this process, by simulating the different welding effect between the welding part and the welding gun at different spatial distances; when adjusting the angle of the welding gun and the welding speed, it makes the trainees feel the welding effect under different welding conditions, so that they can master the best welding posture.

Step 4: Training upgrade. Continuously correct the welding posture according to the recording screen, and when passing the assessment, they can enter the next level of assessment.

Step 5: Multi-scene simulation training. When changing the welding parameters, adjusting the welding scene and welding environment, it makes the trainees exposed to more welding training in other scenarios and enriches their welding experience.

Step 6: Post-training service. Provide post-training services for trainees by backing up their training process and filling out questionnaires to enhance the experience of the simulation system.

4 Conclusion

In order to reduce the environmental pollution, training costs and consumption of welding consumables caused by the training of large thick plates for offshore wind power foundation monopiles, a welding process training system for virtual manufacturing of large diameter thick plates was constructed using VR technology. The virtual welding environment generated in the system improves the safety of the trainers and greatly reduces the welding safety risks associated with the training process for large diameter thick plates. Compared to traditional welding training methods, the virtual technology skills are more systematic and can effectively help the operator to master the skills and gradually improve the adaptability due to changes in the welding scenario. The use of real-time monitoring technology in the system to correct the welding posture of trainees can greatly improve the training efficiency, this system in the offshore wind power single pile large thick plate welding training is extremely important guidance.

Acknowledgments

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