Practical Use of Hull Block Welding Robots Applying Automatic Off-line Teaching System

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The need for production efficiency through manpower saving without relying on welding skills continues to increase, while the inheritance of skills from master mechanics in shipbuilding is becoming a serious challenge. Whether welding robotization, a measure to meet the aforementioned needs, can be realized in shipbuilding depends on how fast and accurately job data can be created for welding robots that can weld diverse targets. Mitsubishi Heavy Industries, Ltd. (MHI) developed an automatic off-line teaching system that creates job data for welding robots using a 3D model produced by 3D-CAD MATES (Mitsubishi Advanced Total Engineering system of Ships) shipbuilding software, which was successfully applied to shipbuilding as welding robots system.

1. Introduction

Creating job data to operate welding robots has been considered a challenge when adopting such robots in shipbuilding. Unlike factories for mass production, where the same work is repeated using one set of job data, various forms of work need to be carried out in shipbuilding. If such job data is created manually piece by piece, it will fall behind the manufacturing tact time and cannot be applied to practical use.

However, as design CAD technology has recently advanced, MHI has been approaching innovative IT-based changes in design and manufacturing processes focusing on 3D models since 2005. Under these circumstances, MHI developed an automatic off-line teaching system that automatically creates job data for welding robots using a 3D hull model built by MATES, and sought to adopt welding robots to shipbuilding.

2. Development of automatic off-line teaching system

2.1 MATES

The Shipbuilding Department's approach to 3D design is from long age, developing 3D-CAD MATES in house for shipbuilding in the 1980s, which has grown to a highly practical shipbuilding system that covers everything from basic design to manufacturing design, with functions still being improved through applications to actual ships(**Figure 1**).

The 3D model for design produced by MATES is broadly used in shipbuilding as a product information model (core data) and as data for 3D viewers for shipbuilding, steel plate printers (NC printing equipment) and various pieces of FA equipment. We also used this 3D model for design to create job data for the welding robot developed this time.

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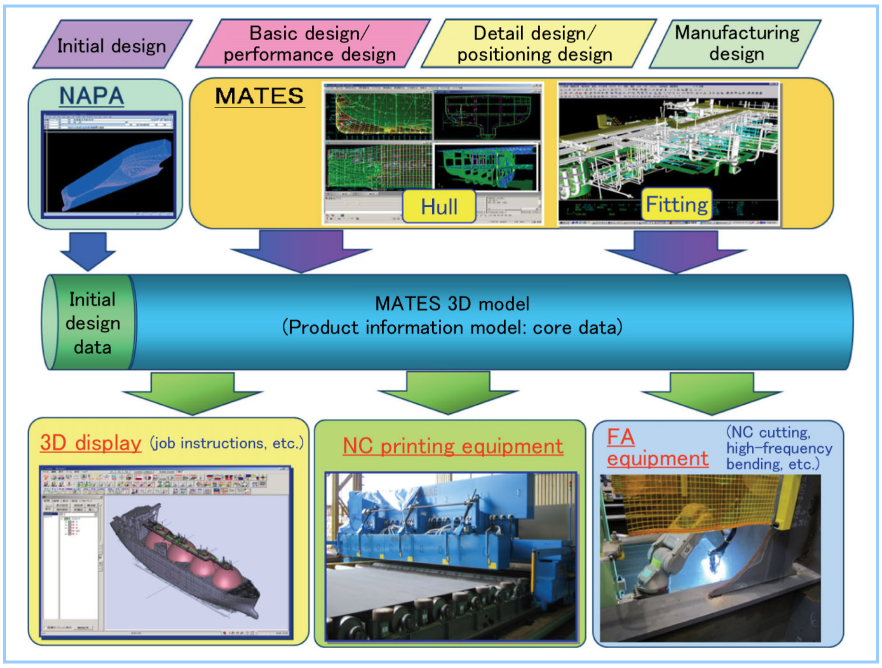

Figure 1 Outline of 3D-CAD MATES shipbuilding software

2.2 Application stage

The application stage for the welding robot adopted this time was set in the welding process in the flat plate assembly block located in the central part of the hull (**Figure 2**). Longitudinal members (longitudinal frame) and transverse members (transverse frame) are structured perpendicularly and parallel when assembling the flat plates in the central part of the hull, which can be described as being suited for automation, since the slot structure in transverse members changes little across different types of vessels. Moreover, many welders are allotted to this stage, where the welding work is limited because of the small spaces surrounded by longitudinal and transverse members and high-level technique is required from welders who need to work in downward, vertical, upward and other positions. In addition, as this flat plate shop is the stage that requires the largest amount of work to assemble the hull, robot adoption can be expected to bring about a significant effect in reducing the required workforce. MHI decided to adopt welding robots for this stage based on these factors.

Figure 2 Welding robot application target: Typical example of slot area

2.3 Flow of welding robot job data creation

Figure 3 shows the flowchart of welding robot job data creation.

MATES creates a 3D model (solid model: PalaSolid format) and welding line data for each assembly block. This 3D model is a shipbuilding-dedicated solid model which not only has 3D form, but also houses qualities such as longitudinal scantling and slot parameters, in addition to the plate thickness and materials.

The automatic off-line teaching system extracts welding lines around the slot section, the target of the welding robot, from the welding line data and outputs welding robot job data for each space surrounded by the longitudinal and transverse members, after determining the robot posture and welding conditions in accordance with the welding lines. The space is the range that the welding robot set in the hull block can weld at one time.

Used in cooperate with robot simulation software available on the market, the system can prevent short-time stop and malfunctions by confirming operation in advance in small spaces where the interference of the members and the welding robot is of concern.

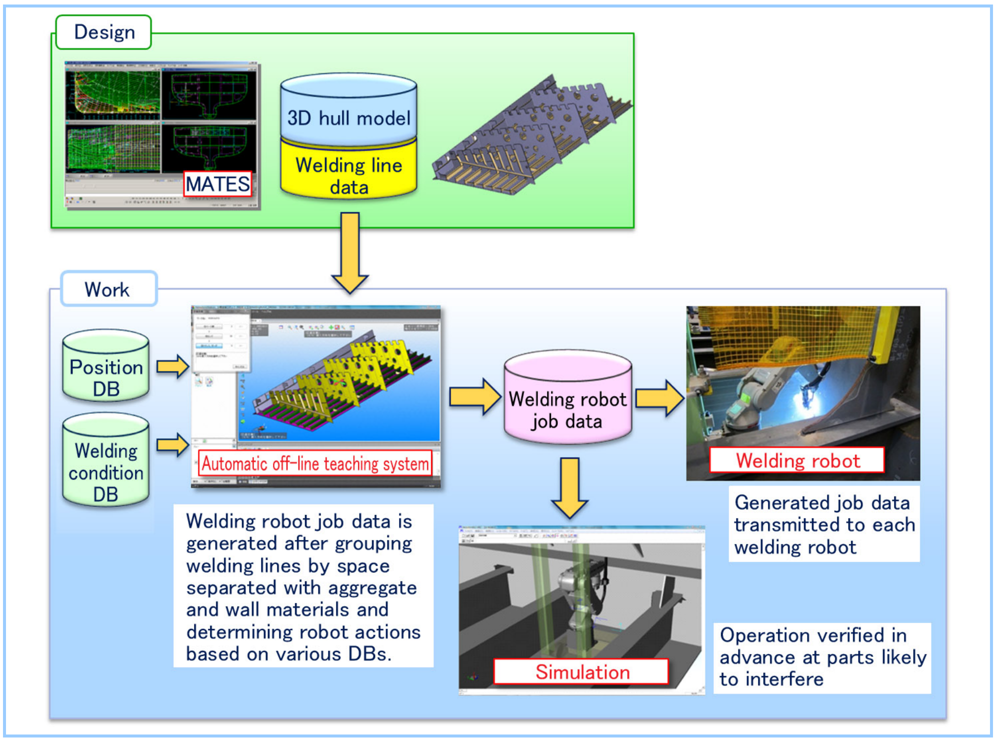

Figure 3 Flow of welding robot job data creation

2.4 Automatic off-line teaching system

The automatic off-line teaching system developed this time determines the optimum robot movements and welding conditions based on the 3D model built by MATES and various databases, and creates welding robot job data.

It derives welding lines around the slot section, the job target of the welding robot, from the 3D hull model taken from MATES and welding line data, and groups them by space (the range that a single welding robot can weld). Then the system categorizes the grouped weld lines into patterns as in **Figure 4**, based on which it automatically decides the most efficient welding route (welding orders). Finally, the system figures out the optimum robot movements in consideration of the welding route and surrounding hull structure and outputs the welding robot job data. It also features a welding condition database determined from welding tests and logic to automatically resolve the optimum welding conditions based on the welding leg length, position (upward, downward, Horizontal) and gap amount.

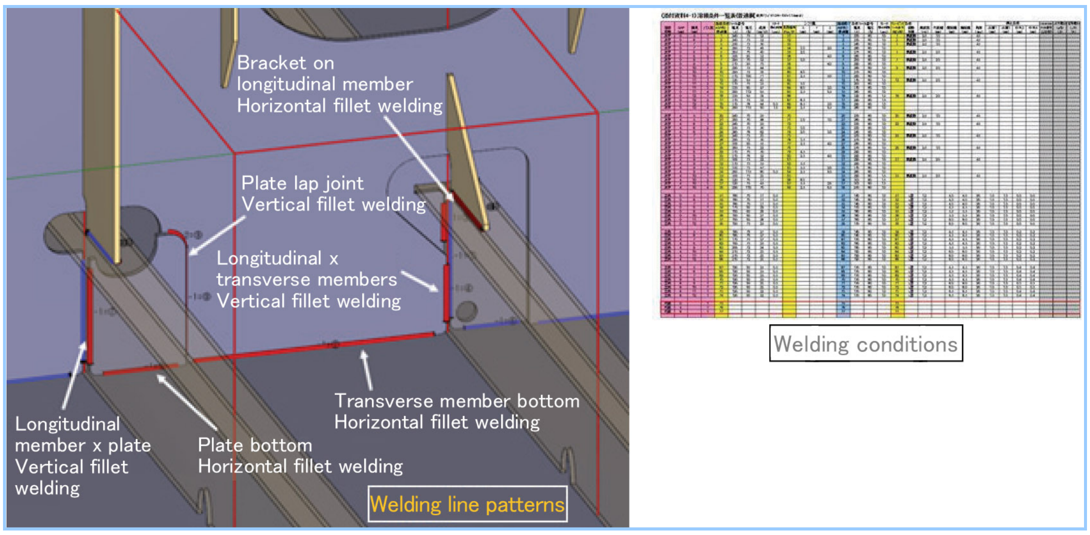

Figure 4 Automatic off-line teaching system

Thanks to the development of this automatic off-line teaching system, job data creation accompanied with welding robots main task was greatly simplified, and the welding robot's adoption in shipbuilding, where a diversity of work is targeted, became possible.

3. Implementation of welding robot system

3.1 Welding system composition

MHI's flat plate assembly block in the hull's central part extends to 40 m in length and 20 m in width at the most, and the number of parts to be welded sometimes reaches 20 per side of a transverse member, which includes up to eight to nine pieces in this block. Accordingly, MHI simplified the system, mounting a robot on a handling carriage which has a positioning capability, and adopted it in a hanging style, hanging it from a ceiling crane. This was aimed at boosting welding efficiency through the increased number of robots by making the system simple. **Figure 5** shows an application image.

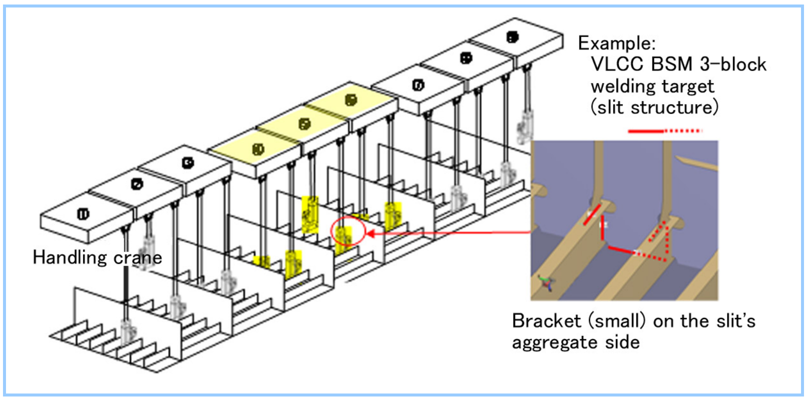

Figure 5 Welding robot application image

The handling carriage is a simplified light-weight type that has automatic positioning capability that can move back and forth and left and right, and 16 of the welding robots were set on a welding line extending to about 50 m. By downsizing the system and automating positioning in this manner, the operator is now required to do no more than two simple jobs: operate the crane between the longitudinal members and press the start button, choosing the welding target's data with the welding robot's pendant, under almost no surveillance. As a result, high-efficiency operation, in which one operator handles eight welding robots, has been realized.

3.2 Data correction and transmission using a tablet

Welding robot operators compose welding job data using the off-line teaching system and transmit the data to the welding robots prior to their actual operation. When it comes to the actual block, however, the operators have to do the construction under different conditions from the welding job data composed beforehand at some points, where the mounting condition of the welding targets differ by space and fittings such as pipes, ladders and handrails prevent the robot from doing the welding job, for example. In such cases, it is easy for the operator to change the job conditions in any manner and start welding by editing and re-transmitting the welding job data while looking at the actual parts to be welded using a tablet as in **Figure 6**.

Figure 6 Data editing using tablet

4. Application to actual ships

Since its setup in February 2012, this system automated fillet welding around slots in 120 blocks for a welded length of 40,000 m, mainly on very large crude oil carriers (VLCCs), as well as LPG and LNG carriers, by November 2012, accelerating the welding of parts that had been semi-automated before and improving process progress and welding efficiency (**Figure 7**). The system currently continues to be applied to consecutive construction of LNG carriers, succeeding in making the welding quality, which has depended on the welder’s skill, steady and high-quality by reducing the amount of work through the decreased number of welders and automating welding.

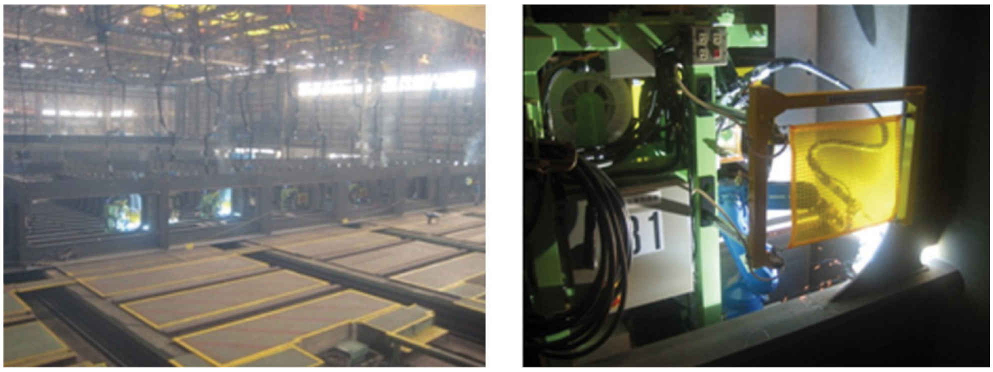

Figure 7 Welding robot applications

5. Conclusion

We introduced an automatic off-line teaching system incorporating our robot teaching expertise in shipbuilding and the adoption of a welding robot based on said system in this report. Reducing the amount of time required to create welding robot job data has been a serious challenge in the adoption of welding robots in shipbuilding, but our development of this system improved the welding robot’s net working time and brought about the true effects of its adoption in shipbuilding.

This approach can be considered as leading to expanding areas of shipbuilding, such as bending and assembly blocks, where this robot can be adopted.