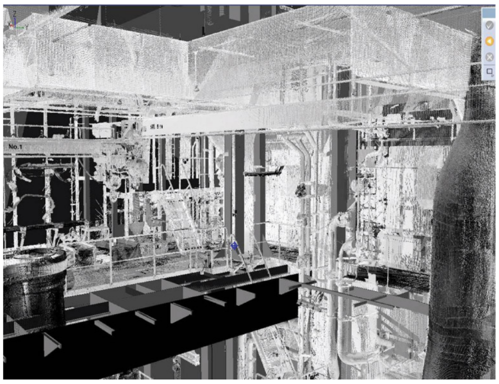
Increasing speed of Ship Repair through Three-Dimensional Laser Measurement in Compliance with Environmental Regulations



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In recent years, to prevent or mitigate atmospheric/marine pollution, regulations over vessels are being applied and tightened. And further technical innovation to preserve our beautiful sea and sky as well as enhanced development of diversified environmental equipment for vessels has also triggered a change with such a trend in engineering needs to repair vessels currently in service. Mitsubishi Heavy Industries, Ltd. (MHI) has integrated the 3D plant measurement technology practicalized at its nuclear power sector with the 3D CAD vessel design technique, actively promoting the engineering to repair vessels currently in service. This is an engineering method based on as-built 3D CAD models of established piping plants reproduced as is on CAD, using a 3D laser scanner. This report explains specific efforts for implementation of the above.

1. Introduction

Discharge regulations for ballast water (seawater used for attitude control of the vessel) and the emission control of air pollutants including SOx are expected to be put in force or tightened in stages within the next few years, favoring greater engineering needs to repair in-service vessels in compliance with such environmental regulations. In terms of ballast water regulations, it is expected that several tens of thousands of ships currently in service will need additional installations of ballast water management systems. Generally, such repair work often requires large amounts of materials, complicated pipe arrangements and the troublesome installation of electric equipment.

At ship repair worksites, on the other hand, repair work has been carried out conventionally relying on freehand drawings for the repair or on workers' arbitrary procedures without referring to drawings. The remote cause of this situation is the poor availability of detailed piping drawings or discrepancies between the actual state of the onboard plant and drawings for construction.

However, if large-scale repair work is carried out in such a situation as mentioned above, problems could occur such as quality deterioration and difficulty in reflecting the customer's needs in the repair results as they are not foreseeable, thus leading to not only a loss of the customer's trust but also schedule delays.

It is, therefore, becoming indispensable for quick repair work to tightly follow a series of repair engineering processes from creating precious "value" that customers expect, to discussing the "value" with customers and delivering the "value" to them. The method we practiced in giving shape to this was as-built 3D CAD modeling of onboard plants with a 3D laser scanner.

We successfully constructed as-built 3D-CAD models from the measurement data acquired by a 3D laser scanner and loaded them not only on general-purpose CAD but also on MATES (Mitsubishi Advanced Total Engineering System of Ships), our proprietary CAD system that supports engineering from design to production in an integrated manner. In this manner, it has become possible to create drawings for repair work. This report presents the series of approaches we have implemented along with several example applications.

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2. Workflow of repair engineering

The workflow of repair engineering is outlined as follows:

(1) Master plan and investigation
(2) Onboard inspection and 3D laser measurement
(3) Measured data processing and construction of as-built 3D CAD model
(4) Modified piping diagram and detailed production drawings

2.1 Master plan and investigation

First, from customers are heard their needs to be suitably blended with our ideas into a concurrent base on which conceptual designs for the piping system, pipe arrangement, a piping diagram, etc. should be put into force for their realization. In parallel, the range of 3D laser measurement is also determined for actual onboard inspection.

2.2 Onboard inspection and 3D laser measurement

Into the target vessel of repair work, a 3D laser scanner and other equipment are brought for measurement.

The 3D laser scanner irradiates laser pulses continuously within a hemisphere having its radius of dozens of meters around the scanner and calculates the distance from a measurement target such as hull part, piping, and auxiliary equipment located within the hemisphere by comparing in terms of phase difference the irradiated wave with the reflected one coming back after hitting and then reflected by the target. Using the angle derived from the direction in which laser was irradiated, the reflection point is identified. A single measurement (scan) obtains tens of millions of point cloud information pieces.

At the end of measurement, the 3D laser scanner is moved to a different place for another similar measurement. Huge volumes of multi-point cloud information thus obtained can be merged into a complementarily compounded piece of location information to view the measurement target as a three-dimensional object.

We have so far completed engine-room 3D laser measurement such as at pure car & truck carriers, container ships, very large crude carriers, and bulk carriers as well as even accumulated a variety of knowledge and knowhow about how point cloud information can be obtained from supposedly hard-to-measure narrow sections of an engine room. It is usually possible with 20-point and some 2.5-hour measurement to obtain necessary point cloud information for the construction of a some 100-m^2 as-built 3D CAD model.

2.3 Measured data processing and construction of as-built 3D CAD model

The point cloud information measured at multiple points, using a 3D laser scanner, is processed in the following procedure:

(1) Merging the point cloud information
(2) Noise filtering
(3) Measurement target modeling by referring to the point cloud data

The accuracy of the above works determines the quality of fresh drawings for repair, thereby gravely affecting the actual process of ship repair works. This is, therefore, the most important stage in a series of engineering processes.

We have been actually engaged for about five years in nuclear power plant reform works, taking advantage of 3D laser measurement. Skilled experts in charge were mobilized to customize the method or knowhow for vessels, enabling high-accuracy as-built 3D CAD models to be built.

Achievable data processing through as-build modeling process completion in some 15 days is another important aspect for quick digestion of repair work schedules.

2.4 Modified piping diagram and detailed production drawings

The constructed as-built mode is loaded on general-purpose 3D CAD software or MATES in a universal 3D CAD format. Pipes and equipment to be added are arranged within the space of the 3D model.

Particularly, in the case of repair work implementation by our company, MATES can attach the manufacturing information to each pipe/equipment and also facilitate delivery of information to the production process, thereby permitting engineering as well as repair works to be executed efficiently without disruption.

3. Examples of repair engineering

3.1 Example of examined ballast water management system installation to a pure car & truck carrier

Figure 1 shows an example of how we examined an additional installation of a ballast water management system in the engine room of a PCTC. The initial idea was to add an intermediate deck with a hull structure in the vicinity of the ballast water pump at the ship bottom and place the ballast water management system on this added deck. Through reviewing the as-built 3D CAD model, however, we confirmed that it could be installed in the recess along the broadside of the ship. As a result, the layout as shown in Fig. 1 was proposed. Using as-built models in this manner, extensive modifications of existing pipe arrangements or large-scale hull construction can be eliminated for available additional installation of a ballast water management system.

As for additional installation of a ballast water management system, it is important to select the right type of system, but of equal or greater importance is how to cope with the restricted space for the installation, which would have a significant impact on the cost and period of the repair work. Therefore, it is of great use in expediting the execution of repair works to obtain a swift and accurate grasp of an actual ship’s spatial information for continual development of an optimum system through as-built 3D CAD models-based communication with customers.

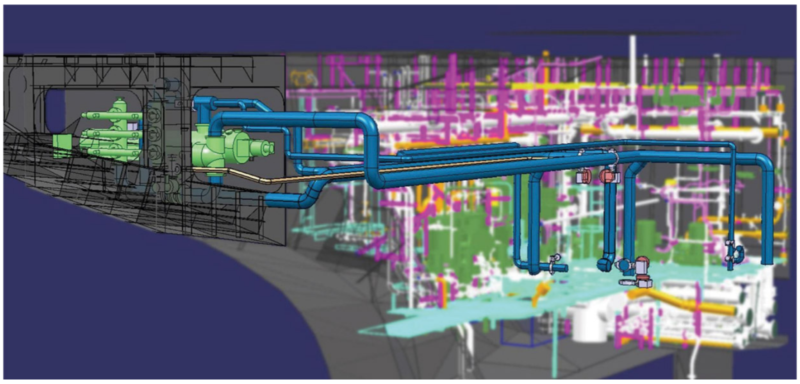

Figure 1 Example of repair engineering - Ballast water management system installation

3.2 Example of MGO Chiller System Installation on a Very Large Crude Carrier

Using MGO (Marine Gas Oil) as engine fuel, the SOx concentration of combustion exhaust gas can be reduced because of the fuel’s low sulfur content. The utilization of MGO is one of the solutions to meet the SOx emission regulations likely to be tightened in stages.

However, MGO has low viscosity compared with Bunker C, which has been conventionally used as fuel oil. The low viscosity can be the cause of engine trouble or problems with other auxiliary systems. The MGO chiller system cools down MGO to increase its viscosity for the reduction of failure risk and a lot of vessels are considering its installation on themselves.

3D laser measurement was carried out to examine how the MGO chiller system could be added to the engine room. The obtained point cloud information is shown in **Figure 2**.

And a repaired portion-added image obtainable from the above point cloud information-based as-built 3D CAD model is shown in **Figure 3**.

In this ship, since the piping system concerned had a 4-layer structure, requiring 3D laser measurement of an extensive area, two 3D laser scanners were arranged for respective use by each of two teams to measure its own preset range. There being numerous pipes running through between upper and lower decks as well as inside and outside the purifier room, the measured point cloud information was merged into a composed as-built 3D CAD model.

Measured sections were wide in area but relatively uncongested with equipment and the risk of interference was low because the pipes to be added were of a small diameter. This is why the 3D CAD model was coarser than usual. Depending such as upon characteristics of the system to be added and the installation area, the degree of elaboration of as-built 3D CAD modeling or “granularity” of the model, so to speak, can be flexibly regulated for available quality-preserved shortening of the engineering period.

In this way, we could also provide customers with the value of a shorter engineering period in meeting their needs to expedite the execution of repair works as scheduled for the vessel.

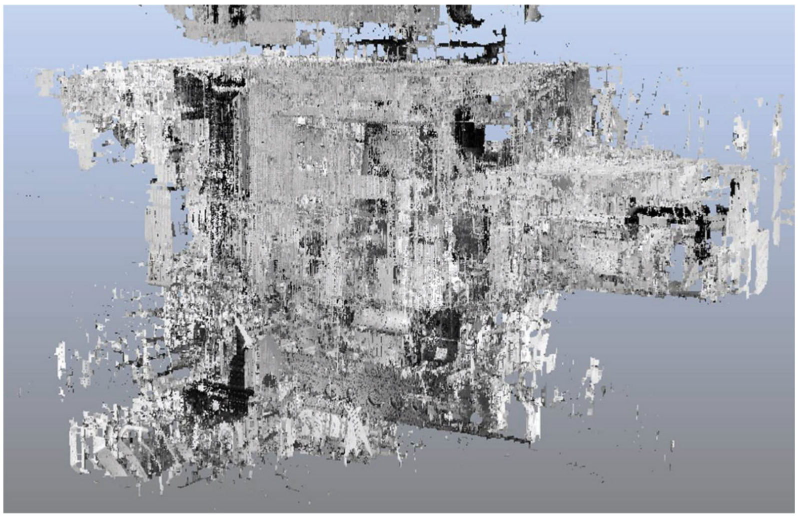

Figure 2 Point cloud data acquired by 3D laser scanner

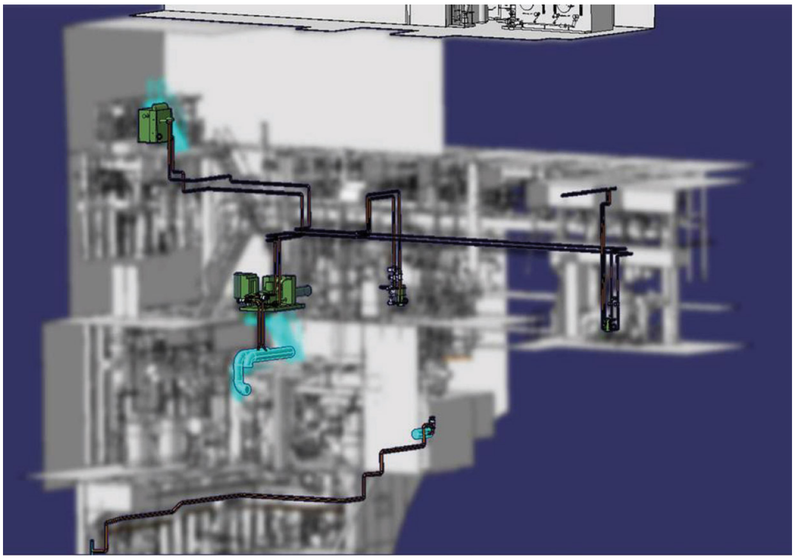

Figure 3 As-Built 3D CAD model with the repair area appended (starboard side of VLCC)

4. Conclusions

Mitsubishi Heavy Industries, Ltd. (MHI) has measured engine rooms of pure car & truck carriers, very large crude carriers, bulk carriers, etc. by a 3D laser scanner and established method of constructing as-built 3D CAD models.

We arranged and laid pipes and auxiliary equipment in the space of these as-built 3D CAD models to prepare fresh drawings for repair works and verified that such 3D information can be used on the detailed design level.

Not to speak of technical innovation, the importance in expediting the execution of large-scale ship repair works in compliance with environmental regulations is to obtain an accurate grasp of the needs customer seek through as-built 3D CAD model-based communication with them for continual proposal of an optimum system.

MHI will carry on this process of customer value creation in the future through our repair engineering.