Digitalization in the Maritime Industry

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1. Introduction

Interest in digitalization and business transformation using digital technology has increased, and even in conventional industries, there are companies making efforts to establish the position of a responsible person such as a CDO (Chief Digital Officer) to oversee digitalization, or to establish a digital department. Various explorations and trials are being carried out in various situations such as what digitalization strategies should be and whether the department responsible for digitization should be a new digital department or an existing business department.[1)]

As the background of the management of conventional industries focusing on digitalization, as embodied by GAFA, there will be a sense of danger of losing competitiveness in medium- to long-term business strategies.

These movements are also rushing to the maritime industry, and there are similar movements in setting up CDOs and specialized departments shipping companies and major manufacturers in Europe and in other areas, and classification societies are competing in creation of guidelines and the revisions of rules in line with the digitization of classification services.

The author has so far been involved in research and development on the application of computer technologies in the maritime field at universities, and in shipbuilding and shipping. This report first looks back on the history of the use of computer technologies that Japan has advanced, and then the essence of digitalization and the related digital twins are described, and based on the author's own experience and work, the role of collaboration with domain experts in data analysis and the open platform for data sharing are described. Finally, issues of the maritime industry and the role of digitalization are described and conclusions are stated.

2. Use of Computer Technology in the Maritime Industry

So what is the difference between this digitalization and the introduction of conventional information systems? First of all, I would like to briefly look back on the introduction of computer technologies so far in Japanese shipbuilding and shipping.

Shipbuilding and shipping have introduced the latest information technologies at an early stage compared to other industries. In shipbuilding, the mainframe was introduced in the 1970s, and advanced numerical calculation methods such as the finite element method (FEM) were applied to structural design, and in the late 1980s, design work was rationalized by detailed design using CAD on workstations and data output from there to the production system called NC machine tools.[2)]

In addition, it has also contributed to shipbuilding development and productivity improvement, such as with technology to develop ship hull forms by combining model tests in tanks and CFD (computational fluid dynamics), and the simulation of production processes using product models.

In shipping, the mainframe was introduced at the same time as shipbuilding in the 1970s, and operations such as B/L (Bill of Lading) issuance and cargo information management were rationalized[3)], and since then, operation work has been further rationalized by introducing a stowage computer for each ship type, such as container ships and car ships, and the introduction of an operation management systems for ship operations and ship management have proceeded.

In addition, with regard to ship equipment itself, the introduction[4)] of autopilots for automatic steering from the 1960s, the formulation[5)] of The M0 (Referred to as "M Zero") specification for the unmanned operation of engine rooms at night and the integrated control monitoring system were developed during the same period. Since the 1990s, along with computer technology innovation, control technology and information systems have been introduced, such as the introduction of GPS and electronic navigational charts (ECDIS) and the introduction of TCS (Track Control System) and AIS in cooperation with autopilots. In the main engine, the utilization of computer technology has proceeded as electronically controlled engines[6)] that replaced mechanical fuel injection using a conventional cam with software control, and this became popular in the 2010s.

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Looking back on history, it can be seen that both shipbuilding and shipping have incorporated the latest computer technologies from time to time into their own businesses and ships themselves for rationalization and efficiency.

3. The Essence of Digitalization

Compared with the introduction of conventional computer technology and information systems and current digitalization, of course, the use of mobile terminals and the use of convenient digital tools such as AR and VR are also important, but this point has been addressed by the introduction of conventional information systems and there is no significant difference.

Here, the purpose of digitalization is to clarify the waste inherent in conventional ways of businesses, to reduce it and promote rationalization. For this purpose, there is an idea to bring the logic of the computer world into the complex real world in a sense using digital tools such as data, simulation, and optimization. This is to promote rationalization and efficiency beyond the boundary of each company by using digital tools. Aiming for an industry that becomes leaner and meaner, the idea of creating an industrial structure that is more competitive than ever through new forms of collaboration with customers and suppliers is inherently included in the term digitalization.

By visualizing the situation with data, increasing transparency, making waste clear through analysis, and working with customers to aim for leaner situation, is it possible to change the competitiveness of a company? I think that is the point of view of managers who are actively engaged in digitalization.

4. Digital Twin

Recently, “digital twin” is a keyword that has been attracting attention. A real-world twin model is created on a computer, current data is extracted by IoT and reflected in a computer model, and an optimal solution is derived through simulation and optimization calculations on the computer and reflected in the real world, and also here, and basically the concept is to highlight and improve the waste that exists in the real world.

The digital twin concept itself was developed from the use of computers in engineering such as CAD/CAM/CAE, and the concept of PLM (Product Life Cycle Management), and is based on the idea of expanding the product model that has conventionally been kept in the manufacturing industry to the operation of products.[7)]

On the other hand, the digital twin is a very powerful concept, and in various industrial fields a part of reality is extracted from each aspect, modeled and expressed on a computer, and the current state sensed by IoT is reflected in the model, and simulation and optimization calculations are performed for the future, and after that, in the current state, companies make important decisions based on simulation predictions, which can be called almost real, as to how best to behave, and companies are always willing to take optimized options.

Taking Uber's dispatch service as an example, cars currently driving in the vicinity are displayed in the smartphone app, the estimated arrival time from each location to the current location is displayed, and the car to be dispatched is selected while referring to attribute information such as vehicle type, fee, and driver ranking. Although it seems that the same fleet management is performed not only in Uber but also in taxi company dispatch services and dispatch center systems, it provides an easy-to-use application that combines the vehicle location information obtained from the IoT, the arrival time prediction based on the optimal route calculation algorithm, and the attribute information database. In this way, users can always find the best driver according to their own standards, and drivers can also provide services only when they can work. All payments are made electronically for both users and drivers. As seen above, this is an example of digitalization in terms of eliminating various levels of waste, and tools such as the digital twin play a central role in realizing this.

Another example of a digital twin is the GE wind turbine (Figure 1). Turbine equipment for wind power generation is already connected to the network and is converted to IoT in the sense that sensor data is sent, and the operation status can be monitored remotely. Using this data, the fleet of wind turbines that make up the power plant is modeled on a computer, and in this example, by combining CFD simulation and optimization calculations, the direction that each windmill should face is optimized, and the concept of maximizing the amount of power generation under wind conditions is shown.

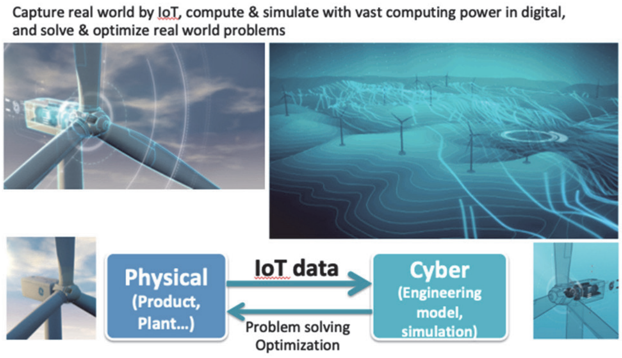

Figure 1 Example of Digital Twin in GE Wind Turbine

What seems to be important here is that engineering knowledge related to CFD is the technical knowledge that has been necessary for design and production in the past. However, in the era of IoT, the knowledge is not only necessary in design and production, but it is also needed in operations in order to optimize wind power generation. IT technology alone cannot solve optimal operation, and it is difficult to realize and utilize an actual digital twin without the cooperation of engineering and IT experts and combining each technology well.

As with the maritime industry, in digitalization in conventional industries, collaboration between domain experts such as engineering and IT experts becomes very important.

5. Collaboration with Domain Experts

Around 2003, when I was working as a graduate school teacher, I worked with a graduate school student in the text mining analysis of problem cases in ship engine & power plants[9]. Background of the research was an article in the Intelligent Systems magazine of IEEE about an airline company using sensor data sent from airplanes and machine learning of maintenance records to predict the replacement timing of aircraft parts from past maintenance records[10]. At that time, with receiving a lot of guidance from the veteran chief engineer, we first conducted a study to analyze available past failure reports.

Although detailed explanations are omitted, using various natural language processing and artificial intelligence technologies, such as ontologies and several machine learning methods, we analyzed past cases of engine failure with a computer, complemented by humans, and we conducted a study to extract a fault tree used in reliability engineering with little effort.

At that time it was still not called *Big data*, but pattern discovery from such large dataset was called *data mining*. In data mining, data is generally organized and analyzed by various machine learning methods, patterns are discovered, and finally, patterns are reviewed and evaluated by domain experts, and since the purpose was to search for treasure from data, such as discovering knowledge, in that sense, we built a method to realize such a process.

However, when we explained the knowledge (in this case, the failure tree) obtained from past failure reports to NYK chief engineers, we got the response that "I see, it was well organized for amateur.", but naturally, we couldn't have such valuable knowledge that a veteran chief engineer would respect.

This was natural results., In a sense, the contents of the fault reports were simply rearranged into the appearance of the fault tree, and it is not more than what was described in the original failure reports. After all, in a normal situation, the designers of manufacturers or chief engineers drill down the root causes behind such failure reports, and valuable knowledge in the true sense can be obtained by examining the methods how to prevent its occurrence, and what to do to minimize consequences after such problems occur.

However, after that, based on the hints obtained from our research, in the department of the chief engineer who made the previous comment, made study on past accidents records, which NYK have experienced so far. At that time, the loss amount evaluated financially was added as teaching data for each trouble, narrowed down to those with large-scale losses, and detailed cause analysis was conducted. A countermeasure manual was then rationally created by repeating hypothesis testing like data mining and a method similar to machine learning with teaching. After that, I heard later that NYK achieved to reduce the number of problems and the resulting damage for targeted engine issues. After all, the concept of data mining is realized when the domain experts understand the concept and methodology of it and work with solid motivations to solve problems.

More than 15 years have passed since then, and now skilled chief engineer leads dedicated teams that use big data of engine and power plants, continuing to show valuable perspectives and judgment as a domain expert, and leading the overall activity. At the same time, I began to observe situations, where data scientists, who are skilled at handling large amounts of data and calculating numerical values, work together with the engineer to find abnormalities using sensor data from ships. This kind of domain experts and IT experts collaboration is exactly what will transform work through digitalization, and I am convinced that this is an approach that uses data to truly solve problems.

In order to create such a situation, on the other hand, it is necessary to have an IT infrastructure experts who can design, develop and operate IT infrastructure to collect sensor data, arrange it into a form that can be analyzed, and the cost of developing and maintaining such an infrastructure is also necessary. Based on these total cost effects, management support for tackling data utilization is also very important, as well as support for introducing digitalization activities into the organization, and understanding and driving by the business divisions. I think the sorts of approaches are digital transformation of companies.

Also, through digitalization, the power of computers is utilized, standardization and tool introduction are promoted so as not to take time and cost, and a cycle in which data can be used continuously with acceptable effort and cost, and the aim is to create a continuously learning organization from data. I think that is the ideal that digitalization should aim for. According to the chief engineer, who is in the story of 15 years ago, mentioned recently to me that the idea to collect data, analyze it, and make objective judgments based on it, has long been existing traditionally in the company and onboard ships. In fact, there were official instruction documents that show how to collect data, by which, every engineers had been able to collect and analyze data. This time, by automating the means of collecting data and using IoT, the amount of data is enormous and tools for analysis and machine learning have been prepared, and have become possible to create a place for data scientists to be active. I received a comment by the engineer saying, “In essence, if you explain that current IoT and abnormality detection is the same way of thinking that has been done in the field traditionally, they will understand well and be pleased.”

In a sense, when the digital twin mentioned above can be used in the field, such as in operating based on the results, there remains a need for domain experts to make comprehensive decisions, including factors that are not considered in more complex computer models and simulations, and on the other hand, we digital engineers continue to refine our skills to make full use of modern tools such as data collection, analysis and simulation. I think that there is a form of modern data utilization and digitalization that we aim for while collaborating with the domain experts responsible for business.

6. Open Platform for Data Utilization

As described so far, it is very important to use data to advance digitalization in traditional industry, and it can be said that it is important to promote the utilization of data in cooperation with domain experts.

This also leads to the importance of sharing data and using data to collaborate with professionals in each field, domain experts on ship products such as shipyards, manufacturers, classifications, and maritime business experts such as shipping, ship management, insurers, brokers, etc.

Although the author began collecting ship data to improve shipping company operations around 2008, and equipped with a data collection device to accurately grasp ship performance and operational status, for ship designers, such as for safety purposes and shipbuilding, there are many uses for such data utilization, and we thought that sharing data with them could create new value. In addition, on the other hand, if a computer for data collection was installed on the ship for each purpose, it would be too much installation work and cost, and would therefore be wasteful, and eventually data utilization would not be realized, and therefore, computers for data collection need to be generalized and integrated. To that end, we came up with the idea of standardizing the computer specifications for data collection in some way.

At that time, such discussions were held under the activities of the “Research Group of Smart Ship Aiming for Optimization for the Environment” in 2011-2012 of the Japanese Marine Equipment Association. After that, in response to these discussions, since February 2013, the Smart Ship Application Platform Project (SSAP) activity at the Japanese Marine Equipment Association was started, aiming to propose the standardization of onboard data collection servers from Japan.

The activities of the study group included the trial design of onboard data servers, prototype development and trial on domestic vessels, and concept creation of the open platform between shore and ship (Figure 2). Based on these experiences, finally, two new ISO standard proposals NP (New work item Proposals) were conducted in cooperation with the Japan Ship Technology

Research Association (JSTRA), the official secretariat of Japan's ISO/TC8.

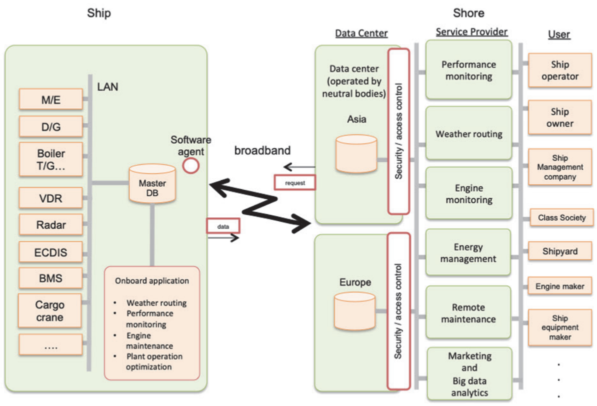

Figure 2 Conceptual Diagram of the Open Platform between Shore and Ship

After that, at the New Smart Ship Application Platform Project (SSAP2 Project) from August 2015, ISO work was promoted with JSTRA, and the draft standards were revised with the cooperation of experts including Norway and Denmark, and in October 2018, it was officially registered as ISO19847 (specification of onboard data collection server) and ISO19848 (data format used by onboard data server) [11, 12].

Although there has been an international standard called IEC61162 for navigation data[13], and it is easy to extract the IEC61162 signal output from each navigational device. On the other hand data output from integrated control and monitoring systems, which collect engine and power plant data, did not have a fixed protocol. and there are hundreds to thousands of data points in such system. Therefore, conventionally, it has been a troublesome task and costly to deal with for each individual ship to extract data about engine and power plant. However, by adopting equipment that complies with ISO19847 / ISO19848, it became possible to retrieve the list of tag names collected by the system and the time-series data of each tag in a standardized manner, and this is expected to greatly reduce the difficulty of data collection from such system.

In addition, ShipDC was established at the end of 2015 as a wholly-owned subsidiary of ClassNK as a mechanism to transfer data collected from ships to the land and share it with participants in the maritime field at a shore data center while controlling security and access authority. The IoS-OP (Internet of Ships-Open Platform) consortium, the user group of ShipDC, was established in 2018 after a preparation period in 2017. The IoS-OP discusses (1) rules for data sharing, (2) data quality, and (3) data catalogs.

Although a detailed description is omitted here, the ship data naming framework provided by ISO19847 / 19848 and ShipDC/IoS-OP provides a structured mechanism for linking data collected on ships to the final application, and theoretically, any application or sensor data on the ship, and has a very systematic structure that incorporates a mechanism for firmly connecting within this framework.(Fig.3) In the future, it is expected that the momentum of data utilization will increase in various areas such as ship performance, motion, structure, engine, auxiliaries, and cargo. However, we hope that the utilization of such data will be promoted by collaboration with various domain experts, while maintaining the same scheme that handles such wide range of IoT data collection and utilization systematically.

In this way, the international technical standard of ISO19847 / 19848 and the open platform for data sharing composed of ShipDC / IoS-OP is a platform for neutral data sharing and business consensus building regarding industrial data sharing and utilization, such as in the establishment of rules for data utilization implemented as an industry. This is a very unique and advanced example both globally and in comparison with other industries. In an effort to take advantage of the characteristics and goodness of Japan's maritime cluster, where various technical collaborations have been conducted, in the future, it is expected that the number of supporters and users will increase globally and will be established as a data sharing standard in the maritime field.

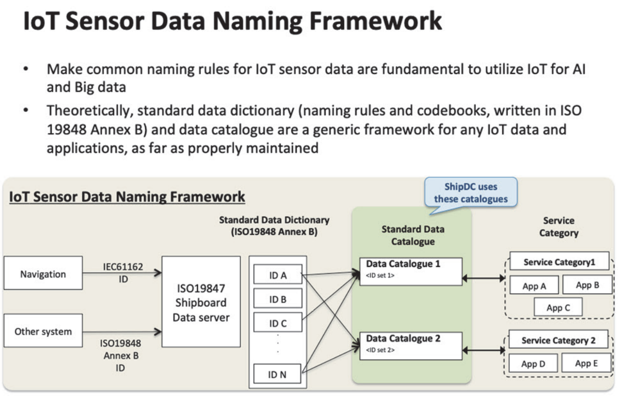

Fig.3 IoT Sensor Data Naming Framework

7. Future Issues in Digitalization

Next, I would like to describe future issues in incorporating digitalization into the maritime industry.

First, it is thought that digitalization will proceed in relation to each business and customer from the standpoints of shippers, shipping, shipbuilding, marine, ship classification, insurance, and brokers that make up the maritime industry. As they are business issues, it might be difficult to understand latest activities from outside, however I think that improvements of actual business and operations by digitalization will evolve at very fast speeds. Here too, collaborations between business experts and IT professionals are essential.

In addition, shipping as a whole has two major challenges: technological development for zero-emission ships and saving of crew workloads of ship operations through the realization of autonomous ships.

In the field of zero emission, although I think the issues will be sorted out in the future, including further optimizing the hull form and propeller based on not only by model scale, but based on full scale by advanced combination of model scale test, full scale measurement and full scale CFD. This is an effort that can be made by using advanced computer technology and measurement technologies in cooperation with shipyards, shipping companies, and manufacturers.

Evaluation technologies for ship performance in services are also an expected field. National Maritime Research Institute of Japan (NMRI) is currently leading OCTARVIA project. It aims at to develop common measures to evaluate the performance of ships under wind and waves, and common base analysis tools.

In addition, with regard to technologies such as structural health monitoring of ships, condition diagnosis of equipment such as engines and steam turbines, and remaining life diagnosis, research is currently underway to improve the design and operation of ships more rationally, and future commercialization is awaited.

As mentioned above, there is data collected by ships as one of the keys for various future use cases. I expect that the open platform mentioned earlier will be used for these various purposes.

Another major issue is technology development for autonomous ships. The main theme here is the technical development of marine manufacturers, and the other is the operational, organizational and social issue of how to safely operate such highly sophisticated and complex systems. However, in case of Japan, with declining birthrate and coming shortage of labors, although efforts to deal with this issue are inevitable, it is necessary to cultivate seeds of these technologies and raise them to a state that is socially acceptable. Japan has historically been actively engaged in the research area of autonomous ships since the 1970s. There are also new issues such as comprehensive safety assessment, system integration, software reliability, cyber security, and many of these are extremely computer technology and software related.

In the future, maritime industry is expected to steadily advance research and development, demonstration, practical application, and operation in both hardware and software to overcome these issues. The advancement of digitalization as a whole in the maritime field while also utilizing the data sharing framework has an extremely close relationship with the movement toward solving major problems in the maritime field such as zero emissions and autonomous ships.

8. Conclusions

A view on maritime digitalization is introduced. Beyond individual companies, the entire maritime industry is required to promote rationalization and efficiency through digitalization. The importance of using data, and the importance of working with domain experts and IT experts are also mentioned. In the utilization of ship data, an open platform framework has been proposed by Japan, and this utilization is expected in the future.

In the future, although it will be necessary to move toward major issues such as zero emissions and autonomous ships, I believe that digitalization is the driving force for that. We will continuously utilize data, vast computational power and domain knowledge to promote rationalization and efficiency improvement for the entire maritime industry as one of main players of global society.

References

1) Michael Wade, DX Execution Strategy; Create an organization that earns digitally, 2019
2) Masahiro Sonda, Current Status and Future Prospects of Shipbuilding Systems, collection of papers of lectures of the Society of Naval Architects of Japan, No.5, 2005
3) Hundred Years History of Nippon Yusen Kabushiki Kaisha (NYK Line), 1988
4) Diesel oil carrier (including combined use) NK-M0 Engine Department Automation Standard Specification, Japan Institute of Marine Engineering Vol.9 No.1, 1974.1
5) Takeo Koyama, Research on Optimal Automatic Steering System for Ships Sailing in the Open Sea, collection of papers of the Society of Naval Architects, 1967 122, p.18-35, 1967
6) What is an electronically controlled diesel engine? http://www.marine-engineer.or.jp/images/denshiseigyo_diesel.pdf
7) Michael Grieves, Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management (English Edition), 2012
8) Tomas Kellner, Wind in the Cloud? How the Digital Wind Farm Will Make Wind Power 20 Percent More Efficient, GE Industrial Report, Sep 2015 http://www.gereports.com/post/119300678660/wind-in-the-cloud-how-the-digital-wind-farm-will/
9) Ando, Yamato, Hori, Masuda, Shiroyama, Research on failure report analysis method using text mining, collection of papers of the Society of Naval Architects of Japan, 2002 192 p. 475-483
10) S. Letourneau et.al.,: Data Mining to Predict Aircraft Component Replacement, IEEE Intelligent Systems and their Applications, Volume 14 Issue 6 Nov/Dec 1999
11) ISO 19847:2018 - Ships and marine technology — Shipboard data servers to share field data at sea
12) ISO 19848:2018 - Ships and marine technology — Standard data for shipboard machinery and equipment
13) IEC 61162-1:2016 - Maritime navigation and radio communication equipment and systems - Digital interfaces - Part 1: Single talker and multiple listeners