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Research on Basic Concept Design for Digital Twin Ship Platform

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디지털트윈 선박 플랫폼 설계를 위한 연구

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Abstract : *The International Maritime Organization is establishing international agreements on maritime safety and security to prepare for the introduction of autonomous ships. In Korea, the industry is focusing on autonomous navigation system technology development, and to reduce accidents involving coastal ships, research on autonomous ship technology application plans for coastal ships is in progress. Interest in autonomously operated ships is increasing worldwide, and maritime demonstrations for verification of developed technologies are being pursued. In this study, a basic investigation was conducted on the design of a demonstration ship and an onshore platform (remote support center) using digital twin technology for application to coastal ships. To apply digital twin technology, an 8-m small battery-powered electric propulsion ship was selected as the target. The basic design of the twin-integrated platform was developed. The ship navigation and operation data were stored on a server system, and remote-control commands of the electric propulsion ship was achieved through communication between the ship and the onshore platform. Ship performance management, operation and operation optimization, and predictive control are possible using this digital twin technology. This safe and economical digital twin technology is applicable to ships responding to crisis scenarios.*

Key Words : *Autonomous ship, Digital twin, Denomstration ship, Onshore platform, Electric propulsion system*

요 약 : 국제해사기구(IMO, International Maritime Organization)를 중심으로 자율운항선박 도입을 대비한 해사안전 및 보안관련 국제 협약을 제정하고 있다. 국내에서도 선급 및 산업체를 중심으로 자율운항시스템 기술개발에 착수하고 있으며 연안선박에서 발생하는 사고를 줄이기 위해 연안선박을 대상으로 하는 자율운항선박 기술적용 방안 연구가 진행되고 있다. 국내외적으로 자율운항선박에 대한 관심이 크게 증가하고 있으며 실제 개발된 기술의 검증을 위한 해상실증이 본격적으로 추진되고 있다. 본 연구에서는 연안선박에 적용하기 위한 디지털트윈 기술 관련 실증선박과 육상 플랫폼(원격지원센터)의 설계를 위한 기초연구를 진행하였다. 디지털트윈 기술을 선박에 적용하기 위해 8m 소형 배터리 전기추진선박을 대상으로 선정하였으며, 선박과 육상 플랫폼 간 통신을 통해 선박 항해 및 운전 데이터가 서버 시스템에 저장되고 전기추진선박의 원격제어 명령이 가능한 디지털트윈 통합 플랫폼의 기본 설계를 진행하였다. 이러한 디지털트윈 기술을 적용한 선박 성능관리, 운항 및 운영 최적화, 예지제어 등이 가능할 것으로 판단되며, 위기상황에 대응이 가능한 안전하고 경제성 있는 디지털트윈 기술의 선박적용이 가능할 것이라 사료된다.

핵심용어 : 자율운항선박, 디지털트윈, 실증선박, 육상플랫폼, 전기추진시스템

1. Introduction

At the 99th Maritime Safety Committee (MSC) of the International Maritime Organization (IMO), the definition of MASS (Maritime Autonomous Surface Ships) and the degree of autonomy were decided and the enactment of international agreements related to maritime safety and security that may arise when introducing autonomous vessels was initiated (IMO, 2018). As a result, interest in autonomous vessels is increasing both domestically and internationally and related technology development and maritime

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demonstration using vessels are being actively pursued (Son and Lee, 2018; Bae, 2020).

In Korea, various research institutes and industries centered on Korean Register are in the process of developing autonomous navigation system technology for coastal ships (KASS, 2020). According to the statistics of maritime accidents by the Central Maritime Safety Tribunal of the Ministry of Oceans and Fisheries in 2021, 63.3 % of the deaths and missing from coastal ships were caused by safety accidents and most of the accidents are human resources such as missteps, hull crash, and fall on board (Statistics Korea, 2021). This is partly related to the aging of the workers engaged in coastal ships, and discussions are being made on the application of autonomous ships targeting coastal ships as a way to reduce the occurrence of such accidents (Kim, 2021).

In this study, we conducted a basic research on platform design related to digital twin technology, which is a key element among various technologies of autonomous ships that can be applied to coastal ships and in order to apply digital twin technology to ships, an 8m small battery electric propulsion ship was selected as a target ship. In addition, we established the concept of an onshore digital twin system integration platform for real-time communication with ships and as a remote control center, the basic design of a digital twin integrated platform where ship navigation and operation data is stored in a server system and remote control commands of electric propulsion ships is possible was carried out.

2. Overview of Digital Twin and Technology Development Trend

2.1 Overview of Digital Twin

Digital twin technology converts the shape, form, nature, and structure of the object to be modeled into data and makes the real object the same in the digital world in the computer (Choi et al., 2021). By using digital twin technology, which is one of the main technologies of autonomous ships, various scenarios that can occur in the sea environment, such as weather, wave height, wind speed, and direction, are simulated with a computer to predict possible results in advance in the virtual world. Therefore the integrated platform using the cloud platform-based digital twin virtual ship model can be very usefully used in the shipbuilding and shipping field (Son and Lee, 2018).

2.2 Digital twin technology development trends and application examples

Since digital twin technology appeared in 2002, it has been reflected in NASA's space exploration roadmap and has been continuously applied to the space industry. In the early days, most of the applications were in space exploration-related fields, but GE (General Electric) of the United States applied digital twin technology to products such as turbines and engines and became widely known. The development of digital twin technology is progressing and being applied to buildings and smart cities, automobiles and aircraft, transportation fields such as drones, and process plants (Lim, 2018).

Singapore is a smart city using representative digital twin technology. A virtual Singapore called ‘Virtual Singapore’ was created as a 3D model, which includes parts of the entire city including buildings, transportation systems, waterways, etc. Through this, by building a smart city with digital twin technology, it is possible to simulate traffic jams, building energy efficiency, and pedestrian movement patterns, which are important management areas in a city-state. Also it is possible to capture and track all moving parts in a city in real time (NRF, 2022). Fig. 1 shows the concept of Virtual Singapore.

Fig. 1. Concept of Virtual Singapore.

GE of the United States introduced a digital twin technology for power plant operation called 'Digital Power Plant', which integrates data generated in the entire plant process with a digital system to create a virtual power plant, and temperature and pressure of various sensors, vibration, environmental changes, etc. are collected and used as a predictive maintenance function to analyze and diagnose problems in advance (GE, 2021). Fig. 2 shows the concept of digital power plant using digital twin technology.

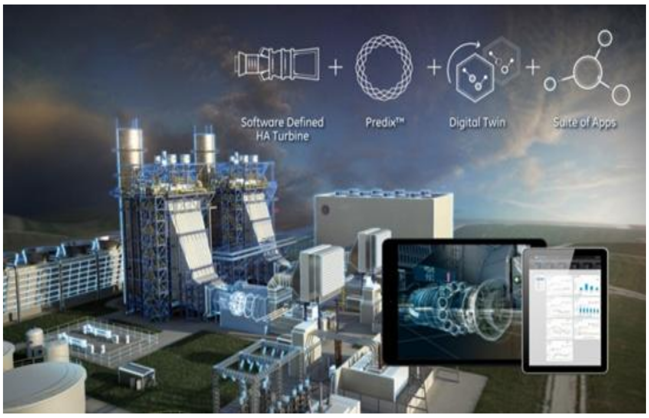

Fig. 2. Concept of digital power plant of GE.

In order to apply the digital twin technology in the shipbuilding and shipping sector, platform development is underway by defining the technology, setting the scope, and presenting the direction, centering on Norwegian Classification (DNV), Japanese Classification (NK), French Classification (BV) and Korean Classification (KR) (Son and Lee, 2018). Based on this, Korea Shipbuilding & Marine Engineering and Avikus succeeded in test-driving an autonomous passenger ship in a virtual space to which HiDTS-VCS (HiDTS-VCS) was applied using digital twin technology. The autonomous passenger ship, which succeeded in test operation, was applied with advanced technologies such as autonomous navigation technology, remote control smart solution, and electric propulsion system equipped with an LNG dual fuel engine (Avikus, 2022). Fig. 3 shows the concept of Avikus's digitnal twin system.

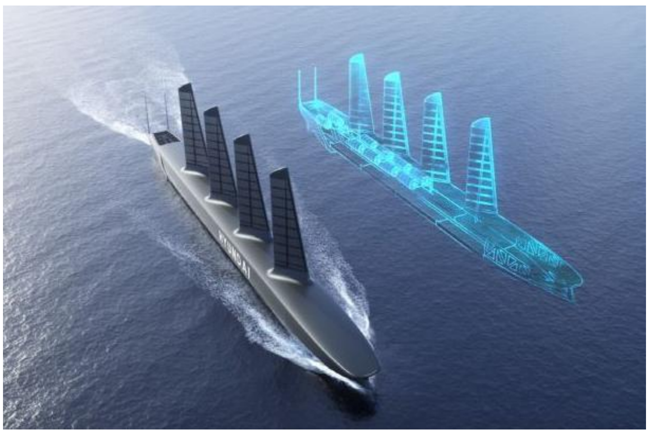

Fig. 3. Concept of digital twin system of Avikus.

3. Digital twin technology for ship application system configuration

3.1 Entire system configuration of digital twin

Digital twin technology instantaneously collects and transmits various data and visualizes it. For this, equipment that can measure data from the target vessel is required, and it is important to adopt a communication method that delivers it to the onshore platform. In addition, the server system that stores the transmitted data and the monitoring and analysis system that can analyze the data should be simultaneously reflected when designing the system.

Fig. 4 shows the overall system configuration of the battery electric propulsion ship and the digital twin integrated platform capable of onshore remote control for the demonstration of digital twin ship technology. In order to apply the digital twin technology to ships, the propulsion system mounted on the ship should have a simple structure without being complicated. The mechanical propulsion system equipped with an existing engine has complex parts to control and monitor, such as the fuel supply system, lubricant system, and cooling system for driving the engine. Therefore, in this study, the target ship for applying the digital twin was selected as a full electric propulsion ship using only batteries as a power source.

For the basic design of the platform of the electric propulsion ship subject to the digital twin demonstration, the parts installed on the target ship and onshore platform are divided into navigation communication system, transmission/reception system, data collection system, electric propulsion system, image information collection system and other ship systems.

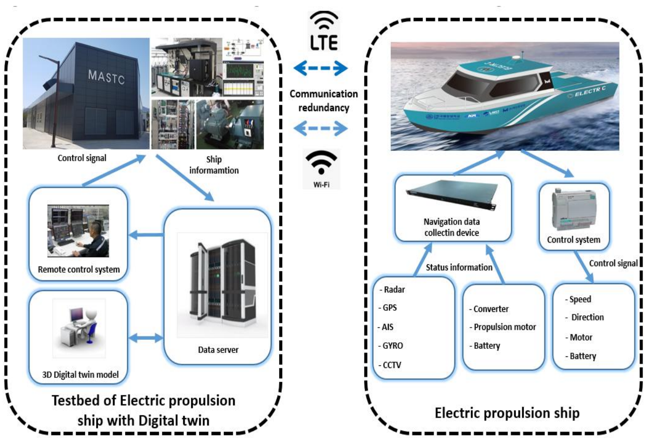

Fig. 4. System configuration of digital twin ship.

3.2 Detailed system configuration

3.2.1 Demonstration ship system

The systems mounted on the target demonstration ship are the navigation communication system, the transmission/reception system, the data collection system, the electric propulsion system, and the image information collection system. The components of each system are as follows.

1) Navigation communication system

Navigation communication system is composed of auto pilot system, radar, heading sensor, satellite navigation system using GNSS or GPS, ECDIS, weather seonsor to collect navigation data,, position and motion information of the ship for demonstration and control the electric propulsion ship. Fig. 5 shows the navigation communication system configuration.

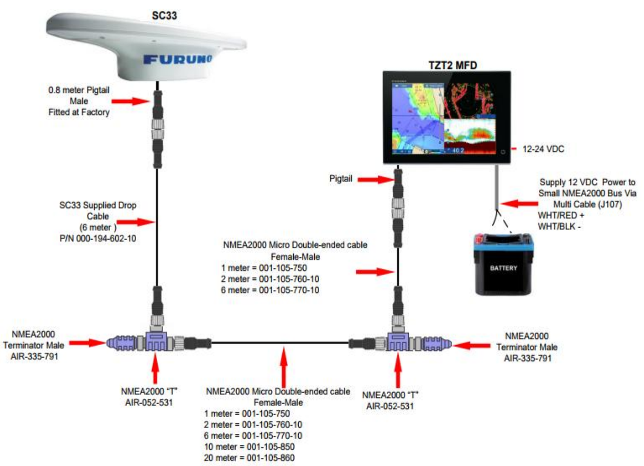

Fig. 5. Satellite navigation system connection.

2) Transmission / reception system

The transmission / reception system is a system for control signal and data communication with onshore and consists of LTE and Wifi. The basic communication method uses LTE communication to maintain control signals and data communication signals with onshore, and a control communication duplication method using Wifi communication signals is applied.

3) Data collection system

As in Fig. 6, the data collection system uses NI's cRIO-9047 controller to receive and process various types of information and data from the navigation communication system, image information collection system, and electric propulsion system. After that, it transmits to the onshore digital twin platform using the transmission/reception system and transmits the control signal transmitted from the onshore platform to the navigation and electric propulsion system.

Fig. 6. cRIO-9047 of NI.

4) Electric propulsion system

As in Fig. 7, the electric propulsion system is a system that uses a propulsion motor rather than obtaining propulsion with an existing engine. The electric propulsion system of the demonstration ship in this study consists of a battery and battery management system (BMS) that stores electric energy, and a propulsion motor and an inverter for propulsion of the ship.

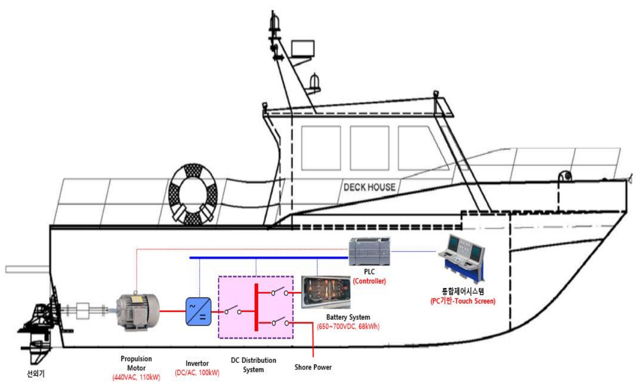

Fig. 7. Diagram of Electric propulsion system configuration.

5) Video information collection system

The image information collection system is a system for collecting real-time images around the ship, and it consists of one PTZ camera and four fixed cameras. The acquired image is transmitted to the data collection device and stored, and it is transmitted in real time to the onshore platform through the transmission/reception system. Fig. 8 shows the video data collection system.

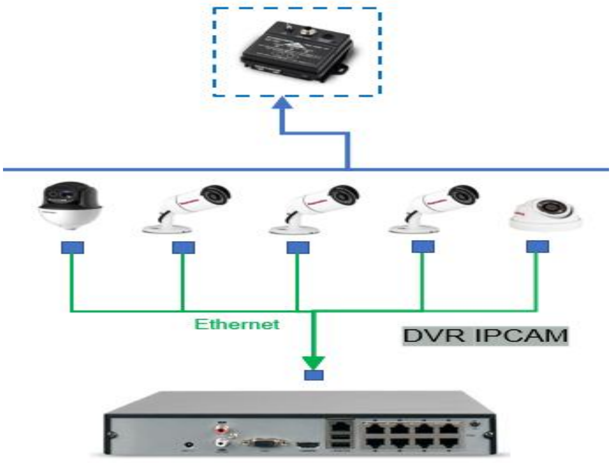

Fig. 8. Configuration of video information collection system.

3.2.2 Onshore digital twin platform

As show in Fig. 9, the onshore digital twin platform basically consists of a communication system, network and data server system, and monitoring system for remote control and real-time status check of the electric propulsion ship to be tested. The onshore communication system is a system for control and data communication with the ship, and is designed to maintain control and data communication with the ship by applying dual LTE and Wifi communication as the basis.

The onshore network and data server system is a network, data storage and processing system for transmitting information received through a communication system to the server system, and the network is composed of a network switch through security equipment. The data server system performs a data processing function of storing and analyzing various data transmitted from the ship.

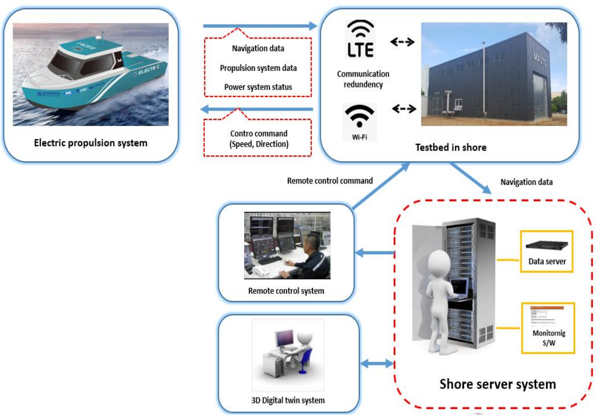

Fig. 9. Concept of onshore digital twin platform.

The onshore monitoring and control system is a system that can monitor and control the ship's data on the onshore digital twin platform. It is possible to display the ship radar and electronic chart data on the display of the control console and transmit the control signal to the ship through the communication system.

3.2.3 Data exchange method between the demonstration ship and the onshore digital twin platform

The data generated by the ship can be utilized for ship control, autonomous navigation, and information provision in case of emergency through various communication methods, and the main equipment applied to the ship adopts the NMEA standard communication method. Since the components of the digital twin ship system communicate using protocols such as Ethernet, CAN, NMEA-0183 and NMEA-2000, an integrated network system for integrating them is mounted. Data exchange between the demonstration ship and the onshore platform is carried out in real time through the integrated network system.

4. Conclusions and considerations

In this study, basic research related to the design of demonstration ships and onshore platforms related to digital twin technology for application to coastal ships was conducted. In order to apply the digital twin technology to ships, an 8m small battery electric propulsion ship was selected as a target ship. The basic design of a digital twin integrated platform that allows ship navigation and operation data to be stored in the server system and remote control commands for electric propulsion ships through communication between the ship and the onshore platform was carried out.

Currently, the integrated solution of digital twin technology specialized for ships is insufficient. In addition, the digital twin technology link between the basically designed demonstration ship and the onshore platform should be made, and the verification process of creating a scenario that enables anomaly detection and problem prediction through the onshore platform should be carried out through these studies.

Through this study, it is judged that it will be possible to apply and demonstrate ship performance management, ship’s operation and operation optimization, AI-based predictive control, data storage through cloud network, and cyber security technology throughout the life cycle of the ship. It is thought that it will be possible to apply safe and economical digital twin technology to ships that can respond to crisis situations.

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