INTERNATIONAL MARITIME ORGANIZATION

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MARITIME SAFETY COMMITTEE
107th session
Agenda item 5

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DEVELOPMENT OF A GOAL-BASED INSTRUMENT FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS)

Results of a transoceanic voyage test with autonomous navigation system

Submitted by the Republic of Korea

SUMMARY

Executive summary:	This document provides information on the results of the world's first transoceanic voyage with an autonomous navigation system with autonomous navigation, manoeuvring, collision detection, and collision avoidance (CDCA) functions, as well as information that autonomous navigation system improves the safety and economic efficiency of ship operations.
Strategic direction, if applicable:	8
Output:	2.23
Action to be taken:	Paragraph 9
Related documents:	None

Introduction

1 With the soaring development of digital technologies and artificial intelligence (AI), research and development of technologies of autonomous ships and systems are being conducted all over the world. In line with this, the Republic of Korea is continuously researching and developing autonomous navigation systems and conducted the world's first autonomous transoceanic voyage test with an autonomous navigation system that has the functions of autonomous navigation, manoeuvring, collision detection, and collision avoidance (CDCA).

The MASS development status in the Republic of Korea

2 The Republic of Korea is carrying out the development of some core technologies for MASS through the Korea Autonomous Surface Ship (KASS) Project. Intelligent navigation systems, machinery automation systems, and some other key technologies are under development. In line with these efforts of the public sector, Avikus Co. Ltd. in the Republic of Korea also participated in KASS Project and pushed forward in the development and testing of the MASS.

Purpose of transoceanic voyage test

3 The purpose of this test is to equip an autonomous navigation system that includes functions of autonomous navigation, manoeuvring, collision detection, and collision avoidance (CDCA) on existing LNG carriers in operation in order to demonstrate the feasibility of the technologies and prove that the application of autonomous navigation system has a positive impact on safe navigation and economic efficiency. This will lay the groundwork for developing a higher degree of autonomous navigation technology and help in the development of further tiers of the MASS Code.

Test process

4 The ship of this test was the 180K LNG carrier **Prism Courage**. As her classification was ABS (American Bureau of Shipping), the implementation of the autonomous navigation technologies was carried out in accordance with the requirements in the 'ABS Guide for Autonomous and Remote Control Functions'. As recommended by ABS, the risk assessment was conducted according to the method presented by Osiris A. Valdez Banda. From the simulation test to the actual transoceanic voyage test, ABS guided Avikus Co. Ltd., reviewed requisite engineering plans and carried out required surveys to issue the Statement of Fact (SoF) of this test. For a more specific test process, refer to annexes 1 and 2.

Result of transoceanic voyage test

5 This test verified the target detection function using AIS, radar, and camera vision and proved that the sensor-fusion technology can provide reliable target information to users. In other words, it was found that the autonomous CDCA function based on detected target information worked well, and it proved that autonomous navigation can be implemented only by interfacing with the autopilot.

6 During the entire voyage from the eastern US to the Republic of Korea, the vessel navigated autonomously for about 360 hours, 10,000 km after passing the Panama Canal to southwestern Japan without any human intervention. The autonomous navigation system detected about 100 potential collision situations and after a collision risk assessment, it gave alarms at the proper time and avoided collisions autonomously after the permission of the OOW (Officer of the Watch). And after the action to avoid a risk of collision, it returned to its original course autonomously too. Also, in terms of economic operation, through route optimization, fuel efficiency was increased by about 7%, while reducing greenhouse gas emissions by 5%. For a more specific test result, refer to annexes 1 and 2.

Commercialization status

7 Even though it was not a fully autonomous navigation system, this test proved that the autonomous navigation system with the function of CDCA provides enough customer value in terms of safety and economic efficiency as evidenced by the order book of about 50 new ships for the autonomous navigation system. It has obtained certifications from ABS, KR, and the Liberia flag, and the certification process for LR, NK, and DNV is currently ongoing. This track record of orders shows that the commercialization of autonomous systems is already happening, and the industry will continuously be pushing for the commercialization of higher degrees of autonomous navigation systems.

Conclusion

8 The transoceanic voyage test did not end as a one-off event but yielded significant results, leading to actual orders. The industry is taking a stepwise approach towards the commercialization of a higher degree of autonomous navigation, and this transoceanic voyage test is a positive step in that direction. It also indicates that the era of MASS may come sooner than expected. Given the current state of the maritime industry, the development of autonomous navigation technology is expected to improve the safety and economic efficiency of ship operations.

Action requested of the Committee

9 The Committee is invited to note the information regarding the transoceanic voyage test of the autonomous navigation system with CDCA functions, including annexes 1 and 2.

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ANNEX 1

DETAILS OF AUTONOMOUS NAVIGATION SYSTEM WITH AUTONOMOUS NAVIGATION, MANOEUVRING, COLLISION DETECTION, AND COLLISION AVOIDANCE (CDCA) FUNCTIONS

Introduction

HiNAS2.0 is an autonomous navigation system that has the functions of autonomous navigation, manoeuvring, collision detection, and collision avoidance (CDCA). It is a partially autonomous system, not a fully autonomous system which means all the responsibility of autonomous operation is belonging to the certified officers/captain on board. The definition of 'MASS' and 'Degree of Autonomy' is still under discussion, and the concept of 'autonomous navigation' and 'remote-controlled/unmanned navigation' is different. Therefore, to make clear the stepwise development by using the word that can express more detailed and subdivided for autonomous navigation technology.

Concept of Operation

The purpose of the HiNAS2.0 is to assist the navigation and manoeuvring work of the certified officers/captains of ships by autonomously performing the behaviours (planning - recognition – decision – control) of humans. The main role of the system is to follow the planned route and speed as the voyage plan, take action to avoid the risk of grounding and/or collision, then come back to the original planned route. Since this system is designed for assistance, the responsibility of the operating function belongs to the certified officers/captain on board. Also, the loop of the function is not interfaced with outside the vessel.

Function Description

In HiNAS2.0, the scope of function is limited to 'monitoring - planning- recognition – decision – control' in the limited operational envelope. The detailed terms of each function are as follows.

- Monitoring: Monitoring the voyage status by video streaming and geoinformation display
- Planning: Route planning for the voyage (The system adopts route plan from ECDIS or another route planning module)
- Recognition: Danger target recognition by using vision, AIS, radar, and ENC
- Decision: Decide if the recognized target is dangerous or not. Decide the direction for collision avoidance. If not, it guides the ship to follow the planned route and speed.
- Control: Automated command input to the autopilot and BMS for planned route tracking and collision avoidance (Auto Mode, CA Mode)
- *Note: Here, the control does not mean controlling the rudder or main engine directly. It means assigning the proper command to each control unit replacing the command of humans (i.e. autopilot, BMS)

System Operation Mode

HiNAS2.0 has the following operation modes, 'monitoring' mode, 'recommend' mode, 'auto' mode, and 'CA (Collision Avoidance)' mode.

The first one is the 'monitoring' mode. In this mode, the system conducts interfaced sensor reading and monitoring voyage statuses such as camera streaming, geoinformation display, and collision risk evaluation. This mode is activated when the initial system starts, or the system returns control authority caused by an alert or warning level alarm or not in the operational envelope.

The second mode is the 'recommend' mode. This mode is activated when the user activates recommend button. In this mode, the system suggests a proper collision avoidance strategy (heading or speed) to the user to support decision-making. Since this mode does not have a control authority to autopilot or BMS, it can be activated regardless of alarm or operational envelope constraints.

The third mode is the 'auto' mode. In this mode, the system can control the autopilot and BMS to conduct an autonomous voyage by tracking the planned route and speed without collision avoidance. It can be activated if and only if no alert or warning level alarm is indicated and the voyage condition is in the defined operational envelope.

The last mode is the 'CA (Collision Avoidance)' mode. This mode is enabling the activation of collision avoidance in addition to the auto mode. In the normal operation condition (no alarm and no operational envelope constraint), the mode is going back to auto mode when CA mode is deactivated. If it is not, it returns to the monitoring mode. The detailed functions to be implemented in each mode are as below in table 1.

For the autonomous navigation function, the operational envelope is divided into three categories. The first one is a system envelope, the second one is an environmental envelope, and the other is a human envelope. Regarding the autonomous navigation function, the Auto mode and CA mode can be activated if and only if the defined operational envelope is satisfied.

Functions To Be Implement	Mode Name			
	Monitoring	Recommend	Auto*	CA*
Monitoring	O	O	O	O
Planning	O	O	O	O
Recognition (Object Detection)	O	O	O	O
Decision (Collision Risk Evaluation)	O	O	O	O
Control (Route/Speed Tracking)	X	X	O	O
Control (Collision Avoidance)	X	X	X	O
Remark	-Default mode -No control authority	-Support decision-making -No control authority	-Conduct autonomous voyage -Has control authority without collision avoidance -Only valid no alarm and within operational envelope	-Conduct autonomous voyage -Has control authority with collision avoidance -Only valid no alarm and within operational envelope
*Note: Users can set the control unit for Auto/CA mode activation such as autopilot only (H mode), BMS only (S mode), and both (HS mode)				

Table 1: Modes of the autonomous navigation system

Function Flow of HiNAS2.0

Once the HiNAS2.0 is executed, the system checks the health condition of the interface and internal software module. If the system health status does not meet the requirement of auto mode, the system notifies the operation condition does not meet the requirement and only monitoring mode is available to use.

The function starts with the route planning stage. HiNAS2.0 is interfaced with the ECDIS module and optimal route planning module. The user can plan and optimize the overall voyage plan with HiNAS2.0 and applies the plan to the system. In this stage, users decide on autonomous voyage LEGs based on their experience saying whether the voyage area is congested or not.

After applying the route planning, users conduct and monitor the voyage. If the requirements to conduct auto mode are met, the auto mode button is activated, and users can click the button to conduct an autonomous voyage. In this mode, autonomous route and speed tracking is conducted. Also, the background watch system monitors voyage conditions, and the alarm is always running to see if an autonomous voyage can be conducted or not. Based on the decision of the background watch system, the auto mode can be deactivated at any time. If the auto mode is deactivated, the system returns the control authority to the control unit (i.e. autopilot and BMS) with a visual, audible alarm and goes back to the monitoring mode.

In addition to the auto mode, users can activate CA mode, which stands for collision avoidance mode. In this mode, the system makes a decision for collision avoidance and conducts it autonomously. In normal operation (no alarm and no operational envelope constraint), it goes back to auto mode when it is deactivated. If it does not (with alarm or operational envelope constraint), it returns to monitoring mode. In this mode, the background watch system is always running in the auto mode. Since the recommend mode can be activated regardless of auto mode constraints, the function flow for recommend mode has not been described in this mode.

User category

HiNAS2.0 assigns the control command to autopilot and BMS. It is directly related to the safe operation of the ship therefore; the user level is categorized into four levels and each level has a different authority. The detailed access authority describes below in table 2.

Menu	User Category			
	Administrator	Captain	Normal User	Custom User
Admin/Auth	O	X	X	X
Function Activation -Auto -Collision avoidance	O	O	X	X
Function Activation -Recommend	O	O	O	X
Alarm -Ack	O	O	X	△
Route Planning -Apply plan -Cancel plan -Save (Server)	O	O	X	△
Route Planning	O	O	O	O

Menu	User Category			
	Administrator	Captain	Normal User	Custom User
-Save (Local) -Calculate (Optimization) -Validation Check				
Display change	O	O	O	O
Monitoring	O	O	O	O
O: Can access, and control freely / X: Cannot control /△: Can control if the admin gives authority				

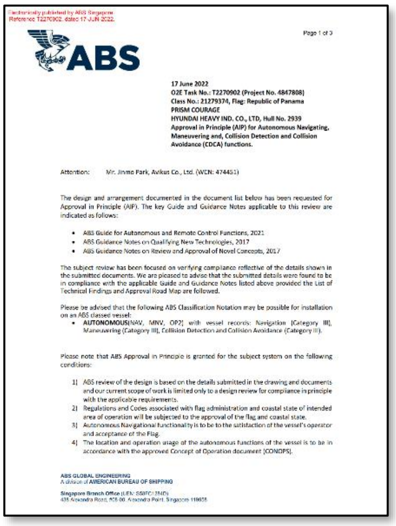
Table 2. User category

Cybersecurity

For cybersecurity, HiNAS2.0 is equipped with devices for software-wise and hardware-wise views. The methods are hardware firewall, software firewall, USB port blocking device, LAN port blocking device, and third party management policy. By using those methods, HiNAS2.0 ensures the cybersecurity level of the 'Cybersecurity System' defined by ABS. Also, it is guaranteed cybersecurity by receiving cybersecurity certification SL3 of KR too.

Certifications

In line with these functions and effectiveness, HiNAS2.0 has received certifications as below in table 3 and the certification process for LR, NK, and DNV is currently ongoing too.

Class/Status	Certification
ABS AIP (Approval in principle) obtained (17 June 2022)	

Electronically published by ABS Singapore.
Reference T2270902. dated 17-JUN-2022.

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ABS

17 June 2022
O2E Task No.: T2270902 (Project No. 4847808)
Class No.: 21279374, Flag: Republic of Panama
PRISM COURAGE
HYUNDAI HEAVY IND. CO., LTD, Hull No. 2939
Approval in Principle (AIP) for Autonomous Navigating, Maneuvering and, Collision Detection and Collision Avoidance (CDCA) functions.

Attention: Mr. Jinmo Park, Avikus Co., Ltd. (WCN: 474451)

The design and arrangement documented in the document list below has been requested for Approval in Principle (AIP). The key Guide and Guidance Notes applicable to this review are indicated as follows:

- ABS Guide for Autonomous and Remote Control Functions, 2021
- ABS Guidance Notes on Qualifying New Technologies, 2017
- ABS Guidance Notes on Review and Approval of Novel Concepts, 2017

The subject review has been focused on verifying compliance reflective of the details shown in the submitted documents. We are pleased to advise that the submitted details were found to be in compliance with the applicable Guide and Guidance Notes listed above provided the List of Technical Findings and Approval Road Map are followed.

Please be advised that the following ABS Classification Notation may be possible for installation on an ABS classed vessel:

- **AUTONOMOUS**(NAV, MNV, OP2) with vessel records: Navigation (Category III), Maneuvering (Category III), Collision Detection and Collision Avoidance (Category III).

Please note that ABS Approval in Principle is granted for the subject system on the following conditions:

1) ABS review of the design is based on the details submitted in the drawing and documents and our current scope of work is limited only to a design review for compliance in principle with the applicable requirements.
2) Regulations and Codes associated with flag administration and coastal state of intended area of operation will be subjected to the approval of the flag and coastal state.
3) Autonomous Navigational functionality is to be to the satisfaction of the vessel's operator and acceptance of the Flag.
4) The location and operation usage of the autonomous functions of the vessel is to be in accordance with the approved Concept of Operation document (CONOPS).

ABS GLOBAL ENGINEERING
A division of AMERICAN BUREAU OF SHIPPING

Singapore Branch Office (UEN: S88FC1284D)
435 Alexandra Road, #08-00, Alexandra Point, Singapore 119958

<table>
<tr><th>Class/Status</th><th>Certification</th></tr>
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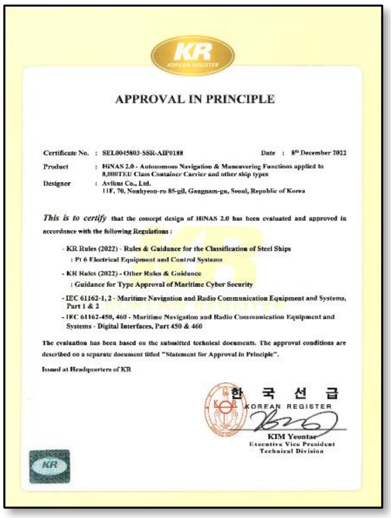
obtained (08 December 2022)</td><td>
KR KOREAN REGISTER
APPROVAL IN PRINCIPLE
Certificate No. : SEL0045803-SSR-AIP0188 Date : 8th December 2022
Product : HiNAS 2.0 - Autonomous Navigation & Maneuvering Functions applied to 8,000TEU Class Container Carrier and other ship types
Designer : Avikus Co., Ltd. 11F, 70, Nonhyeon-ro 85-gil, Gangnam-gu, Seoul, Republic of Korea
This is to certify that the concept design of HiNAS 2.0 has been evaluated and approved in accordance with the following Regulations :
- KR Rules (2022) - Rules & Guidance for the Classification of Steel Ships : Pt 6 Electrical Equipment and Control Systems
- KR Rules (2022) - Other Rules & Guidance : Guidance for Type Approval of Maritime Cyber Security
- IEC 61162-1, 2 - Maritime Navigation and Radio Communication Equipment and Systems, Part 1 & 2
- IEC 61162-450, 460 - Maritime Navigation and Radio Communication Equipment and Systems - Digital Interfaces, Part 450 & 460
The evaluation has been based on the submitted technical documents. The approval conditions are described on a separate document titled "Statement for Approval in Principle".
Issued at Headquarters of KR
한 국 선 급
KOREAN REGISTER
KIM Yeontae
Executive Vice President
Technical Division</td></tr>
<tr><td>ABS
PDA (Product Design Assessment)
obtained (28 December 2022)</td><td>
Electronically published by ABS Singapore
Reference T2341808, dated 28-DEC-2022
ABS
CERTIFICATE NUMBER 22-2341808-PDA
EFFECTIVE DATE 28-December-2022
EXPIRATION DATE 27-December-2024
ABS TECHNICAL OFFICE Singapore Engineering Services
CERTIFICATE OF
Product Design Assessment
This is to certify that a representative of this Bureau did, at the request of
AVIKUS CO., LTD.
located at
11TH F, 70, NONHYEON-RO 85-GIL, GANGNAM-GU, SEOUL, KOREA, REPUBLIC OF
assess design plans and data for the below listed product. This assessment is a representation by the Bureau as to the degree of compliance the design exhibits with applicable sections of the Rules. This assessment does not waive unit certification or classification procedures required by ABS Rules for products to be installed in ABS classed vessels or facilities. This certificate, by itself, does not reflect that the product is Type Approved. The scope and limitations of this assessment are detailed on the pages attached to this certificate.
Product Autonomous Function
Model HiNAS 2.0
This Product Design Assessment (PDA) Certificate remains valid until 27-December-2024 or until the Rules and/or Standards used in the assessment are revised or until there is a design modification warranting design reassessment (whichever occurs first).
Acceptance of product is limited to the "Intended Service" details prescribed in the certificate and as per applicable Rules and Standards.
This Certificate is valid for installation of the listed product on ABS units which exist or are under contract for construction on or previous to the effective date of the ABS Rules and standards applied at the time of PDA issuance. Use of the Product for non-ABS units is subject to agreement between the manufacturer and intended client.
American Bureau of Shipping
Wu Guanying, Senior Engineer
NOTE: This certificate evidences compliance with one or more of the Rules, Guides, standards or other criteria of ABS or a statutory, industrial or manufacturer's standards. It is issued solely for the use of ABS, its committees, its clients or other authorized entities. Any significant changes to the aforementioned product without approval from ABS will result in this certificate becoming null and void. This certificate is governed by ABS Rules 1-1-A3/5.9 Terms and Conditions of the Request for Product Type Approval and Agreement
ENG-ATT-00797 Revision 0 Page 1 of 1</td></tr>
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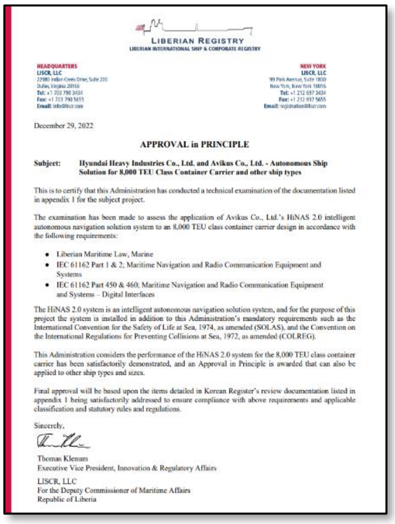
obtained (29 December 2022)</td><td>
LIBERIAN REGISTRY
LIBERIAN INTERNATIONAL SHIP & CORPORATE REGISTRY
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22980 Indian Creek Drive, Suite 200
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Fax: +1 212 697 5655
Email: registration@liscr.com
December 29, 2022
APPROVAL in PRINCIPLE
Subject: Hyundai Heavy Industries Co., Ltd. and Avikus Co., Ltd. - Autonomous Ship Solution for 8,000 TEU Class Container Carrier and other ship types
This is to certify that this Administration has conducted a technical examination of the documentation listed in appendix 1 for the subject project.
The examination has been made to assess the application of Avikus Co., Ltd.'s HiNAS 2.0 intelligent autonomous navigation solution system to an 8,000 TEU class container carrier design in accordance with the following requirements:
• Liberian Maritime Law, Marine
• IEC 61162 Part 1 & 2; Maritime Navigation and Radio Communication Equipment and Systems
• IEC 61162 Part 450 & 460; Maritime Navigation and Radio Communication Equipment and Systems – Digital Interfaces
The HiNAS 2.0 system is an intelligent autonomous navigation solution system, and for the purpose of this project the system is installed in addition to this Administration's mandatory requirements such as the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS), and the Convention on the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREG).
This Administration considers the performance of the HiNAS 2.0 system for the 8,000 TEU class container carrier has been satisfactorily demonstrated, and an Approval in Principle is awarded that can also be applied to other ship types and sizes.
Final approval will be based upon the items detailed in Korean Register's review documentation listed in appendix 1 being satisfactorily addressed to ensure compliance with above requirements and applicable classification and statutory rules and regulations.
Sincerely,
Thomas Klenum
Executive Vice President, Innovation & Regulatory Affairs
LISCR, LLC
For the Deputy Commissioner of Maritime Affairs
Republic of Liberia</td></tr>
</table>

Table 3: Certifications

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ANNEX 2

RESULTS OF TRANSOCEANIC VOYAGE TEST OF AUTONOMOUS NAVIGATION SYSTEM

The objective of the transoceanic voyage

The object of this test was a 180K LNG carrier equipped with an autonomous navigation system that has the functions of autonomous navigation, manoeuvring, collision detection, and collision avoidance (CDCA) to perform an autonomous transoceanic voyage and demonstrate the successful implementation of the autonomous functions under the guide of ABS surveyor.

The functions validated on board the LNG carrier were (according to ABS guidelines):

.1 Navigation (NAV): Computer Vision based Obstacle Detection, Vision, Radar, and AIS Sensor Fusion

.2 Manoeuvring (MNV): Automatic Heading Control, Course Tracking, Collision Avoidance

Steps of the transoceanic voyage

Before conducting the transoceanic voyage test, Avikus and ABS discussed the scope of the test and procedures and agreed below steps.

.1 Avikus to submit the 'Test Programme for the LNG carrier Ocean Voyage Test'.

.2 ABS to review the documents submitted in item(i) in accordance with the 'ABS Guide for Autonomous and Remote Control Functions for Test, Installation, and Commissioning Surveys'.

.3 Based on the test plan, Avikus conducts a simulation test before conducting a transoceanic voyage under the witnessing ABS surveyor and person in charge of the shipping company.

.4 Avikus installs an autonomous navigation system (HiNAS2.0) on the LNG carrier.

.5 Upon satisfactory resolution of comments, the ABS surveyor is to use the acceptance criteria for witnessing the autonomous functions onboard the LNG carrier during the ocean voyage test.

.6 Upon witnessing the autonomous functions, ABS is to issue a Statement of Observation Report.

The transoceanic voyage test programme

The test programme document is comprised of CONOPS of HiNAS2.0, hardware configuration, software configuration, risk analysis (inc. risk level analysis, emergency plan), and test procedure for transoceanic voyage test.


Avikus

Test Procedure for

Autonomous LNG Carrier Ocean Voyage Test

REVIEWED
Details of this review are as indicated in the ABS letter
ABS
WITH ABS AMENDMENTS ON PAGES - see Remarks on page 17
WITH ABS COMMENTS #s —N/A—

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Avikus

CONOPS for

Autonomous LNG Carrier Ocean Voyage Test

REVIEWED
Details of this review are as indicated in the ABS letter
ABS

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Figure 1: Test programme submitted to ABS

Simulation verification test

The simulation verification test proceeded at a simulation centre which supports the simulation of the full bridge system before the transoceanic voyage test. This simulation validated a path following and collision avoidance functions to be used for the transoceanic voyage test.

Figure 2: Simulation verification test for ABS surveyor and person in charge of the shipping company

System installation on LNG carrier

HiNAS2.0 can be divided into hardware installed inside and outside the bridge. The camera module and junction box installed outside the bridge are a kind of sensor module for target detection. What is installed inside the bridge consists of a server with software running the core algorithm and a junction box interfaced with various navigation equipment. HiNAS2.0 is necessary to be interfaced with existing navigation/manoeuvring systems such as ECDIS, autopilot steering unit, and conning display.

Based on the current regulations of maritime navigation/manoeuvring equipment, the TCS function of the ECDIS is the only way to exchange signals with autopilot. In order for HiNAS2.0 to control autopilot, HiNAS2.0 uses the same protocol as TCS. In other words, from the perspective of autopilot, regardless of which equipment the command signal is from ECDIS or HiNAS2.0, it is possible to send and receive signals with the same protocol. In this case, neither ECDIS nor autopilot needs to modify hardware and software, so there is no need to undergo new inspections or certificates for existing equipment.

The server and monitor of HiNAS2.0 were installed in the chart table, but this is not useful for the officers/captain to actively use it for navigation. For this reason, to display HiNAS2.0 at the centre console it was connected to the input part of the conning display monitor at the centre console.

Figure 3: Hardware selector for switching between ECDIS TCS and HiNAS2.0

Figure 4: Hardware selector for switching between conning display and HiNAS2.0 display at the centre console

Figure 5: HiNAS2.0 monitor on the chart table (checking the installation is well completed)

Figure 6: HiNAS2.0 display on Conning Display monitor at the centre console

The camera module of HiNAS 2.0 is installed on the handrail of the compass deck. In order not to affect the magnetic compass located in the centre line in the longitudinal direction of the ship, so the camera module is installed slightly to the right to avoid the magnetic zone.

Figure 7: HiNAS2.0 camera module

Transoceanic voyage test

The overall transoceanic test was followed by the simulation test procedure and test procedure that is submitted to ABS on 29 March and 6 April 2022. Avikus conducted the transoceanic voyage test as in table 1. The test is conducted based on the test programme reviewed by ABS. The test is composed of the below tasks. All the tasks are conducted under the supervision of certified onboard personnel (officers/captain).

.1 Target detection performance (AIS, Radar, Camera Image)
.2 Route planning and following (Autonomous heading control, Speed control*)
.3 Collision avoidance with detected targets

* Speed control is conducted manually to prove the effect of fuel saving by the speed optimization function

Period	**Section**	**Demonstration Contents**
05/04 ~ 05/09 (5 days)	Navigation Pattern Analysis Section	- Captain/officer interview - Navigation pattern analysis - HiNAS2.0 internal logic update
05/10 ~ 05/16 (1 week)	System Feedback Section	- Intermittent HiNAS2.0 operations for some sections (Autonomous navigation + collision avoidance) - Captain/officer feedback & analysis + HiNAS2.0 software update
05/17 ~ 05/31 (2 weeks)	Full-Time Autonomous Navigation Section (10,000 km)	- Autonomous navigation through HiNAS2.0 without any intervention of the captain/officer - World's first autonomous LNGC transoceanic demonstration

Table 1: Transoceanic voyage test schedule

During the entire voyage from Freeport, USA (2 May departure) to Boryeong, Republic of Korea (2 June arrival), the test route was from Panama to southwestern Japan as shown in figure 8 below.

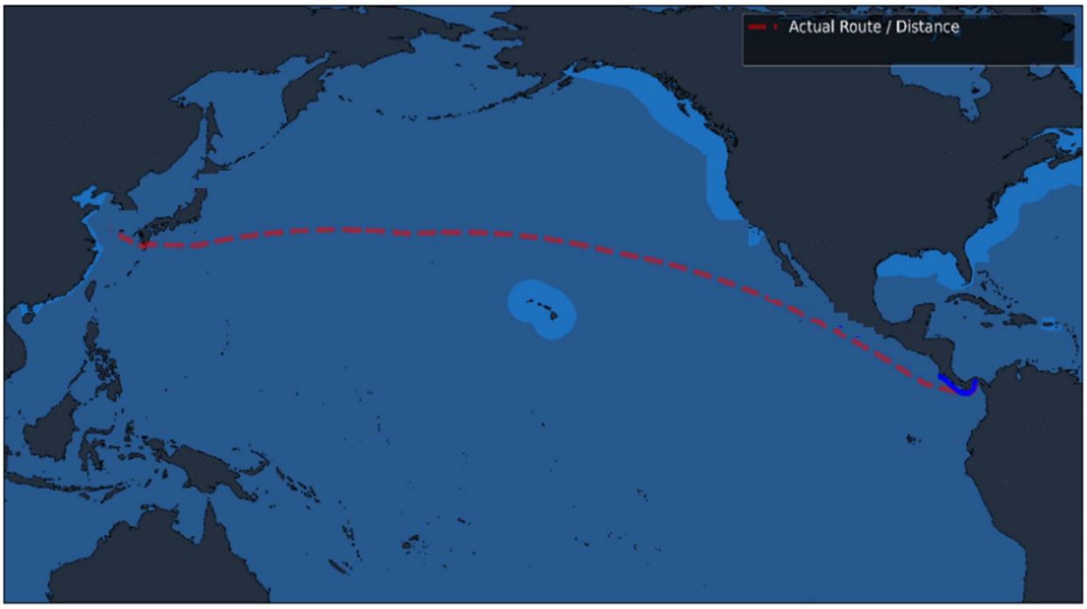


Figure 8: Transoceanic route

To prove the autonomous control function, HiNAS2.0, ECDIS, and actual human behaviour in bridge video are recorded for the entire period and submitted to ABS. Also, the test report during the transoceanic voyage is submitted.

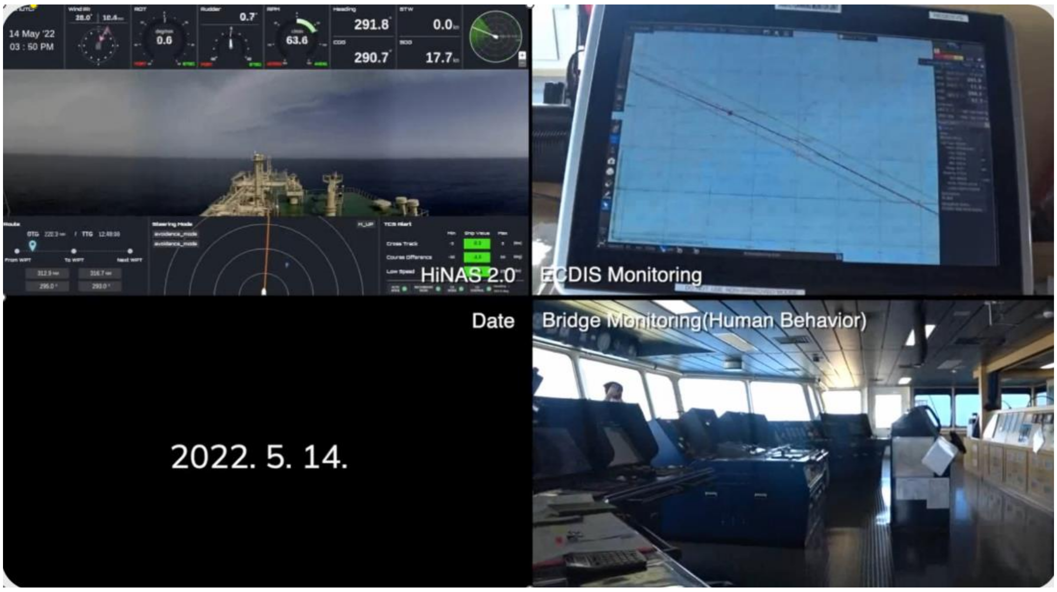


Figure 9: Submitted video to ABS (HiNAS2.0, ECDIS, Bridge Monitoring)

Autonomous route control was succeeded without any intervention of captain/officers for about 2 weeks (control within 1NM track limit). And in the case of the CDCA function, autonomous collision avoidance also succeeded. The HiNAS2.0 detected about 100 potential collision situations and after a collision risk assessment, it performed proper actions autonomously after the permission of the OOW. Detailed results refer to below table 2.

Cases	Control on/off	Results of CDCA function
About 70 cases	HiNAS2.0 control On	After the risk assessment, decided to maintain the course
About 10 cases	HiNAS2.0 control On	After the risk assessment, decided to alter course (altered course autonomously)
About 20 cases	HiNAS2.0 control Off	The calculation result of HiNAS2.0 is the same as that of the captain/officer

Table 2. Result of CDCA functions

Route optimization test

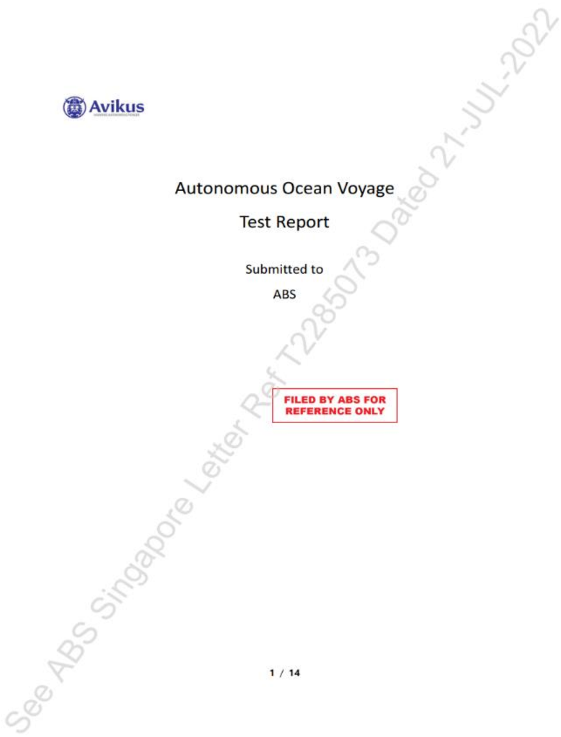
The navigation and manoeuvring work on ships is inevitably strongly connected to route planning work. However, unlike navigation and manoeuvring, route planning is an item that requires some review and confirmation with supervisors and charterers in the onshore office, so it is difficult to be automated based on only the ship's own decision or the system's own decision. Although this test is Autonomous Function Test, Avikus proceed with the test by adding the route optimization by taking advantage of the precious opportunity of this test. Using the route optimization function in HD Hyundai (HHI) group's smart ship solution (ISS, Integrated Smart ship Solution), onshore offices/onboard officers can make an improvement route from the previously planned route, and if necessary, an economic evaluation of the route after the voyage will be performed. In fact, the route economy is not the main concern because the main task of officers is to navigate safely while keeping ETA. If the route created by the route optimization function can be followed by the automatic function of HiNAS2.0, it could be the world's first test to simultaneously demonstrate the 'optimal route' and 'autonomous navigation/manoeuvring' for 'real operated ship' and 'real operated routes'. Of course, since the essence of this test is Autonomous Function Test, the test procedure is well distinguished so that the function of the route optimization or the performance of the result does not affect the Autonomous Function Test at all. Before the transoceanic voyage test, it also proceeded verification and validation at a simulation centre that supports the simulation of the full bridge system.

It was conducted speed control only in some sections and recommended optimal RPM to the captain. In line with this, if applying recommended optimal RPM to the entire voyage, it can reduce about 7% fuel consumption.

Conclusion

Based on ship dynamic modelling and manoeuvring analysis technology, HiNAS2.0 provides optimal collision avoidance routes and avoids autonomously. And it is an enabler of safe and economical navigation, improving fuel efficiency and CII through optimal route planning.

All these simulation tests and actual transoceanic test results were submitted to ABS and SoF (Statement of the Fact) for the transoceanic voyage test was also issued from ABS.



Avikus

Autonomous Ocean Voyage

Test Report

Submitted to

ABS

FILED BY ABS FOR REFERENCE ONLY

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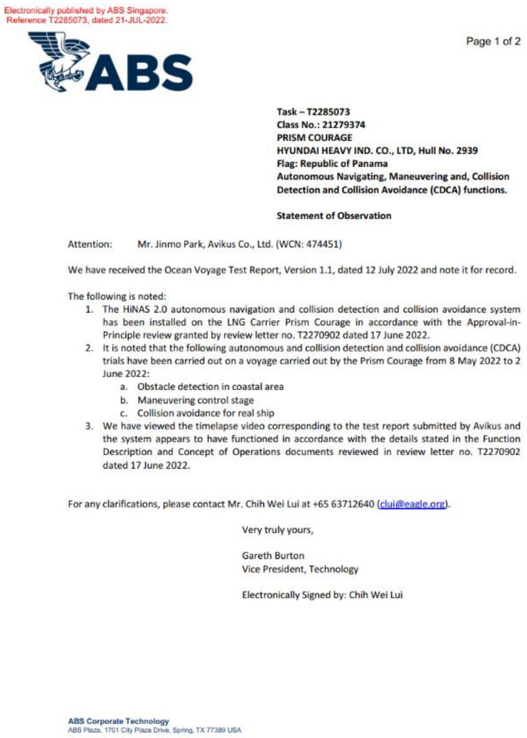
See ABS Singapore Letter Ref T2285073 Dated 21-JUL-2022

Figure 8: Test report submitted to ABS



Electronically published by ABS Singapore.
Reference T2285073, dated 21-JUL-2022.

ABS

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Task – T2285073
Class No.: 21279374
PRISM COURAGE
HYUNDAI HEAVY IND. CO., LTD, Hull No. 2939
Flag: Republic of Panama
Autonomous Navigating, Maneuvering and, Collision Detection and Collision Avoidance (CDCA) functions.

Statement of Observation

Attention: Mr. Jinmo Park, Avikus Co., Ltd. (WCN: 474451)

We have received the Ocean Voyage Test Report, Version 1.1, dated 12 July 2022 and note it for record.

The following is noted:

1. The HiNAS 2.0 autonomous navigation and collision detection and collision avoidance system has been installed on the LNG Carrier Prism Courage in accordance with the Approval-in-Principle review granted by review letter no. T2270902 dated 17 June 2022.
2. It is noted that the following autonomous and collision detection and collision avoidance (CDCA) trials have been carried out on a voyage carried out by the Prism Courage from 8 May 2022 to 2 June 2022:
   a. Obstacle detection in coastal area
   b. Maneuvering control stage
   c. Collision avoidance for real ship
3. We have viewed the timelapse video corresponding to the test report submitted by Avikus and the system appears to have functioned in accordance with the details stated in the Function Description and Concept of Operations documents reviewed in review letter no. T2270902 dated 17 June 2022.

For any clarifications, please contact Mr. Chih Wei Lui at +65 63712640 (clui@eagle.org).

Very truly yours,

Gareth Burton
Vice President, Technology

Electronically Signed by: Chih Wei Lui

ABS Corporate Technology
ABS Plaza, 1701 City Plaza Drive, Spring, TX 77389 USA

Figure 9: Issued SoF

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