Automation of FRAMO Cargo Pump purging with IoT

[1]R. Prasanna Kumar, [2]Dr. V Ajantha Devi

[1]Associate Professor, Indian Maritime University- Kolkata Campus, India
[2]Research Head, AP3 Solutions, Chennai, TN, India

[1] Prasanna.r@imu.ac.in
[2] Ap3solutionsresearch@gmail.com

Abstract. Liquid cargo tankers of variable size can preferably choose FRAMO system for their cargo transfer requirements. FRAMO [1] system has been proved as a reliable technology with maker recommended human supervision. The reliability of the pump is mainly depending upon the seals fitted on both cargo and hydraulic oil sides. The major damage of these seals makes the pump completely in- operatable or minor damage leads to the maintenance requirement to bring the pump back to normal. To determine the condition of seals, FRAMO recommends to perform purging operations of cargo pumps whenever the tanker is loaded with cargo on daily basis. This procedure will help us to decide the choice of the particular pump for cargo discharging operations. On today's onboard practices the complete purging procedure is performed manually. The pressurized air supply through the cofferdam forcefully removes the content in that space and it helps the crew member to identify any failure of seals and the extent to which the failure is. This paper discusses about automating the purging process under unmanned environment and communicating the test results to the control center for the decision making on the use of the particular pump. In this paper details of electronic control circuit to automate the purging procedure is described. Added with the above, the detailed testing methods to determine the cofferdam space content and the data transmission of collected test results to control center also explained.

Keywords: FRAMO, Autonomous Ship, IoT, Automation

1. Introduction

Today's big issue is autonomous and remote-controlled vessels. It's no surprise that people believe this is the next stage in the evolution of marine technology in an era where artificial intelligence is closer to reality than it has ever been. Unmanned aerial vehicles and self-driving automobiles are now available, but there are no unmanned vessels in use till date.

The future of maritime technology may be autonomous technology [2], but in what form remains to be seen. There is still need of crew on some cases, no matter how interesting or cool new developments are. New technology must not only substitute but also build upon what came before, and this is also true in the case of autonomy. There are a variety of ways to operate an autonomous vessel, one among them is without any on-board computing system and all command and control from shore [3]. Because of more cargo space available due to replacing the crew (at least some of them), with autonomous or remote-controlled technology could reduce operating expenses and save money. The creators of this technology claims that it would create safe environment with less or nil incidents. Human error is the leading cause of maritime incidents [4] today, so reducing this element could help the industry.

Autonomy can be applied in tiny chunks to make it simpler for a ship's crew, for example, assisting them with docking the vessel. While both autonomous and remote-controlled vessels are unmanned, there is a distinction. Remotely operated vessels [5] are piloted from a control station on shore, while autonomous vessels use computers, algorithms, and sensors to navigate and operate. These two types of unmanned vessels are often discussed in the same breath as a potential solution for sea voyages, implying that they are not mutually exclusive. Both would almost certainly be present in vessels that employ these technologies. There have already been a few real-world examples of autonomy and remote control [6], and more are on the way.

1.1.Various degree of autonomy

A seaborn vessel that navigates the seas without human intervention is described as an autonomous vessel [7], but as previously mentioned, this is not always the case. When it comes to MASS [8], there are various levels of autonomy. Companies, organizations, and individuals all have their own definitions of autonomy and degrees of autonomy, which may lead to some misunderstanding. In order for MASS to be implemented on a global scale, clear definitions of the various levels of autonomy are needed. MSC had their 100th meeting in December 2018, and they made progress on the regulatory scoping exercise for MASS. The current set of MASS rules and regulations must be differentiated based on the degree of autonomy of a vessel.

Degree 1: The crew is present and running the vessel with the help of automated systems: In some conditions, certain tasks can be automated and unmonitored. If required, the crew is prepared to take command.

Degree 2: Ship with seafarers on board that is controlled remotely: The vessel is controlled remotely. The crew stay on board and is prepared to take command if necessary.

Degree 3: Remotely controlled ship with no onboard seafarers: The vessel is controlled from shore.

Degree 4: The vessel is totally self-contained and runs on its own. In all cases, the vessel will decide the best approach and make the necessary decision.

1.2.Maritime autonomy vs Industry 4.0

In Industry 4.0, data and machine learning will be used to construct smart and autonomous systems. As the use of cyber-physical systems, cloud technology and the Internet of Things (IoT) rises in manufacturing, so does the demand for cyber security. Autonomous automobiles have already been deployed. Ships, without a doubt, have different challenges than autos, and the maritime industry [9] is known for its slow adaptability to change.

Number of autonomous functions in maritime vessels on specific applications are growing for example, Automated fire safety systems and Automated energy optimization technics. Still, it is lagging behind the trajectory of other industry including aviation. Even though same basic elements such as motors, pumps, and fans are used in the ships too, they are not connected with Information Technology, communication, or data. New evolution in this area needs, a range of networked gadgets and ICT systems.

Cyber vulnerabilities [10] have also been discovered in planes and Automated avionic vessels are in use. There's no reason to expect that ships will not be more secure, which are one among our vital infrastructure in the maritime industry.

2. Review of Existing Maritime autonomy

MUNIN [11] is a cooperative research venture financed by the European Commission. Maritime Unmanned Navigation with Network Intelligence is what it stands for. This was the first study to investigate whether and how autonomous applications in big commercial ships might reach the same levels of safety as conventional ships [11,12]. The goal is that a ship constructed in this project will deliver goods to its destination autonomously, safely, and independently. The world's first remotely operated commercial vessel has been developed by Rolls-Royce Commercial Marine [6] and global towage operator Svitzer. A demonstration was held in Copenhagen port in Denmark in early 2017 [13], and the development is part of the SISU project. The tug Svitzer Hermod successfully completed a number of remotely controlled manoeuvres.

Kongsberg Maritime [14], or KM for short, is developing a new self-driving ship. AutoBarge is the name of the vessel they're working on, and it's a collaboration with Asko. The project will conclude in two autonomous, electric, and zero-emission vessels crossing the Oslo fjord. AutoBarge will suit 16 semitrailers and replace 150 truck journeys between Moss in Stfold and Holmestrand in Vestfold [15] every day. It will reduce CO2 emissions while also improving traffic congestion and safety. Each of the ships is equipped with a standard bridge, however they will be supervised from a shore control centre, just like Yara Birkeland [16]. The idea is to have Kalmar's autonomous and electric tractors drive semitrailers on and off the ships. Asko wants to be able to drive the trailers from the ports to his storage facility using electricity. The goal is to begin testing in 2021 and to be self-driving, electric, and emission-free by 2024.

Autonomous ships must function at least as safely and reliably as modern ships operated by on-board people in order for their development to be beneficial [17-20]. While algorithm-based decision making can eliminate certain human errors [20], new risks and concerns, such as cybersecurity for autonomous ships, will undoubtedly develop. The simplest remote operation of a ship necessitates a reliable means of monitoring its health and precisely observing the ship's environment without substantial delays. Adopting and further development on existing sensor technology and computer vision to work precisely in the maritime environment, where climatic conditions might be vastly different from those on land. This is one of the first stage in achieving this reality. The findings of vision-based tracking of marine traffic ships [18] and collision avoidance have proven promising in recent investigations. As a result, successful sensory data interpretation is critical for autonomous ships to perform the appropriate action at the right time. As a result, smart decision algorithms must be thoroughly created and validated.

3. FRAMO submerged cargo pumps

FRAMO Cargo pumps as shown in the Fig.1 are vertical, single-stage centrifugal pumps that operate safely and efficiently with hydraulic motors. FRAMO cargo pumps are composed of stainless steel and restricted number of flanges to improve its efficiency to pump any liquid. These pumps are widely used in product carriers and on the introductory phase in large crude carriers.

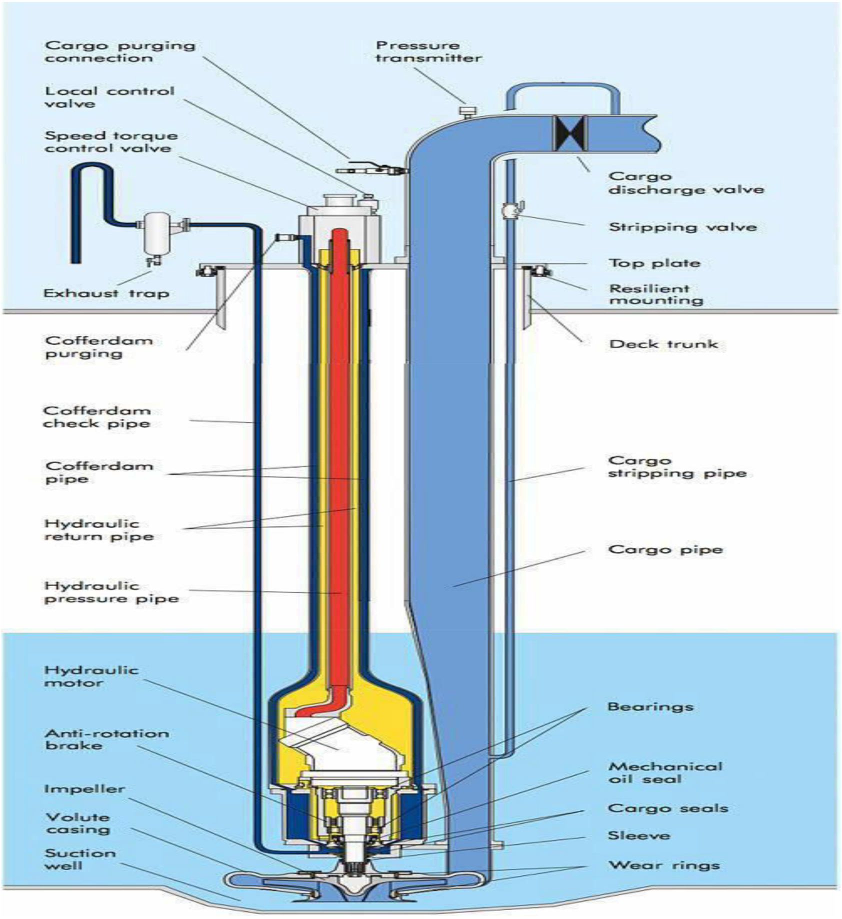


Fig.1.FRAMO PUMP [1]

3.1.FRAMO Pump Operation

Hydraulic motor drives the FRAMO pump [21], which receives pressurized hydraulic oil from the power packs. The high-pressure hydraulic oil goes into the hydraulic motor in the red area as in the Fig.2a, and the hydraulic oil returns in the yellow area. Both of these pipes are in a circle around each other.

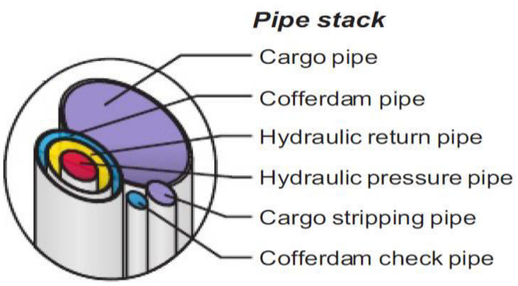
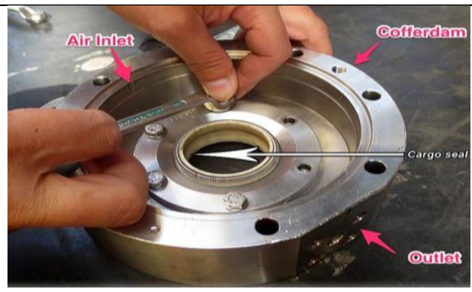
	

Fig.2.a	Fig.2.b

As this pump is located within the cargo tank, two liquids (hydraulic oil and cargo) must not come into contact. The cargo may be contaminated if hydraulic oil leaks into tank. The hydraulic system will be contaminated if cargo gets into the hydraulic system. The FRAMO pump has a feature that prevents this, Hydraulic oil leaking to the cargo side is prevented with a hydraulic seal. There's also a cargo seal as shown in Fig.2.b to keep cargo from seeping into the hydraulic side. As a steel cup with a cargo seal at the bottom, a cofferdam will collect any hydraulic oil or cargo leaks.

3.2.Onboard Condition based Maintenance

Monitoring the condition of seals regularly ensure the trouble-free operation of cargo pumps. Seal monitoring is done by purging the cofferdam from the cargo pump top plate. On the use of FRAMO submerged Cargo pump, one of the most critical preventive maintenance routines is to purge the cofferdam. This is one kind of method to inspect the pumps' seals, and hence their condition, without having to enter the cargo tanks. Any leakage through the seals will accumulate in the cofferdam. By regularly purging the cofferdam, the leakage rates may be assessed, and action (if necessary) may be planned to ensure the cargo pump's safe and efficient functioning.

The cargo pump cofferdam must be purged on a regular basis in line with the FRAMO Purging Instruction, which may be found in Ship's Service Manual. The ship's crew bears primary responsibility for purging, logging results, and any further actions. They are familiar with the actual operating circumstances on board and are entrusted with the proper operation and maintenance of the equipment on a regular basis. If the purging findings suggest that maintenance is required, the ship's crew must take action as soon as possible.

4. Proposed Methodology

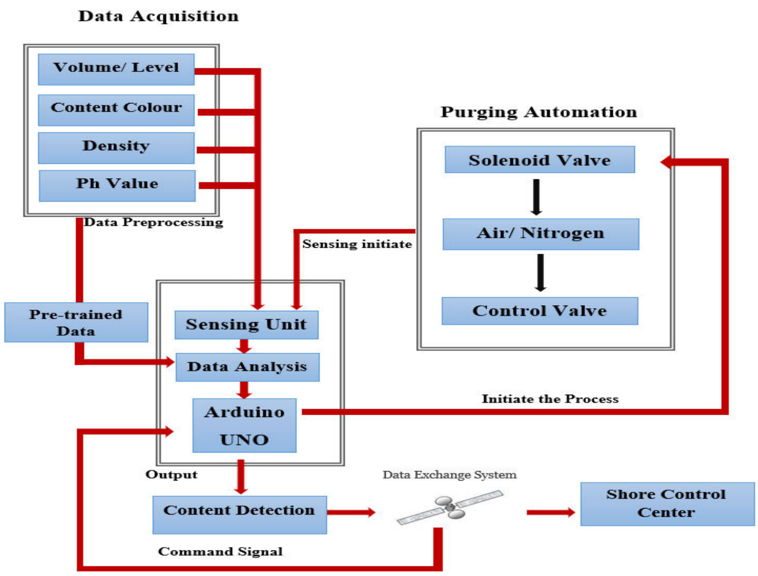


Fig.3.Proposed Methodology on Automation of Purging

To automate this purging operation, this paper describes the Proposed methodology as Fig.3 consist of the following:

1. Initiation of this purging operation triggered either by delay timer or command signal through IoT from shore control station.
2. Automating the purging process under unmanned environment [22] and collect the leakage content if any.
3. Analyze the physical properties of the leakage content with different electronic sensors.
4. Compare the physical property data measured with the sensors and pre-defined database stored to identify the leakage content.
5. Identified result will be notified to the shore control centre using IoT communication [23].

4.1.Purging Automation

When the pump is idle at sea, the purging procedure is started by a delay timer or a command signal from the control station. The cofferdam pipe (Dark blue in colour as depicted in the Fig.1) is pressurized by air or nitrogen depending on the cargo type carried, by opening the cofferdam purging supply control valve (Fig 4) located in the main deck.

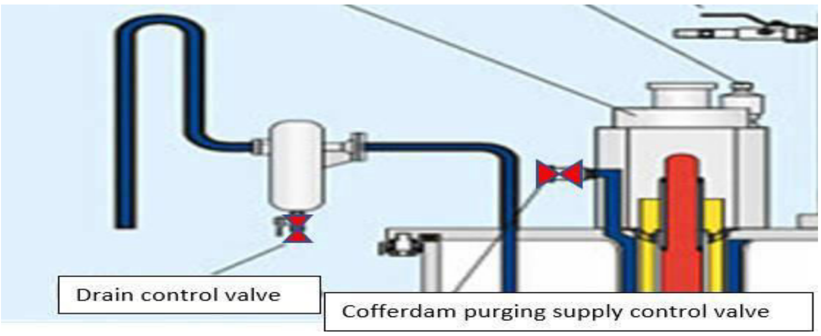


Fig. 4. Purging Automation

Through the cofferdam check pipe, pressurized air forces the content gathered in the cofferdam to the exhaust trap in the main deck (Dark blue in colour as shown in the Fig.1). The exhaust trap's drain control valve (Fig 4) opens, and the contents are emptied into the sample container. In each operations sample will be collected in a new container to ensure that the test sample is clean. This complete sequence of operation is accomplished by Automation using Arduino UNO system.

4.2.Data Acquisition:

Basis on the sample content following results is derived

- The cofferdam is empty if simply get air into the purging line's exit. There is no hydraulic oil or cargo leakage, and both seals are intact.
- If cargo is detected in the cofferdam, that means the FRAMO pump's cargo seal is leaking.
- If hydraulic oil is detected in the cofferdam, that means the FRAMO pump's hydraulic oil seal is leaking.

The sample content is analyzed on its physical properties to conclude weather the content is cargo or hydraulic oil.

- The ship is equipped with various sensors for short and long-range proximity measurements, as well as software for the control unit and sensors, which is run on an Arduino. The control unit runs on the on-board edge cloud, which is an Arduino in this case, and the edge device connects with other components.
- The information acquired from the ship's sensors has to be saved as attributes in Data base. We propose to use larger data sets for simple debugging and test data collection, which necessitated a more robust design.

4.3. Control Unit:

Control unit in this proposal perform the following activities,

- Initiating the cargo pump purging operation either of the two conditions.
    1. Pre-defined interval from Timer.
    2. Command signal from Shore control station
- Supervision of purging sequence and alarming if any faults in the sequence.
- Operate and monitor the Sequential flow of sample containers to different sensing devices.
- Data acquisition from different measuring sensors.
- Comparative study of both the measured value and stored database.
- Detect the sample content
- Communication exchanges info based on events.
- The shore control centre (SCC) ensures that the ship is operating safely and, if necessary, acknowledges the decision.

5. Feasibility of the Proposal:

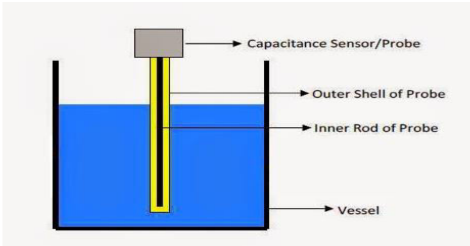
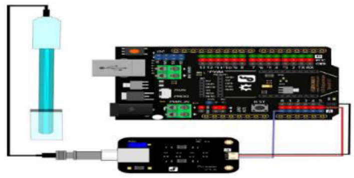
As this paper discuss about automation of Purging process on FRAMO cargo pumps, this feasibility study can be tripartite as following sub segments

5.1. Automation of Purging Operation

This is an operation in which the functions of various valves are intertwined with time intervals. All of the valves can be hydraulically powered and controlled by an electronic signal to OPEN/CLOSE. The hydraulic power required can be obtained from the same FRAMO system. The ARDUINO board could be used to programme the signal that controls the sequence.

5.2. Analysis of Purged Content

Analysis of the content is based on their physical properties which are measured using different sensors.

A. Volume of leakage • Leakage volume estimated using measured liquid level and known container cross sectional area. Capacitive level sensors are used for level measuring. • This sensor is inserted into the sample container as indicated in the image to measure the liquid level.	 Fig 5. Level sensor
B. PH value of the content • The PH value is used to distinguish cargo, particularly if it is chemicals and hydraulic oil. In the sample container, prob type PH metres are used to determine this value.	 Fig 6. PH meter
C. Density of the leakage fluid • Because some of the oil cargo and hydraulic oil are generated from the same crude oil source, density is a key criterion for distinguishing the two. Density metres with forks are a good choice for this application	 Fig 7. Fork type Density meter
D. Appearance of the liquid • The colour of the liquid is another useful physical parameter for determining the content. The identification of content liquid can be sped up by colour comparision. Using a high-definition camera to capture the image of sample content and comparing it to a database helps to attain this task.	 Fig 8.Different coloured cargo

5.3. Data Transmission

As ship is always floats distance away from the shore, the communication system gets much more priority in the maritime industry. With today's developments in the efficient satellite communication and real time data transfers [24] between ship and shore ensures un- interrupted service in the proposed automated process.

The existing available data communication used for the vessel operation eliminates the vessel identification (Address) during the data communication with multiple vessels [25]. we'll use Arduino UNO because the setup needs to be easily scalable and cloud-integrable. Also, Arduino is the right choice due to its size is ideal and it has adequate computational capacity to handle the data processed on the edge cloud under Shore control centre.

Integrated sensors eliminate the need for external components, which speeds up and simplifies the automation of this process. The data exchange system as a bridge between the real-world environment and the control unit embedded with Arduino UNO system. To ensure low latency and consequently proper control unit operation, sensor data is transmitted directly to the control unit via the edge device. The control unit receives raw sensor data, which it can pre-process when the type of data it receives requires to Analysis the content of the sample.

6. Barriers

With the current study of the proposal, few of the following barriers were identified. By performing additional number of experiments these barriers can be removed.

i. **Accuracy of sensors:** Accurate results of measurements were expected if the volume of sample is considerable in size. If the leakage of the seal is less and the sample volume also less, it affects the accuracy of sensor's result.

ii. **Mixed liquids:** At one scenario, if both cargo and hydraulic seals were leaking, the properties sensed on the sample collected in the container does not match with the properties of either cargo or hydraulic oil. To conclude this situation, additional data such as sensor accuracy and properties related to mixer of both liquid need to be considered.

iii. **Different cargo in different Tanks:** Parcel Tankers loaded with different cargo in different tanks. To identify the leakage content, system required to predefine that what cargo loaded in which tank. By including additional parameters sensing such as vapour pressure, can eliminate this limitation. This can be achievable after adding other suitable parameters also in the database.

iv. **Cyber security:** In order to maintain safe marine operations, cyber security [10] is a crucial factor to consider. Because of the increased information and communication technology (ICT) onboard, different attackers may attempt to exploit the system remotely, causing serious damage or disruption. As a result, illegally manipulating or exploiting the system be possible under any circumstances. To be protected from cyber threats, vulnerabilities in the ICT infrastructure must be addressed. Outsiders should not be able to interfere with communication between a ship and the SCC.

7. Conclusion:

Autonomous ships are very near to reality. The first step toward autonomous ships is for the ships to be unmanned and operated from a shore control centre [26]. This necessitates a comprehensive ability to remotely monitor the ship's condition in real time, which creates a slew of new issues. To enable correct decision-making, the data gathered from the ship's state must be precise and conveniently available to the operator.

Each and every small operation performed by crewmembers out at sea, which are essential for the operation of the vessel or pre-preparation of vessel for its cargo operation required to be automated. This paper chooses one such an operation. This proposal identified how FRAMO cargo pump purging operation can be automated and can produce the accurate result. This study analyzed the feasibility of the proposal along with current hurdles to achieve the same. Overall, the detailed study produced in this paper shows the much confidence on the proposal.

8. Reference

1. www.framo.com
2. Höyhtyä, M., Huusko, J., Kiviranta, M., Solberg, K., Rokka, J. Connectivity for autonomous ships: Architecture, use cases, and research challenges. Jeju, South Korea, 2017. ISBN 978-1-5090-4032-2.
3. Xu, T., Qian, Y., Hu Z., Dandan, C. Reliability Analysis of Ship Equipment Based on Maintenance Data. Beijing, P. R. China, 2014. ISBN 978-1-4799-7958-5.
4. Park, J., Cho, Y., Yoo, B. Autonomous collision avoidance for unmanned surface ships using onboard monocular vision. Washington, DC, USA, 2015. ISBN 978-0-9339-5743-5.
5. Batalden, B., Leikanger, P., Wide, P. Towards Autonomous Maritime Operations. Annecy, France, 2017. pp. 1-4. ISBN 978-1-5090-4253-1.
6. AAWA, 2016. Remote and Autonomous Ships The next steps. [ONLINE] Available at: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/aawa-whitepaper-210616.pdf.
7. IMO. 2018a. Regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS). MSC 99/WP.9.
8. IMO, 2018b. Regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS). MSC 100/WP.8.
9. Rødseth, Ø. J. 2017. Towards Shipping 4.0. Proceedings of Smart Ship Technology. London, UK: Royal Institution of Naval Architects. ISBN 978-1-909024-63-2.
10. Mukherjee, A., Fakoorian, S., Huang, J., Swindlehurst, A. Principles of physical layer security in multiuser wireless networks: A survey, IEEE Communications Surveys & Tutorials, vol. 16, pp. 1550–1573, Third Quarter 2014.
11. Burmeister, H., W. Bruhn, Ø. J. Rødseth, and T. Porathe. 2014. "Autonomous Unmanned Merchant Vessel and Its Contribution Towards the E-navigation Implementation: The MUNIN Perspective." International Journal of e-Navigation Maritime Economy 1: 1–13. doi:10.1016/j.enavi.2014.12.002.
12. MUNIN. 2015. D9.3: Quantitative assessment. FP7 GA-No 314286.
13. Antikaine, P. (2017). Digitalization and Autonomous Ships: Conference on Maritime Autonomous Surface Ships, Copenhagen 14.11.2017. Ministry of Transport and Communications, Finland.pdf
14. Kongsberg Maritime AS. 2018. "Autonomous Ship Project." https://www.km.kongsberg.com
15. Stensvold, T. (2019) Asko får Enova-støtte til å utvikle autonome transportferger, Teknisk Ukeblad. Tilgjengelig fra: https://www.tu.no/artikler/asko-far-enova-stotte-til-a-utvikle-autonome-transportferger/460645 (Hentet: 16.02.20)
16. Moll, J.B., Melin, S. (Tilretteleggere), & Thuestad, E.B. (Redaktør). (2018). Varer levert utan sjåfør [Episode fra TV-serie]. I Pedersen, H. (Produksjonsleder), Framtidas superframkomstmiddel. Tilgjengelig fra: https://tv.nrk.no/serie/framtidas-superframkomstmiddel/sesong/1/episode/3/avspiller (Hentet: 11.02.20)
17. Fan, C., Wr´obel, K., Montewka, J., Gil, M., Wan, C., Zhang, D., 2020. A framework to identify factors influencing navigational risk for Maritime Autonomous Surface Ships. Ocean. Eng. 202, 107188.
18. Xue, J., Van Gelder, P.H.A.J.M., Reniers, G., Papadimitriou, E., Wu, C., 2019a. Multiattribute decision- making method for prioritizing maritime traffic safety influencing factors of autonomous ships' maneuvering decisions using grey and fuzzy theories. Saf. Sci. 120, 323–340.
19. Wrobel, K., Montewka, J., Kujala, P., 2018a. System-theoretic approach to safety of remotely-controlled merchant vessel. Ocean Eng. 152, 334–345. https://doi.org/10.1016/j.oceaneng.2018.01.020.
20. Wrobel, K., Montewka, J., Kujala, P., 2018b. Towards the development of a system-theoreticmodel for safety assessment of autonomous merchant vessels. Reliab. Eng. Syst.Saf. 178, 209–224. https://doi.org/10.1016/j.ress.2018.05.019.
21. FRAMO Services AS : FRAMO cargo pumping system Broschure, Service Bulletin, Bergen Published 2019.
22. DNV GL. 2018. "Remote-controlled and Autonomous Ships in the Maritime Industry." Group Technology and Research, Position Paper 2018.
23. Nordahl, H. and Rødseth, Ø. J. (2017) Definitions for Autonomous Merchant Ships. Norwegian Forum for Autonomous Ships (NFAS).
24. Pole Star (u.å.) How sole reliance on AIS data could undermine your organisation's gBMP. Tilgjengelig fra: https://www.polestarglobal.com/media/1163/documents2fhow_sole_reliance_on_ais_data_could_undermine_your_organisationsplusgbmp.pdf (Hentet: 25.02.2020).
25. Jones, K. and Tam, K. (u.å.) Cyber-Risk Assessment for Autonomous Ships. England: University of Plymouth.
26. Baldauf, R Mehdi, M Kitada, D Dalaklis, " Shore Control Centers for Marine Autonomous Systems: Exploring Equipment Options", Paper presented at MATS - Marine Autonomy & Technology Showcase, Southampton, 2017