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MARINE TRANSPORT AND THE FOURTH INDUSTRIAL REVOLUTION

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Summary: Around the middle of the twenty first century the world will be facing the fourth industrial revolution that will be the result of enormous increase of computing power. Traditional ships may be replaced by smart ships, either totally autonomous and unmanned, unmanned but remote controlled from shore station or autonomous but carrying skeleton crew on board. At present already to build such ships is technically possible and first unmanned ship will be send across Atlantic next year. But before smart ship may be introduced into operation some important problems must be solved. Apart from technical problems, there are strongly interconnected problems of economy and environment protection, problems of safety and security of ships as well as legal problems and problems related to human relations. The above problems are discussed in the paper

Key words: Fourth industrial revolution, maritime transport, smart ships

1. INTRODUCTION

The idea that the world is subject to industrial revolutions is well known. The first industrial revolution, invention of steam engine, that started in the middle of nineteenth century was followed by the second industrial revolution at the end of nineteenth century and the beginning of the twentieth century mainly caused be the wide use of electricity and combustion engines. We are witnessing the third industrial revolution that basically will cause the world will enter ecological post-coal era saving us from the climatic catastrophe [4]. Now we are witnessing also dawning of the forth industrial revolution. Fourth industrial revolution (4ir) presumably will happen around the middle of the twenty first century causing that the world will became intelligent on the basis of enormous increase of computing power.

In this paper the author tries to discuss possible repercussion of the new era on the shipping world. There is no doubt, that those repercussions will be important and may introduce changes that happen only once in the lifetime. Generally, it is deemed that those changes will lead to smart ships and smart marine transport and the first indications of those changes are already visible [5].

Most people are familiar with the Moore’s law which states that computing power is doubling every eighteen months. In fact we observe enormous increase of computing power
during recent years at the scale that few years ago was really not imaginable. Although logically Moore’s law cannot work indefinitely, in coming years computing power and communication means may increase to the level that will completely change our world. Amount of data collected, processed, and transmitted in the middle of this century will be really big. This would be the fourth industrial revolution.

The Moore’s law is in a way also applicable to every industry or discipline that depends on computing power. And in fact this tendency is changing the development of all these domains from linear to exponential grow and effect of this is that the forecast of the future is extremely difficult, because it may lead to dangerous miscalculations [4].

It appears that Moore’s law is also valid when applied to the development of science and technology in modern times as also there exponential growth may be discovered. In everyday life such effects are clearly seen if we consider, for example, development of mobile telephones in recent years, the development of personal computers, actually everywhere where computing power is important. This is particularly applicable to the development of communication technology recently and this is actually announcing advent of the fourth industrial revolution.

2. IMPACT OF THE 4IR ON SHIPPING

But what could be the main impact of 4ir in the shipping world?. In shipping world we already observe rapid development of satellite communication and development of Time Division Multiple Access networks and this actually allows unlimited on line communication between ships at the ocean with shore base and allows to transfer rapidly and cheaply increasing amount of data (Big data) from ships to shore offices and reverse. The main consequence of this would be development of smart ships that includes autonomous ships or unmanned ships. This may be the main feature of the 4ir.

The idea of building smart ships is not new. This idea was discussed about thirty years ago, but at that time needed technology was not available. Now, it appears, that required technology is already in our hands, nevertheless there may be some important problems to be solved.

It is assessed that smart ship at sea may create something as large amount of data as 60 GB per day. In spite of the fact that processing the data on board can considerably reduce the amount of data that need to be transmitted to shore station this amount still remains big. However it was actually shown that processing and transmitting this amount data could be done as cheaply as 1$ per day [2], therefore there are no practical difficulties to do so. The largest classification society, DNV GL, admitted this year that actually they were taken by this as a surprize. Now, it appears, that required technology is already in our hands, nevertheless there may be some important problems to be solved. These facts show that with the advent of fourth industrial revolution building smart ships is possible.
3. SMART SHIPS

When we say smart ships there is no clear definition on what we have in mind. Certainly under the definition of smart ships may be understood ships that have onboard or located in the shore control station sophisticated software that may advise human operator on board to take appropriate decisions and in consequence induce action. This is actually happening for some time with the introducing of sophisticated equipment in the wheelhouse, such as ARPA (Automatic Radar Plotting Aid), ECDIS (Electronic Chart Display and Information System) INS (Integrated Navigational System) and others, some of them already compulsory in all or only in certain types of ships. Those ships are not considered in this paper as “smart”. In this paper smart ships are defined as ships where the ship is:

- unmanned, autonomous, where human operator is replaced by software controls taking action themselves, but with remote supervision and emergency control from the shore station,
- unmanned, remotely controlled from the shore station
- autonomous, but with small crew onboard for inspections and emergency control.

4. SHIP TYPES OF THE FUTURE

Ships are expensive investment that should be in use for a long time, at least for twenty years or more. Therefore progress in ship construction cannot be very fast from the reasons of economy. Nevertheless, sometimes old ship have to be replaced by new construction or new type bearing in mind new factors or events or with changes of conditions of trade. This affects ship types and size. The most remarkable changes during last fifty years apply to container vessels. The first container ships emerged in early sixties of the last century and they were rather small with capacity around 100 to 150 TEU (standard containers), now 50 years later capacity of container ships increased up 20 000 TEU, with prospects that in foreseeable future they may reach 30 000 TEU. (fig. 1). This is the result of economic consideration, because transport of containers in such monstrous ships, about 400 m long or more cost fraction of the cost of transport in small ships. The limits for increasing size of container vessels are dimensions of locks and canals and port facilities and depth of water in passages.

The other popular ship types that presumably will still in use in the middle of twenty first century are tankers and bulk carriers, although dimensions of those ships in future will be not much larger from those at present because of the same limitations that are applicable to container vessels. One reason for not increasing dimensions of tankers is danger of excessive pollution in case something happens to the ship.

The other type of ship which was not known at all fifty years ago is cruise vessel. Cruise vessels replaced passenger ships which disappeared altogether because passengers traffic was taken over by aeroplanes. The cruise vessels developed to really monstrous dimensions and it looks that they may in foreseeable future resemble small floating towns. Cruise vessels
are defined as ships that leave different ports and are coming back usually to the same port which they leave. The passenger traffic is now and possibly will remain as such in future only in passenger car ferries used on short voyages.

Another remarkable development of ship types are ships, mainly tankers, designed to be operated in arctic waters. This is possible because of the global warning and also because arctic regions are rich with gas and oil reserves that could be exploited.

Finally there is a tendency to use large variety of supply and service vessels including tugboats for different purposes, such as for serving an supplying off-shore platforms and facilities, wind farms, for carriage of heavy loads, handling anchors. etc.

It seems however that smart ship concept in not equally realistic in application for all types of ships. Certainly nobody would risk to operate unmanned or even remotely controlled cruise vessel, which in essence is floating hotel and its master actually performs duties as ship master but also general manager of the hotel. The same is probably applicable to ships entering arctic waters where environment situation must be assessed constantly and decisions taken instantly on the basis of experience.

Also all service and supply vessels of different kind although fitted with highly automated equipment obviously require on board skilled master directing different operations performed. This possible will not apply to underwater autonomous unmanned vehicles used for underwater inspections or repairs, but those vehicles are not called ships.

The area where smart ships may be used is possibly transport of goods, presumably in bulk or in containers. Therefore it may be assumed that in the future container ships, tankers and bulk carriers may be constructed as “smart”.

### 5. SMART SHIPS. PROBLEMS TO BE SOLVED

Before introduction of smart ships into practical operation would be realistic the solution of several basic problems must be necessary. Those problems may be categorized in the
following way (Fig. 2) and they include apart from technical problems, environment protection, economy, maritime law, safety and security and human factor, not listed in the order of importance. Those factors are obviously strongly interconnected.

Fig. 2. Schematic representation of problems related to smart ships, Source: own

6. TECHNOLOGY

Technically smart ships, totally autonomous or remotely controlled and unmanned could be already constructed as shown by some small military craft or drones. Currently work is in progress by DNV GL and Rolls Royce in cooperation with Southampton University on the prototype of fully autonomous ship unmanned and battery powered ship that will be send across Atlantic next year (ReVolt concept). Originally planned to 2020 this event was now few years earlier. They announced also that by 2025 fully automated ships will be entering the market.

The DNV GL autonomous ship concept ReVolt
Source: (https://youtube.com)
It seems that recently technology required to build and operate “smart” ships is already available. The most important point is, as mentioned, development of the incredible increase of computing power in recent years and possibilities to transmit extremely large amount of data from the ship to the shore station. The last was the result of the installation of global satellite systems.

The other important factor is mass production of sensors of different kind allowing to observe and control of all necessary parameters of working engines, details of cargo units on board, all characteristic quantities of the ship, such as trim, draught, stability, rolling and pitching angles, also external conditions during the voyage, wind direction and speed, characteristics of incoming waves, actually everything that may be important for taking decisions in respect of controlling the ship at sea.

Also data from navigational instruments like ARPA, ECDIS, INS and others including data from collision avoidance system, could be recorded and transmitted online to shore base.

7. ECONOMY AND GREEN SHIPS CONCEPT

Everybody may agree that smart ships must be economically viable unless other important factors may be assessed as prevailing. One these factors that should be considered as predominant is environment protection. Environment protection requires low emission of noxious gases and wastes. Ships that will meet those requirements are called “Green ships”. It is obvious that from the reasons of economy and pollution smart ships must be “green”.

Emission of noxious gases and wastes depends on the fuel properties and power of ship engines. The smaller power, the lower noxious emissions. Ship powering is a problem of ship hydrodynamics. From the ship hydrodynamics point of view this actually means reduced propulsion power which could be achieved by reducing resistance and increasing propulsion efficiency.

Resistance is function of speed and it varies depending of ship form. Propulsion efficiency depends on propeller efficiency and wake field in place where propeller works.

Currently optimisation of ship form, propeller efficiency and overall propulsion efficiency during the design stage of slow steaming conventional ships usually resulted in about 4-6% power saving, but in certain cases gain may be as high as 15%. This is achieved by using CFD computer programs for analysing flow and extensive model tests [6].

Several ways of reducing resistance and propulsion are now being investigated by naval architects. For example method of air lubrication of the wetted surface of the hull, idea that is known for a long time but was never practically applied, is considered anew. Installation of rigid sails on slow steaming ships is another possibility. It is well known that the lower loading of the propeller (therefore increased propeller diameter) will increase propeller efficiency, therefore solutions where large diameter propellers or twin propellers could be installed are also under investigation. All these solutions could be installed on smart ships reducing power of ship engines and in consequence noxious emissions. We may assume, that development of advanced methods of ship design may result in further considerable
increase of propulsion efficiency (presumably up to about 15 per cent) causing reduction of required power and decrease pollution.

The largest reduction of power of ship engines may be achieved however by reduction of speed. Choice of speed is a matter of economic calculations. The higher speed the higher turnover of goods, but on the other hand the higher cost of transport. With rising fuel costs rising speed influences the overall cost of transport negatively. In late twentieth century there was tendency to increase the speed of transporting goods and ships were designed for higher speed. Currently it was discovered that lower speed may reduce overall cost of turnover goods, therefore ships not necessarily must be built for high speed. Lower speed means lower power needed to propel the ship, therefore at lower speed it would be easier to meet new international regulations related to lower emission of noxious gases and wastes.

Ships of the future must, however, meet requirements related to pollution. International Maritime Organisation (IMO), agenda of the United Nations responsible for maritime affairs adopted in 2013 the most important technical measure of pollution from ships, Energy Efficiency Design Index (EEDI) with the aims of promoting the use of more energy efficient and less polluting equipment and engines. This is now part of the MARPOL convention [3]. Meeting those requirements which will be tightened every five years will affect in important way power and use of fuel for propulsion and other engines and equipment and in will also affect smart ships of the future. The tightened requirements concerning EEDI may cancel gain caused by increase propulsion efficiency, therefore the other ways must be sought to reduce pollution.

But the most important question is whether transport goods in smart ships would be really cheaper? This is questionable. It is obvious that salaries to ship crew will disappear in unmanned ships or will be reduced when only skeleton crew is on board. But on the other hand there will be need to employ additional staff in the control stations that must have very high qualifications. Moreover, if something serious happens on board of the smart ship during the voyage, the operation of sending repair or rescue team might be very expensive. Some recent analyses revealed that unmanned Panamax container ship would be economically unattractive [5]. This is the problem that must be investigated further.

8. SAFETY AND SECURITY

Safety and security are other matters that may affect the possibility of introduction of smart ships into practical operation. Most important safety problems are safety against adverse effects of the sea (intact stability), safety against collisions and groundings that may cause damage to the hull and safety against fire (fire protection).

The measures of safety against capsizing of intact ships for smart ships are not different from the measures applicable to conventional vessels. Intact stability of a ship may be impaired in adverse conditions of weather. Generally ship should avoid dangerous situations at sea where there is a possibility of resonance or parametric resonance with oncoming waves that may result in extreme rolling angles. There are also some other situations is rough sea to be avoided, for example broaching and surf riding. However already ships are usually provided with the instruction to the master to avoid those situations that could be done by
changing speed or heading or both. On board of smart ships this could be done automatically without problems.

However at sea there may arise situation almost impossible to forecast. One of these situation is tsunami. Tsunami is rare event and usually is not dangerous for ships in open sea, because the wave created by earthquake in open sea in extremely long and only approaching shoreline became dangerous. However another rare event that may happen in open sea is freak wave. Freak waves, although extremely rare, may reach height up to forty metres or even more in certain conditions and may cause ship to founder. Freak waves are unpredictable, they appear at random and it would be rather impossible to develop automatic system of avoid or mitigate consequences of this phenomenon. The positive fact is that probability of meeting freak wave is extremely small.

The same applies to fire protection. Fire protection currently is assured with restrictions of the use non-flammable materials as well as automatic fire fighting appliances such as automatic sprinkler systems etc. The same will be applicable to smart ships. Also with using fire fighting ships there would be no difference whether the ship is conventional or unmanned. The problem may be present in passenger ships where evacuation problems require human command. But actually no proposal to introduce unmanned passenger ships, apart from river crossing ferries, are proposed.

The most serious problem with smart ships may be security against pirate attack. It could be physical attack such as they happen now in some parts of the world, but, more important electronic attack, where pirats-hakers may overtake control of the ship that is unmanned or manned only with small crew. It seems that physical attack on unmanned ship is not very realistic, because unmanned ship may be constructed without any easily accessible openings and in such ships pirates actually have very limited ways to enter. The purpose of physical attack usually is to get ransom.

Another case would be when pirates take over control of the ship electronically. In such cases ship could be directed to certain harbours, opened, unloaded and expensive goods removed. Ransom in such cases may be not the prime purpose of attack.

9. MARITIME LAW AND HUMAN RELATIONS

Smart ships may create great challenge to the current maritime law. It appears that commercial operation of unmanned or remotely controlled ships may require amending almost all international conventions related to marine transport.

In all legal instruments “ship” is defined as manned object. Manned ships with some autonomous systems fall under this definition. However it is clear that unmanned ships do not. The old principle with regard to shipping was based on the assumption that the full responsibility for the ship at sea lies on the master who is onboard and is “the first after the God”. This view is already challenged partially with the development of on line communication with the ship owner office on shore that may recommend the master to take certain actions, although those actions at present mainly concern commercial affairs not affecting technical operation of the ship which still remains sole responsibility of the master. But still full responsibility for operation of the ship at sea is in hands of the master.
Operation of autonomous ships controlled from the shore station put full responsibility for the ship at sea to this station. It is, however, questionable whether the man at control in the shore office could be assessed as “the captain” This would be the most important issue, acceptance of this change by the conservative shipping world would need to overcome legal, and emotional barriers.

Emotional barriers against introduction of autonomous ships should not to be dismissed lightly. As said before, shipping world is rather conservative and seafarers profession has high self esteem. Abandoning the position of ship master and replacing it by anonymous controller in the shore control station may be considered as devaluation of the profession. This may induce negative feelings against introduction of unmanned ships. Replacing active ship crew in ships with minimal crew staff for inspections and emergency working on boring shifts will also devaluate attractiveness of profession.

Also important issue is that present regulation in respect of manning in the international STCW Convention (Standards of Training, Certification and Watchkeeping) must be entirely changed, which may create important protests from the side of trade unions.

Another problem not easy to be solved is how to implement to smart ships the present regulations on search and rescue operations at sea. According to present regulations all ships are obliged to participate in search operations at sea and rescue people at distress. This certainly could not be applicable to smart ships.

10. CONCLUSIONS

Extremely fast development of computing power in recent years shows that we are facing advent of the fourth industrial revolution that presumably will happen around the middle of the twenty first century. The effect of the fourth industrial revolution on marine transport would almost certainly be introduction of smart ships. Smart ships may be unmanned, totally autonomous, unmanned and remote controlled from shore station, or highly autonomous but with skeleton crew for inspection and emergency. The last solution seems to be most realistic.

The idea of smart ships is not equally realistic to all types of ships. It seems that the most realistic application of this idea would be with regard to tankers, gas carriers, bulk carriers and eventually container ships. Ships carrying large number of passengers, such as cruise vessels possibly still will require large crew on board.

Technology to build smart ships is already available and the first unmanned, battery powered ship will be send across Atlantic next year. But before practical application of this idea would be realistic several important problems have to be solved that may prohibit wider employment of such ships. Those problems, a part of some technical problems, include economic viability and environment protection aspects, safety and security aspects and legal and human aspects.
References


TRANSPORT MORSKI A CZWARTA REWOLUCJA PRZEMYSŁOWA

Streszczenie: Około połowy wieku dwudziestego pierwszego pojawią się na świecie oznaki czwartej rewolucji przemysłowej, która będzie rezultatem niesłychanego powiększenia mocy obliczeniowej komputerów. Świat stanie się „inteligentny”. Tradycyjne statki mogą być zastąpione statkami inteligentnymi, które będą albo całkowicie autonomiczne i bezzałogowe, albo bezzałogowe i sterowane z bazy brzegowej lub też autonomiczne jedynie ze szkieletową załogą dla zapewnienia nadzoru i bezpieczeństwa w przypadku awarii. Budowa takich statków jest możliwa już obecnie i pierwszy eksperymentalny bezzałogowy statek będzie wysłany poprzez Atlantyk już w roku przyszłym. Jednakże zanim podejmie się budowę statków inteligentnych na przemysłową skalę, należy rozwiązać szereg poważnych problemów. Niezależnie od problemów technicznych występują ścisłe ze sobą związane problemy ekonomii oraz ochrony środowiska, problemy bezpieczeństwa oraz zabezpieczenia przed atakami piratów hakerów mogących opanować statek oraz problemy prawne a także związane z interesami różnych grup ludzi. Problemy te omawia niniejszy artykuł.

Słowa kluczowe: Czwarta rewolucja przemysłowa, transport morski, intelligentne statki