

## **STUDY ON THE EFFECT OF CHANGING HULL RESISTANCES TO TURBOCHARGER OPERATION OF MARINE DIESEL ENGINE**

**V. QUAN PHAN<sup>\*</sup>, C.A. TRUONG PHAN<sup>\*\*</sup>**

<sup>\*</sup> Faculty of Naval Architecture and Offshore Engineering, <sup>\*\*</sup> Faculty of Marine Engineering  
Ho Chi Minh City University of Transports (HCMC-UT)  
2D3 St. Binh Thanh Dist. Ho Chi Minh City, Vietnam  
E-mail: phanquan@otm.vn, Web : <http://www.utc.edu.vn>

**Keywords:** Hull Resistance, Turbocharger, Main Engine, Load Diagram, Compressor Surge.

**Abstract.** Ship's hull resistances will change in according to the ship's operation time, caused by several different reasons: the development of sea creatures clinging to the hulls; sea water corrosion and distortions of hulls; the abrasion and corrosion of propellers; the abrasion of driving shaft bearings etc... It is considered the changing of hull resistances is independent on the main engine turbocharger operation. In fact, this may cause some influences on the main engine. In this paper, we would like to study on the effect of turbocharger operation on main engine power due to the changing of hull resistances, as well as the inverse effect of power changing to the turbocharger operation. It's useful to design and select a suitable turbocharger for main engine, and prevent it dropping in unstable area, or not reaching the desired efficiency after short time operation. Otherwise, this research will advise the marine operators to deeply understand and avoid running the turbocharger at overload range, consequently the turbine blades are burnt, or turbocharger drops in the unstable surge margin operation.

# 1 INTRODUCTION

## 1. Introduction

Hull resistance is an important factor affected on the ship's operation. The ship's characteristic is to carry cargo, survey, research and serve other services at sea. So, most of hull immerses in the sea water. As sailing in water, the ship will be influenced by many external factors such as wave, wind, current, clung by sea creatures, and seaweed, or corroded, coating peeled off by friction, surface deformed due to collision, and propulsion system damaged. All will cause the hull resistance changing and increasing proportionally to the time of operation.

Studying the effect of changing hull resistance on the working condition of propulsion system, or turbocharger in focus is one of the important missions to assist marine architect engineers and operating engineers have general visionary in design, improve safety and effective operation of ship's propulsion system.

## 2. Ship's hull resistance

The operation of ship in water will create several actions against the direction of ship, which are called hull resistance. The ship's hull resistance in water includes resistance of external shell friction, pressure difference around ship, draft air... [1]. Here, we will study each kind of resistances on ship :

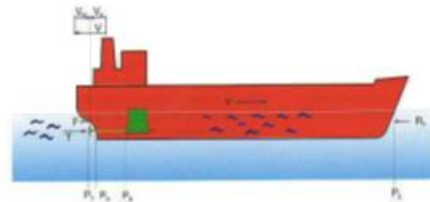


Figure 1. Ship's hull resistance

### 2.1 Frictional resistance $R_F$ :

The frictional resistance of ship's hull depends on the wet surface area of the hull  $A_s$  and the frictional coefficient  $R_F$ . The resistance goes up as result of clinging of sea creatures, seaweed and rust on external shells. The frictional resistance increases to approximately the square of ship velocity and is about 70 - 90% of the total resistance for bulk carriers, oil tankers, or large low speed vessels. For high speed ships, the frictional resistance may reduce less than 40% [2].

The friction resistance is calculated as:

$$R_F = C_F \cdot K \tag{1}$$

### 2.2 Residual resistance $R_R$ :

Residual resistance comprises the resistance of wave and eddy. The wave resistance refers to the energy loss caused by waves produced by the ship's sailing through the water. The eddy resistance is the least effect on the ship's operation, and often prevalent at the stern.



Figure 2. Ship's hull resistance diagram

The wave resistance at low speeds is proportional to the square of ship's velocity, and rapidly increases for high speed vessels.

From the ship's hull resistance curves in figure 2 [1], as referring to the wave resistance, the residual resistance of ship's hull will change under the effect of wave resistance, and vary around the the hull frictional resistance curve. The residual resistance is determined as [2]:

$$R_R = C_R \cdot K \quad (2)$$

### 2.3 Air resistance $R_A$ :

In case of ship sailing in calm water, air resistance is proportional to the square of ship velocity, and proportional to the cross sectional surface area of ship above the waterline. Normally, it equals to approximately 2% of total hull resistance, and may raise to 10% of total resistance for some special types of ship.

The air resistance [2] is defined as:

$$R_A = 0.9 \times \frac{1}{2} \times \rho_A v^2 \times A_A \quad (3)$$

Where  $R_A$ : Air resistance,  $\rho_A$ : air density,  $v$ : air speed, and  $A_A$ : cross-sectional surface area of ship above waterline.

### 2.4 Total hull resistance

The total hull resistance is experimentally determined as the below table 1:

**Table 1:** Percentage of ship's total hull resistance

Resistance type	% of total hull resistance $R_T$
$R_F$ : Frictional resistance	45 – 90%
$R_R$ : Residual resistance	45 – 8%
$R_A$ : Air resistance	10 – 2%

### 2.5 Ship resistance change during operation

From the above analysis, and in this study range, the residual resistance and air resistance are nearly not changed during time of ship operation. The main factor causing the change of hull resistance after an interval of operation is only frictional resistance  $R_F$ . When a ship has berthed for long time, under the effect of sea creatures and seaweed on the external shells, the frictional resistance will increase from 25% to 50% in comparison with the initial resistance.

The ship's hull resistance goes up by time from undry-dock, which the resistance is minimum due to new clean surface of hull without corrosion or scratch. Then, the frictional resistance of ship's hull will increase under the effect of sea water environment depending on the time of operation and berthing period. As the result from the calculation and analysis, the change rate of hull resistance in a 6 months interval will go up from 10% to 20% [2] in comparison with initial undry-dock resistance depending on the ship's operation time and draught.

Figure 3 describes the change of resistance characteristic of ship's hull after 6 months of undry-dock of ships with basic particular: 5m in width, 178m in length, 11,700 DWT, wet area: 3,650 m<sup>2</sup>.

From the characteristic curves (Figure 3), the hull resistance changes by time of operation due to the increasing of frictional resistance, and at rate of 10% to 20% in comparison with the initial value after undry-dock.

The residual resistance and air resistance will change with amplitude depending on the effect of wave and wind. From table 1, the total of both these resistances may go up to 55% of the total resistance in some special situations (Figure 3).

It's found that the increasing of hull resistance by time of operation will make the thrust power raising significantly if the ship's speed is still kept constant. This requires the engine power raising accordingly to the increasing of hull resistance. Consequently, the engine power will increase, the exhaust gas volume from engine also raises, and requires a larger volume of inlet air. This is the reason why the changing of hull resistance will affect on the working condition of main engine turbo charger.

### 3. Supercharging by exhaust gas turbocharger, and load diagram of marine diesel engines

Turbocharger is a complete equipment installed in the diesel engine, which uses the exhaust gas energy outlet from the engine combustion to power a turbine shaft, driving a compressor wheel to push more air into the engine. Turbocharger makes the power and thermal efficiency of engine increasing (Figure 4). To clearly understand the importance of turbocharger for engine, in this part, we will study the description of an exhaust gas turbocharger system and the load diagram of FPP propulsion engine.

#### 3.1 Arrangement of an exhaust gas turbocharger

Figure 4 shows the basic principle system of turbocharger [3], [6], including two main parts:

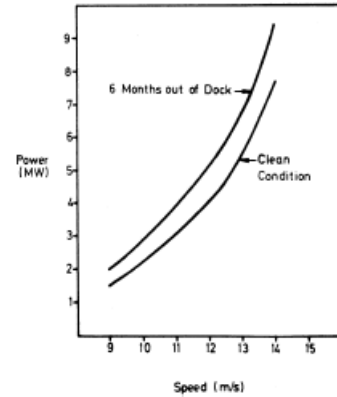


Figure 3. Change on ship's hull resistance

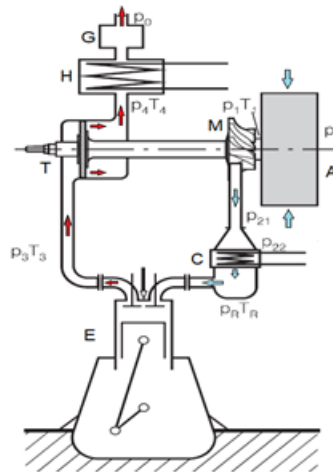


Figure 4. A diesel engine turbocharger arrangement

Where:  $P_0$ : ambient air pressure;  $P_1, T_1$ : air pressure and temperature before compressor;  $P_{21}$ : air pressure after compressor;  $P_{22}$ : cooler inlet air pressure;  $P_R, T_R$ : engine inlet air pressure and temperature;  $P_3, T_3$ : engine outlet exhaust air pressure and temperature;  $P_4, T_4$ : air pressure and temperature after turbine;  $A$ : silencer;  $M$ : compressor;  $C$ : air cooler;  $E$ : diesel engine;  $T$ : turbine;  $H$ : heat exchanger;  $G$ : exhaust muffler.

- Turbine part in the exhaust side of engine uses the exhaust gas energy to power the turbine shaft.
- Compressor part in the air inlet of engine is directly driven by the turbine shaft. Ambient air is drawn and compressed to desired pressure, and pushed into the air inlet.

To improve the engine efficiency, and reuse the exhaust gas energy, it is installed a heat exchanger on the passage of exhaust gas after turbine, and an air cooler in the air inlet after compressor to extend the air volume for engine. Furthermore, to enhance the efficiency and reliability of turbocharger unit, several auxiliary equipment are fitted such as silencer, heat insulating sheets, pressure gauges, and thermometers...

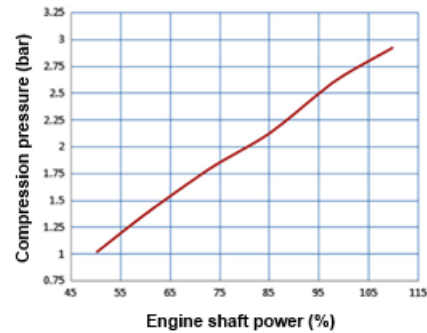


Figure 5. Compression pressure diagram

### 3.2 Load diagram and operation range of marine diesel engine

Compression pressure is important and effect on the quality of combustion. It raises linearly with engine power [4] (figure 5).

Engine load diagram describes the relation of engine moment, and power with speed. By experimental building, we can determine the basic engine parameters and operation ranges. Figure 6 shows the engine load diagram of a 2 stroke diesel engine with turbocharger.

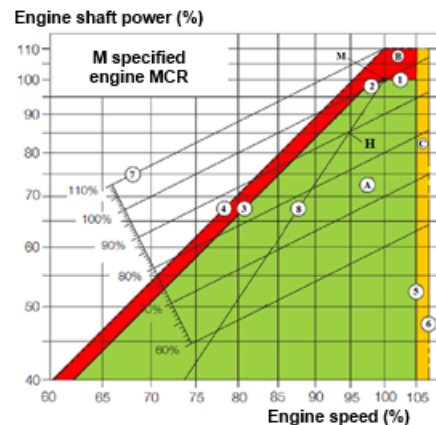


Figure 6. Engine load diagram

From the load diagram, the engine operation area is divided into 3 ranges: A, B, and C, in which A is the normal & safety service operation range. During the operation, engine should be controlled to work in point H with 85% MCR at 95% max rating engine speed. At this optimising point, the engine will run safety and reach high efficiency with minimum specific fuel oil consumption.

### 4. Effect of hull resistance on turbocharger operation

In fact, there may be different types of arrangement for propulsion a propeller shaft. In this study, it is considered for a 2 stroke low speed diesel engine directly driving propeller shaft.

Where: A. Normal engine load range, B. Overload limit range, C. Overspeed limit load range, M. Specified engine MCR point (Max continuous rating), H. Service operating point, Line 1. Specified engine MCR; Line 2. Torque through specified MCR; Line 3. Torque limit; Line 4. Overload limit; Line 5. Speed limit; Line 6. Overspeed limit; Line 7. Torque at 110% MCR; Line 8. Load limit through M specified MCR.

#### 4.1 Ship propulsion system

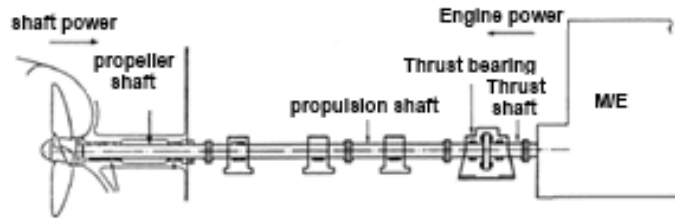


Figure 7. Ship propulsion system

As the driving model of propulsion system in figure 7, the rotating speed of engine will be same as propeller shaft, and engine power will be transmitted to the propeller shaft to force the ship. Energy loss due to friction at bearings, or sealing of propulsion system is quite low, and ignored. In this case, it's considered the shaft power is approximately equal to engine power.

#### 4.2 Combination of engine and propeller

As the propulsion system in figure 7, we have the load diagram of engine with propeller in figure 8. From the graph, it's seen that the operating point of engine with propeller is the intersection between propeller curve and load curve (point M, N and I). As the hull resistance increases, the propeller curve tends to shift to the left, but the load curve is still constant, so the operating point will move to the left, cause the engine power and speed reducing, and consequently the speed of vessel goes down. If the operator still keeps the speed of vessel, it will make the engine overload partially, and exhaust gas temperature highly increases (fig.8).

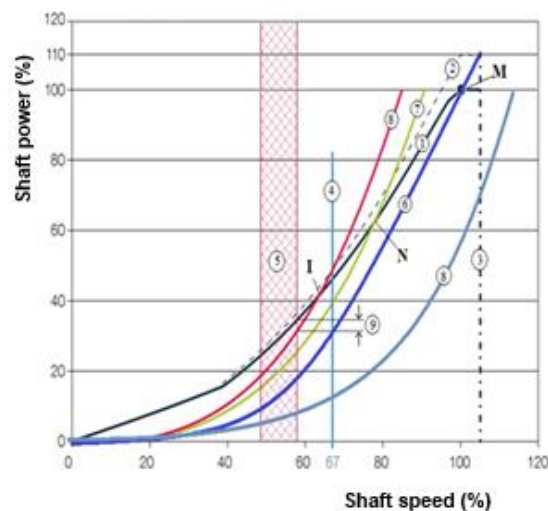


Figure 8. Combination between engine and propeller shaft

Where: 1. Load limit, 2. Overload limit, 3. Speed limit, 4. Speed limit at 50% MCR, 5. Resonant speed range, 6. Initial full load propeller curve, 7. Heavy load, resistance propeller curve, 8. Trial propeller curve, 9. Power reserved range for resonant speed, M – MCR working point, N, I – working points of engine with propeller.

#### 4.2 Turbocharger characteristics and efficiency working area.

In order to analysis the effect of hull resistance on the turbocharger operation, we should study compressor map, and the peak efficiency area of turbocharger.

Figure 9 describes the compressor map of an ABB turbocharger, series VTR304P [3]. The operating point of turbocharger is the intersection point N between the engine performance curve and turbocharger curve. At this point, the turbocharger works stably (on the right side of stable limit curve) with the highest efficiency of approximately  $\eta = 0.81\%$ , and the speed of compressor reaches approximately 90% service speed of turbocharger. It's very important to determine the operating point of turbocharger. This point must be as close as the peak efficiency curve of compressor to optimise the power capacity of engine.

In the first trials on engine with turbocharger, the parameters will be recorded to analysis and determine the optimising point. If the operating point is not correct, consequently the compression pressure will be too high or low, or drop in the unstable area in the right of compressor surge line. To select the operating point of turbocharger, it is necessary to adjust the outlet air guide, or change the throat area or size of nozzle ring.

As the operating point drops in the low efficiency area with low speed of turbine, it causes compression pressure decreased, consequently the engine can not reach the optimum of turbocharger. Less compression air, the combustion will be worse, and the engine power will be reduced.

#### 4.3 Effect of hull resistance on the turbocharger operation

From the above analysis, the ship's hull resistance will increase by operating time and maintenance interval. As resistance arising, the operating point of engine with propeller will change. It will shift to the left side, from point M to point N or I. At point N or I, the engine speed decreases significantly 20% to 30% of continuous rating speed. Referring to the resonant speed, it needs to reduce the speed lower resonant range, at 50% below the continuous rating speed. This causes the ship's speed far slow down in comparison with the design speed. Moreover, changing the engine working condition once hull resistance arising will affect on the turbocharger operation as below:

- As hull resistance arising, engine condition is changed to new condition with low power and speed. From figure 5, compressor pressure will decrease, turbine service speed drops,

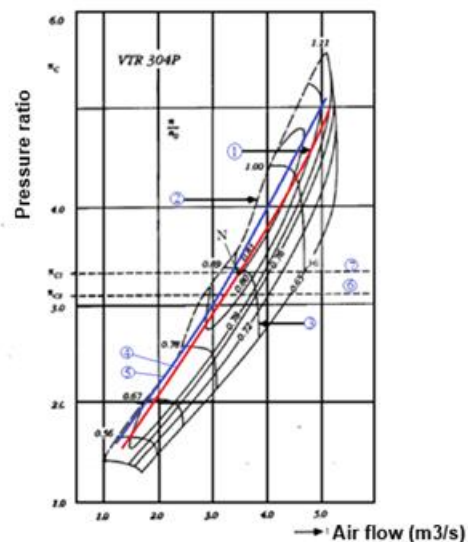


Figure 9. Compressor map

Where: 1. Peak efficiency line, 2. Surge line, 3. Turbine speed curve, 4,5. Engine performance curves, 6,7 compressor efficiency curves.

exhaust outlet resistance increases, the combustion will delay through the exhaust stroke. Consequently, the efficiency of engine and turbocharger reduces.

- Beside that, as the hull resistance increases, the engine may drop in the partial overload area with high exhaust temperature. Under this condition, the turbine inlet gas temperature will raise excessively, and may cause damage on nozzle ring, and turbine blades, even cracked, or burned [5], (figure 10).

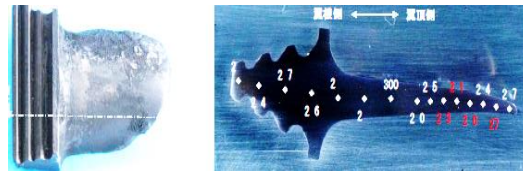


Figure 10. Excessive heat causing damage on blade profile part.

- Hull resistance rising also makes the engine condition overloaded partially, consequently speed of engine and turbocharger reduced. From the compressor map in figure 9, the operating point N of turbocharger tends moving to the left, drops in the surge margin, and causes turbocharger unstable in operation. If running under this condition for long time, the energy balance will be broken out, and causes rotor unbalanced. Consequently, the turbocharger may be damaged during operation.

## 5. Conclusion

The resistance raising by operating time will affect not only on the working condition of engine, but also turbocharger.

Increasing hull resistance will lead the effect on the operating characteristics of turbocharger such as: the efficiency of engine and turbocharger reduces; engine is partially overloaded which makes exhaust gas temperature increase excessively, then causes damage or bent on nozzle ring, and turbine blades, consequently turbocharger is damaged. Moreover, hull resistance raising will cause the turbocharger working unstably, unbalanced, and other parts damaged.

During designing, installing and operating of turbocharger on main engine driving propeller shaft, it is necessary to highly pay attention to the changing of hull resistance effected on the working condition of turbocharger to reach the optimising selection, installation and operation.

## Reference

- [1] Kees Kuiken, "Diesel Engine II for ship propulsion and Power plans", Target Global Energy Training Noorderhooijdijk 29755 PJ ONNEN The Netherlands, pp 40, (2008).
- [2] KJ Rawson, EC Tupper, "Basic ship theory" Butterworth Heinemann, ISBN 02750653973, Chapter 10 pp: 381 – 395, (2001).
- [3] V. Quan Phan, T. Phuoc Ho "The phenomenon surging of turbocharger compressor of marine diesel engine" The transport Journal (2011).
- [4] M. Morsy El Gohary, Khaled M. Abdou, "Alexandria Engineering Journal", Alexandria Engineering Journal 50, 1–11, (2011).
- [5] Training Course of MET turbocharger – Mitsubishi, (2016).
- [6] Hermann Hiereth, Peter Prenninger, "Charging The Internal Combustion Engine Power Train" Springer Wien New York (2003).



## SEA TRAFFIC MANAGEMENT AND THE SMART MARITIME COMMUNITY

Sergio Velasquez Correa\*, Xavier Martinez de Oses\* and Ulf Siwe† Barcelona School of  
\*Nautical Studies (FNB/UPC-BarcelonaTech) Universitat Politècnica de Catalunya –  
BarcelonaTech Pla de Plau, 18, 08003 Barcelona, Spain e-mail: svelasquez@cen.upc.edu,  
fmartinez@cen.upc.edu web page: <http://www.dcen.upc.edu>

† Swedish Maritime Administration (SJÖFARTSVERKET) SE-601 78 Norrköping, Sweden e-  
mail: E-mail: [ulf.siwe@sjofartsverket.se](mailto:ulf.siwe@sjofartsverket.se) web page: <http://www.sjofartsverket.se/en/>

**Keywords:** Sea Traffic Management, European Maritime Simulators Network (EMSN), Port CDM, SeaSWIM

### ABSTRACT

Sea Traffic Management is a concept developed during the last six years creating the culture of sharing information and collaborating to optimise the maritime transport and extending the benefits to the logistics chain and at the same time, enhancing maritime safety and environment. The project takes advantage of the several technology and equipment now installed on-board ships, improved by the use of information and communication technologies and the need of standardization procedures and protocols in the transport sectors. Few complementary tools introducing the use of VDES (VHF Data Exchange System) will make possible a radio communication system that operates between ships, shore stations and satellites on Automatic Identification System (AIS), Application Specific Messages (ASM) and VHF Data Exchange (VDE) frequencies in the Marine Mobile VHF band. With the available data, communication channels and infrastructures, the digital information on-board and on shore is abundant; however, the interconnection today is point-to-point and proprietary and stops the industry becoming more efficient. We will discuss how Sea Traffic Management will help the industry achieve improved predictability by introducing standards for key information and supplying an infrastructure for information exchange. This enables all actors involved in the transport to plan better and utilise their resources more efficiently. Shorter routes, just-in-time arrivals, shorter port calls are factors that will strengthen the competitiveness of the maritime sector. Improved situational awareness on the bridge and knowledge of planned routes will help optimised planning as well as reducing the number of incidents and accidents. The standard route exchange format submitted by the EU-financed MONALISA 2.0 project partners in 2014 is included in the current edition of the IEC standard, which was launched in August 2015. Ship operators, savings on fuel and other cost, society saves on reduced emissions, and other actors associated to maritime operations benefit from a higher degree of infrastructural use. This paper explains the progress and preliminary results of the key enablers of STM Validation Project and the steps beyond the current EU funding support that must complete a promising picture of next decade maritime transport industry.

### INTRODUCTION

The recent past of maritime navigation has been focused on the skills of the bridge and engine officers on board. During the last years of the past century and the first decade of century XXI, the manoeuvring, safety and security of ships have evolved on different equipment and systems designed to support, aid and contribute to the own navigation tasks. The RADAR, ARPA, GPS, AIS and ECDIS have represented an evolution on the tasks of watch-keeping and decision-making processes during the navigation stages. The improvements on safety and the reduction on

maritime accidents are a good signal about the synergy between human – machine interaction. The four main navigation problems that seafarers must solve during the sea navigation,

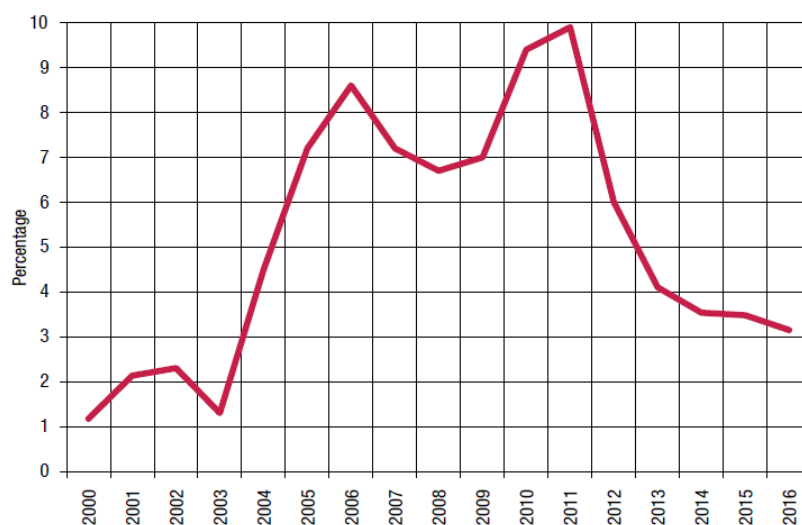
- to establish the position (in terms of latitude and longitude),
- to establish the heading (with reference to geographic north),
- to establish the time, speed and distance during the trip and
- to know the hydrography, meteorology and state of the sea during its navigation,

are now simplified with basic functions pressing some buttons or giving instructions through computer screens. This can be thought as first technological revolution in maritime industry after the invention of chronographer. Nevertheless, the shipping industry is currently passing through probably the most important change it has seen in the last two hundred years, “digitalization”. The conjunction of sea transportation, port activities and logistics synchronization, have shown one or two milestones in the development of the industry, not least the move from wood to steel hulls and from sail to steam. However, the most recent innovations, which are forcing all mariners to re-think on basic bridge functions, are the advances of electronic navigation systems and the introduction of internet. Watch keeping operations are constantly changing with enforced simplified bridge systems. Officers are being given additional tasks to carry out (e.g. communications) while some of the older operations (like chart correction, as known) have changed becoming obsolete. Information and communication technologies (ICT) are here to stay and go on, beyond the integrated bridges, where Internet of the Things (IoT), 5G communication technology and big data analysis have become the dominant issues in the maritime domain to improve safety reducing the number of accidents, reduce fuel consumption, minimize environmental damages and optimizing routes and port calls. E-navigation promoted by IMO and EU e-maritime initiative boosted by European Commission have become in the drivers to think in global solutions involving maritime transport, port operations and logistics because the current need to know, share and exchanged information. Sea Traffic Management Validation Project Sea Traffic Management project (STM), sequel of former MONALISA and MONALISA 2.0 projects is one of the wider and ambitious projects to implement the electronic and digital management of the global transport chain. Motorways of the Sea is the flagship project of Europe and requires of instruments like STM to create a common maritime arena, similar to the Air Traffic Management programme SESAR. This ambitious project is lead by the Swedish Maritime Administration, composed by 13 EU Member States, more than 70 companies and organizations, public and private academia and funded by the European Commission through Connecting Europe Facilities budget approved by the Innovation and Network Executive Agency (INEA). The project has been broken down in four key enablers: • Voyage Management services will provide support to individual ships in both the planning process and during a voyage, including route planning, route exchange, and route optimisation services. • Flow Management services will support both onshore organisations and ships in optimising overall traffic flow through areas of dense traffic and areas with particular navigational challenges. • Port Collaborative Decision Making (Port CDM) services will increase the efficiency of port calls for all stakeholders through improved information sharing, situational awareness, optimised processes, and collaborative decision making during port calls. • SeaSWIM (System Wide Information Management) will facilitate data sharing using a common information environment and structure (e.g. the Maritime Connectivity Platform). This ensures interoperability of STM and other services. In addition to the digitalization of the maritime industry, it is important to mention that no technological advances can be optimally employed without proper training. The proliferation of systems and information on board is aimed to support crew in their watchkeeping tasks during voyages by avoiding hazards earlier and more clearly. They way how crews must adopt new standards and manage huge amounts of information (big data) at screens must be learnt by updating knowledge through training. New competences related to the actors involved in STM at shore side, on board and for

operational safety, is a part of the analysis of the project, in order to know future competence requirements regarding the new scenarios coming from the implementation of STM services, with the resulting variations in operational techniques and procedures. The internal and external project stakeholders, the clusters and the international forums need to be consulted in order to provide suitable answers promoting the engagement of skilled and qualified professionals and staff into the maritime and port industries in the coming years when STM will be deployed.

## 1. Current shipping market situation

Thanks to globalisation, global trade has experienced an accelerated growth between 2000 and 2008 producing a huge impact on the demand of shipping as the mass transportation mode worldwide (Figure 1). In parallel and not since the event of industrialisation in XIX century has there been a technological significant change as enormous as digitalisation already is nowadays and in the near future is expected to be. Even information systems have represented a third industrial revolution since the end of 70's in XX century, new generations are living for the first time a new change in the technology development based on information and communication infrastructures. Big Data can be collected on the go by several devices, stored and exchanged on the “cloud”, processed in real time and smartly connected. This progress allows for a whole new quality in communication, connectivity and ultimately also in production, in transport and logistics. The digital possibilities of connectivity mean that time and space are being completely computed/predicted simultaneously, “contradicting” Heisenberg's uncertainty principle<sup>1</sup>. In terms of economical parameters, this is linked to a reallocation of resources, which will entail a massive shift in production, trade and logistics. These developments and changes have to impact on shipping industry in different ways, as it will be discussed further.



**Figure 1. Annual growth of world fleet, 2000–2016 (Percentage annual change). Source: UNCTAD, Review of Maritime Transport, various issues.**

The new technological solutions to process Big Data and connect them smartly has inspired a group of experienced shipping officers in Scandinavia to apply such technology into the maritime field. The most important of these solutions from shipping industry perspective has been:

- Digital platforms,
- Big data analysis,

<sup>1</sup> The authors allow themselves the freedom to paraphrase this principle of quantum mechanics: Introduced first in 1927, by the German physicist Werner Heisenberg, this principle states that the more precisely the position of some particle is determined, the less precisely its momentum can be known, and vice versa.

- Maritime cloud,
- Use of simulators in networks
- Artificial Intelligence,
- Internet of Things,
- Blockchain,

Since the STM concept started to be a reality, many of these digital innovations have played a major role for shipping looking at the future, both directly and indirectly. Because trade, transport and logistics are dependent variables, developments and changes in shipping have to play at least as important a role as the direct changes in processes and business models within the shipping industry including maritime ports. These are the key pillars of STM Validation Project, the way in which technology will improve shipping industry, maritime transport, logistics and international trade operations smartly under collaboration philosophy among parties.

## **2. The Context of STM Validation Project**

In 2010, the European Union (EU) commenced a multi-year project to fund innovation in the shipping industry to improve efficiency, safety, and sustainability, goals which parallel the triple bottom line of profits, people, and planet [1]. The initial project, MONALISA 1.0, concentrated on increasing ship-to-ship collaboration through sharing routes among ships and shore-based vessel management authorities. The project operated in the Baltic Sea Region. This project was then extended, MONALISA 2.0 (2013-2015), to cover more regions in Europe with more partners and an increased budget. The focus, inspired by the Single European Sky Air Traffic Management Research (SESAR) project, was to enhance Sea Traffic Management (STM) by applying three concepts (voyage management, flow management, and port collaborative decision-making) supported by a digital data-sharing infrastructure. In 2015, the project was renamed STM validation and the consortia was granted €43 million to validate STM concepts in 13 ports with over 300 participating ships.

The EU sees acceleration of the industry's digitization as critical to meeting its goals<sup>2</sup> and it expects STM to revolutionize the shipping business.

## **3. Collaboration in shipping and global trade requires data sharing**

In the maritime sector, as with nearly all industries related, no one can act independently. Sea transport is dependent on multiple players' contributions to the value network. Ecosystems should be efficient in all their parts because there is a need for each organization to base its planning on the actions and intentions of the others. This means that to improve operational performance data needs to be shared among involved organizations within the ecosystem and merged with each organization's data. Data sharing for collaborative decision-making is at the core of the Sea Traffic Management (STM) enabler Port Collaborative Decision Making (Port CDM) in which two message formats are promoted; the route exchange format and the port call message format.

Within the STM validation project, 13 ports are engaged in validating Port CDM where there have been concerns raised for what would happen with the data that a single organization might share. Port CDM aims at improving situational awareness through data sharing based on the port call message format. Hence, it is vital that all actors contribute with relevant data to a port's system of records to support mutually beneficial port planning [2]. A port is a meta system of production composed of independent, yet interdependent, systems of production linked through

---

<sup>2</sup> The digital transformation of EU business and society. EU Growth Initiative: Internal market, industry, entrepreneurship and SMEs. 2018.

a ship's sequence of episodic tight couplings. To optimize this meta system, we need a meta system of records to enable a holistic analysis to improve a port's competitiveness.

By the other hand, Sea Traffic Management takes a holistic approach to services making the berth-to-berth ship voyage efficient, safe, and environmentally sustainable. Hence, STM puts the voyage in focus and uses that as a core element for enhanced safety, optimised processes for involved actors and stakeholder interaction.

In order to define STM, focus is put on user needs and a holistic view of the voyage is achieved by using legal/institutional; operational; information; and technical perspectives. STM requires enhanced interaction between ship-to-ship, ship-to-shore, shore-to-ship, shore-to-shore enabled by information sharing empowered by enhanced service interaction. In summary:

*STM is a concept building on services made for sharing secure, relevant and timely maritime information between authorised service providers and users, enabled by a common framework and standards for information and access management, and interoperable services*

The scope of STM includes private, mandatory, and public service opportunities along the whole voyage from berth-to-berth. Further, STM relates to existing practices and on-going initiatives within IMO's e-navigation Strategy Implementation Plan, e-maritime, and the collaborative port. STM complements and adds to existing/on-going initiatives. STM includes concepts for Strategic and Dynamic Voyage Management (DVM), Flow Management (FM), Port Collaborative Decision-Making (Port CDM), enabled by distributed and service based information management; a maritime service infrastructure [3].

#### **4. Basic principles of Sea Traffic Management**

To achieve these benefits, a service-based and regulated information sharing framework is required. The basic logic behind STM builds upon the following principles:

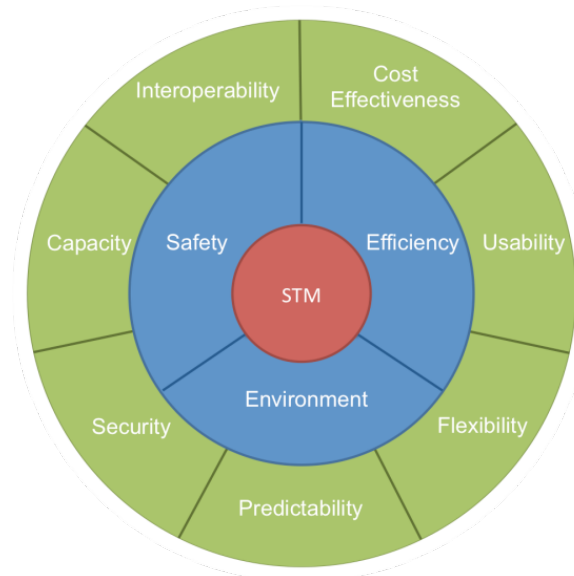
- 4.1. A voyage is defined and all its attributes are connected through a unique voyage identifier;
- 4.2. Information related to the voyage, and thus basis for sharing, is connected via the voyage identifier;
- 4.3. Operational intentions of sea- and land based actors are provided to others well in advance and kept up to date;
- 4.4. ICT services supporting personal contacts;
- 4.5. A collaborative attitude is empowered in information sharing and decision making;
- 4.6. One single point of reporting;
- 4.7. Situational awareness is derived from multiple informational sources;
- 4.8. Secure and authorised service realisation; and
- 4.9. Discovery and distribution of services are realised through an infrastructure governed by a Federation/Organisation.

Further, the following prerequisites are used in the STM definition:

- The Master is in command;
- United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on the International Regulations for Preventing Collisions at Sea (COLREG) are complied with;
- Existing systems and on-going initiatives are considered; and
- Information ownership is managed by a secure system of access control and authentication.

STM is a framework, harmonisation of data formats and standards for information management and operational services. Some of the standards enabling STM are:

- route exchange format;
- port call message format;
- other text message format;
- time stamp definitions;
- service specification language;
- geospatial and location data standards;
- processes for approval, distribution, and discovery of services;
- processes for federated governance of service portfolio; and
- access management.

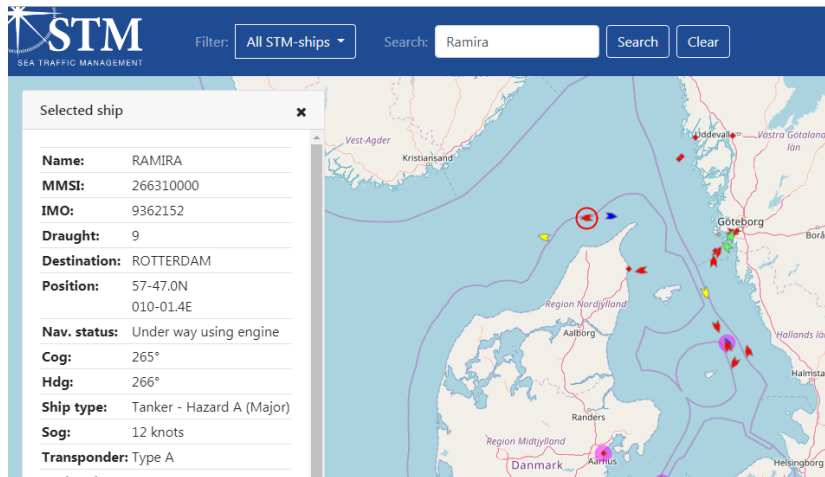


**Figure 2. Sea Traffic Management’s main and subordinate objectives. Source: STM Project Technical documents**

## 5. Milestones up to now with STM Project

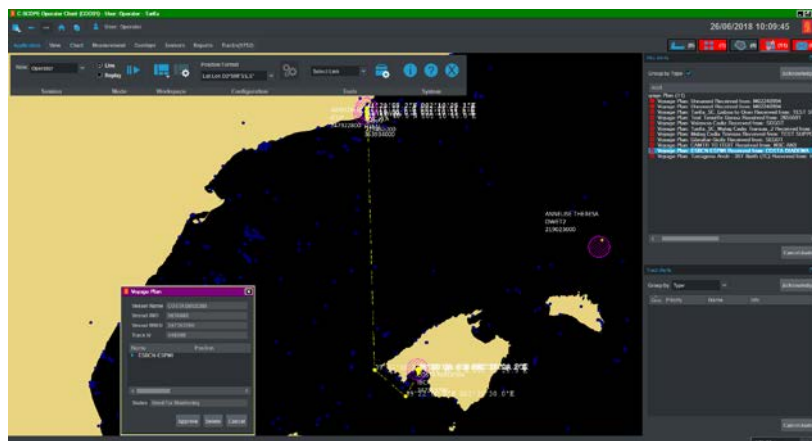
In the final stretch of the STM project, the installation of the necessary systems on land and on board ships has been achieved. The work in the simulators using the European Maritime Simulators Network (EMSN) has managed to validate many of the proposed services for the exchange of routes and the exchange of information with the shore centres. Some of the milestones achieved and that will be presented at the IMO at the final conference in November in London on 13<sup>th</sup> November 2018 are:

- May 2018, Ramira vessel departed Gothenburg and shared her voyage plan with destination port Rotterdam. The receipt of the voyage plan's ETA was confirmed by Rotterdam's Pronto system via a text message back to Ramira. Thereby, the first live port call synchronization in the STM history took place.



**Figure 3. Ramira vessel sharing her voyage plan with the port of destination. Source: STM Project Technical documents**

- June 2018, Kongsberg installed their STM capable C-Scope VTS software in Horten, Kvitsøy and Tarifa - Spain and the systems were used for live Exchange of voyage plans. Ships from Costa (partner of the project) and MSC (with many ships equipped for STM project) are now sharing real data from the first ships via the Neptune Fleet Operations system. This is a clear showcase for how proprietary platforms like fleet operations can be connected to other systems via STM standards and infrastructure.



**Figure 4. Screenshots from ships that have shared their voyage plans that passes in the area of the Shore Center in Tarifa. Source: STM Project Technical documents**

## 6. Conclusions

In the distributed world of maritime transportation, different actors have taken up digitisation in the way that it serves them best. Typically, big actors have created systems for coordinating their transport operations. They do however rely on other actors' ability to become more efficient because of the complex scheme of international trade. To overcome this situation, Sea Traffic Management has been proposed in which intentions of upcoming, and the accomplishment of actions are communicated prior to and during a sea voyage. STM puts an emphasis on interoperable and harmonised systems allowing a ship to operate in a safe and efficient manner while also lowering its carbon footprint.

Maritime operations build upon the interplay between three types of core actors; shipping companies, ports, and cargo owners. This is an inseparable trinity meaning that neither of them exists without the other. Connected to this trinity there are numerous coordinators (such as the shipping agent) and service providers (such as tug operators) enabling efficient operations.

STM is based on the premise that the data owner decides on who shall be able to access the data it provides. By regarding the port as a hub, this would mean that the data provider authorizes access to all actors within the port. This would enrich situational awareness for a port's actors and enable a port to operate as an efficient system of production. Limited sharing of data restricts PortCDM to a system of engagement, which means that actors only share intentions to enable episodic coupling among each other, but a port perspective would enable integrated coupling across a port visit.

STM project is now representing a step forward in the natural shipping industry evolution as part of three milestones reached in shipping and navigation:

- RADAR – You could see that something is near or close to you, or on the route you are following
- AIS – In this stage you knew who is near to you, the name of the ship, the type of vessel, its position shown on an electronic chart, its course and speed
- STM – Now you know about the plans, situation and behaviour (navigation intentions of the other)

For more information, visit STM Validation Project website: <http://stmvalidation.eu/>

## 7. References

- [1] Elkington, J., *Cannibals with forks. The triple bottom line of 21st century.* 1997, Oxford: Capstone.
- [2] Lind M., Bergmann M., Haraldson S., Watson R.T., Park J., Gimenez J., Andersen T. (2018) *The skilled collaborators - the winners in a digitized maritime sector*, STM Validation Project.
- [3] Mikael Lind, Mikael Hägg, Ulf Siwec, Sandra Haraldsona. *Sea Traffic Management – Beneficial for all Maritime Stakeholders.* Proceedings of 6th Transport Research Arena, April 18-21, 2016, Warsaw, Poland.
- [4] Adner R. (2006) *Match Your Innovation Strategy to Your Innovation Ecosystem*, Harvard Business Review
- [5] Andersen & Schellhorn (2015). *Business case analysis report*
- [6] Andersson, P., Ivehammar, P. (2014). *Economic Impacts - Cost Benefit Analysis of Implementing Dynamic Route Planning at Sea.* Norrköping, Sweden: MONALISA Project Bureau.
- [7] Elkington, J., (1998). *Cannibals with Forks: the Triple Bottom Line of 21st Century Business.* New Society Publishers
- [8] Haraldson S. (2015) *Digitalization of Sea Transports – Enabling Sustainable Multi-Modal Transports*, Twenty-first Americas Conference on Information Systems, Puerto Rico
- [9] IMO. (2013). *A concept of sustainable maritime transportation system.* Retrieved 2014-08-30
- [10] Osterwalder, A., & Pigneur, Y. (2011) *Business Model Generation: Ein Handbuch für Visionäre, Spielveränderer und Herausforderer.* Campus Verlag.



- [11] Södahl, B, Hanning, A., Hult, C., Garne, K., Hindrum, K. (2013). Svallvåg 2013 - Svensk maritim forsknings- och innovationsagenda. Gothenburg, Sweden: Chalmers University of Technology.
- [12] Stankiewicz, M., Backer, H., Vlasov, N. (2010). Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region Baltic Sea Environment Proceedings. Helsinki, Finland: Helsinki Commission.
- [13] Target Concept. (2015) MONALISA 2.0 Project, Activity 2 – Defining Sea Traffic Management, “The Target Concept”, Document No: MONALISA 2 0\_D2.3.1.