

ANALYSIS OF AUXILIARY EXERGY FLOW STREAM DURING THE CHANGE IN MARINE STEAM PROPULSION SYSTEM LOAD

Josip Orović
University of Zadar
Maritime Department
E-mail: jorovic@unizd.hr

Vedran Mrzljak
University of Rijeka
Faculty of Engineering
E-mail: vedran.mrzljak@riteh.hr

Igor Poljak
University of Zadar
Maritime Department
E-mail: ipoljak1@unizd.hr

UDK 621.1:629.5.018

Summary

The paper presents analysis of steam auxiliary exergy flow stream during the change in marine steam propulsion system load. The change in auxiliary steam exergy flow from marine steam generators during the increase in steam system load is compared with the change in main steam exergy flow. Exergy flow stream to each auxiliary device in steam system is analysed and operation dynamics of auxiliary devices are explained. The presented analysis provides an insight into operation of each observed marine steam system auxiliary device from the lowest to the highest steam system load.

Keywords: Marine steam propulsion, Load change, Exergy flow, Auxiliary steam systems

1. INTRODUCTION

Steam power systems today are the mostly land-based and its main function is electricity production, [1] and [2]. Marine power systems are mainly based on internal combustion engines with a lot of different variations in power and operational principle, [3] and [4]. Marine steam propulsion systems are relatively rare, but due to a lot of advantages they are dominant on LNG carriers [5] and [6]. As a land-based steam power system, each marine steam propulsion system consists of many components, necessary for safe and reliable operation [7] and [8].

The marine steam propulsion system consists of two steam flow streams from steam generators - main and auxiliary [9]. The main flow stream is used for steam turbines operation [10] and [11], while auxiliary steam flow stream is used for proper operation of auxiliary marine equipment [12] and [13]. The auxiliary steam flow stream has a lower pressure and temperature in comparison with a main one [14]. For both flow streams, it is interesting to analyse its operation dynamics during the change in marine steam system load.

In this paper an analysis of steam auxiliary exergy flow stream during the change in marine steam propulsion system load is presented. Steam auxiliary exergy flow stream and its dynamic is compared with the main exergy flow stream. Exergy flow stream to each auxiliary device in steam system was calculated and analysed. Operation dynamics of auxiliary devices and share of the current auxiliary exergy flow, from steam

generators to each auxiliary device, are explained. This analysis provides an insight into operation of marine steam system auxiliary devices from the lowest to the highest steam system load.

2. MAIN AND AUXILIARY EXERGY FLOW STREAMS IN MARINE STEAM PROPULSION SYSTEM

Steam propulsion system in which main and auxiliary exergy flow streams were analysed is mounted on the conventional LNG carrier. Main characteristics and specifications of the LNG carrier are presented in Table 1.

Table 1 LNG carrier main characteristics and specifications

Dead weight tonnage	84812 DWT
Overall length	288 m
Max breadth	44 m
Design draft	9.3 m
Steam generators	2 x Mitsubishi MB-4E-KS
Propulsion turbine	Mitsubishi MS40-2 (max. power 29420 kW)

Steam flow streams which leave steam generators in marine propulsion system are main and auxiliary flow streams. Main steam flow stream represents a steam with maximum pressure and temperature. The auxiliary steam flow stream is produced from main flow stream in a way that part of produced main steam is sent back to the steam generators. That steam passes through steam drums and transfers heat to feed water. Due to heat transfer, steam temperature and pressure decreases. The auxiliary steam flow stream is used for the operation of auxiliary steam system devices. Those devices require steam with lower temperature and pressure when compared to main steam stream.

In marine steam propulsion system, auxiliary steam flow is used in the atomizing steam system, dump system, deaerator, desuperheater and air heater, Fig. 1. Operation principle of each auxiliary device is:

- Atomizing steam system: at atomizing steam system represents a small amount of auxiliary steam from steam generators that is used for fuel oil atomizing and for cooling of burners when they are not in use.
- Dump line: At low steam system loads, steam generators produce more steam than an entire system requires. Steam excess is led directly to the main steam condenser through the steam system dump line.
- Deaerator: Deaerator is a component which uses auxiliary steam from steam generators for feed water heating and for gas removal from feed water in order to avoid cavitation.
- Desuperheater: Desuperheater is an open heater (with direct mixing of auxiliary steam and water). Desuperheater in the marine steam system is used to prepare auxiliary steam for additional heating purposes.
- Air heater: Before entrance in each steam generator combustion chamber, air is heated in air heater by auxiliary steam. Heating medium is auxiliary steam only, because flue gas temperature is not sufficient for air heating purposes.

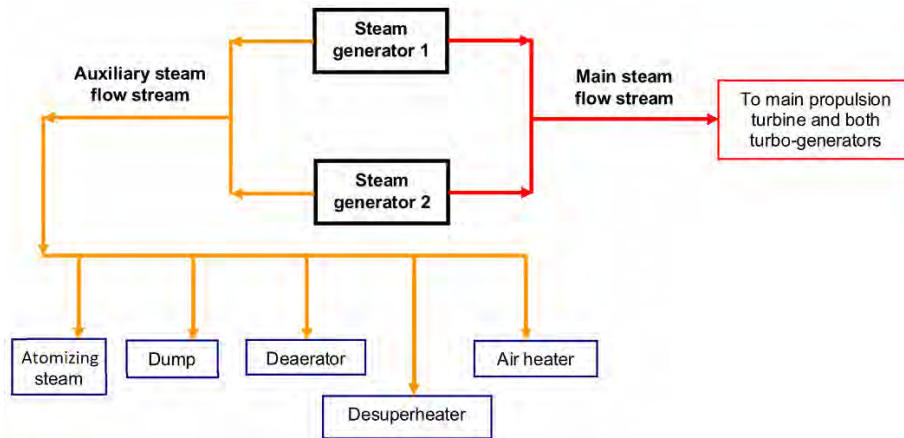


Figure 1 Scheme of marine steam generators with main and auxiliary steam flow streams

3. EXERGY FLOW STREAMS NUMERICAL ANALYSIS

3.1. Governing equations of exergy analysis

Mass flow rate balance equation for any flow stream is expressed as [15]:

$$\sum \dot{m}_{IN} = \sum \dot{m}_{OUT} \quad (1)$$

The second law of thermodynamics defines exergy analysis [16]. The main exergy balance equation is [17]:

$$\dot{X}_{heat} - P = \sum \dot{m}_{OUT} \cdot \varepsilon_{OUT} - \sum \dot{m}_{IN} \cdot \varepsilon_{IN} + \dot{E}_{ex,D} \quad (2)$$

where the net exergy transfer by heat () at the temperature T is [18]:

$$\dot{X}_{heat} = \sum \left(1 - \frac{T_0}{T}\right) \cdot \dot{Q} \quad (3)$$

According to [19], specific exergy is defined as:

$$\varepsilon = (h - h_0) - T_0 \cdot (s - s_0) \quad (4)$$

The exergy power of a flow, according to [20] is:

$$\dot{E}_{ex} = \dot{m} \cdot \varepsilon = \dot{m} \cdot [(h - h_0) - T_0 \cdot (s - s_0)] \quad (5)$$

3.2. Calculation of main and auxiliary exergy flow streams

Exergy power of main and auxiliary steam flow stream was calculated by using measured steam pressures, temperatures and mass flow rates, according to equation (5). Steam specific enthalpies and specific entropies were calculated from measured steam pressures and temperatures by using NIST REFPROP software [21].

Throughout this paper, exergy power values are presented for both steam generators (cumulative exergy power). A steam flow stream which enters to any system device was produced by both steam generators. Therefore, only the cumulative flow streams can be relevant in the steam system exergy analysis.

Auxiliary steam specific enthalpy and specific entropy are not the same as at the steam generator's outlet, when compared to flow streams to each auxiliary device, due to losses through the pipeline. Decrease in auxiliary steam pressure and temperature in the pipeline (and consequentially decrease in specific enthalpy and specific entropy) is small and in this paper is neglected. Auxiliary steam flow streams to each

auxiliary device were calculated with the same specific enthalpy and specific entropy as at the steam generator's outlet, but with corresponding steam mass flow rates.

Cumulative steam mass flow rate, which exits from both steam generators, is defined as:

$$\dot{m}_{CU} = \dot{m}_{MA} + \dot{m}_{AUX} \quad (6)$$

Cumulative steam exergy power from steam generators is:

$$\dot{E}_{ex,CU} = \dot{E}_{ex,MA} + \dot{E}_{ex,AUX} \quad (7)$$

where cumulative main and auxiliary steam exergy power are defined as:

$$\dot{E}_{ex,MA} = \dot{m}_{MA} \cdot \varepsilon_{MA} \quad (8)$$

$$\dot{E}_{ex,AUX} = \dot{m}_{AUX} \cdot \varepsilon_{AUX} \quad (9)$$

The share of cumulative main steam exergy power in cumulative exergy power from steam generators is:

$$SH_{MA} = \frac{\dot{E}_{ex,MA}}{\dot{E}_{ex,CU}} \cdot 100 \quad (10)$$

The share of cumulative auxiliary steam exergy power in cumulative exergy power from steam generators is:

$$SH_{AUX} = \frac{\dot{E}_{ex,AUX}}{\dot{E}_{ex,CU}} \cdot 100 \quad (11)$$

Cumulative auxiliary steam flow stream is divided on flow streams to each auxiliary device (auxiliary devices are atomizing steam system, dump, deaerator, desuperheater and air heater), Fig. 1.

Mass flow rate balance for cumulative auxiliary steam flow stream is:

$$\dot{m}_{AUX} = \dot{m}_{AS} + \dot{m}_{DU} + \dot{m}_{DEA} + \dot{m}_{DES} + \dot{m}_{AH} \quad (12)$$

The change in auxiliary steam pressure and temperature through the pipeline is neglected, so cumulative auxiliary steam exergy power divided to each auxiliary device is:

$$\dot{E}_{ex,AUX} = \dot{m}_{AUX} \cdot \varepsilon_{AUX} = (\dot{m}_{AS} + \dot{m}_{DU} + \dot{m}_{DEA} + \dot{m}_{DES} + \dot{m}_{AH}) \cdot \varepsilon_{AUX} \quad (13)$$

Steam exergy power to each auxiliary device is then:

$$\dot{E}_{ex,AD} = \dot{m}_{AD} \cdot \varepsilon_{AUX} \quad (14)$$

The share of each auxiliary device exergy power in the entire (cumulative) auxiliary exergy power is:

$$SH_{AD} = \frac{\dot{E}_{ex,AD}}{\dot{E}_{ex,AUX}} \cdot 100 \quad (15)$$

Exergy analysis depends greatly on the ambient state (pressure and temperature of the ambient) in which system operates. The ambient state in the LNG carrier engine room during the measurements was:

- pressure: $p_0 = 0.1 \text{ MPa} = 1 \text{ bar}$,
- temperature: $T_0 = 25 \text{ }^\circ\text{C} = 298.15 \text{ K}$.

4. REQUIRED MEASUREMENT RESULTS OF MAIN AND AUXILIARY STEAM FLOW STREAMS

Steam temperature, pressure and mass flow rate at each steam system load were measured with equipment already mounted on the steam system pipeline. The same equipment is used for control and regulation of the entire steam system during LNG carrier exploitation. Steam operating parameters are presented in relation to propulsion propeller speed. Increase in propulsion propeller speed is directly proportional to increase in steam system load and vice versa.

Table 2 present measurement results of main and auxiliary steam flow streams. Cumulative auxiliary steam flow stream is divided on flow streams to each auxiliary device. Losses of steam pressure and temperature in auxiliary steam pipeline are small and in this paper are neglected. Therefore, for exergy power calculation it was necessary to measure only steam mass flow rate to each device.

Table 2 Measurement results for main and auxiliary steam flow streams

Propulsion propeller speed (rpm)	Main steam flow stream			Auxiliary steam flow stream-cumulative			Atomizing steam mass flow rate (kg/h)	Dump steam mass flow rate (kg/h)	Deaerator steam mass flow rate (kg/h)	Desuperheater steam mass flow rate (kg/h)	Air heater steam mass flow rate (kg/h)
	Steam temperature (°C)	Steam pressure (MPa)	Steam mass flow rate (kg/h)	Steam temperature (°C)	Steam pressure (MPa)	Steam mass flow rate (kg/h)					
25.00	501	6.20	16744	313	6.01	29876	428	15764	5881	3022	4781
34.33	500	6.20	22696	309	6.08	27710	441	13178	6467	2797	4827
41.78	500	6.19	29394	304	6.11	17708	416	3696	6049	2687	4860
53.50	509	6.10	47985	297	6.07	12170	442	0	3639	2792	5297
56.65	498	5.98	40363	297	5.94	17038	475	0	8392	2796	5375
61.45	500	5.98	49438	297	5.94	14486	472	0	5367	2685	5962
62.52	499	5.99	48977	299	5.95	14528	470	0	5282	2903	5873
63.55	500	5.99	52080	298	5.95	14915	478	0	5657	2677	6103
65.10	504	6.10	54438	299	6.10	15633	470	0	6318	2587	6258
66.08	515	6.08	56078	300	6.04	16133	489	0	6541	2690	6413
67.68	515	6.08	59201	301	6.04	16756	494	0	6983	2797	6482
68.66	516	6.09	61300	302	6.05	13618	488	0	3840	2685	6605
69.49	515	6.09	62723	302	6.05	14039	483	0	4077	2792	6687
70.37	516	6.09	64366	302	6.05	14150	472	0	4078	2688	6912
71.03	516	6.10	65019	302	6.06	13954	464	0	3994	2687	6809
73.09	515	6.10	70515	301	6.07	14690	494	0	4484	2584	7128
74.59	515	6.07	77211	299	6.04	10641	491	0	0	2688	7462
76.56	515	6.07	82881	299	6.04	10848	468	0	0	2793	7587
78.41	515	6.09	89907	299	6.06	10744	472	0	0	2687	7585
79.46	498	5.94	95990	298	5.92	3273	479	0	0	2794	0
80.44	502	6.00	100540	297	5.94	3384	478	0	0	2906	0
81.49	500	5.99	102883	290	5.99	483	483	0	0	0	0
82.88	501	5.99	108601	280	5.99	474	474	0	0	0	0
83.00	501	5.99	109961	280	5.99	477	477	0	0	0	0

5. MAIN AND AUXILIARY STEAM FLOW STREAMS EXERGY ANALYSIS RESULTS WITH THE DISCUSSION

The mass flow rate difference between main and auxiliary steam flow streams can be seen in Fig. 2. At the lowest observed propulsion propeller speeds this difference is negative (25.00 rpm and 34.33 rpm) because at the propulsion system start-up, mass flow rate of the auxiliary steam flow stream is higher. Increase in propulsion system load resulted with an increase in mass flow rate of main steam stream (from 41.78 rpm to

the highest system load). At the highest observed steam system load, the mass flow rate difference between main and auxiliary steam flow stream is the highest and amounts 109484 kg/h, Table 2.

It should be noted that the increase in propulsion system load resulted in a proportional increase of main steam mass flow rate (with the exception of just a few operating points at middle load), which means that steam system turbines use more and more steam. At high steam system loads, the majority of analysed auxiliary devices in this study get steam for its operation from the main turbine subtractions. Following the operation principle of this steam propulsion system, it can be concluded that increase in main and the decrease in auxiliary steam mass flow rate during the load increase is expected.

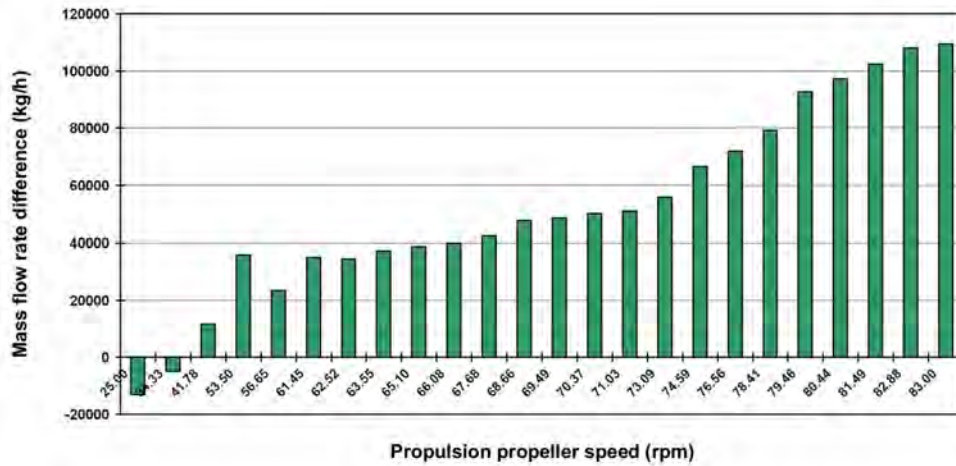


Figure 2 Mass flow rate difference between main and auxiliary steam flow stream

Main and auxiliary exergy power of steam flow streams was calculated according to equations (8) and (9). Increase in steam system load resulted with increase in main flow stream exergy power, while at the same time auxiliary flow stream exergy power decreases, Fig. 3.

Only at the lowest observed load at 25.00 rpm, exergy power of the auxiliary flow stream is higher than exergy power of the main flow stream. From the lowest to the highest steam system load, exergy power of main steam flow stream increases from 6418.53 kW up to 42057.03 kW, while exergy power of the auxiliary flow stream decreases from 9147.04 kW up to 137.26 kW. At high steam system load exergy power of the auxiliary steam flow stream is so small in comparison with the exergy power of the main steam flow stream that it can be declared as negligible.

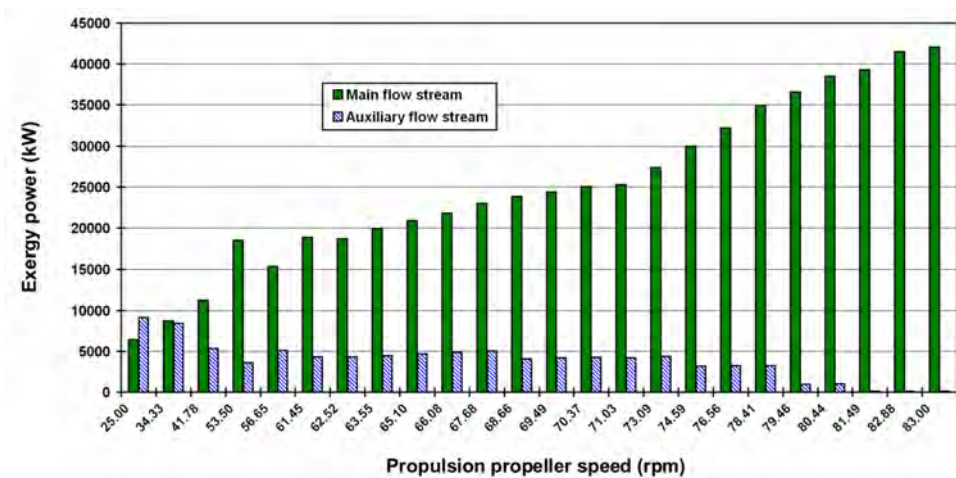


Figure 3 Change in exergy power of main and auxiliary steam flow stream

Analysis of auxiliary steam exergy power which was transferred from steam generators to each auxiliary device must be presented in two parts, for lower and for higher propulsion propeller speeds, Fig. 4 and Fig. 5.

At the lowest propulsion propeller speeds (25.00 rpm and 34.33 rpm) the highest auxiliary steam exergy power is sent to the main condenser through dump line (4826.41 kW and 4010.50 kW), Fig. 4. That amount of auxiliary steam exergy power is lost because at the lowest loads it is not required in the steam system. It can also be seen from Fig. 4 that increase in system load resulted with a decrease in dump exergy power and already on 41.78 rpm dump exergy power is not the dominant one. After 41.78 rpm, dump line is closed because from that moment on, all produced steam exergy power is used in the steam system.

After dump line at low propulsion propeller speeds, the most dominant amount of auxiliary steam exergy power is sent to deaerator and air heater. Atomizing steam system at low steam system loads takes a significantly smaller amount of auxiliary steam exergy power in comparison to other auxiliary components.

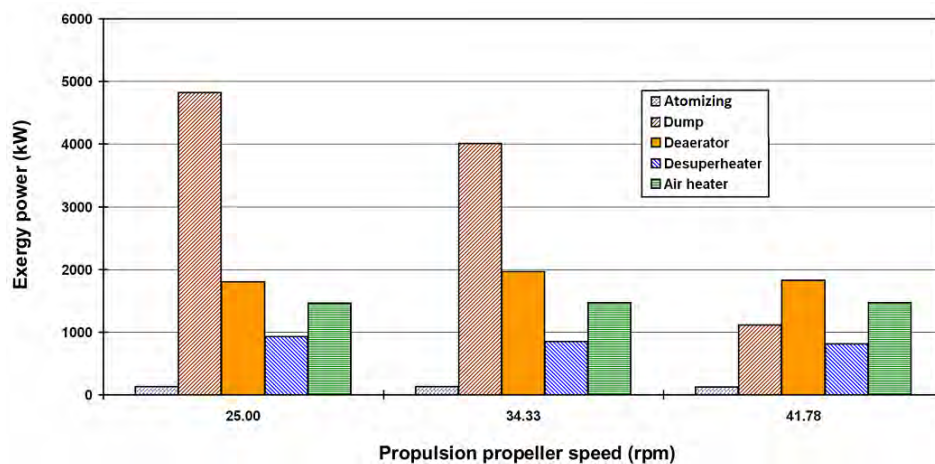


Figure 4 Steam exergy power to each auxiliary device - low propulsion propeller speeds

At middle and high propulsion system loads (from 53.50 rpm up to 83.00 rpm) dump line is closed and the auxiliary steam exergy power is sent to other auxiliary devices, Fig. 5. The greatest consumers of auxiliary steam exergy power are deaerator and air heater, after which follows desuperheater. The atomizing steam system uses almost constant auxiliary steam exergy power in the entire area of middle and high steam system loads. At the highest observed propulsion system loads atomizing steam system is the only auxiliary device which consumes auxiliary steam exergy power.

Auxiliary steam from steam generators is sent to auxiliary devices until the moment when each auxiliary device (with an exception of the atomizing steam system) gets steam for its operation from the main steam turbine subtractions. The first device which gets steam for its operation from a main steam turbine is deaerator after 73.09 rpm. After deaerator, main steam turbine subtraction brings steam to the air heater after 78.41 rpm. The auxiliary device which gets steam from the main turbine the latest is desuperheater and this occurrence happens after 80.44 rpm. Only the atomizing steam system gets auxiliary steam for its operation from the steam generators the entire time, irrespective of steam system load.

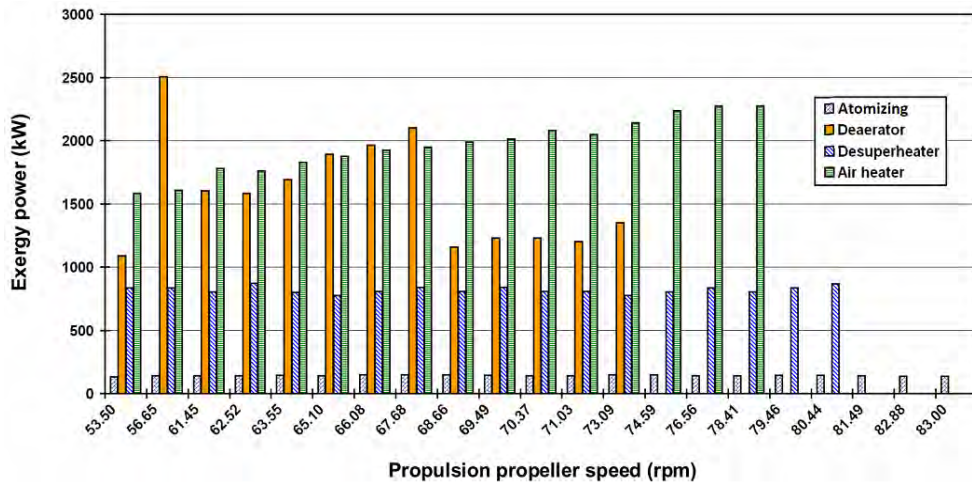


Figure 5 Steam exergy power to each auxiliary device - middle and high propulsion propeller speeds

At three different steam system loads (at three different propulsion propeller speeds) the share of each auxiliary device in current cumulative auxiliary steam exergy power is presented in Fig. 6, Fig. 7 and Fig. 8.

At the lowest observed steam system load (25.00 rpm) dump system takes the most significant share of current cumulative auxiliary steam exergy power with 53%, Fig. 6. At this propulsion system load, the deaerator takes 20% and air heater takes 16% of cumulative auxiliary steam exergy power. The atomizing steam system has the lowest share in cumulative auxiliary steam exergy power (only 1%) at the lowest observed propulsion propeller speed as measurements were taken on dual burning mode, with minimum fuel and maximum gas mode, what results in only small mass variation of that system during all measured modes.

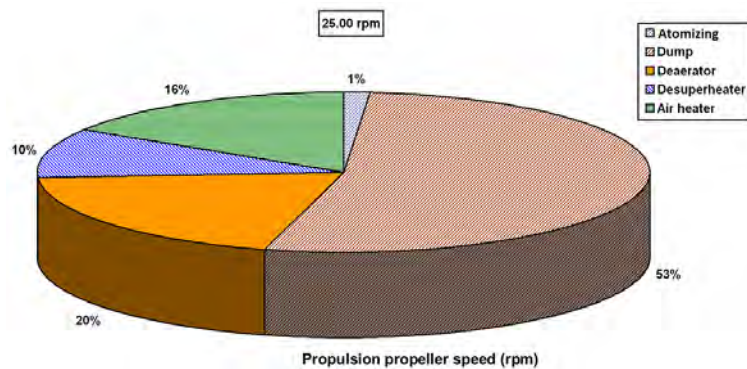


Figure 6 Share in the cumulative auxiliary exergy power of each auxiliary device - propulsion propeller speed of 25.00 rpm

At middle steam system load of 65.10 rpm, Fig. 7, dump line is closed and all steam exergy power produced in the steam generators (main and auxiliary) is used in the steam system. At observed system load, deaerator and air heater take the highest share in current cumulative auxiliary steam exergy power (40% each). In desuperheater goes 17% of cumulative auxiliary steam exergy power, while the atomizing steam system takes a share of 3%. When compared with the lower steam system load, it can be concluded that share in current cumulative auxiliary steam exergy power of each auxiliary device increases with an increase in steam system load.

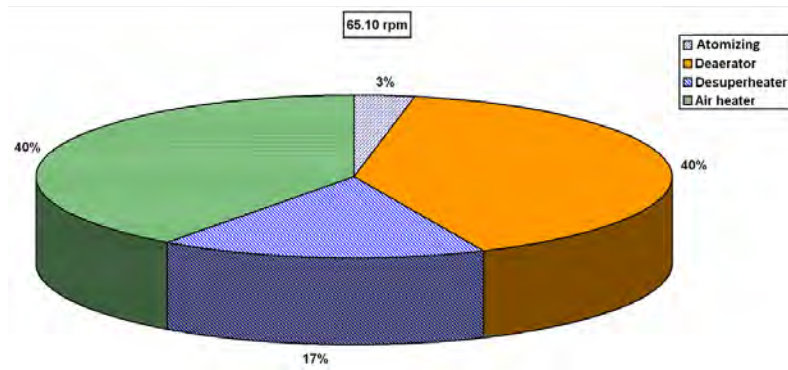


Figure 7 Share in the cumulative auxiliary exergy power of each auxiliary device - propulsion propeller speed of 65.10 rpm

At propulsion propeller speed of 78.41 rpm, auxiliary steam flow is sent to just three auxiliary devices (air heater, desuperheater and the atomizing steam system). Air heater takes the highest share in current cumulative auxiliary steam exergy power with 71%, Fig. 8. Desuperheater takes 25% and atomizing steam system takes 4% of current cumulative auxiliary steam exergy power.

At the highest observed propulsion propeller speeds (from 81.49 rpm to 83.00 rpm) cumulative auxiliary steam exergy power is sent only to atomizing steam system, so its share in that steam system operation area is 100%.

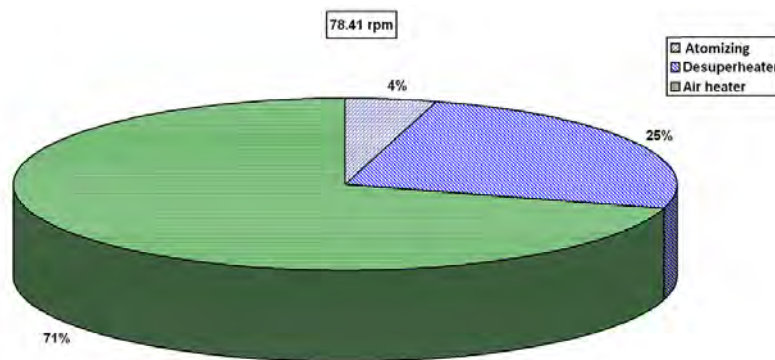


Figure 8 Share in the cumulative auxiliary exergy power of each auxiliary device - propulsion propeller speed of 78.41 rpm

6. CONCLUSION

This paper presents an analysis of steam auxiliary exergy flow stream during the change in marine steam propulsion system load.

At low propulsion propeller speeds the highest auxiliary steam exergy power is sent to the main condenser through dump line. That amount of auxiliary steam exergy power is lost because at the lowest loads it is not required in the steam system. After dump system, at low system loads the most dominant amount of auxiliary steam exergy power is sent to the deaerator and air heater while the atomizing steam system takes a significantly smaller amount of auxiliary steam exergy power in comparison to other components.

At middle and high propulsion system loads, dump line is closed and the greatest consumers of auxiliary steam exergy power are deaerator and air heater, after which follows desuperheater. The atomizing steam system uses low and almost constant auxiliary steam exergy power in the entire area of middle and

high steam system loads due to dual burning mode, with minimum fuel and maximum gas mode. At the highest observed system loads atomizing steam system is the only auxiliary device which consumes auxiliary steam exergy power.

Auxiliary steam from steam generators is sent to auxiliary devices until the moment when each auxiliary device (with an exception of the atomizing steam system) gets a steam for its operation from the main steam turbine subtractions.

Share in current cumulative auxiliary steam exergy power of each auxiliary device increases with an increase in steam system load.

Acknowledgment

The authors would like to extend their appreciations to the main ship-owner office for conceding measuring equipment and for all help during the exploitation measurements. This work has been fully supported by the Croatian Science Foundation under the project IP-2018-01-3739.

Nomenclature

Abbreviations:

LNG Liquefied Natural Gas

Latin Symbols:

\dot{E} stream flow power, kJ/s
 h specific enthalpy, kJ/kg
 \dot{m} mass flow rate, kg/s or kg/h
 p pressure, MPa
 P power, kJ/s
 \dot{Q} heat transfer, kJ/s
 s specific entropy, kJ/kg·K
 SH share, %
 T temperature, °C or K
 \dot{X}_{heat} heat exergy transfer, kJ/s

Greek symbols:

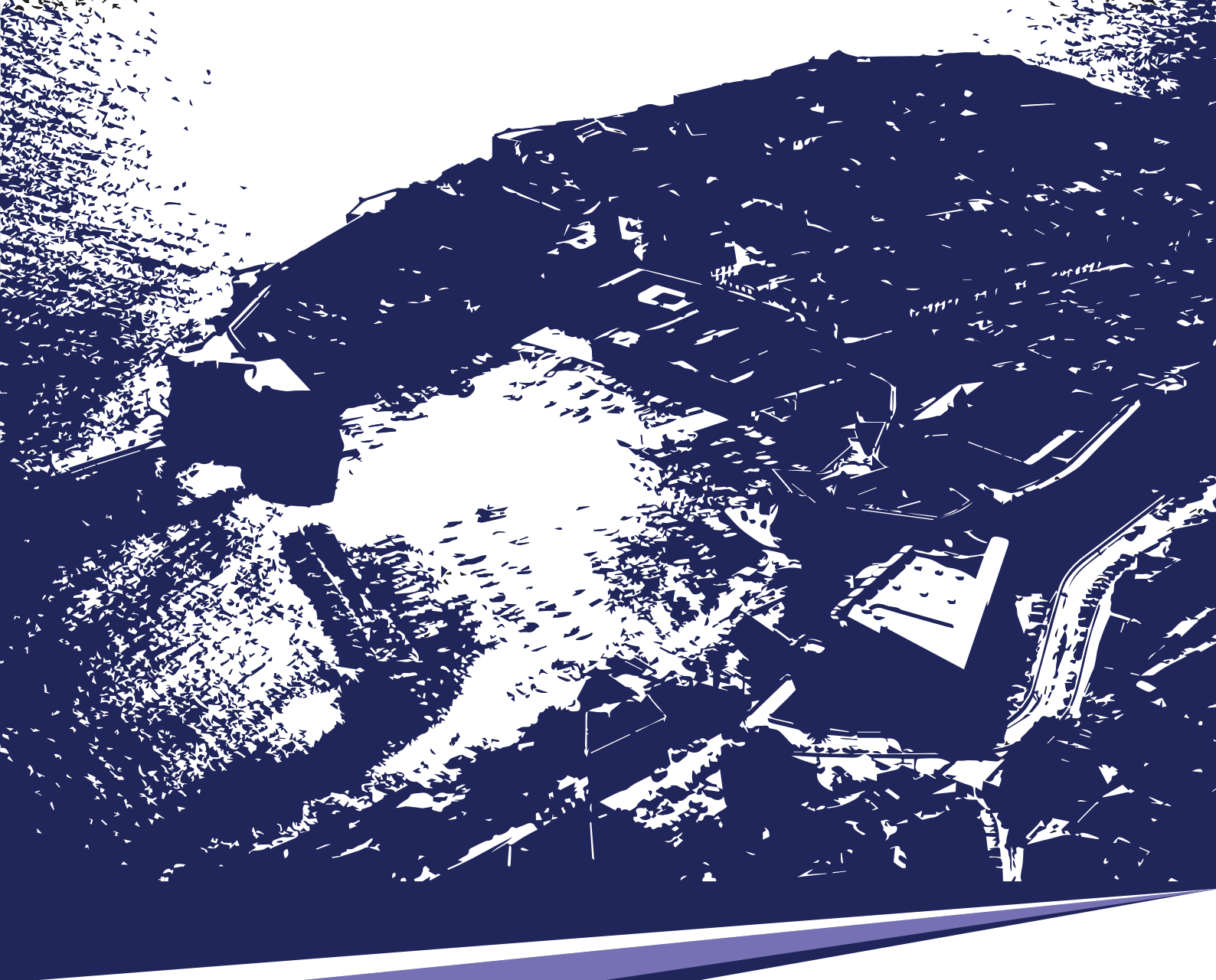
ε specific exergy, kJ/kg

Subscripts:

0 ambient conditions
 AD Auxiliary device
 AH Air heater
 AUX Auxiliary
 CU Cumulative
 D destruction (losses)
 DEA Deaerator
 DES Desuperheater
 DU Dump
 ex exergy
 IN inlet (input)
 MA Main
 OUT outlet (output)
 AS Atomizing steam

REFERENCES

- [1] Kumar, S., Kumar, D., Memon, R. A., Wassan, M. A., Ali, M. S.: Energy and Exergy Analysis of a Coal Fired Power Plant, *Mehran University Research Journal of Engineering & Technology* 37 (4), p. 611-624, 2018. (doi:10.22581/muet1982.1804.13)
- [2] Ahmadi, G., Toghraie, D., Akbari, O. A.: Solar parallel feed water heating repowering of a steam power plant: A case study in Iran, *Renewable and Sustainable Energy Reviews* 77, p. 474-485, 2017. (doi:10.1016/j.rser.2017.04.019)
- [3] Mrzljak, V., Medica, V., Bukovac, O.: Simulation of a Two-Stroke Slow Speed Diesel Engine Using a Quasi-Dimensional Model, *Transactions of Famena*, 2, p. 35-44, 2016. (doi:10.21278/TOF.40203)
- [4] Mrzljak, V., Medica, V., Bukovac, O.: Volume agglomeration process in quasi-dimensional direct injection diesel engine numerical model, *Energy* 115, p. 658-667, 2016. (doi:10.1016/j.energy.2016.09.055)
- [5] Koroglu, T., Sogut, O. S.: Conventional and Advanced Exergy Analyses of a Marine Steam Power Plant, *Energy* 163, p. 392-403, 2018. (doi:10.1016/j.energy.2018.08.119)
- [6] Mrzljak, V., Poljak, I., Mrakovčić, T.: Energy and exergy analysis of the turbo-generators and steam turbine for the main feed water pump drive on LNG carrier, *Energy Conversion and Management* 140, p. 307-323, 2017. (doi:10.1016/j.enconman.2017.03.007)
- [7] Mrzljak, V., Poljak, I., Medica-Viola, V.: Dual fuel consumption and efficiency of marine steam generators for the propulsion of LNG carrier, *Applied Thermal Engineering*, 119, p. 331-346, 2017. (doi:10.1016/j.applthermaleng.2017.03.078)
- [8] Poljak, I., Orović, J., Mrzljak, V.: Energy and Exergy Analysis of the Condensate Pump During Internal Leakage from the Marine Steam Propulsion System, *Scientific Journal of Maritime Research* 32 (2), p. 268-280, 2018. (doi:10.31217/p.32.2.12)
- [9] Mrzljak, V., Prpić-Oršić, J., Senčić, T.: Change in Steam Generators Main and Auxiliary Energy Flow Streams During the Load Increase of LNG Carrier Steam Propulsion System, *Scientific Journal of Maritime Research* 32 (1), p. 121-131, 2018. (doi:10.31217/p.32.1.15)
- [10] Mrzljak, V., Poljak, I., Prpić-Oršić, J.: Exergy analysis of the main propulsion steam turbine from marine propulsion plant, *Shipbuilding: Theory and Practice of Naval Architecture, Marine Engineering and Ocean Engineering Vol. 70., No. 1*, p. 59-77, 2019. (doi:10.21278/brod70105)
- [11] Mrzljak, V.: Low power steam turbine energy efficiency and losses during the developed power variation, *Technical Journal* 12 (3), p. 174-180, 2018. (doi:10.31803/tg-20180201002943)
- [12] Mrzljak, V., Poljak, I., Medica-Viola, V.: Thermodynamical analysis of high-pressure feed water heater in steam propulsion system during exploitation, *Shipbuilding: Theory and Practice of Naval Architecture, Marine Engineering and Ocean Engineering* 68 (2), p. 45-61, 2017. (doi:10.21278/brod68204)
- [13] Mrzljak, V., Poljak, I., Medica-Viola, V.: Efficiency and losses analysis of low-pressure feed water heater in steam propulsion system during ship maneuvering period, *Scientific Journal of Maritime Research* 30, p. 133-140, 2016. (doi:10.31217/p.30.2.6)
- [14] Orović, J., Mrzljak, V., Poljak, I.: Efficiency and Losses Analysis of Steam Air Heater from Marine Steam Propulsion Plant, *Energies* 2018, 11 (11), 3019, (doi:10.3390/en11113019)
- [15] Noroozian, A., Mohammadi, A., Bidi, M., Ahmadi, M. H.: Energy, exergy and economic analyses of a novel system to recover waste heat and water in steam power plants, *Energy Conversion and Management* 144, p. 351-360, 2017. (doi:10.1016/j.enconman.2017.04.067)
- [16] Mrzljak, V., Poljak, I., Medica-Viola, V.: Energy and Exergy Efficiency Analysis of Sealing Steam Condenser in Propulsion System of LNG Carrier, *International Journal of Maritime Science & Technology "Our Sea"* 64 (1), p. 20-25, 2017. (doi:10.17818/NM/2017/1.4)
- [17] Mrzljak, V., Poljak, I., Žarković, B.: Exergy Analysis of Steam Pressure Reduction Valve in Marine Propulsion Plant on Conventional LNG Carrier, *International Journal of Maritime Science & Technology "Our Sea"* 65(1), p. 24-31, 2018. (doi:10.17818/NM/2018/1.4)
- [18] Ahmadi, G., Toghraie, D., Azimian, A., Ali Akbari, O.: Evaluation of synchronous execution of full repowering and solar assisting in a 200 MW steam power plant, a case study, *Applied Thermal Engineering*, 112, p. 111-123, 2017. (doi:10.1016/j.applthermaleng.2016.10.083)
- [19] Tan, H., Shan, S., Nie, Y., Zhao, Q.: A new boil-off gas re-liquefaction system for LNG carriers based on dual mixed refrigerant cycle, *Cryogenics* 92, p. 84-92, 2018. (doi:10.1016/j.cryogenics.2018.04.009)
- [20] Mrzljak, V., Senčić, T., Žarković, B.: Turbogenerator Steam Turbine Variation in Developed Power: Analysis of Exergy Efficiency and Exergy Destruction Change, *Modelling and Simulation in Engineering* 2018. (doi:10.1155/2018/2945325)
- [21] Lemmon, E. W., Huber, M. L., McLinden, M. O.: NIST Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 9.0, User's Guide, Colorado, 2010.



NAŠE MORE 2019

1st International Conference of Maritime Science & Technology

Dubrovnik, 17 - 18 October, 2019



University of Dubrovnik
Maritime Department

University of Rijeka
Faculty of Maritime Studies

1st International Conference of Maritime Science & Technology

NAŠE MORE 2019

CONFERENCE PROCEEDINGS

Maritime Department, University of Dubrovnik

Faculty of Maritime Studies, University of Rijeka



**Dubrovnik, Croatia
17 – 18 October 2019**

ORGANIZED BY

University of Dubrovnik, Maritime Department
University of Rijeka, Faculty of Maritime Studies

PUBLISHER

University of Dubrovnik, Maritime Department

EDITOR IN CHIEF

Žarko Koboević, PhD

CO-EDITOR

Darijo Mišković, PhD

GENERAL CHAIR

Srećko Krile, PhD

PROGRAMME COMMITTEE

Mario Anžek, PhD, (Croatia)
Hrvoje Baričević, PhD, (Croatia)
Sanja Bauk, PhD, (Montenegro)
Leszek Chybowski, PhD, (Poland)
Andrzej Grzadziela, PhD, (Poland)
Alen Jugović, PhD, (Croatia)
Rudolf Kampf, PhD(Czech Republic)
Serđo Kos, PhD, (Croatia)
Srećko Krile, PhD (Croatia)
Leonardo Marušić, PhD, (Croatia)
Waldemar Mironiuk, PhD, (Poland)
Ana Peric Hadzic, PhD, (Croatia)
Igor Rudan, PhD, (Croatia)
Aleksandar Sladkowski, PhD, (Poland)
Sanja Steiner, PhD, (Croatia)
Le Van Vang, PhD, (Vietnam)
Pero Vidan, PhD, (Croatia)
Goran Vukelić, PhD, (Croatia)

ORGANISING COMMITTEE

Maro Ćorak, PhD, President of the Organizing Committee (Croatia)
Darijo Mišković, PhD, Vice President of the Organizing Committee (Croatia)
Dean Bernečić, PhD, (Croatia)
Sandra Buratović Maštrapa, (Croatia)
Vlado Frančić, PhD, (Croatia)
Ivan Gospić, PhD, (Croatia)
Ivan Grbavac, (Croatia)
Mirano Hess, PhD, (Croatia)

Martina Hrnić, (Croatia)
Nguyen Phung, Hung PhD, (Vietnam)
Renato Ivče, PhD, (Croatia)
Ivošević Špiro, PhD, (Montenegro)
Mate Jurjević, PhD, (Croatia)
Žarko Koboević, PhD, (Croatia)
Predrag Kralj, PhD, (Croatia)
Srećko Krile, PhD, (Croatia)
Damir Kukić, PhD, (Bosnia and Hercegovina)
Marijana Lujo, (Croatia)
Martinović Dragan, PhD, (Croatia)
Ivona Milić Beran, PhD, (Croatia)
Đani Mohović, PhD, (Croatia)
Josip Orović, PhD, (Croatia)
Tanja Poletan Jugović, PhD, (Croatia)
Ondrej Stopka, PhD, (Czech Republic)
Davorka Turčinović, (Croatia)
Damir Zec, PhD, (Croatia)

INTERNATIONAL SCIENTIFIC COMMITTEE

Aleksandar Sladkowski, PhD, Silesian University of Technology, Faculty of Transport, Katowice, Poland
Alen Jugović, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Andrzej Grzadzela, PhD, Polish Naval Academy, Gdynia, Poland
Antun Asić, PhD, Dubrovnik, Croatia
Branka Milošević Pujó, PhD, University of Dubrovnik, Maritime Department, Croatia
Branko Glamuzina, PhD, University of Dubrovnik, Department of Aquaculture, Croatia
Damir Kukić, PhD, University of Zenica, Bosnia & Hercegovina
Damir Zec, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Dean Bernečić, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Denis Gračanin, PhD, Virginia Tech University, USA
Dragan Martinović, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Đani Mohović, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Elen Twrdy, PhD, University of Ljubljana, Faculty of Maritime Studies and Transport, Portorož, Slovenia
Francesc Xavier Martínez de Osés, PhD, Polytechnic University of Catalonia, Department of Nautical Science and Engineering, Barcelona, Spain
František Adamčík, PhD, Technical University of Košice, Faculty of Aeronautics, Slovak Republic
G. M. Younis, PhD, Suez Canal University, Faculty of Engineering, Port Said, Egypt
Goran Vukelić, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Gospić Ivan, PhD, University of Zadar, Maritime Department, Croatia
Hakan Tozan, PhD, Marmara University in Turkey, Naval Academy, Turkey
Hrvoje Baričević, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
Igor Nesteruk, PhD, Institute of Hydromechanics, National Academy of Sciences of Ukraine, Kyiv, Ukraine
Irina Makarova, PhD, Kazan Federal University, Kazan, Russia
Ivan Maršić, PhD, Rutgers, The State University of New Jersey, USA
Ivana Palunko, PhD, University of Dubrovnik, Electric Engineering and Computing Department, Croatia

Ivica Đurđević-Tomaš, University of Dubrovnik, Maritime Department, Croatia
 Ivona Milić-Beran, PhD, University of Dubrovnik, Maritime Department, Croatia
 Josip Kasum, PhD, University of Split, University Department for Forensic Science, Croatia
 Josip Orović, PhD, University of Zadar, Maritime department, Croatia
 Joško Parunov, PhD, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia
 Jozef Gnap, PhD, University of Žilina, The Faculty of Operation and Economics of Transport and Communications, Slovak Republic
 Kalman Žiha, PhD, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia
 Kevin Cullinane, University of Gothenburg, Sweden
 Le Van Vang, PhD, Ho Chi Minh City University of Transport, Vietnam
 Leonardo Marušić, PhD, University of Zadar, Maritime Department, Croatia
 Leszek Chybowski, PhD, Maritime University of Szczecin, Poland
 Luko Milić, PhD, Dubrovnik, Croatia
 Marija Mirošević, PhD, University of Dubrovnik, Electric Engineering and Computing Department, Croatia
 Marijana Pećarević, University of Dubrovnik, Department of Aquaculture, Croatia
 Maro Jelić, PhD, University of Dubrovnik, Maritime Department, Croatia
 Martin Lazar, PhD, University of Dubrovnik, Electric Engineering and Computing Department, Croatia
 Matko Bupić, PhD, University of Dubrovnik, Maritime Department, Croatia
 Mirano Hess, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
 Miro Alibašić, Captain, Commodore USN, USA
 Nenad Jasprica, PhD, University of Dubrovnik, Institute for Marine and Coastal Research, Croatia
 Nguyen Duy Trinh, PhD, Ho Chi Minh City University of Transport, Vietnam
 Nguyen Phung Hung, PhD, Ho Chi Minh City University of Transport, Vietnam
 Nikolai Nikolaevich Maiorov, St. Petersburg State University of Aerospace Instrumentation (SUAI), Russia
 Nikša Koboević, PhD, University of Dubrovnik, Maritime Department, Croatia
 Paul Filmore, PhD, University of Plymouth, School of Computing and Mathematics, United Kingdom
 Pavel Kolpahchyan, PhD, Rostov State Transport University, Rostov, Russia
 Pero Vidan, PhD, University of Split, Faculty of Maritime Studies, Croatia
 Peter Monka, PhD, Technical University of Košice, Faculty of Manufacturing Technologies in Prešov, Slovak Republic
 Predrag Kralj, PhD, PhD, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
 Renato Ivče, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
 Robert Sutton, PhD, University of Plymouth, Institute of Marine studies, United Kingdom
 Rudolf Kampf, PhD, Faculty of Business in České Budejovice, Czech Republic
 Sanja Bauk, PhD, University of Montenegro, Maritime Faculty Kotor, Montenegro ; Maritime Studies, Faculty of Applied Sciences, Durban University of Technology, South Africa
 Serđo Kos, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
 Srđan Vujičić, PhD, University of Dubrovnik, Maritime Department, Croatia
 Tomasz Jalowiec, PhD, War Studies University, Poland
 Tomislav Galeta, PhD, University of Osijek, Mechanical Engineering Faculty, Croatia
 Vladimir Perliouk, PhD, St. Petersburg State University of Aerospace Instrumentation, St. Petersburg, Russia
 Vlado Frančić, PhD, University of Rijeka, Faculty of Maritime Studies, Croatia
 Waldemar Mironiuk, PhD, Polish Naval Academy, Gdynia, Poland
 Wang Xiaodong, PhD, University of International Business and Economics, Beijing, China
 Žarko Koboević, PhD, University of Dubrovnik, Maritime Department, Croatia

TECHNICAL EDITOR

Davorka Turčinović, mag. oec.

GRAPHIC DESIGN & EDITING

Katarina Banović, mag. oec

Daniela Tomašević, univ. spec. oec.

LANGUAGE EDITOR

Martina Hrnić, univ. spec. philol.

CLASSIFICATION OF ARTICLES

Ana Pujo, Sc. librarian

The papers are peer-reviewed by international experts.

ISBN 978-953-7153-52-6

CIP 580564063

CONTENT

Igor Ariefjew GRAPH-ANALYTICAL METHOD FOR ASSESSING THE STATE OF THE OBJECT BEING DIAGNOSED	1
Hrvoje Baričević, Tanja Poletan-Jugović, Siniša Vilke INTEGRAL TRAFFIC MODEL OF THE DUBROVNIK-NERETVA COUNTY	8
Silvija Batoš CONTROVERSIES IN THE S/S STEFANO MULTIDISCIPLINARY RESEARCH	20
Tadeusz Bodnar, Tomasz Praczyk USING ARTIFICIAL INTELLIGENCE METHODS TO DETECT THE HORIZON LINE IN MARINE IMAGES	41
Clara Borén, Loïc Falevitch, Marcella Castells-Sanabra, Manel Grifoll Colls ADDED RESISTANCE PARAMETRIZATIONS DUE TO WAVES IN A WEATHER SHIP ROUTING SYSTEM	50
Juraj Bukša, Alen Jugović, Donald Schiozzi, Renato Oblak THE COMPROMISE MODEL AS A METHOD OF OPTIMIZING THE OPERATION OF NAUTICAL TOURISM PORTS ²	60
Maro Car, Srđan Vujičić, Srđan Žuškin, David Brčić HUMAN MACHINE INTERFACE: INTERACTION OF OOWs WITH THE ECDIS SYSTEM	74
Agnieszka Czapiewska, Ryszard Studański, Andrzej Żak, Bogdan Żak ECHOES REDUCTION DURING DIGITAL DATA TRANSMISSION IN HYDROACOUSTIC CHANNEL – LABORATORY EXPERIMENT	87
Lia Dragojević, Branka Milošević Pujo EIGHT MARITIME LEGAL TERMS ACCORDING TO CARRIAGE OF GOODS BY SEA ACT; RESEARCH INTO ENGLISH LANGUAGE AND CROATIAN TRANSLATION EQUIVALENTS	95
Joško Dvornik, Srđan Dvornik, Ivan Radan ANALYSIS OF THE EFFECTS OF LOW-SULFUR FUELS ON THE CYLINDER LINER LUBRICATION IN THE MARINE LOW-SPEED TWO-STROKE DIESEL ENGINE	103
Anamarija Falkoni, Nikša Koboević, Žarko Koboević, Goran Krajačić OPPORTUNITIES FOR ALL-ELECTRIC SHIPS IN SMART ENERGY SYSTEMS	114
Sergey German-Galkin, Dariusz Tarnapowicz OPTIMAL CONTROL OF GENERATOR SET WITH PERMANENT MAGNET SYNCHRONOUS MACHINE	128

Darko Glujić, Dean Bernečić THE INFLUENCE OF SLOW SPEED DIESEL ENGINES CYLINDER LINER TEMPERATURE ON SPECIFIC FUEL CONSUMPTION	138
Nermin Hasanspahić, Srđan Vujičić, Leo Čampara, Niko Hrdalo ANALYSIS OF CARGO SHIPS ACCIDENTS IN THE PAST DECADE	145
Alin Hobjila, Liliana Rusu STUDY OF ADDED MASSES AND DAMPING FACTORS FOR A TYPICAL CARGO SHIP FROM BLACK SEA	156
Stanisław Hożyń, Tomasz Praczyk, Piotr Szymak MEASUREMENT AND CONTROL SYSTEM FOR A DIVER'S ROBOTIC LEG	170
Špiro Ivošević, Rebeka Rudolf, Draško Kovač THE OVERVIEW OF THE VARIED INFLUENCES OF THE SEAWATER AND ATMOSPHERE TO CORROSIVE PROCESSES	182
Tomasz Jałowiec, Dariusz Grala, Katarzyna Pietrzyk-Wiszowaty USE OF MARITIME TRANSPORT BY POLISH ARMED FORCES - EXPERIENCE AND FUTURE	194
Karolina Jurczyk, Joanna Sznajder, Piotr Szymak, Paweł Piskur, Andrzej Grzędziela WATER TUNNEL MEASUREMENT STAND FOR RESEARCH ON UNDULATING PROPULSION	202
Irena Jurdana, Biserka Rukavina, Sandra Tominac Coslovich SUSTAINABLE DEVELOPMENT OF SUBMARINE OPTICAL CABLE INFRASTRUCTURE: TECHNICAL AND LEGAL ASPECTS	222
Alena Khaslavskaya, Violeta Roso, Ivan Sanchez-Diaz SWEDISH DRY PORTS' SERVICES	232
Marcin Kluczyk, Andrzej Grzędziela MARINE DIESEL ENGINES INJECTION PUMPS VIBRATION DIAGNOSTICS SUPPORTED BY MODELLING	247
Predrag Kralj, Dragan Martinović, Mato Tudor MARINE FRESH WATER GENERATOR PROCESS OPTIMIZATION	256
Srećko Krile, Nikolai Maiorov, Vladimir Fetisov RESEARCH OF THE OPERATION PROCESSES OF THE SYSTEM «MARINE PASSENGER TERMINAL- FERRY LINE» BASED ON SIMULATION	264
Tomislav Krljan, Siniša Vilke APPLICATION OF THE MICROSIMULATION TRAFFIC MODEL IN ASSESSING CONGESTION OF THE CONTAINER TERMINAL "BRAJDICA" ACCESS ROAD NETWORK	275
Vivien Lorenčič, Elen Twrdy FORECASTING CRUISE PASSENGER DEMAND IN MEDITERRANEAN CRUISE PORTS	297

Livia Maglić, Adrijana Agatić, Lovro Maglić, Marko Gulić INTELLIGENT TRANSPORTATION SYSTEMS IN CROATIAN SMART CITIES	308
Irina Makarova, Aleksey Boyko, Larisa Gubacheva, Aleksandr Barinov PROSPECTS FOR THE NORTHERN SEA ROUTE DEVELOPMENT: ECONOMIC AND ENVIRONMENTAL ASPECTS	318
Irina Makarova, Larisa Gubacheva, Aleksey Boyko, Polina Buyvol, Ksenia Shubenkova INTERNATIONAL TRANSPORT CORRIDORS AS A WAY TO IMPROVE LOGISTIC PROCESSES IN MODERN CONDITIONS	334
Józef Małecki, Stanisław Hożyń, Bogdan Żak PRECISE CONTROL OF THE UNMANNED SURFACE SHIP - SELECTED PROBLEMS	349
Nikola Marvučić, Enis Kočan OVERVIEW OF COMMUNICATION SOLUTIONS FOR INTERNET OF THINGS IN MARITIME INDUSTRY	358
Ivona Milić Beran, Romana Capor Hrošik, Dario Stjepović CORRELATION ANALYSIS OF MARITIME TRAFFIC	375
Zhanna Mingaleva, Vladimir Postnikov, Mariia Kamenskikh RESEARCH OF CARGO SEAPORTS DEVELOPMENT IN THE RUSSIAN FEDERATION IN THE CONTEXT OF PORT BASINS	382
Anna Mingaleva, Irina Shorohova PROSPECTS FOR THE DEVELOPMENT OF THE INFRASTRUCTURE OF SEAPORTS OF THE NORTHERN SEA ROUTE	395
Waldemar Mironiuk INFLUENCE OF FLOODING BOAT DECK COMPARTMENT ON THE SHIP'S SAFETY	404
Darijo Mišković, Renato Ivče, Žarko Koboević, Maro Car IMPACT OF MARITIME REGULATORY COMPLIANCE ON MARITIME SAFETY	415
Antonija Mišura, Tatjana Stanivuk, Katarina Balić, Maja Račić INTRODUCING ELECTRIC SHIPS IN THE COASTAL MARITIME TRAFFIC SYSTEM OF THE REPUBLIC OF CROATIA	425
Đani Mohović, Mate Barić, Robert Mohović, Renato Ivče A NEW E-PLATFORM FOR SUCCESSFUL LEARNING OF COLREGs	435
Andrzej Montwiłł SEAPORT AS A STIMULATOR OF THE DEVELOPMENT OF INTEGRATE LAND-SEA TRANSPORT CORRIDORS	442
Krzysztof Naus, Mariusz Waz THE METHODS OF ACQUISITION AND EXTRACTION OF SMALL AMPLITUDE SIGNAL RADAR ECHOES	454

Igor Nesteruk, Srećko Krile, Žarko Koboević COMFORTABLE ELECTRICAL YACHTS WITH SPECIAL SHAPED UNDERWATER HULLS	463
Josip Orović, Vedran Mrzljak, Igor Poljak ANALYSIS OF AUXILIARY EXERGY FLOW STREAM DURING THE CHANGE IN MARINE STEAM PROPULSION SYSTEM LOAD	470
Vasile Rata, Liliana Rusu ASSESS THE RISK OF SHIPPING ACCIDENTS IN THE BLACK SEA THAT MAY BE BASED ON STRUCTURAL DAMAGE	481
Ninna Roos MARITIME AUTOMATION – THE ROLE OF THE HUMANS IN THE FUTURE?	495
Peter Ivar Sandell AUTONOMOUS AND REMOTE CONTROLLED VESSELS – HOW WILL THE RISK BE ASSESSED BY HULL UNDERWRITERS?	501
Vu Quoc Sang, Yun Chul Jung, Phung Hung Nguyen SETTING UP INPUT DATA OF MODEL FOR ASSESSING LEVEL OF A COUNTRY'S ACCEPTANCE OF PARTICIPATION IN THE INTERNATIONAL COMPENSATION REGIMES FOR OIL POLLUTION	511
Tatjana Stanivuk, Marko Šundov, Rino Bošnjak, Tomislav Skračić IMPACTS OF TRANSPORT ON THE EFFICIENCY OF THE SHIPBUILDING SUPPLY CHAIN	517
Tatjana Stanivuk, Marko Šundov, Rino Bošnjak, Nena Tomović MODEL OF RATIONALIZATION OF TRANSPORT COSTS FOR THE CONSTRUCTION OF A SHIP HULL - Case study for the Brodotrogir	531
Ladislav Stazić, Karlo Bratić, Vice Mihanović, Jure Matjašić MAINTENANCE PROCESS ADJUSTMENT BASED ON COMPUTERIZED PMS DATA	547
Joanna Sznajder, Leszek Flis, Paweł Piskur, Marek Gąsiorowski MODELLING AND EXPERIMENT OF A FIN FOR BIOMIMETIC UNDERWATER VEHICLE	554
Senka Šekularac – Ivošević, Dragana Milošević INNOVATION THROUGH COLLABORATION: THE APPLICATION IN MARITIME INDUSTRY	567
Kimberly Tam, Kevin Jones A CYBER-SECURITY REVIEW OF EMERGING TECHNOLOGY IN THE MARITIME INDUSTRY	579
Nguyen Quang Vinh, Le Van Vang, Bui Hong Duong RESEARCHING ADJUSTMENT OF NOZZLES OF TURBOCHARGER TO IMPROVE THE POWER OUTPUT OF MARINE DIESEL GENERATOR ENGIN	587
Miroslav Vukičević, Miloš Bogdanović, Draško Kovač, Srđan Vujičić PROSPECTIVE JOBS FOR MONTENEGRIN SEAFARERS IN THE EPICONTINENTAL AREA OF MONTENEGRO	600

Miroslav Vukičević, Nikola Račić, Denis Vukašinović WAYS OF REDUCING THE CONTENT OF CATALYTIC FINES IN MARINE HEAVY FUEL OIL	611
Luka Vukić, Zvonimir Lušić, Danijel Pušić, Silvija Galić TRENDS AND PERSPECTIVES OF CARGO TRAFFIC ACTIVITIES IN THE PORT OF SPLIT	625
Ante Vuković, Željko Mišić THE MAXIMUM DURATION OF A CONCESSION FOR MARINAS IN CROATIAN AND COMPARATIVE LAWS	645
Bogdan Žak, Andrzej Žak, Józef Małecki THE METHOD OF OPTIMAL CONTROL OF THE SHIP IN A COLLISION SITUATION	655
Marek Zellma, Agata Załęska-Fornal DESCRIPTION OF THE DYNAMIC CHARACTERISTIC OF THE FLOATING OBJECTS BY MEANS OF THE SMOOTHING SPLINES	666
Dražen Žgaljić, Alen Jugović, Donald Schiozzi, Renato Oblak MULTI-CRITERIA ANALYSIS OF CROATIAN PORT SYSTEM FOR IMPLEMENTATION OF SUSTAINABLE MOTORWAYS OF THE SEA SERVICES	679