EXERGY ANALYSIS OF TWO WATER PUMPS FROM STEAM POWER PLANT AT FOUR DIFFERENT LOADS

PhD. Mrzljak Vedran[1], PhD. Orović Josip[2], PhD. Poljak Igor[2], PhD. Čulin Jelena[2]
[1]Faculty of Engineering, University of Rijeka, Vukovarska 58, 51000 Rijeka, Croatia
[2]University of Zadar, Maritime Department, M. Pavlinovića 1, 23000 Zadar, Croatia
E-mail: vedran.mrzljak@riteh.hr, jorovic@unizd.hr, ipoljak1@unizd.hr, jculin@unizd.hr

Abstract: *Paper presents exergy efficiency and loss analysis of condensate extraction pump (CEP) and main boiler feed pump (BFP) from a conventional steam power plant. Based on the required measured operating parameters at four different loads, it was observed that an increase in driving power for both pumps follows an increase in power plant cumulative developed power. Both analyzed pumps do not have the highest exergy losses at the highest observed load, as can be usually expected. Main boiler feed pump has the highest exergy efficiency, which is equal to 87.00%, at power plant nominal load, while the highest exergy efficiency of condensate extraction pump (95.77%) was observed at 60% of power plant nominal load. The influence of the ambient temperature on both pumps exergy efficiencies and losses is almost negligible.*

KEYWORDS: CONDENSATE EXTRACTION PUMP, BOILER FEED PUMP, EXERGY LOSSES, EXERGY EFFICIENCY, AMBIENT TEMPERATURE VARIATION

1. Introduction

Water pumps are essential elements of steam power plants [1] where they are used on the condensate/feed water returning line from condenser to main boiler [2]. The number and arrangement of water pumps in steam power plant depend on the number and operation principles of water heaters [3].

Two main pumps in the condenser/feed water returning line from condenser to main boiler, which inevitably have to be installed in each steam power plant, are condenser extraction pump (CEP) and main boiler feed pump (BFP) [4]. Regardless of the type and inner structure, those two pumps operate in heavy conditions. The CEP takes condensate at low pressure, significantly lower than atmospheric pressure, while BFP delivers feed water to high pressures significantly higher than atmospheric pressure [5].

Such two pumps from steam power plant with nominal power of 210 MW were analyzed in this paper from the exergy aspect. Both pumps were analyzed at four different power plant loads to obtain their exergy losses and efficiencies along with the aim to compare their operations. The influence of the ambient temperature on both pumps exergy efficiencies and losses is also analyzed and presented. Presented investigation can be used not only for the analyzed water pumps, but also for every other pump to obtain its proper operation characteristics at various loads.

2. Condensate extraction pump and main boiler feed pump description and operation characteristics

In thermal power plants, steam after low pressure turbine cylinder (or more of them) is delivered to steam condenser where it condenses. Produced condensate is then delivered by the pump (low-pressure or mid-pressure) to deaerator through a several low pressure condensate heaters. Water after deaerator is then taken by another high-pressure pump which delivers it to boiler through several high pressure water heaters. The water line between the condenser and deaerator is usually called condensate line and water line between deaerator and boiler is usually called feed water line. Condensate pressure increasing and distribution is ensured with CEP, while the feed water pressure increasing and distribution is ensured with BFP. Those two pumps from the thermal power plant with nominal power of 210 MW were analyzed in this study.

Condensate extraction pump, Fig. 1 (a), is a pump which takes a condensate from power plant condenser and delivers that condensate to deaerator through low pressure feed water heaters. Condensate at the CEP inlet has a pressure much lower than the atmospheric pressure (point 1 at Fig. 1), so the CEP can be considered as a pump that operates under harsh working conditions. Pressure at which CEP delivers condensate (point 2 at Fig. 1) is above atmospheric pressure. In order to increase condensate pressure, CEP consumes power (P_{CEP}) which is usually delivered by electric motor [6].

Main boiler feed pump, Fig. 1 (b), takes feed water from power plant deaerator and delivers it to boiler through high pressure feed water heaters. Feed water at the BFP inlet (point 3 at Fig. 1) has a pressure higher than atmospheric, while at the BFP outlet (point 4 at Fig. 1) feed water has a pressure slightly higher than the boiler pressure which is in power plants much higher than the atmospheric one. Feed water delivering at pressures significantly higher than the atmospheric one ranges also BFP in the category of the harsh working conditions pump. In order to increase feed water pressure, BFP consumes power (P_{BFP}) which is usually delivered by electric motor [7] or in some situations by low power steam turbine [8].

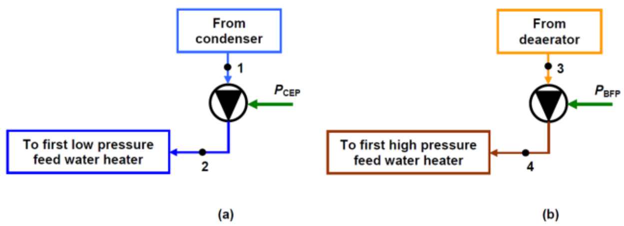

Fig. 1. *Condensate extraction pump (a) and main boiler feed pump (b) schemes with marked water streams for exergy analysis*

3. Equations required for exergy analysis

3.1. Base equations for exergy analysis of control volume

For a volume in steady state disregarding potential and kinetic energy, mass balance equation is [9]:

$$\sum \dot{m}_{IN} = \sum \dot{m}_{OUT} \tag{1}$$

As noted in the literature [10], exergy analysis is based on the second law of thermodynamics. For a volume in steady state, the main exergy balance equation can be defined according to [11] as:

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

In the Eq. 2, exergy transfer by heat ($\dot{X}_{heat}$) at the temperature T is defined as [12]:

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

Specific exergy is defined, according to [13] and [14] as:

$$\varepsilon = (h - h_0) - T_0 \cdot (s - s_0) \tag{4}$$

The exergy power of a flow is calculated according to [15]:

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

Exergy efficiency can have different forms which are dependable on a control volume, but in general exergy efficiency is defined according to [16] by an equation:

$$\eta_{ex} = \frac{\text{Exergy output}}{\text{Exergy input}} \quad (6)$$

3.2. Exergy analysis equations of condensate extraction pump and main boiler feed pump

For the analyzed condensate extraction pump and main boiler feed pump, all required operating points were presented in Fig. 1.

Mass and exergy balances at each observed load for the condensate extraction pump and main boiler feed pump are (Fig. 1):

Mass balances:

→ Condensate extraction pump: $\dot{m}_1 = \dot{m}_2$ (7)

→ Main boiler feed pump: $\dot{m}_3 = \dot{m}_4$ (8)

Exergy balances:

- *Exergy power inputs (only water flow):*

→ Condensate extraction pump: $\dot{E}_{ex,CEP,IN,w} = \dot{m}_1 \cdot \varepsilon_1$ (9)

→ Main boiler feed pump: $\dot{E}_{ex,BFP,IN,w} = \dot{m}_3 \cdot \varepsilon_3$ (10)

- *Exergy power inputs (cumulative):*

→ Condensate extraction pump: $\dot{E}_{ex,CEP,IN,cu} = \dot{m}_1 \cdot \varepsilon_1 + P_{CEP}$ (11)

→ Main boiler feed pump: $\dot{E}_{ex,BFP,IN,cu} = \dot{m}_3 \cdot \varepsilon_3 + P_{BFP}$ (12)

- *Exergy power outputs:*

→ Condensate extraction pump: $\dot{E}_{ex,CEP,OUT} = \dot{m}_2 \cdot \varepsilon_2$ (13)

→ Main boiler feed pump: $\dot{E}_{ex,BFP,OUT} = \dot{m}_4 \cdot \varepsilon_4$ (14)

- *Exergy destructions:*

→ Condensate extraction pump:

$$\dot{E}_{ex,CEP,D} = \dot{E}_{ex,CEP,IN,cu} - \dot{E}_{ex,CEP,OUT} \quad (15)$$

→ Main boiler feed pump:

$$\dot{E}_{ex,BFP,D} = \dot{E}_{ex,BFP,IN,cu} - \dot{E}_{ex,BFP,OUT} \quad (16)$$

- *Exergy efficiencies:*

→ Condensate extraction pump:

$$\eta_{ex,CEP} = \frac{\dot{E}_{ex,CEP,OUT} - \dot{E}_{ex,CEP,IN,w}}{P_{CEP}} = \frac{\dot{m}_2 \cdot \varepsilon_2 - \dot{m}_1 \cdot \varepsilon_1}{P_{CEP}} \quad (17)$$

→ Main boiler feed pump:

$$\eta_{ex,BFP} = \frac{\dot{E}_{ex,BFP,OUT} - \dot{E}_{ex,BFP,IN,w}}{P_{BFP}} = \frac{\dot{m}_4 \cdot \varepsilon_4 - \dot{m}_3 \cdot \varepsilon_3}{P_{BFP}} \quad (18)$$

Pumps real driving power at all observed loads was calculated from water mass flows through each pump and water specific enthalpy differences at each pump outlet and inlet:

→ Condensate extraction pump: $P_{CEP} = \dot{m}_1 \cdot (h_2 - h_1)$ (19)

→ Main boiler feed pump: $P_{BFP} = \dot{m}_3 \cdot (h_4 - h_3)$ (20)

The base ambient state (dead state) is taken as proposed in [17]:

- pressure: $p_0 = 0.1$ MPa = 1 bar,
- temperature: $T_0 = 25$ °C = 298.15 K.

4. Measurement results of analyzed condensate extraction pump and main boiler feed pump

Measurement results of water flow streams for the condensate extraction pump and main boiler feed pump at all observed loads were found in [18] and presented in Table 1. Both pumps loads are presented in accordance to percentage of power plant nominal load (plant nominal load is 210 MW). Along with water flow streams measurement results (water temperature, pressure and mass flow), in Table 1 specific enthalpies and specific exergies of each water flow stream calculated with NIST REFPROP 9.0 software [19] are presented. Water specific exergies are calculated for the base ambient state.

Table 1. *Condensate extraction pump and main boiler feed pump measurement results in all observed loads (base ambient state) [18]*

Percentage of power plant nominal load	OP*	Temp. (°C)	Pressure (bar)	Water mass flow (kg/s)	Water specific enthalpy (kJ/kg)	Water specific exergy (kJ/kg)
40%	1	46.00	0.101	60.41	192.62	2.864
	2	46.28	21.359	60.41	195.64	5.068
	3	129.74	2.682	71.93	545.28	63.288
	4	133.40	154.533	71.93	571.10	82.02
60%	1	46.00	0.101	84.88	192.62	2.864
	2	46.09	20.143	84.88	194.74	4.894
	3	141.45	3.766	103.22	595.38	76.925
	4	144.33	157.220	103.22	617.60	95.08
75%	1	46.00	0.101	103.34	192.62	2.864
	2	46.16	18.878	103.34	194.92	4.787
	3	148.46	4.570	127.29	625.54	85.640
	4	151.18	159.937	127.29	646.93	103.84
100%	1	46.00	0.101	137.93	192.62	2.864
	2	46.15	15.759	137.93	194.61	4.472
	3	159.03	6.031	173.28	671.25	99.537
	4	161.86	166.713	173.28	692.99	118.45

* OP = Operating Point (streams numeration refers to Fig. 1)

5. Condensate extraction pump and main boiler feed pump exergy analysis results and the discussion

5.1. Exergy analysis results of both pumps at the base ambient state

The change in real (polytropic) driving power of analyzed CEP and BFP in relation to power plant load is presented in Fig. 2. Increase in power plant load resulted with an increase in water mass flow through both pumps (Table 1), but the driving power of both pumps does not follow such trend.

Real driving power of BFP continuously increases during the increase in power plant load from 1857.29 kW at 40% of power plant nominal load up to 3767.05 kW at plant nominal load, Fig 2.

CEP real driving power is 182.44 kW at 40% of power plant nominal load. An increase in power plant load firstly results in a decrease of CEP driving power to 179.95 kW (60% of power plant nominal load). At 75% of power plant nominal load CEP real driving power is 237.68 kW, while at plant nominal load CEP real driving power is 274.48 kW, Fig. 2.

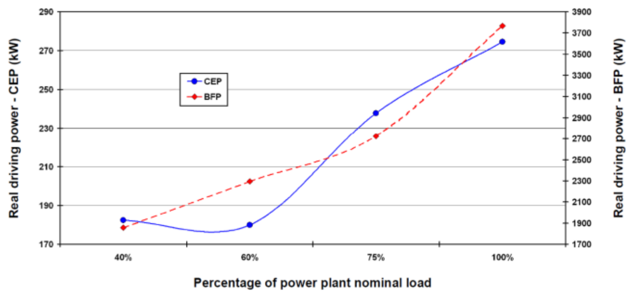

Fig. 2. *Change in real driving power of CEP and BFP in relation to power plant load*

Cumulative exergy power inputs and outputs for both analyzed pumps are presented in Fig. 3 in relation to power plant load. Cumulative exergy power input (which consist of water exergy flow at the pump inlet and power delivered for pump driving) for each pump must have a higher value than exergy power output at each observed load; otherwise pump operation would be impossible.

The difference in the exergy cumulative power input and exergy power output for each pump at each load represents exergy destruction (exergy loss). For the CEP it can be seen that during the increase in power plant load, differences between cumulative exergy power inputs and outputs significantly deviate, indicating sensible change in CEP exergy losses and efficiencies. The change in BFP cumulative exergy power inputs and outputs during the increase in power plant load indicate that BFP exergy efficiencies will be changed in significantly smaller range in comparison to CEP, Fig. 3.

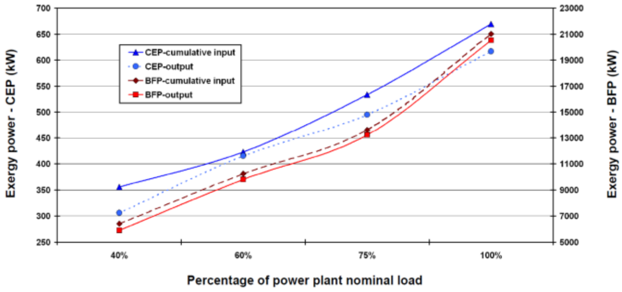

Fig. 3. *Change in exergy power inputs and outputs of CEP and BFP in relation to power plant load*

CEP exergy destruction at 40% of power plant nominal load is equal to 49.26 kW after which decreases to 7.61 kW at 60% of power plant nominal load, Fig. 4. Further increase in power plant nominal load resulted with an increase in CEP exergy destruction. The highest CEP exergy destruction can be noticed at the highest observed power plant load and is equal to 52.65 kW.

BFP has the highest exergy destruction (509.78 kW) at the lowest power plant observed load (40% of nominal power plant load). An increase in power plant load firstly resulted with a decrease of BFP exergy destruction and the lowest BFP exergy destruction (406.05 kW) was observed at 75% of plant nominal load. At the highest power plant load BFP exergy destruction increases to 489.85 kW, Fig. 4.

Contrary to many other components of the steam power plant which have the highest exergy destruction (exergy loss) at the highest power plant load, both analyzed pumps do not follow such trend.

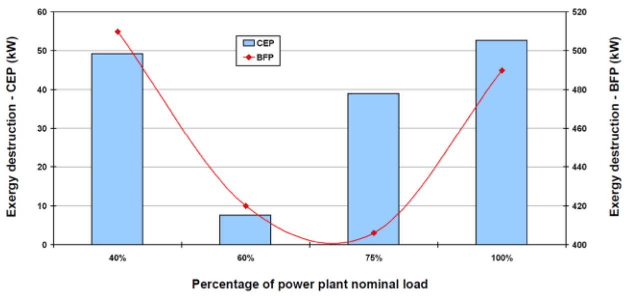

Fig. 4. *Change in exergy destructions of CEP and BFP in relation to power plant load*

Exergy efficiency change of CEP during the increase in power plant load is diametrically opposed to change in CEP exergy destruction, Fig. 4 and Fig. 5. At the lowest observed power plant load (40% of nominal load) CEP exergy efficiency is the lowest and equal to 73.00%, while the highest exergy efficiency of CEP is obtained at 60% of power plant nominal load and is equal to 95.77%. At the highest power plant load CEP exergy efficiency is 80.82%. It can be concluded that the highest CEP exergy efficiency is not obtained at the highest power plant load.

BFP has much different exergy efficiency change during the increase in power plant load when compared to CEP because the increase in power plant load causes a continuous increase in BFP exergy efficiency from 72.55% at 40% of power plant nominal load up to 87% at the highest observed power plant load, Fig. 5.

Comparison of CEP and BFP resulted with a conclusion that during the change in power plant load CEP has a significantly larger range of exergy efficiency change (22.77%) than BFP (14.44%).

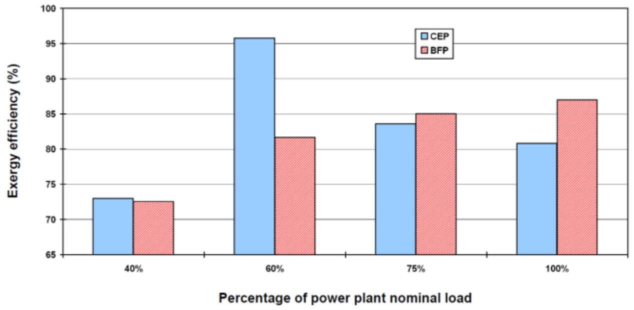

Fig. 5. *Change in exergy efficiencies of CEP and BFP in relation to power plant load*

5.2. Exergy analysis results of both pumps during the ambient temperature variation

Fig. 6 presents a change in exergy destructions for both analyzed pumps at two ambient temperatures: 5 °C and 45 °C. An increase in the ambient temperature resulted with an increase in the exergy destruction of both analyzed pumps at any observed load.

An increase in the ambient temperature has a much smaller influence on CEP exergy destruction because an increase in the ambient temperature from 5 °C to 45 °C increases CEP exergy destruction for small values at each observed load. The same increase in the ambient temperature (from 5 °C to 45 °C) increases the exergy destruction of BFP for a much higher values when compared to CEP, at each observed power plant load.

An increase in power plant load at any observed ambient temperature must result with a same exergy destruction trend of any steam plant component, which is also valid for the analyzed CEP and BFP when compared Fig. 4 and Fig. 6.

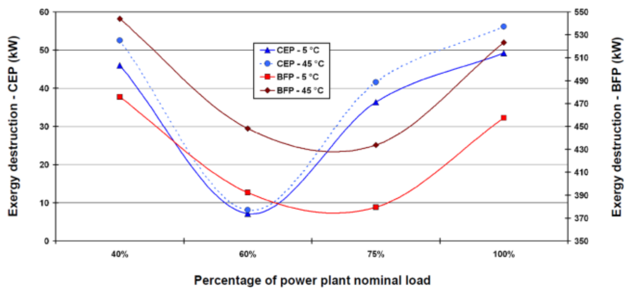

Fig. 6. *Change in exergy destructions of CEP and BFP in relation to power plant load during the ambient temperature change*

An increase in the ambient temperature from 5 °C to 45 °C resulted with a decrease of exergy efficiencies for both analyzed pumps, at each observed power plant load, Fig. 7.

The highest difference in exergy efficiency of CEP is observed at 40% of power plant nominal load and is equal to 3.61% (CEP exergy efficiency at the ambient temperature of 5 °C is 74.80%, while at the ambient temperature of 45 °C CEP exergy efficiency is equal to 71.19%). As concluded for CEP, the highest difference in exergy efficiency of BFP is also observed at 40% of power plant nominal load and is equal to 3.67% (BFP exergy efficiency at the ambient temperature of 5 °C is 74.39%, while at the ambient temperature of 45 °C BFP exergy efficiency is equal to 70.72%).

CEP and BFP are the steam plant components for which it can be concluded that change in the ambient temperature does not have significant influence on its exergy efficiencies because the change in the ambient temperature for 10 °C will result with the change of CEP and BFP exergy efficiency for a less than 1%.

As for the most other steam plant components, for both analyzed pumps will be the best option to operate at the lowest possible ambient temperature.

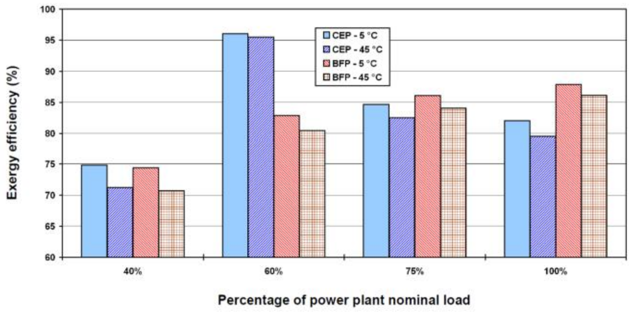

Fig. 7. *Change in exergy efficiencies of CEP and BFP in relation to power plant load during the ambient temperature change*

6. Conclusions

In this paper an exergy analysis of condensate extraction pump (CEP) and main boiler feed pump (BFP) from steam power plant with nominal power of 210 MW is presented. Operation dynamics of both pumps and the change of their exergy destructions and efficiencies during the increase in power plant load are investigated. The most important conclusions are:

- The real driving power of BFP continuously increases during the increase in power plant load, while the CEP does not follow the same trend due to a change in required water pressures.
- Exergy destructions (exergy losses) for both pumps are not the highest at the highest power plant load, which could be expected and valid for a majority of power plant components.
- The lowest exergy destruction of CEP is obtained at 60% of power plant nominal load and amounts 7.61 kW, while the lowest exergy destruction of BFP is obtained at 75% of power plant nominal load and amounts 406.05 kW.
- An increase in power plant load causes a continuous increase in BFP exergy efficiency. The CEP exergy efficiency change does not follow the same continuous trend as BFP.
- The highest exergy efficiencies are 95.77% for CEP (at 60% of power plant nominal load) and 87.00% for BFP (at the power plant nominal load).
- For all observed power plant loads, CEP has a significantly larger range of exergy efficiency change when compared to BFP.
- The change in the ambient temperature does not have significant influence on the change of CEP and BFP exergy efficiencies.

7. Acknowledgment

This work has been fully supported by the Croatian Science Foundation under the project IP-2018-01-3739.

8. Nomenclature

Abbreviations:		***Greek symbols:***	
BFP	Boiler Feed Pump	ε	specific exergy, kJ/kg
CEP	Condensate Extraction Pump	η	efficiency, -
Latin Symbols:		***Subscripts:***	
$\dot{E}$	stream flow power, kW	0	ambient state
h	specific enthalpy, kJ/kg	cu	cumulative
$\dot{m}$	mass flow rate, kg/s	D	destruction
p	pressure, bar	ex	exergy
P	power, kW	IN	inlet (input)
$\dot{Q}$	heat transfer, kW	OUT	outlet (output)
s	specific entropy, kJ/kg·K	w	water (condensate)
T	temperature, °C or K		
$\dot{X}_{\text{heat}}$	heat exergy transfer, kW		

9. References

[1] Kowalczyk, T., Ziółkowski, P., Badur, J.: *Exergy Losses in the Szewalski Binary Vapor Cycle*, Entropy 17, p. 7242-7265, 2015. (doi:10.3390/e17107242)

[2] 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)

[3] 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)

[4] 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)

[5] Mrzljak, V., Poljak, I., Medica-Viola, V.: *Thermodynamical analysis of high-pressure feed water heater in steam propulsion system during exploitation*, Shipbuilding 68 (2), p. 45-61, 2017. (doi:10.21278/brod68204)

[6] 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)

[7] Uysal, C., Kurt, H., Kwak, H. Y.: *Exergetic and thermoeconomic analyses of a coal-fired power plant*, International Journal of Thermal Sciences 117, p. 106-120, 2017. (doi:10.1016/j.ijthermalsci.2017.03.010)

[8] 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)

[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] Szargut, J.: *Exergy Method - Technical and Ecological Applications,* WIT Press, 2005.

[11] 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)

[12] Mrzljak, V., Poljak, I., Prpić-Oršić, J.: *Exergy analysis of the main propulsion steam turbine from marine propulsion plant*, Shipbuilding Vol. 70., No. 1, p. 59-77, 2019. (doi:10.21278/brod70105)

[13] 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)

[14] 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)

[15] 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)

[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] Sengupta, S., Datta, A., Duttagupta, S.: *Exergy analysis of a coal-based 210 MW thermal power plant*, International journal of energy research 31, p. 14-28, 2006. (doi:10.1002/er.1224)

[19] 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.

IV INTERNATIONAL SCIENTIFIC CONFERENCE - SUMMER SESSION
INDUSTRY 4.0
24-27.06.2019, BURGAS, HOTEL ATLANTIS
www.industry-4.eu

Year III **Volume 1/5** **JUNE 2019**

ISSN (Print) - 2535-0153
ISSN (Online) - 2535-0161

THEMATIC FIELDS

TECHNOLOGICAL BASIS OF "INDUSTRY 4.0"
DOMINANT TECHNOLOGIES IN "INDUSTRY 4.0"

BUSINESS & "INDUSTRY 4.0"
SOCIETY & „INDUSTRY 4.0"

ORGANIZER

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING
"INDUSTRY 4.0"

108 Rakovski str., 1000 Sofia
e-mail: office@industry-4.eu
www.industry-4.eu

C O N T E N T S

TECHNOLOGICAL BASIS OF "INDUSTRY 4.0". DOMINANT TECHNOLOGIES IN "INDUSTRY 4.0"

BUSINESS & “INDUSTRY 4.0”. SOCIETY & „INDUSTRY 4.0”