

# NUMERICAL ANALYSIS OF TURBO-GENERATOR STEAM TURBINE ENERGY EFFICIENCY AND ENERGY POWER LOSSES CHANGE DURING THE VARIATION IN DEVELOPED POWER

PhD. Mrzljak Vedran<sup>1</sup>, PhD. Poljak Igor<sup>2</sup>, Prof. PhD. Prpić-Oršić Jasna<sup>1</sup>

<sup>1</sup>Faculty of Engineering, University of Rijeka, Vukovarska 58, 51000 Rijeka, Croatia

<sup>2</sup>University of Zadar, Maritime Department, M. Pavlinovića 1, 23000 Zadar, Croatia

E-mail: vedran.mrzljak@riteh.hr, ipoljak1@unizd.hr, jasna.prpic-orasic@riteh.hr

**Abstract:** Developed power variation of turbo-generator (TG) steam turbine allows insight into the change of turbine energy efficiency and energy power losses. Measurements were performed in five different TG steam turbine operating points and analysis is presented in three randomly selected operating points. Turbine developed power was varied from 500 kW until the maximum power of 3850 kW in steps of 100 kW. Turbine energy efficiency increases from 500 kW to 2700 kW and maximum energy efficiency was obtained at 70.13 % of maximum turbine power (at 2700 kW) in each operating point. From 2700 kW until the maximum of 3850 kW, TG turbine energy efficiency decreases. Change in TG turbine energy efficiency is caused by an uneven intensity of increase in turbine power and steam mass flow. For all observed operating points, energy efficiency during turbine exploitation is approximately 10 % or more lower than the maximum obtained one. A continuous increase in turbine energy power losses during the developed turbine power increase are the most influenced by the continuous increase in steam mass flow through the turbine.

**KEYWORDS:** STEAM TURBINE, ENERGY EFFICIENCY, ENERGY POWER LOSSES, POWER VARIATION

## 1. Introduction

Steam turbine propulsion plants are not a rarity for a number of LNG carriers [1]. Such steam propulsion plants have many essential components, not only for ship propulsion, but also for electricity and heat production. Each component from the steam propulsion plant can and should be investigated and optimized to achieve the optimal operating parameters. One of the constituent components of such marine steam propulsion plant is turbo-generator (TG) which steam turbine is analyzed in this paper from the energy aspect [2].

Measurements of required TG steam turbine operating parameters were performed on conventional LNG carrier. Every LNG carrier with steam propulsion system has at disposals at least two or more turbo-generator sets which are designed to cover all ship requirements for electrical power.

On the analyzed LNG carrier is mounted two identical TG operating sets. Each TG turbine has identical operating parameters (inlet and outlet temperatures, pressures and mass flows). For the analysis in this paper is selected one TG steam turbine. Steam turbine, which drives an electric generator on the analyzed LNG carrier comprises of nine Rateau stages. Steam turbines with Rateau stages, analysis of their operation and its characteristics is presented in [3]. Usual and specific designs of marine steam turbines along with their auxiliary systems are presented in [4].

The main goal of the TG steam turbine analysis in this paper was to present change in steam turbine energy efficiency and energy power losses during the change in turbine developed power. Measurements of necessary operating parameters were provided in five different turbine operating points, at five different loads. In each turbine operating point was varied turbine developed power from the lowest to the highest one. During the power variation was calculated turbine energy efficiency and energy power losses. The results of the analysis were presented for three selected turbine operating points, but presented conclusions are valid also for all the other operating points. Steam turbine developed power variation allows detecting optimal turbine loads with the highest energy efficiency, for each operating point. It was compared turbine energy efficiency and energy power losses from the real exploitation (measured operating parameters) with achieved optimal operating conditions when the turbine has the highest energy efficiency. TG steam turbine load depends on ship electrical consumers and their current needs for the electrical power. From the aspect of energy efficiency, for the analyzed TG steam turbine will be better to be more loaded to achieve maximal energy efficiency in each operating point.

Main characteristics and specifications of the LNG carrier in which steam propulsion system is mounted analyzed TG steam turbine are presented in Table 1.

**Table 1.** Main characteristics of the analyzed LNG carrier

Dead weight tonnage	84,812 DWT
Overall length	288 m
Max breadth	44 m
Design draft	9.3 m
Propulsion turbine	Mitsubishi MS40-2 (max. power 29,420 kW)
Turbo-generators	2 x Shinko RGA 92-2 (max. power 3.850 kW each)

## 2. Low power steam turbine energy analysis

### 2.1. Steam turbine energy analysis equations

The first law of thermodynamics defined energy analysis of any steam system component [5]. Mass and energy balance equations for a standard volume in steady state disregarding potential and kinetic energy can be expressed according to [6]:

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

$$\dot{Q} - P = \sum \dot{m}_{OUT} \cdot h_{OUT} - \sum \dot{m}_{IN} \cdot h_{IN} \quad (2)$$

Energy power of a flow for any fluid stream can be calculated according to the [7] by using the equation:

$$\dot{E}_{en} = \dot{m} \cdot h \quad (3)$$

Energy efficiency may take different forms and types. Usually, energy efficiency can be written as [8]:

$$\eta_{en} = \frac{\text{Energy output}}{\text{Energy input}} \quad (4)$$

### 2.2. Energy efficiency and energy power losses for the TG steam turbine

Steam turbine for a turbo-generator drive is a condensing type [9]. Schematic view of steam turbine connected to an electric generator (the whole set of steam turbine and electric generator is usually called turbo-generator) is presented in Fig. 1. Superheated steam mass flow, specific steam enthalpies and specific steam entropies at the TG steam turbine can also be seen in Fig. 1. All variables important for TG turbine numerical analysis were marked with 1 for inlet variables and with 2 for outlet variables.

According to producer specifications [9], TG turbine power can be expressed with the following third degree polynomial:

$$P_{TG} = -4.354 \cdot 10^{-10} \cdot \dot{m}_{TG}^3 + 6.7683 \cdot 10^{-6} \cdot \dot{m}_{TG}^2 + 0.251318 \cdot \dot{m}_{TG} - 256.863 \quad (5)$$

where  $P_{TG}$  was obtained in (kW) when  $\dot{m}_{TG}$  in (kg/h) was placed in the equation (5). Steam mass flow through the TG turbine ( $\dot{m}_{TG}$ ) was measured component, while the developed TG turbine power was calculated according to equation (5).

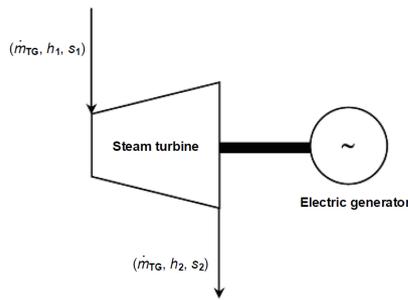


Fig. 1. Inlet and outlet variables for the TG steam turbine

During measurements, no steam leakage on the analyzed TG turbine was observed, so the mass balance for the TG steam turbine inlet and outlet is:

$$\dot{m}_{TG,1} = \dot{m}_{TG,2} = \dot{m}_{TG} \quad (6)$$

According to Fig. 1 and Fig. 2,  $h_1$  is steam specific enthalpy at the turbine inlet, and  $h_2$  is steam specific enthalpy at the turbine outlet after real (polytropic) expansion. Steam specific enthalpy at the turbine inlet was calculated from the measured pressure and temperature at each operating point. Steam specific entropy at the turbine inlet  $s_1$  was also calculated from measured steam pressure and temperature at the turbine inlet. Steam real specific enthalpy at the turbine outlet was calculated from the turbine power  $P_{TG}$  in (kW) and measured steam mass flow  $\dot{m}_{TG}$  in (kg/s) according to [10] by using an equation:

$$h_2 = h_1 - \frac{P_{TG}}{\dot{m}_{TG}} \quad (7)$$

Steam specific enthalpy after isentropic expansion  $h_{2S}$  was calculated from the measured steam pressure at the turbine outlet  $p_2$  and from known steam specific entropy at the turbine inlet  $s_1$ . Ideal isentropic expansion assumes no change in steam specific entropy ( $s_1 = s_{2S}$ ), Fig. 2.

Steam specific enthalpy at the turbine inlet, steam specific enthalpy at the end of isentropic expansion and steam specific entropy at the turbine inlet were calculated by using NIST REFPROP 8.0 software [11].

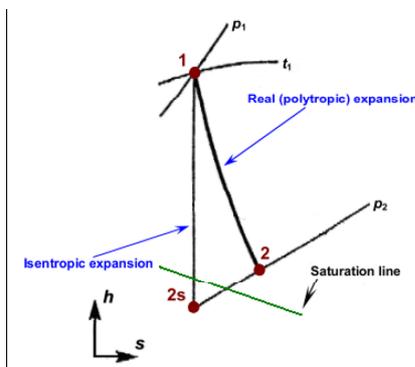


Fig. 2. TG real (polytropic) and ideal (isentropic) expansion

TG steam turbine energy power losses in each operating point can be calculated according to Fig. 2 as:

$$\dot{E}_{TG,en,PL} = \dot{m}_{TG} \cdot h_2 - \dot{m}_{TG} \cdot h_{2S} = \dot{m}_{TG} \cdot (h_2 - h_{2S}) \quad (8)$$

Energy efficiency of TG steam turbine can be calculated according to [12] by using the following equation:

$$\eta_{TG,en} = \frac{(h_1 - h_2)}{(h_1 - h_{2S})} \quad (9)$$

### 2.3. The principle of the TG developed power variation

TG steam turbine real developed power can be calculated according to Fig. 2 by an equation:

$$P_{TG} = \dot{m}_{TG} \cdot (h_1 - h_2) \quad (10)$$

Three different methods can be used for the power change of TG turbine (if it is assumed always the same inlet pressure and temperature and the same outlet pressure):

- 1) Change in steam mass flow through the TG steam turbine
- 2) Change in the value of steam specific enthalpy at the steam turbine outlet ( $h_2$ )
- 3) Combination of method 1 and 2

To present the change of TG steam turbine energy efficiency and energy power losses in this paper is selected combined method (method 3) for each operating point.

Turbine developed power was varied from 500 kW up to a maximum of 3850 kW in steps of 100 kW. Power change requires a change in steam mass flow through the turbine, so the adequate steam mass flow for any turbine power was calculated by using the reversed equation (5). In each operating point, steam pressure and temperature at the turbine inlet and steam pressure at the turbine outlet remain identical to the measured data. Steam enthalpy at the turbine outlet ( $h_2$ ) was calculated for each turbine power and mass flow by using equation (7). Change in steam enthalpy at the turbine outlet ( $h_2$ ) along with the change of steam mass flow causes the change of TG steam turbine energy efficiency and energy power losses, equations (8) and (9).

### 3. Measurement results of the analyzed TG

Measurement results for TG steam turbine at different loads are presented in Table 2. Measured operating parameters were: steam pressure at the TG turbine inlet and outlet, steam temperature at the TG turbine inlet and the steam mass flow through TG turbine.

Table 2. Measurement results for TG steam turbine at several loads

Operating point	Steam pressure at the TG turbine inlet (MPa)	Steam temperature at the TG turbine inlet (°C)	Steam pressure at the TG turbine outlet (MPa)	Steam mass flow through TG turbine (kg/h)
1	5.97	490.5	0.00425	4000.58
2	6.07	491.0	0.00392	3838.78
3	6.07	502.5	0.00397	3778.91
4	6.02	504.0	0.00412	3951.37
5	5.80	493.0	0.00557	4428.43

### 4. Used measuring equipment

All the measurement results were obtained from the existing measuring equipment mounted on the TG steam turbine inlet and outlet. All measuring equipment is calibrated by producers. List of all used measuring equipment was presented in Table 3.

Table 3. Used measuring equipment for the TG turbine analysis

Steam temperature (TG inlet)	Greisinger GTF 601-Pt100 - Immersion probe [13]
Steam pressure (TG inlet)	Yamatake JTG980A - Pressure Transmitter [14]
Steam pressure (TG outlet)	Yamatake JTD910A - Differential Pressure Transmitter [15]
Steam mass flow (TG inlet)	Yamatake JTD960A - Differential Pressure Transmitter [15]

### 5. Energy efficiency and energy power losses during TG turbine developed power variation

Change in TG steam turbine energy efficiency and energy power losses during the turbine developed power variation was presented in three operating points from Table 2 – operating points 1, 3 and 5. Obtained conclusions and trends are also valid for the other TG steam turbine operating points.

#### 5.1. Developed power variation for operating point 1

Change in energy efficiency for TG turbine in operating point 1 (Table 2), during the developed power variation is shown in Fig. 3. Increase in turbine developed power causes an increase in energy efficiency until the maximum value, after which follows a decrease in turbine energy efficiency. Maximum turbine energy efficiency is obtained at power of 2700 kW (70.13 % of maximum turbine power) and amounts 67.82 %. At the highest turbine load of 3850 kW, energy efficiency amounts 65.72 % in this operating point.

Turbine energy efficiency in each operating point, as well as in operating point 1, is calculated by using equation (9). For each operating point, energy efficiency change is affected only with the change in steam specific enthalpy after real polytropic expansion ( $h_2$ ) which is calculated according to equation (7). Steam mass flow through the TG turbine in equation (7) is calculated by using the reversed equation (5) where the turbine power is known, and steam mass flow is an unknown variable. Values of steam specific enthalpy after real polytropic expansion ( $h_2$ ) decreases in the turbine power range from 500 kW until the 2700 kW, because the intensity of increase in turbine power is higher in comparison with an increase in steam mass flow through the turbine. In the turbine power range from 2700 kW until the highest turbine load of 3850 kW, steam specific enthalpy after real polytropic expansion ( $h_2$ ) increases because the intensity of increase in turbine power is lower in comparison to an increase in steam mass flow through a turbine in that operating area.

TG steam turbine load depends on ship electrical consumers and their current needs for the electrical power. In operating point 1, TG steam turbine energy efficiency during LNG carrier exploitation amounts only 56.13 % what is much lower energy efficiency than possible maximum one for this operating point. To obtain better energy efficiencies of TG steam turbine in exploitation, it can be recommended that TG turbine should be more loaded, but not more than 2700 kW.

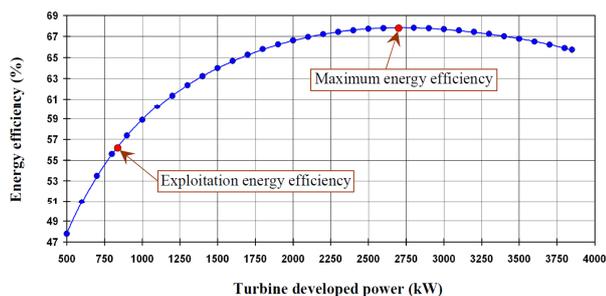


Fig. 3. Steam turbine energy efficiency change during the developed power variation for operating point 1

TG steam turbine energy power loss is calculated by using equation (8) for each observed operating point. Turbine energy power loss is the most influenced by steam mass flow through the turbine. Continuous increase in steam mass flow during the TG turbine power increase from 500 kW to 3850 kW causes a continuous increase in turbine energy power loss, Fig. 4.

During LNG carrier exploitation in operating point 1, TG steam turbine energy power loss amounts 648 kW, while at TG turbine maximum energy efficiency in this operating point (at turbine developed power of 2700 kW) turbine energy power loss amounts 1281.16 kW. At maximum turbine power of 3850 kW, energy power loss is the highest and amounts 2008 kW.

For TG steam turbine is not valid a conclusion that the lowest energy power losses are obtained at the highest energy efficiency.

TG steam turbine developed power variation showed that energy power losses are proportional to turbine load - higher load results with the higher energy power losses and vice versa. Energy power losses are not proportional to the energy efficiency of the TG steam turbine.

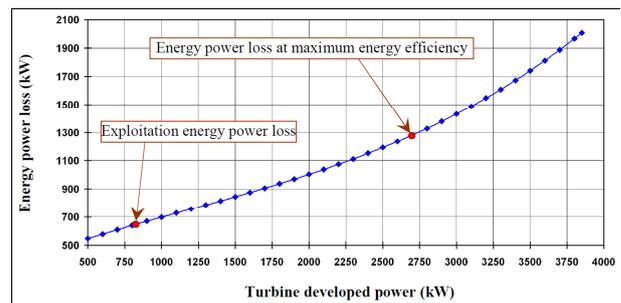


Fig. 4. Steam turbine energy power loss change during the developed power variation for operating point 1

#### 5.2. Developed power variation for operating point 3

Change in energy efficiency for TG turbine in operating point 3 (Table 2), during the developed power variation is shown in Fig. 5. As in observed operating point 1, an increase in turbine developed power causes an increase in energy efficiency until the maximum value, after which follows decrease in turbine energy efficiency.

In operating point 3, maximum energy efficiency is obtained also at turbine developed power of 2700 kW and amounts 66.50 %. For this operating point, at the highest turbine load of 3850 kW, energy efficiency amounts 64.44 %, while during LNG carrier exploitation turbine energy efficiency amounts only 53.84 %. The reasons for such TG turbine energy efficiency change are identical as in operating point 1 described earlier.

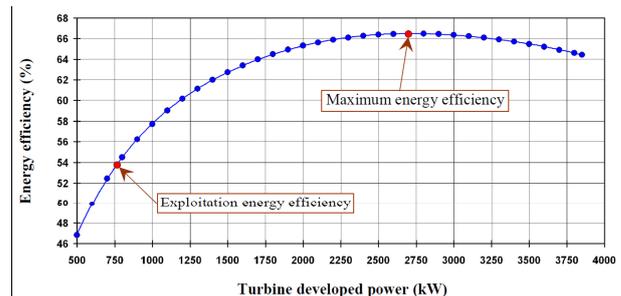


Fig. 5. Steam turbine energy efficiency change during the developed power variation for operating point 3

Continuous increase in steam mass flow during the TG turbine power increase from 500 kW to 3850 kW causes a continuous increase in turbine energy power loss, as presented in Fig. 6, also in TG turbine operating point 3.

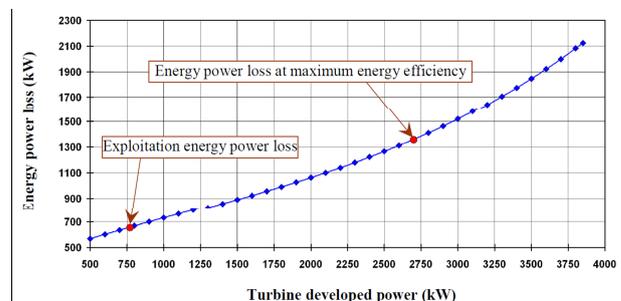


Fig. 6. Steam turbine energy power loss change during the developed power variation for operating point 3

TG steam turbine energy power loss during LNG carrier exploitation in operating point 3 amounts 656.86 kW. At maximum energy efficiency (2700 kW) turbine energy power loss amounts 1360.24 kW, while at maximum turbine power of 3850 kW, energy power loss is the highest and amounts 2124.40 kW in this turbine

operating point. As in TG turbine operating point 1, energy power losses are proportional to turbine load - higher load results with the higher energy power losses and vice versa.

### 5.3. Developed power variation for operating point 5

The same trends and conclusions obtained from TG steam turbine operating points 1 and 3 are also valid for operating point 5 (Table 2). In operating point 5 maximum turbine energy efficiency amounts 69.37 % and as before, is obtained at turbine developed power of 2700 kW. At the highest turbine load (3850 kW) in this operating point energy efficiency is 67.22 %, while during LNG carrier exploitation TG turbine energy efficiency is 59.50 %, Fig. 7. TG turbine operating point 5 also confirmed conclusion that energy power losses are proportional to turbine load - higher load results with the higher energy power losses and vice versa, Fig. 8.

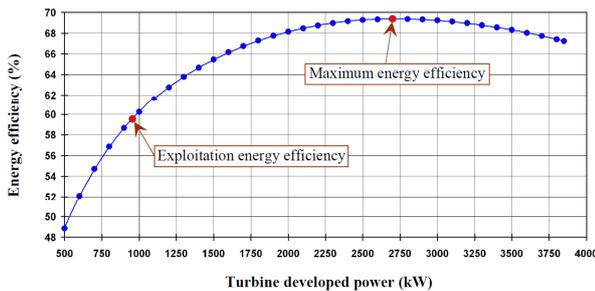


Fig. 7. Steam turbine energy efficiency change during the developed power variation for operating point 5

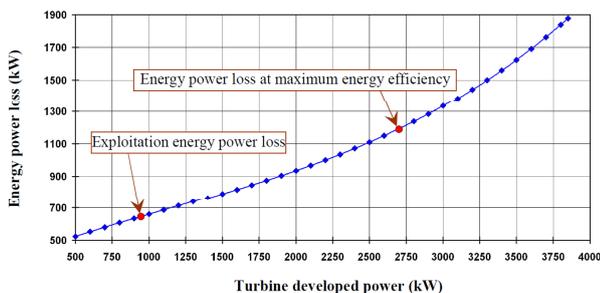


Fig. 8. Steam turbine energy power loss change during the developed power variation for operating point 5

## 6. Conclusions

The paper presents numerical analysis of TG steam turbine energy efficiency and energy power losses change during the variation in turbine developed power. Measurements were performed in five different TG steam turbine operating points and analysis is presented in three randomly selected operating points, but major conclusions are valid in each of them.

Analyzed TG steam turbine energy efficiency increases from 500 kW to 2700 kW of developed power and maximum energy efficiency was obtained at 70.13 % of maximum turbine power (at 2700 kW) in each operating point. From 2700 kW until the maximum of 3850 kW, TG turbine energy efficiency decreases. Increase and decrease in TG turbine energy efficiency is caused by an uneven intensity of increase in turbine power and steam mass flow. For all observed operating points, turbine energy efficiency in LNG carrier exploitation is approximately 10 % or more lower than the maximum obtained ones.

TG steam turbine energy power losses are proportional to turbine load - higher load results with the higher energy power losses and vice versa. The main reason for continuous increase in turbine energy power losses during the developed power increase are found in continuous increase in steam mass flow through the turbine.

## 7. Acknowledgment

The authors would like to extend their appreciations to the main ship-owner office. This work has been fully supported by the Croatian Science Foundation under the project IP-2018-01-3739.

## NOMENCLATURE

### Abbreviations:

LNG Liquefied Natural Gas  
TG Turbo-generator

### Latin Symbols:

$\dot{E}$  stream flow power, kJ/s  
 $h$  specific enthalpy, kJ/kg  
 $\dot{m}$  mass flow rate, kg/s  
 $p$  pressure, MPa  
 $P$  power, kJ/s  
 $\dot{Q}$  heat transfer, kJ/s  
 $s$  specific entropy, kJ/kg-K

### Greek symbols:

$\eta$  efficiency, -

### Subscripts:

en energy  
IN inlet  
OUT outlet  
PL power loss

## 8. References

- [1] Schinas, O., Butler, M.: *Feasibility and commercial considerations of LNG-fueled ships*, Ocean Engineering 122, p. 84–96, 2016. (doi:10.1016/j.oceaneng.2016.04.031)
- [2] 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)
- [3] Bloch, H. P., Singh, M. P.: *Steam turbines-Design, Applications and Re-rating*, 2<sup>nd</sup> edition, The McGraw-Hill Companies, Inc., 2009.
- [4] Baldi, F., Ahlgren, F., Melino, F., Gabriellii, C., Andersson, K.: *Optimal load allocation of complex ship power plants*, Energy Conversion and Management 124, p. 344–356, 2016. (doi:10.1016/j.enconman.2016.07.009)
- [5] 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)
- [6] Hafdhi, F., Khir, T., Ben Yahyia, A., Ben Brahim, A.: *Energetic and exergetic analysis of a steam turbine power plant in an existing phosphoric acid factory*, Energy Conversion and Management 106, p. 1230–1241, 2015. (doi:10.1016/j.enconman.2015.10.044)
- [7] 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, p. 121–131, 2018. (doi:10.31217/p.32.1.15)
- [8] 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)
- [9] *Final drawing for generator turbine*, Shinko Ind. Ltd., Hiroshima, Japan, 2006., internal ship documentation
- [10] 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)
- [11] Lemmon, E.W., Huber, M.L., McLinden, M.O.: *NIST reference fluid thermodynamic and transport properties-REFPROP*, version 8.0, User's guide, Colorado, 2007.
- [12] 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)
- [13] <https://www.greisinger.de>, (accessed 15.10.18.)
- [14] <http://www.industriascontrolpro.com>, (accessed 15.10.18.)
- [15] <http://www.krtproduct.com>, (accessed 12.10.18.)

**XVI INTERNATIONAL SCIENTIFIC CONGRESS**

**WINTER SESSION**

**13 - 16.03.2019, BOROVELS BULGARIA**



**MACHINES.**  
**TECHNOLOGIES.**  
**MATERIALS 2019**  
**PROCEEDINGS**

**VOLUME I**  
**MACHINES. TECHNOLOGIES.**  
**MATERIALS**

**ISSN 2535-0021 (PRINT)**

**ISSN 2535-003X (ONLINE)**

**SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING - INDUSTRY 4.0  
BULGARIA**

INTERNATIONAL SCIENTIFIC CONFERENCE  
**MACHINES. TECHNOLOGIES. MATERIALS**

13-16.03.2019, BOROVEDS, BULGARIA

# PROCEEDINGS

YEAR III, ISSUE 1 (12), BOROVEDS, BULGARIA 2019

**VOLUME I**  
**MACHINES. TECHNOLOGIES. MATERIALS**

ISSN 2535-0021 (PRINT)  
ISSN 2535-003X (ONLINE)

PUBLISHER:

**SCIENTIFIC TECHNICAL UNION OF MECHANICAL  
ENGINEERING  
INDUSTRY-4.0**

108, Rakovski Str., 1000 Sofia, Bulgaria  
tel. (+359 2) 987 72 90,  
tel./fax (+359 2) 986 22 40,  
office@mtmcongress.com  
www.mtmcongress.com

# INTERNATIONAL EDITORIAL BOARD

**Chairman:** Prof. DHC Georgi Popov

**Members:**

Acad. Ivan Vedyakov	RU
Acad. Yuriy Kuznetsov	UA
Prof. Aleksander Mihaylov	UA
Prof. Anatoliy Kostin	RU
Prof. Adel Mahmud	IQ
Prof. Ahmet Ertas	TR
Prof. Andrzej Golabczak	PL
Prof. Boncho Bonev	BG
Prof. Gennady Bagluk	UA
Prof. Detlef Redlich	DE
Prof. Dipten Misra	IN
Prof. Dmitry Kaputkin	RU
Prof. Dmitry Dmitriev	UA
Prof. Eugene Eremin	RU
Prof. Ernest Nazarian	AM
Prof. Juan Alberto Montano	MX
Prof. Esam Husein	KW
Prof. Ilir Doci	KO
Prof. Ivo Malakov	BG
Prof. Katia Vutova	BG
Prof. Krasimir Marchev	USA
Prof. Leon Kukielka	PL
Prof. Lyudmila Ryabicheva	UA
Prof. Milan Vukcevic	ME

**Vice Chairman:** Prof. Dr. Eng. Tsanka Dikova

Prof. Mihail Aurel Titu	RO
Prof. Mladen Velez	BG
Prof. Mohamed El Mansori	FR
Prof. Movlazade Vagif Zahid	AZ
Prof. Nikolay Dyulgerov	BG
Prof. Oana Dodun	RO
Prof. Olga Krivtsova	KZ
Prof. Peter Kostal	SK
Prof. Raul Turmanidze	GE
Prof. Renato Goulart	BR
Prof. Roumen Petrov	BE
Prof. Sasho Guergov	BG
Prof. Seiji Katayama	JP
Prof. Sergej Dobatkin	RU
Prof. Sergej Nikulin	RU
Prof. Stefan Dimov	UK
Prof. Svetan Ratchev	UK
Prof. Svetlana Gubenko	UA
Prof. Sveto Cvetkovski	MK
Prof. Tale Geramitchioski	MK
Prof. Vadim Kovtun	BY
Prof. Viktor Vaganov	RU
Prof. William Singhose	USA
Prof. Yasar Pancar	TR
Prof. Wu Kaiming	CN

# CONTENTS

## SECTION “MACHINES”

<b>SPATIAL GEARING: KINEMATIC CHARACTERISTICS OF THE INSTANTANEOUS CONTACT</b> Assoc. Prof. Abadjieva E. PhD., Prof. Sc. D. Abadjiev V. PhD. ....	5
<b>OPTIMISATION OF GEAR GEOMETRICAL PARAMETERS USING KISSOFT</b> Emre Can, Mehmet Bozca .....	10
<b>FINITE ELEMENTS METHOD MODELLING OF ROLLING BEARINGS</b> Mustafa Koç, Mehmet Bozca .....	14
<b>SUBSTITUTION OF GEAR-BAR MECHANISM WITH BAR MECHANISM ON THE INFEED MECHANISM OD BOTTLE WASHER</b> Spec. Sci. Vidak Šabanović , Prof. Dr. Goran Ćulafić .....	18
<b>NUMERICAL ANALYSIS OF TURBO-GENERATOR STEAM TURBINE ENERGY EFFICIENCY AND ENERGY POWER LOSSES CHANGE DURING THE VARIATION IN DEVELOPED POWER</b> PhD. Mrzljak Vedran, PhD. Poljak Igor, Prof. PhD. Prpić-Oršić Jasna .....	22
<b>INFLUENCE OF THE AMBIENT TEMPERATURE CHANGE ON STEAM PRESSURE REDUCTION VALVE EXERGY DESTRUCTION AND EXERGY EFFICIENCY</b> PhD. Mrzljak Vedran, PhD. Poljak Igor, PhD. Orović Josip, Prof. PhD. Prpić-Oršić Jasna .....	26
<b>COMPARISON OF NUMERICAL METHODS FOR MODELING THE EFFECT OF EXPLOSION ON PROTECTIVE STRUCTURES</b> PhD.Bisyk S., PhD.Davydovskiy L., PhD.Hutov I., Ass. Prof. PhD. Slyvinskyi O., M.Sc. Aristarkhov O., Prof. PhD. Lilov .....	30

## SECTION “TECHNOLOGIES”

<b>МОДЕЛИРОВАНИЕ РАДИАЛЬНО-СДВИГОВОЙ ПРОКАТКИ АУСТЕНИТНОЙ НЕРЖАВЕЮЩЕЙ СТАЛИ AISI-321 С ЦЕЛЬЮ ОПРЕДЕЛЕНИЯ ОПТИМАЛЬНЫХ ТЕХНОЛОГИЧЕСКИХ ПАРАМЕТРОВ ДЛЯ ПОЛУЧЕНИЯ УМЗ-СТРУКТУРЫ</b> Д.т.н., проф. Найзабеков А.Б., к.т.н., доцент Лежнев С.Н., PhD Арбуз А.С., PhD Панин Е.А. ....	34
<b>A-TIG WELDING AS A SOLUTION FOR NICKEL AND MANGANESE SAVINGS IN DUPLEX STAINLESS STEEL WELDED JOINTS</b> Ph.D. Bušić M., Ph.D. Jurica M., Prof. Ph.D. Garašić I., Prof. Ph.D. Kožuh Z. ....	38
<b>CALCULATING CONTOURING TOOL BY FINITE DIFFERENCE METHOD</b> Prof. Dr. Kikvidze O., Assoc.Prof. Dr.Sakhanberidze N., senior teacher Kordzadze L .....	42
<b>AN EXPERIMENTAL STUDY FOR THERMAL AND HYDRAULIC PERFORMANCE OF A MINI CHANNEL SHELL AND TUBE HEAT EXCHANGER USING LOW CONCENTRATION NANOFLUIDS PREPARED WITH AL<sub>2</sub>O<sub>3</sub> NANOMATERIALS</b> M.Sc. Mehmet Senan Yilmaz, Assist. Prof. PhD. Hasan Kucuk, Res. Assist. PhD. Murat Unverdi .....	47
<b>DETERMINATION OF GEOMETRIC PARAMETERS OF GRADIENT STRUCTURES FORMED IN OPTICAL GLASS BY THE ELECTRON BEAM METHOD</b> Grechana O., Skoryna E., PhD Bondarenko I. ....	54
<b>UNIVERSAL THERMAL MICROSYSTEMS BASED ON SILICON CARBIDE</b> Phd Student Eng Daniil Evstigneev, Prof. Grand PhD in Engineers Science Eng . Vladimir Karachinov, Master's degree courses Eng. Anton Varshavsiy, PhD Applicant Eng. Petrov Dmitriy .....	59
<b>DIAGNOSTICS OF THERMAL PIPES WITH SYMMETRIC STRUCTURE THERMAL IMPACT METHOD</b> Grand PhD in Engineers Science Eng . Vladimir Karachinov, Phd Student Eng Daniil Evstigneev, Prof., PhD in Engineering sciences Eng. Alexander Abramov, , PhD Applicant Eng. Petrov Dmitriy .....	62
<b>AN EFFICIENT COMBINATION OF WATER TREATMENT AND ELECTRICITY GENERATION BY DIFFERENT MICROORGANISMS</b> Assoc. Prof. PhD M. Nicolova, Assoc. Prof. PhD I.Spasova, Assoc. Prof. PhD P. Georgiev, Prof. PhD V. Groudeva, Prof. DSc S. Groudev .....	65
<b>AN EXPERIMENTAL STUDY ON CUTTING FORCES AND SURFACE ROUGHNESS IN MQL MILLING OF ALUMINUM 6061</b> B.Sc. Conger D.B., M.Sc. Emiroglu U., Assoc. Prof. M.Sc. Uysal A. PhD., Prof. M.Sc. Altan E. PhD. ....	67
<b>FLANK WEAR OF SURFACE TEXTURED TOOL IN DRY TURNING OF AISI 4140 STEEL</b> Mech. Eng. Eskizara H. B., R. Assist. Emiroglu U., Prof. Dr. Altan E. ....	71
<b>EFFECTS OF PROCESS PARAMETERS IN PLASMA ARC CUTTING ON STAINLESS STEELS AND STRUCTURAL STEEL</b> Erbilen M., Çakır O. ....	75
<b>ГЛОБАЛЕН МАКСИМУМ – ПРАКТИЧЕСКИ ОЦЕНКИ В ОБЛАСТТА НА МЕТАЛУРГИЧНИЯ ДИЗАЙН</b> Йордан Калев, Николай Тончев .....	78

<b>TECHNOGENIC RAW MATERIALS FOR THE PRODUCTION OF MAGNESIUM AND SILICON-CONTAINING COMPOUNDS</b> Candidate of technical sciences Shayakhmetova R.A., PhD student Mukhametzhanova A.A. , Candidate of geological and mineralogical sciences Samatov I.B.1, doctor of chemical sciences, assoc. prof. Akbayeva D.N. ....	85
<b>GEOMETRIC METHOD FOR DETERMINING RADIANT HEAT EXCHANGE IN VACUUM FURNACE</b> PhD Eng. Angelova E, Assoc.Prof. PhD Eng. Ronkova V., Assoc.Prof. PhD Eng. ....	88
<b>HOME PAGES, DEFINITION AND CLASSIFICATION OF THEIR ELEMENTS AND THEIR DISPLAY ON THE USERS' COMPUTERS</b> Asst. Prof. Bidjovski Goran PhD. ....	91
<b>DAMAGE FUNCTIONS EVALUATION COHERENT TO WEAPON TARGET INTERACTION</b> Assistant M.Sc. Ing. Katsev I., Prof. PhD. Evlogiev S. ....	96
<b>СТЕГНАЛИЗ НА ИЗОБРАЖЕНИЯ ЧРЕЗ ИЗПОЛЗВАНЕ НА МУЛТИ-КЛАСИФИКАТОР</b> Диан Велев, Ст. Павлова, полк. проф. д-р инж. И.Лилов, И. Кичуков .....	99
<b><u>SECTION "MATERIALS"</u></b>	
<b>INCREASE IN STRENGTH PROPERTIES OF LOW-CARBON STEELS DUE TO STRUCTURAL TRANSFORMATIONS AT DEFORMATION BY ROTARY SWAGING</b> Prof., Dr.Sci. Dobatkin S.V., Dr. Rybalchenko O.V., Tokar A.A., Prof., Dr.Sci. Odessky P.D., Lunev V.A., Morozov M.M., Dr.Sci. Yusupov V.S. ....	102
<b>FEATURES OF STRUCTURE FORMATION AND MECHANICAL BEHAVIOR OF METALLIC MATERIALS UNDER CONDITIONS OF APPLICATION OF GRADIENT DEFORMATIONS</b> A.G. Raab - Ph.D., A.P. Zhilyaev – Dr. Sci, I.S.Kodirov, G.N. Aleshin - Ph.D. ....	105
<b>TRIBOLOGICAL PROPERTIES OF COMMERCIAL PURE COPPER AND A LOWALLOYED CHROMIUM BRONZE</b> Lead. Res., Dr. Semenov V.I., PhD Stud. Alemayehu D.B., Prof., Dr. Lin H.-C., Lead. Res., Prof. Raab G.I.1, Prof., Dr. Huang S.-J., Prof., Dr. Chun Chiu .....	107
<b>COMPARATIVE TRIBOLOGICAL PROPERTIES OF AZ91D MAGNESIUM ALLOY AFTER STRENGTHENING BY SiC POWDER AND AFTER SEVERE PLASTIC DEFORMATION</b> Lead. Res., Dr. Semenov V. I., Prof., Dr. Lin H.-C., Prof. Shuster L.Sh., Prof. N. Tontchev, Prof., Dr. Chun Chiu, Prof., Dr. Huang S.-J. ....	111
<b>PREPARATION AND PROPERTIES OF CARBON ADSORBENTS BASED ON PLANT RAW MATERIALS AND POLYMERIC WASTE</b> Доц. к.т.н. Нистратов А.В., проф. д.т.н. Клушин В.Н. ....	115
<b>GEOPOLYMERS BASED ON BULGARIAN RAW MATERIALS – PRELIMINARY STUDIES</b> Ass. Prof. Dr. Eng. Nikolov A. ....	120
<b>CRACK RESISTANCE EVALUATION FOR Al+3.5% Mg ALLOYS BY MEASUREMENTS OF ULTRASONIC VELOCITIES AND HARDNESS</b> Assoc. Prof. PhD Alexander Popov, PhD. Eng. Georgy Dobrev .....	124
<b>DETERMINATION OF GEYSER EVENTS IN A THERMOSYPHON WORKING WITH GRAPHENE OXIDE NANOFUID</b> Kujawska A., Zajaczkowski B., Woluntarski M., Buschmann M.H. ....	128
<b>GRADIENT STRUCTURE AND METHODS FOR THEIR PREPARATION</b> G.I. Raab – Dr.Sci, A.G. Raab - Ph.D., A.P. Zhilyaev – Dr.Sci .....	132
<b>SURFACE HARDENING OF METALLIC MATERIALS BY USE OF COMBINED MAT-FORMING TREATMENT AND ELECTROSPARK DOPING</b> Prof. Bagliuk G., Dr. Sc., Makovey V., PhD. Borodiy Yu., PhD. ....	134
<b>INFLUENCE OF THE SYNTHESIS METHOD ON THE CRYSTALLINE STRUCTURE, PHASE COMPOSITION AND PROPERTIES OF TiCrFeNiCuC EQUIATOMIC ALLOYS</b> M.Sc. Marych M., Mamonova A., PhD., Prof. Bagliuk G., Dr. Sc. ....	138
<b>FATIGUE ANALYSIS APPROACHES FOR VEHICLE COMPONENTS MADE OF RUBBER</b> M.Sc. Tomposne Szüle V. ....	141
<b>RECYCLED TIRE RUBBER MODIFIED BITUMENS FOR IMPROVING THE QUALITY OF THE ROAD CONSTRUCTIONS IN ALBANIA</b> Dhoska K. PhD., Markja I. PhD. ....	145
<b>SURFACE TREATMENTS AND COATINGS APPLICATION ON THE ALUMINUM PRODUCTS</b> PhD. Markja I, PhD. Dhoska K., Prof. As. Elezi D. ....	147
<b>IDENTIFICATION OF TEKRONE POLYMER MATERIAL</b> д. н. гос. упр., к.т.н., проф. Кобец А., к.т.н. доц. Деркач А., к.т.н. доц. Кабат О., асп. Муранов Е., инж. Шаповал А. ....	149