University of Maribor

Faculty of Energy Technology

Journal of ENERGY TECHNOLOGY

Volume 12 / Issue 2

SEPTEMBER 2019

www.fe.um.si/en/jet.html

Journal of
ENERGY TECHNOLOGY

VOLUME 12 / Issue 2

Revija Journal of Energy Technology (JET) je indeksirana v bazah INSPEC© in Proquest's Technology Research Database.

The Journal of Energy Technology (JET) is indexed and abstracted in database INSPEC© and Proquest's Technology Research Database.

JOURNAL OF ENERGY TECHNOLOGY

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Fakulteta za energetiko, UNIVERZA V MARIBORU /
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Revija izhaja štirikrat letno v nakladi 100 izvodov. Članki so dostopni na spletni strani revije - www.fe.um.si/si/jet.html / The journal is published four times a year. Articles are available at the journal's home page - www.fe.um.si/en/jet.html.

Cena posameznega izvoda revije (brez DDV) / Price per issue (VAT not included in price): 50,00 EUR

Informacije o naročninah / Subscription information: http://www.fe.um.si/en/jet/subscriptions.html

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Fotografika, Boštjan Colarič s.p.

Naslovna fotografija / COVER PHOTOGRAPH

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Še nekaj desetletij nazaj smo ljudje verjeli v neuničjivost narave oziroma prepričanje, da s posegi vanjo ne povzročamo bistvene škode. Povečevanje števila ljudi na Zemlji ter posledično vedno večja poraba energije na prebivalca v svetu, požiganje pragozdov, so privedli do velikih ekoloških sprememb, kot sta taljenje ledenikov in višja povprečna temperatura ozračja. Energetske tehnologije in proizvodnja energetskih goriv bistveno vplivata na ekološke dejavnike. Zato je načrtovanje naprav, kjer je tudi ekološka oz. okoljevarstvena komponenta ena od primarnih komponent, bistvenega pomena za optimizacijo energetskih naprav v prihodnosti. Ljudje so prepoznali negativne posledice sprememb, ki jih povzročamo, zato se organizirajo v ekološka gibanja, in na posledice glasno opozarjajo. Večji korak v to smer bodo morali narediti tudi politiki, ki imajo za dosego sprememb več vzvodov.

Jurij AVSEC
odgovorni urednik revije JET

Dear Readers of the Journal of Energy Technology (JET)

Until a few decades ago, most people believed in the indestructibility of nature – that nature was so vast that it could not be significantly harmed. Increasing numbers of people on Earth, as well as increasing energy consumption per capita, have led to major ecological changes, such as glaciers melting and increasing average ambient temperatures. Also, actions such as the burning of forests are certainly not beneficial to the ecological situation. There have been major ecological movements, as well as many people who are aware of and very concerned about the consequences of ecological changes that are happening. Unfortunately, a significant number of politicians throughout the world are not yet sufficiently aware of the coming consequences. Energy technologies, including the production of fuels, have a significant impact on ecological factors, so designing plants in which the ecological or environmental element is one of the primary components is essential for optimizing energy installations in the future.

Jurij AVSEC
Editor-in-chief of JET

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Issue 2, September 2019
Type of article 1.01
www.fe.um.si/en/jet.html

PSPICE SIMULATIONS FOR SINGLE-PHASE RECTIFIERS FOR TESTING DC FUSES

PSPICE SIMULACIJE ZA ENOFAZNE USMERNIKE ZA TESTIRANJE DC VAROVALK

Adrian Plesca[1], Costica Nituca[1], Gabriel Chiriac[1ℜ], Zhiyuan Liu[2], Yingsan Geng[2]

Keywords: Power Rectifiers, Simulation, PSpice, DC fuse

Abstract

In this article, simulations were realized for different power rectifiers used for testing DC fuses. Using the OrCAD PSpice software, a single-phase uncontrolled bridge rectifier and a single-phase controlled bridge rectifier are simulated for different loads. From the data analysis, some important conclusions were realized regarding the form of the temperature waveforms in transient conditions and quasi-steady state thermal conditions.

Povzetek

V tem članku so bile izvedene simulacije za različne usmernike moči, ki se uporabljajo za preskušanje enosmernih varovalk. S programsko opremo OrCAD PSpice se simulirajo enofazni nenadzorovani mostni usmernik in enofazni mostični usmernik za različne obremenitve. Iz analize podatkov je bilo ugotovljenih nekaj pomembnih zaključkov glede oblike temperaturnih valov v prehodnih pogojih.

ℜ Corresponding author: Ph.D. Gabriel Chiriac, Tel.: +04 0727 645058, Mailing address: Bd. Dimitrie Mangeron, nr. 21- 23, 700050 IASI, Romania, E-mail address: gchiriac@tuiasi.ro

[1] 1 Technical University “Gheorghe Asachi” from Iasi, Faculty of Electrical Engineering, Bd. Dimitrie Mangeron, nr. 21- 23, 700050 IASI, Romania

[2] Xi’an Jiaotong University, Department of Electrical Engineering, 28 Xianning W Rd, JiaoDa ShangYe JieQu, Beilin Qu, Xian Shi, Shaanxi Sheng, China.

1 INTRODUCTION

Considered to be simple and well-known devices after more than a century of research and development, certain phenomena of fuses' operating are not totally known and understood. The construction of the fuses, their components, geometry, and basic operation are well known and described in the bibliography *[1, 2, 3]*. The main components are the fusible and the quenching medium with the role of overcurrent protection and disconnection of the electric arc that forms in the fuse, respectively. A very important aspect is to convey the heat developed into the fuse during its protection operating. In the case of normal operating mode, the energy due to the Joule effect into the fuse link is released to the surrounding medium, and a thermal balance is established. In the case of high amplitude overload, the fuse holds more energy than can be released, increasing the internal temperature *[4-10]*.

Utilization of the DC fuses are expanding due to development of photovoltaic plants, electric vehicles, and DC microgrids, but in the case of Direct Current, the cutting-off of short-circuit current by using fuses is more difficult *[11, 12].* The existing protection in the DC section of the photovoltaic plant consists of fuses that are not sufficient to protect against over-current due to their slow reaction *[13]*. Some studies compare how adding fuses to the DC link affects the operating times of fuses and the total energy in the circuit *[14, 15].* Thus, testing the DC fuses becomes important for a large domain *[16].* In this aspect, it is considered that the semiconductor devices are to support different types of stresses, including mechanical, thermal, electrical, environment and incident radiations, with effects in their operating and reliability *[17-19]*.

In this article, using the OrCAD PSpice software, different simulations were realized, highlighting the differences between the waveforms in the case of the variation of some elements of the power rectifiers used for testing DC fuses. A single-phase uncontrolled bridge rectifier and a single-phase controlled bridge rectifier are considered for the simulations.

2 THERMAL ASPECTS OF POWER SEMICONDUCTOR DEVICES

The operation of the power semiconductor devices in different working conditions, both steady-state and transient, is accompanied by the heating of the device due to the dissipated power.

The simplest situation is the heating by a rectangular pulse power. In the case of power pulses with other waveforms, the heating estimation can be achieved by having an approximation with the rectangular pulses. The periodical power pulses can be replaced with rectangular pulses. A more exact estimation of the diode heating in the case of certain power pulses can be realized with OrCAD PSpice software.

Therefore, simulations and their analysis are considered using OrCAD PSpice software for two types of single phase bridge rectifiers, which can be used in a fuse test bench (uncontrolled and controlled rectifiers).

Waveforms of the power pulses and of the junction temperatures are presented as elements of power rectifiers. The waveforms of the temperatures in the case of the quasi-stationary regime as also considered from the thermal point of view.

The unit of measurement for the power pulses waveforms is the Watt (considered for Y-axis), and for the temperatures is the Celsius degree, in contrast to the unit of measure Volt, which is presented on the graphs. This is because the thermal aspects were modelled for electrical circuits, and the specialized software preserves the units of measure of the electrical units.

P1, P2, and P3 denote the power pulses corresponding to the variation of the important parameters, while T1, T2, and T3 represent the temperatures, respectively.

3 PSPICE SIMULATIONS FOR THE SINGLE-PHASE UNCONTROLLED BRIDGE RECTIFIER

The variation of the power pulse waveforms P1, P2, and P3, depends on the variation of the resistive load. Thus, with increasing of the loads, the amplitude of the impulse will decrease, which implies a decreasing of the amplitudes of the junction temperatures T1, T2, and T3, and a decreasing of the temperature variation.

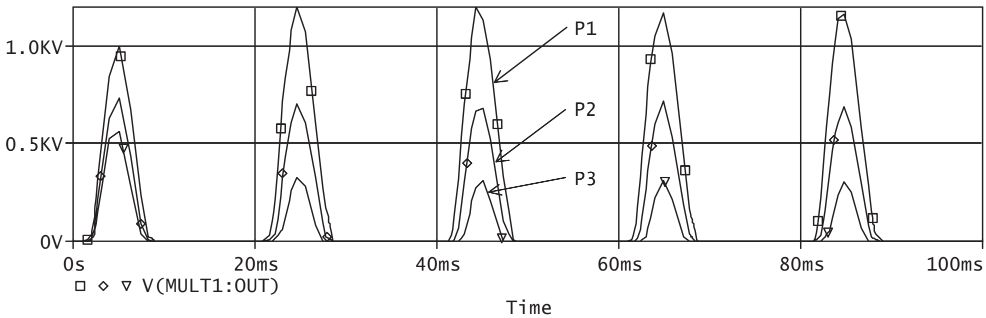

Figure 1: *Input power waveforms at load resistance variation with 10, 20, 50Ω*

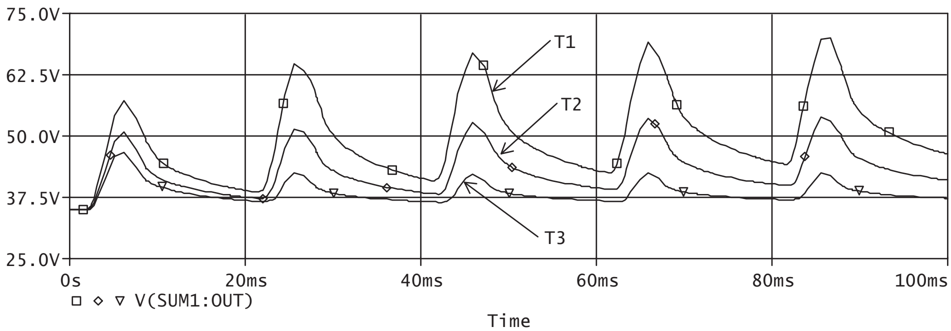

Figure 2: *Temperature waveforms of thermal transient conditions at load variation with 10, 20, 50Ω*

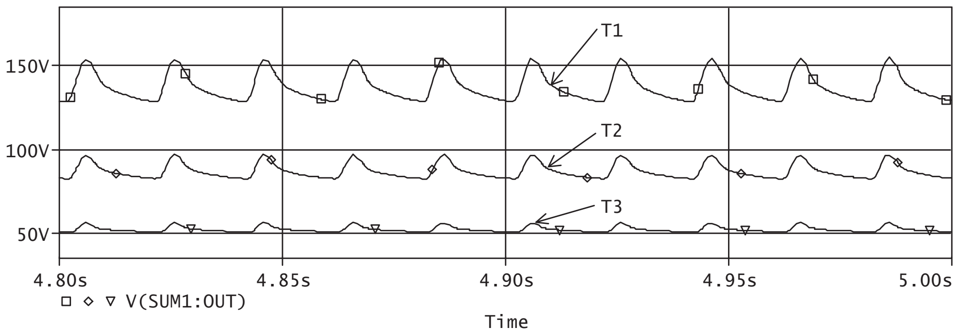

Figure 3: *Temperature waveforms of quasi-steady state thermal conditions at load variation with 10, 20, 50Ω*

In the quasi-stabilized regime, it can be seen that the differences between the temperatures corresponding to the values of the resistive load are increasing, but the temperature variation shapes and the tendency of the apparition of the thermal stabilized regime are maintained. The variation in time for the amplitudes of the temperatures is low. It is also seen, for the quasi-stabilized regime, that the maximum value of the T1 temperature, corresponding for a resistive load of 10Ω, surpasses the maximum admissible value for the junction, which is 125°C. Thus, there some protection measures or the increasing of the load are necessary, as in the case of the T2 and T3 temperatures.

4 PSPICE SIMULATIONS FOR THE SINGLE-PHASE CONTROLLED BRIDGE RECTIFIER

A simulation was realized considering the firing angle variation for the thyristors. It is observed that, as the firing angle increases, the power pulse decreased, and, thus, so does the temperature amplitude. The quasi-stabilized regime highlights the differences between the temperature amplitudes for the considered cases.

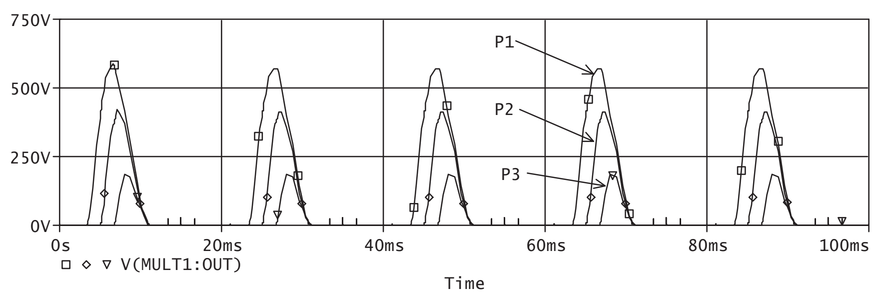

Figure 7: *Input power waveforms at firing angle variation with 60, 90, 120° el*

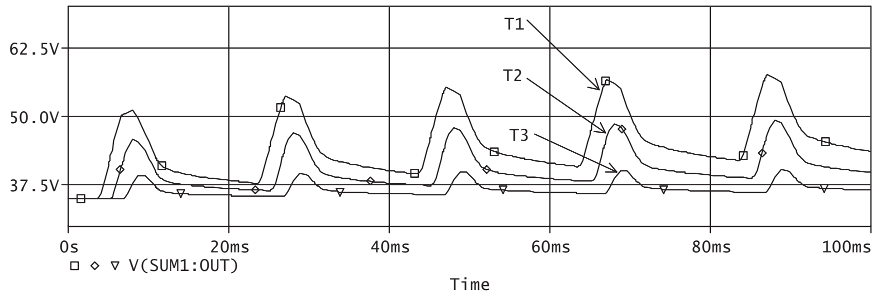

Figure 8: *Temperature waveforms of thermal transient conditions at firing angle variation with 60, 90, 120° el*

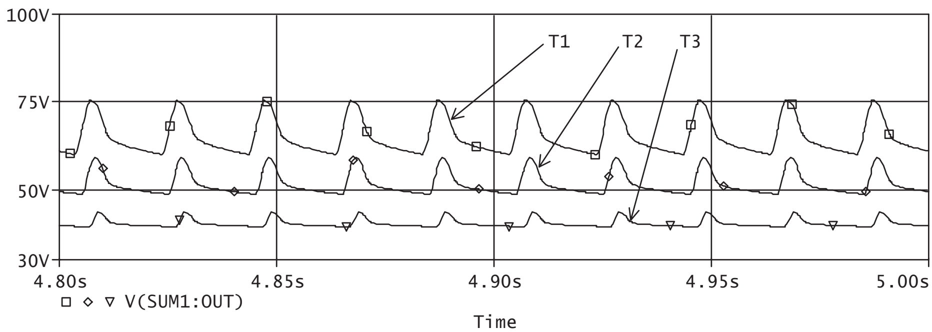

Figure 9: *Temperature waveforms of quasi-steady state thermal conditions at firing angle variation with 60, 90, 120° el*

5 CONCLUSIONS

From the above OrCAD PSpice simulations, some conclusions can be made:

- The power impulse form, and thus the form of the corresponding temperature signals, depends on the load type and value, and on the control angle for the controlled rectifiers;
- With the increasing of the load value (both resistive or inductive ones), a decreasing of the power pulse and a decreasing of the temperature values can be observed;
- In a quasi-stabilized regime the variation of the temperature is much lower at high values of the load, both for resistive or inductive loads;
- In the case of the controlled rectifiers, at high values of the control angle, a decrease of the power pulses is observed, with results in decreasing of the temperature values; in the case of the quasi-stabilized regime, the variation of the temperatures is also lower compared to the case of the low control angle values.

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Journal of Energy Technology

JET Volume 12 (2019) p.p. 19-26
Issue 2, September 2019
Type of article 1.01
www.fe.um.si/en/jet.html

URBAN GREENING AS A COOLING TOOL TOWARDS THE HEAT ISLAND EFFECT

OZELENJEVANJE MEST KOT ORODJE ZA ZMANJŠEVANJE UČINKA TOPLOTNEGA OTOKA

Anja Bubik[1ℜ], Lucija Kolar[2]

Keywords: air temperature, greening principle, heat island effect, pilot study, urban environment

Abstract

Roofs, as the top layer of the urban environment, significantly contribute to overheating and creating a heat island, which is known as one of the most critical global warming effects. There are several ways to mitigate the effects of such heat islands, among which greening is the most natural, sustainable solution, and also economically acceptable and socially valued principle. Vegetation is known to significantly improve the urban microclimate and directly reduce the effect of the urban thermal core.

At the Environmental Protection College in collaboration with the Institute Complementarium, both based in Slovenia, we conducted a pilot experiment to evaluate greening, in our case the principle of a flat green roof, as an effective and promising approach for reducing an urban heat island and its effects. Temperature measurements have shown that the green surface can lower both the surface temperature itself (e.g., the roof) and the air surrounding the green surface. We have presented an initial pilot case, which is planned to be upgraded in the future to confirm our current results and assumptions. In addition, we summarized data showing that Velenje is, in view of annual higher average temperatures, a highly suitable urban environment for the introduction of greening principles on the top urban layers.

ℜ Corresponding author: Anja Bubik, PhD, Environmental Protection College, Trg mladosti 7, 3320 Velenje, Tel: +386 3 898 64 24, E-mail address: anjabubik.vsvo@gmail.com

[1] Environmental Protection College, Trg mladosti 7, 3320 Velenje

[2] Complementarium, Institute for Research of Nature and Development of Environmental technologies, Lopata 60, 3000 Celje

Povzetek

Strehe kot zgornja plast mestnega okolja največ prispevajo k pregrevanju in ustvarjanju mesta kot toplotnega otoka. Le-ta je znan kot eden najpomembnejših učinkov globalnega segrevanja. Obstaja več načinov blaženja učinkov toplotnega otoka, med katerimi je ozelenjevanje najbolj naraven, trajnostno usmerjen način ter hkrati ekonomsko sprejemljiv in družbeno zelo cenjen princip. Znano je, da vegetacija znatno izboljšuje mestno mikroklimo in neposredno zmanjšuje učinek urbanega toplotnega jedra.
Na Visoki šoli za varstvo okolja smo v sodelovanju z inštitutom Complementarium – oba sta locirana v Sloveniji - izvedli pilotni eksperiment, s katerim smo poskusili ovrednotiti ozelenjevanje, v našem primeru princip ravne zelene strehe, kot učinkovit in perspektiven pristop k zmanjševanju urbanega toplotnega otoka in njegovih učinkov. S temperaturnimi meritvami smo ugotovili, da lahko zelena površina znižuje tako temperaturo površine same (npr. strehe) kot tudi zraka v njeni bližnji okolici. Predstavili smo začetni pilotni primer, ki ga želimo v prihodnosti nadgraditi in tako pridobiti podatke, ki bodo naše rezultate in predpostavke potrdili. Hkrati pa smo izpostaviti podatke, ki kažejo, da je mesto Velenje glede na porast letnih povprečnih temperatur zelo primerno urbano okolje za vzpostavitev zelenih površin na zgornjih plasteh mestnega pokrova.

1 INTRODUCTION

The urban heat island is a very well-documented phenomenon related to climate change. It defines the effect by which near-surface air temperatures are higher in cities than in nearby suburban or rural areas, *[1], [2].* The annual mean air temperature of a city with one million people or more can be 1–3 °C warmer than its surroundings. Moreover, the difference can reach 12 °C in the evening, *[3]*. Due to the overheating of buildings, urban temperatures can be up to 5-7 °C higher than in rural areas, *[4]*.
Heat islands affect the environment and communities by increasing energy consumption for cooling, the peak electricity demand, air pollution by forming an inversion layer and greenhouse gas emissions, water pollution and heat-related illness and death, *[1], [2]*. Many cities are already taking actions to reduce urban heat island effects. They follow various development and conservation strategies concerning the natural environment and human health protection and, as a result, cities become more livable and economically stronger. The energy demand and living costs are lowered, and the comfort of citizens and social relationships are improved, *[3]*.

1.1 Urban cooling

In general, an increased number of planted trees and other vegetative areas can lower surface and air temperatures. Trees and vegetation are providing additional shade and cooling through the transpiration and evaporation processes. The installation of cool roofs or pavements reflects more solar energy and contributes to lower roof or pavement surface temperatures. The surrounding air is also cooled, *[2]*.
Green roofs have also been proven to reduce and mitigate heat islands. The solar radiation balance on green roofs is much more favourable compared to conventional roofs, as they reflect 27% of total solar radiation, 60% is absorbed by plants and 13% by soil, while conventional roofs absorb 100% of the solar radiation on their surfaces, *[4], [5].* For example, in Chicago, summertime surface temperatures on a green roof were compared with those on a neighbouring building. In the summer, the green roof surface temperature ranged from 33 to

48 °C, while the dark, conventional roof of the adjacent building reached 76 °C. The near-surface air temperature above the green roof was about 4 °C cooler than that over the conventional roof. A study in Florida determined the average maximum surface temperature of a green roof of 30 °C while the adjacent light-coloured roof had a temperature of 57 °C, *[3]*. In addition, green roofs can reduce building energy use by 0.7% compared to conventional roofs, reducing peak electricity demand and leading to savings, *[6]*, *[1]*. Temperature reduction and energy efficiency benefits are key contributors to the growing popularity of green roofs. For example, the North American green roof industry experienced an estimated 10% growth in 2016 over 2015, *[7]*. However, green roofs also provide other environmental and especially social benefits, which increase the quality of life and are essential reasons for personal greening construction decision.

2 PILOT PROJECT

Education and awareness efforts also help to improve the attitude to the problems of global warming. At the Environmental Protection College (EPC), in collaboration with the Institute Complementarium, we performed two student projects that raised awareness of environmental protection and improvement, and that emphasized the greening potential as a possible environmental solution, *[8]*. With the primary goal of increasing general knowledge about it in Slovenia, mostly in the Savinja statistical region, and of evaluating the effectiveness of the extensive greening principle in the urban environment (e.g. Velenje), we constructed two pilot models (Figure 1). Based on annual monitoring of different physical and chemical parameters and by observing the growth of selected plants in two models using different substrates, we concluded that the implementation of our pilot models in the selected urban environment was successful and has great potential for future urban planning, *[9]*.
One of the main goals of our one-year pilot study was also to determine, how the surface (substrate) and air temperatures (approx. 0.50 m above the green area and 3 m away from it) are changed due to the greening. Here, we summarized our results and compared them with public data of air temperatures in the city of Velenje and three other Slovenian cities.

Figure 1: *EPC model of extensive green roof at the beginning (A) and at the end (B) of the experiment*

2.1 Analysis and Results

Air and substrate temperatures were not directly measured on the roof, but on the balcony of the 2nd floor, below the roof, were the models were placed during the experiment. Temperatures (T) of two different substrates ($T_{sub\ A}$ and $T_{sub\ B}$) in separate models and air temperatures (T_{air}) approx. 0.50 m above the model and approx. 3 m away from it were measured. On average, T_{air} was for 4.09 °C and for 4.00 °C higher than for $T_{sub\ A}$ and $T_{sub\ B}$, respectively. The difference between $T_{sub\ A}$ and $T_{sub\ B}$ was not expected and was minimal; an average annual T_{sub} differs by less than 0.075 °C. Plant adaptation was the same in both models. We did not observe any changes that could be related to differences in T_{sub}. However, T_{air} above the models and T_{air} at least 3 metres away from them differ annually by 0.1 °C, which correlates to 0.57% (Figure 2). If we consider that the experiment was set up in the first year of the greening process, in which plants started to proliferate and grow more significantly in the 7th month (in March 2016), *[9]*, and that the tested green area was relatively small compared to real roofs, the temperature difference could be significant. Namely, until March 2016, an average T difference was only 0.06 °C (0.37%), while the main increase was detected since March 2016 and was 0.13 °C or 0.73%.

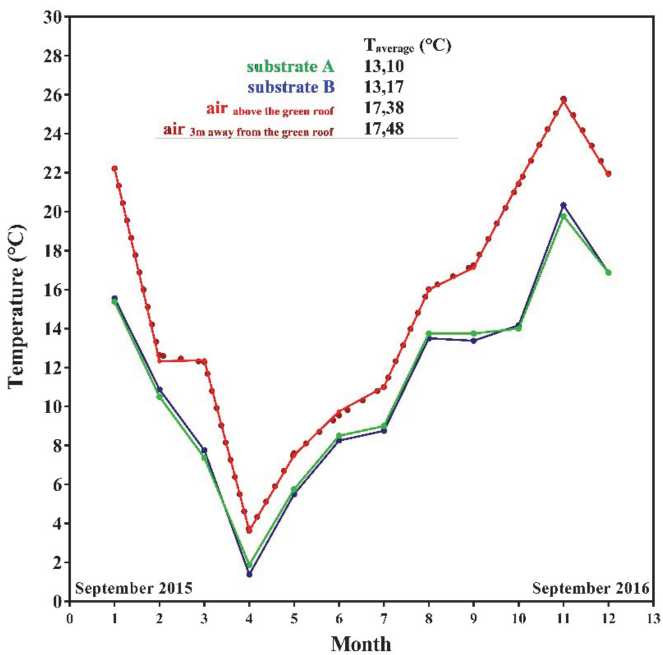

***Figure** 2: Average monthly temperature of two substrates (in blue and green) and approx. 0.50 m above the models (in light red, full line) and approx. 3 m away from them (in dark red, dashed line)*

In addition, we compared experimental monthly mean T_{air} with those measured at the automatic meteorological station (AMS) of the city of Velenje according to the standards of the World Meteorological Organization (2 m above the ground on as open a field as possible, overgrown with low grass) (Table 1). The temperature below the roof was on average 4.1 °C higher compared to public data from the AMS, and the temperature above the green models by 4.0 °C. Results indicated that the roofs are warmer and represent a significant factor for environment warming, especially urban environments. Still, the green area decreased T_{air} by 0.1 °C in our case and contributed to lower annual air temperatures above the green models (Figure 1, Table 1).

Table 1: *Comparison of average monthly air temperatures in Velenje*

Month	Velenje (°C) (experiment)^{1*}	Velenje (°C) (experiment)^{2**}	Velenje (°C) (AMS)	Δ T (°C) (1^{*}- AMS)	Δ T (°C) (2^{**}- AMS)
September 2015	21.8	21.8	15.4	6.4	6.4
October 2015	12.6	12.3	10.0	2.6	2.3
November 2015	12.3	12.4	6.5	5.8	5.9
December 2015	3.6	3.6	2.6	1.0	1.0
January 2016	7.6	7.5	0.8	6.8	6.7
February 2016	9.6	9.8	4.8	4.8	5.0
March 2016	11.0	11.0	6.3	4.7	4.7
April 2016	16.1	16.0	11.6	4.5	4.4
May 2016	17.3	17.1	14.7	2.6	2.4
June 2016	21.6	21.5	18.8	2.8	2.7
July 2016	25.8	25.7	21.7	4.1	4.0
August 2016	22.0	21.9	19.2	2.8	2.7

(experiment)^{1*} *approx. 0.50 m above the green roof model*
(experiment)^{2**}means T_{air} *approx. 3 m away from the green roof model*

We also calculated how our models reduce daily temperature variations between the four seasons (Figure 3). It was already confirmed in a Greek study that a green roof reduces daily temperature variation and thermal ranges between summer and winter, *[4]*. Our results indicate that daily temperatures above the models varied in winter/summer by 3.94/3.98 °C and 3 m away from it for 3.95/4.29 °C (Figure 3). The difference was negligible during the winter but increased during the summer (from 3.98 to 4.29 °C; arrows on Figure 3). This observation is logical, since the T difference was also higher and more obvious in the summer. Temperature variation above the green roof model was lower by approx. 1.24% compared to the variation 3 m away from them.

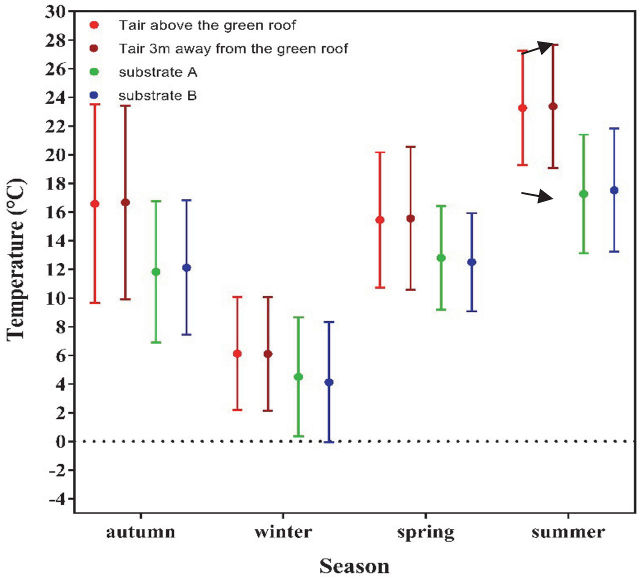

Figure 3: *Season temperature variation in both models (in blue and green) and approx. 0.50 m above the models (in light red) and approx. 3 m away from them (in dark red)*

In addition, we compared monthly and annual temperatures for Slovenian cities: Velenje, Celje, Maribor, and Ljubljana in the previous eight years. Although Velenje is the smallest city regarding the urban area and the number of inhabitants, *[10]*, annual air temperatures from AMS since 2010 showed that Velenje is the 2^{nd} warmest city, just behind Ljubljana, the capital city of Slovenia, *[11]* (Figure 4). However, annual T in all four cities is increasing in previous years, but most drastically in Velenje – by 20% in 2018 over 2010 (Table 2). Such a trend indicates that it is necessary to adopt more development and conservation strategies concerning global warning heat island effects in the city of Velenje in the future.

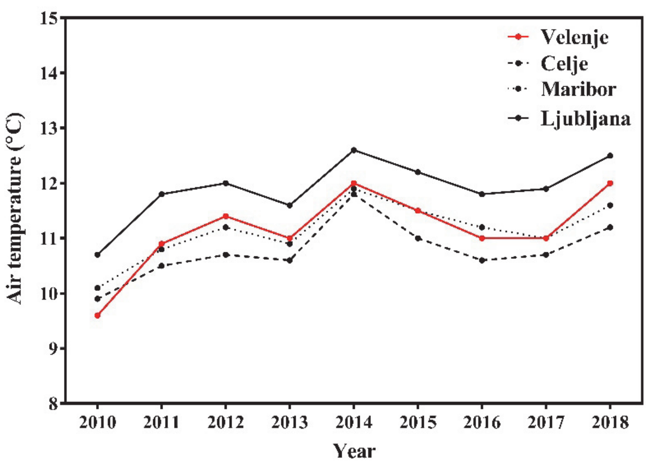

Figure 4: *Annual air temperatures in four Slovenian cities from 2010 to 2019*

An average T_{air} in Velenje, measured at AMS, was 11.03 during the experiment (Table 2) and was lower compared to T_{air}, measured by us (Figure 2). The difference can be attributed to the location of our experiment, in which temperatures correlated more to the temperatures near the roof. Nevertheless, the trend of temperature variation was the same. Compared to Celje, Maribor and Ljubljana, Velenje was not the hottest city during the experiment (Table 2).

Table 2: *Average temperatures in four Slovenian cities from the year 2010 till 2019*

	$T_{average\ (experiment)}$ (°C)	$T_{average\ (2010\text{-}2018)}$ (°C)	$\Delta T_{(2010\text{-}2018)}$ (°C)	$\Delta T_{(2010\text{-}2018)}$ (%)
VELENJE	**11.03**	**11.16**	**2.4**	**20.0 %**
CELJE	10.81	10.68	1.3	11.6 %
MARIBOR	11.36	11.89	1,5	14.4 %
LJUBLJANA	11.89	11.11	1.8	12.9 %

3 CONCLUSIONS

To improve the quality of life and reduce the negative environmental issues because of global warming, we must develop and support proper heat island reduction strategies. Vulnerability to heat is a global urban problem, since many aspects of life are burdened. The rising temperatures also mean that the first heatwaves of the year are coming earlier and catching us by surprise. These higher temperatures are bad for cardiovascular and respiratory diseases and pose severe stress to human health. Therefore, green areas, especially on the top urban layers, contribute positively to the improvement of the thermal performance of an urban environment and human health. Moreover, with increasing energy prices and very strict environmental policies, cheaper heating and cooling and lower energy consumption are essential construction and renovation requirements and give greening an added value. Consequently, with greening principles we can reduce building energy use and peak electricity demand, which leads to annual savings.

On average, in our experiment, T_{air} was by 4.09 °C and 4.00 °C higher than $T_{sub\ A}$ and $T_{sub\ B}$, respectively. The temperature below the roof was on average 4.1 °C higher compared to public data from AMS, and the temperature above the green models by 4.0 °C. To summarize, green area decreased T_{air} by 0.1 °C in our case and therefore contributed to lower annual air temperatures above the green models (Figure 1, Table 1).

Our results demonstrate how green roofs can positively influence the urban temperature. We showed that urban greening serves very well as a cooling tool towards the heat island effect and we tend to develop this research fact further. However, a study over a larger surface and time frame should be performed in the future, maybe on the flat roof of EPC in the city of Velenje, Slovenia.

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Nomenclature

(Symbols)	(Symbol meaning)
T	temperature

Journal of Energy Technology

JET Volume 12 (2019) p.p. 27-40
Issue 2, September 2019
Type of article 1.01
www.fe.um.si/en/jet.html

AN ANALYSIS OF THE RESPONSIBILITY FOR ZERO WASTE

ANALIZA ODGOVORNOSTI ZA DRUŽBO BREZ ODPADKOV

Ivana Buble[1ℜ], Daniel Rolph Schneider[1], Niko Samec[2], Filip Kokalj[3]

Keywords: municipal solid waste, zero waste, recycling, lightweight packaging waste, waste management, material recovery

Abstract

European Union Directive 2008/98/EC sets the priority hierarchy of the prevention of waste, re-using waste, recycling waste, waste recovery, and waste disposal.

Although every one of us is in daily contact with waste, we do not have the knowledge that can lead us to the sound management of waste from the beginning, before products are identified as waste.

Zero waste is a fundamental concept of the sustainable community of the future. It is a phrase frequently used by politicians seeking to upgrade the municipal solid waste management systems in their communities. In this manner, the responsibility of zero waste is given to the waste management process instead of to householders. Householders then equate waste prevention with recycling and the proper waste management of the collectors, public services, or waste management company. In reality, zero waste starts with each one of us at home. Households should aim to reduce consumption and undertake repairs to extend the life span of products.

Behaviour change can only start with knowledge. In reality, waste prevention does not include recycling. Recycling leads to a combined reduction of waste brought to landfill and raw material extraction.

ℜ Corresponding author: Ivana Buble, Kostak d.d., R&D, Savska pot 6, SI-8250 Brežice; Slovenia, Tel.: +386 40 570 568, E-mail address: ivana.buble@kostak.si

[1] 1 University of Zagreb, Department of Energy, Power Engineering and Environment, I. Lučića 5, HR-10000 Zagreb; Croatia; +385 1 6168 157; daniel.schneider@fsb.hr

[2] University of Maribor, Faculty of Mechanical Engineering

[3] University of Maribor, Faculty of Mechanical Engineering

The present paper evaluates household waste to clarify the facts. It analyses the composition of three streams: municipal solid waste, separately collected packaging waste, and bulky waste in different regions of Slovenia.

The research defines waste into five different categories. The first category is waste that can and should be avoided. The second category is waste that can be re-used. Further on, the research expands by researching the market of the third category that defines recyclables, which waste can be recycled; the last two categories are the waste that we are fighting with at the end of the waste management process, either to make it to the waste-to-energy process or to comply with landfill restrictions. At the end of the research, we summarize the situation of household waste in 2018.

Our goal is to reduce the quantity of waste, making only waste that can be recycled. If we consider waste prevention to be a fight against waste, we can put our plan in place by taking the first step: getting to know our enemy.

Povzetek

DIrektiva 2008/98/EC nam postavlja prioritetno vrsti v hierarhiji: 1. Izogibanje odpadkov, 2. Ponovna uporaba odpadkov, 3. Recikliranje, 4. Energetska izraba, 5. Odlaganje odpadkov

Čeprav smo vsi v dnevnem kontaktu z odpadki, vsak od nas nekaj odvrže v kanto za smeti, pa nimamo dovolj informacij, spoznanj, vpogleda, da bi obvladovali odpadke preden to postanejo, preden jih zaznamujejmo kot odpadke.

Zero Waste je koncept trajnostne družbe, prihodnosti. To je fraza katero pogosto uporabljajo politični veljaki, ki promovirajo nadgradnjo obdelave komunalnih odpadkov. Ob takšni uporabi fraze, je odgovornost za zero waste prenešena na proces obdelave odpadkov in soodgovrnost ne prevzamejo uporabniki, oziroma povzročitelji komunalnih odpadkov.

Gospodnjistva tako enačijo izogibanje, oziroma ne povzročanje odpadkov z recikliranjem in kvalitetno obdelavo odpadkov, zbiralcev odpadkov, komunalnim dejavnostmi in komunal.

V resnici pa je zero waste začetek proizvodnje odpadkov. V trenutku, ko stvar poimenujemo kot odpadek, jo odvržemo, smo povzročili odpadek in koncepta zero waste več ni. V resnici so gospodinjstev tista ki vplivajo na količino ustvarjenih odpadkov in imajo v svoji prioritetni vrsti popravila in podaljševanje življenjske dobe produktom.

Sprememba obnašanja se lahko prične z izobraževanjem. Preprečevanje nastanka odpadkov ni recikliranje odpadkov. Recikliranje je način kako zmanjšati količino odpadkov, ki končajo na odlagališčih oziroma v sistemu energetske izrabe.

Naš cilj je zmanjšanje količine odpadkov, in dejansko proizvajati le takšne odpadke, katere se lahko reciklira. Če definiramo zmanjševanje odpadkov kot boj proti odpadkom, lahko naredimo prvi pravi korak v smeri spoznavanja našega sovražnika.

1 INTRODUCTION

Households do not take sufficient responsibility for the concept of zero waste. Merely sorting waste is not enough to acknowledge that a zero waste household exists.

We need to move to a position where there is no such thing as waste, merely transformation; this position is called zero waste, *[1]*.

The article is about waste from households. In Slovenia, 476 kg/per capita/year of municipal solid waste was generated in 2016; 67% of separate collection was reported. Slovenia is achieving the targets of Directive 2008/98/EC. In principle, the directive has shown us the common sense we should use when dealing with our daily waste.

However, with no extra boundaries and knowledge and applying to re-use (in households), and proper recycling (in households), we do not reach the directive's original aim.

With improved standards of living, consumption is growing, and households are producing more waste.

A household's consumption patterns affect the quantity and types of waste creation. High-resource-consuming households produce a higher amount of waste than low-resource-consuming households do, *[2]*.

Many industrial and urban activities, including households, generate a considerable amount of solid waste every day all over the world, even if the recycling and energy generation from solid waste is increasing, *[3]*.

Civilization is evolving, and time-saving methods evolve accordingly: convenient shopping; convenient use of plastic bags; convenient food packaging convenient plastic bottles of water bought on the way.

Time control goes hand in hand with evolving standards. Controlling our time and saving our time means the use of modern materials in packaging. Modern materials are now recognized to be those that pollute our planet, so the only way to save our planet is to substitute modern materials with non-modern materials, such as glass and paper.

As Slovenia has a high share of separate collection and is known to be one of the best in the EU, we decided to investigate separately collected packaging material. To clarify, separate collection is an excellent way to establish minimum losses of recyclable materials, but only when recyclables are appropriately collected and separated with care.

2 REVIEW OF REGULATIONS AND CONCEPT OF ZERO WASTE

2. 1 Directive 2008/98/EC

Directive 2008/98/EC of the European Parliament and of the Council states the priority order in waste prevention and management legislation and policy in Paragraph 1 in Article 4 of Chapter 1: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g., energy recovery and (e) disposal.

For recycling, the directive emphasizes high quality recycling in Paragraph 1 in Article 11 of Chapter 1: Members States shall take measures to promote high-quality recycling and, to this end, shall set-up separate collections of waste where technically, environmentally and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors.

Nevertheless, Directive 2008/98/EC states in Paragraph 2 that Member States shall take the necessary measures designed to achieve the following targets: (a) by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as the waste streams are similar to waste from households, shall be increased to a minimum of 50% by weight overall.

As different areas of waste origin are reflected in different types of waste composition, so too should expectations and credentials.

By aiming for the goal of Directive 2008/98/EC, set in Paragraph 2, we experience consequences, such as:

(1) Contamination with inappropriate materials – The financial aspects of sorting result in loss; it is not economical to sort material where there is a low share of recyclables.

(2) Contamination of organic matter that affects the personnel employed in sorting facilities. The residual organic matter in pots and trays and some films encourages the growth of microbes in this plastic packaging and the contamination of cellulosic substrates, such as paper and cardboard, which provide favourable conditions for growth, *[4], [5].*

2.2 ZERO WASTE concept

The commonly used definition of the "zero waste" concept was proposed by the Zero Waste International Alliance in 2004, *[6]*, as follows: "Zero waste" is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, in which all discarded materials are designed to become resources for others to use.

As the generation of waste is increasing, it is clear that without a comprehensive and strategic roadmap, the zero waste goals may not be achieved in the desired timeframe, *[7].*

There are seven domains for indicators of zero waste concept integration: (1) Geo-administrative, (2) Socio-cultural, (3) Management, (4) Environmental, (5) Financial/economic, (6) Organization/institutional, (7) Policy/governance, *[2].*

The study of Zero Waste has distinct features. Sustainable consumption practices promote responsible consumption behaviour that ensures zero production of unwanted waste. It is possible to avoid and prevent waste creation of unwanted and excessive waste through sustainable consumption. In addition to sustainable consumption, a systematic transformation of existing inefficient manufacturing systems is also required for eliminating waste creation, *[8].*

In the waste hierarchy, waste avoidance is at the top. However, it is difficult to measure it, because it has a subjective perspective. Avoidable waste should not exist in the waste stream. This material is difficult to define, as we do not know the history of its emergence.

3 METHODS AND ANALYSIS OF SORTING SEPARATELY COLLECTED WASTE

Households aim to minimize waste by separating it properly. The quality of separation plays an extremely high role in waste management. Separation at source is significant for the sorting process in waste management. Mere separation does not cover the zero-waste concept. It is just one of the measures we take to walk the path towards zero waste.
Separation of lightweight packaging waste at source is a process of the preparation of input material for sorting line system, which is merely a production process in waste management.

Financial indicators always play a significant role in every production process. As a waste management facility represents a production process, the input material evaluates the determining factor in the decision of optimizing the waste management process in order to achieve the expected results.

In the case of waste, the design of the production process/waste management depends on households.

3.1 Definition of Lightweight packaging waste (LWP).

Lightweight packaging waste (and variations of it) is separately collected in many European countries that follow the EPR (Extended Producer Responsibility) initiative, first established in Germany in the 1990s, *[9]*.

The model and assessment reported in unpublished data, *[9]* on the process and economic efficiency of German sorting facilities, the development of which has been fundamental in shaping material recovery facilities design around the world but has been granted little scientific attention.

Each country has its defined waste quality, depending on socio-cultural and financial/economic structure. The economics of sorting changes with the waste composition, so the design of sorting lines should change accordingly.

As contamination problems of separately collected packaging waste in Slovenia occur, the comparison with German sorting facilities is explained with the definition of LWP in Germany, which is different from that in Slovenia.

3.2 Problems of sorting lightweight packaging waste (LWP)

The problem is described in *[9]*, where the example of lightweight packaging waste (LWP) sorting in Germany was analysed. The complex nature of LWP waste combined with challenging processing conditions were identified as significant factors explaining the relatively low overall recovery efficiencies achieved in these plants.

The authors of *[9]* indicated that LWP waste in Germany is a material mixture with a high content of plastics (around 50%) consisting of a mix of different packaging polymers, ferrous and non-ferrous metals, a fraction of paper and cardboard packaging, aseptic containers (beverage cartons) and other composite packaging. Mis-sorting or contamination levels vary considerably across collection areas, ranging from 5% to as much as 50% of the collected waste, averaging around 20% for the entire country.

The approximate 2.25 million tons of waste collected each year from households in yellow bins or sacks are sorted in fewer than 100 installations, with almost 90% of the total amount being processed in fewer than 50 plants, *[10].*

The lack of access to economic data gives no real data about processing efficiency and economic feasibility of facilities for central sorting. Nevertheless, material recovery facilities play a pivotal role in today's integrated solid waste management systems, *[11].* Such studies are crucial in economic evaluation and planning of separate collection and recycling programmes *[9], [12], [13], [14].*

The more pressure put on a separate collection system, the more contaminants are found in separately collected packaging. Recyclables traders of materials (i.e., aluminium, PET, PP, LDPE, tetrapak, and paper) expect a high purity of materials; otherwise, the material loses the value. The contaminants also cause losses of recyclables in the process.

As households are not aware of the contamination factor in separately collected packaging waste, this article analyses the present situation of the system in Slovenia.

3.3 Waste management system development

Knowledge of the individual material fractions in waste represents the basis of any waste management system planning and development, *[15]*. This information is also crucial for establishing baselines and for evaluating the effectiveness of environmental policies, *[16]*.

Research, *[9]*,assessed the significance of economies of scale of such plants and tackled operational practices as a means of explaining why there are, frequently, significant discrepancies between expected designed process efficiency and real-life experience with material recovery facilities operation.

The lack of information on the financial perspective of sorting waste sets false expectations for the waste-sorting results.

According to *[9],* studies showed that sorting costs represent 30–50% of the total system cost of packaging waste management. Due to competition, confidentiality data is missing from the global perspective of all factors, for which a scientific approach for the best technological approach could be identified.

In the separate collection system, all materials (metal, non-metal, paper, plastic) are mixed together. The more contaminants materials have, the more losses we incurred when deriving recyclables from the stream.

Simulation of technical and economic performances of materials recovery facilities is a basic requirement for planning new, or evaluating existing, separate waste collection and recycling systems.

As the analysis shows *[9]*, the case of Slovenia is different from that of Germany. The contamination of yellow bins or sacks is much greater, and sorting lines are also built for non-recyclable streams of waste (i.e., mixed communal waste), which is in contradiction of energy efficiency principles.

3.4 Material recovery facilities (MRF)

The structure of material recovery facilities, according to *[9]*, is followed in sequence through the typical facility planning steps:

(1) definition of main plant requirements, waste input characteristics and core process flowchart;

(2) sizing of process installations based on (1);

(3) calculation of capital and operational costs (the cost estimation model); and

(4) estimation of material transfers through the plant and costs/revenues related to plant outputs.

MRFs are industrial plants with significantly different process layouts. Nevertheless, different sections or modules in the plants can be identified to have a standard primary function. Based on this function, five main technical sections were identified and used to structure the facility-sizing exercise and subsequent costing model:

(1) feeding and pre-conditioning;

(2) conditioning – ballistic separation, air separation – physics;

(3) sorting – manual, automatic;

(4) refining – quality control;

(5) product handling – baling, loading operation.

Each section has allocated its associated building needs, unit processes and personnel.

It is crucial to evaluate and combine separate collection and recycling programmes, as well as sorting technology.

The non-recyclable waste stream needs to be acknowledged and well defined, and only then can the hierarchy of Directive 2008/98/EC come into effect.

The non-recyclable stream should not end up in the recyclable stream just to follow Directive 2008/98/EC. As presented in this article, the contaminated recyclable stream is a risk.

4 MATERIALS AND METHODS

The analyses were performed with different methodologies according to the waste stream.

The stream of separately collected packaging waste was performed by the National Laboratory of Health, Environment and Food in Novo mesto, Slovenia. The output stream from the sorting line was thoroughly investigated and weighed. The material was identified as: avoidable waste – does not belong in the stream; recyclables, and waste-to-energy material – residue after sorting. In the stream of separately collected packaging waste, there is no material appropriate for landfills. In the stream of separately collected packaging waste, no material was recognized as re-usable, as the material was contaminated or broken.

The stream of municipal solid waste was analysed in a waste management facility in Krško. The waste was weighed and divided into three groups: recyclables, waste-to-energy material, landfill material.

The stream of bulky waste was also analysed in the waste management facility in Krško. Bulky waste has a large volume in comparison to it weight. In bulky waste, material was found that was able to be marked as re-usable material, as there was no contamination with biodegradable matter.

5 RESULTS AND DISCUSSIONS

5.1 Analysis of separately collected packaging waste in Slovenia

An analysis of separately collected packaging waste has been performed for different regions of Slovenia as presented in Table 1. Avoidable waste is waste that is not supposed to end up in the waste stream of separately collected packaging waste. Thoroughly defined material in this stream is presented in Table 2. In different regions, different shares of waste are found, as the socio-cultural impact reflects the waste composition.

Recyclables represent materials that are acceptable to traders. Shares of recyclables in the stream of separately collected packaging also differ according to the region from which it was collected. The more precise the separate collection in households is, the higher the possibility to sort the recyclables from the waste stream. Furthermore, the last data set differs according to the region, and the numbers show an alarming situation. What is extremely important, and which must be acknowledged, is that contaminated recyclables, dirty recyclables, and recyclables destroyed during the collection process are not recyclables. This material can be used only in waste-to-energy technology.

Table 1: *Mass percentage of material in analysed separately collected packaging waste of different sources in Slovenia*

Separately collected waste source in %	Sežana	Idrija	Ljubljana	Lenart
Avoidable waste	36.1	27.8	29.3	12.8
Re-usable waste	0	0	0	0
Recyclables	12.9	34.6	24.5	31.8
Only waste-to-energy	51	37.6	46.2	55.4
Landfill	0	0	0	0

Ljubljana is the capital of Slovenia. Figure 1 presents the quality of lightweight packaging waste. As can be seen, only 24.5 % of the material are recyclables. Other materials are not usable, contaminated, or missorted.

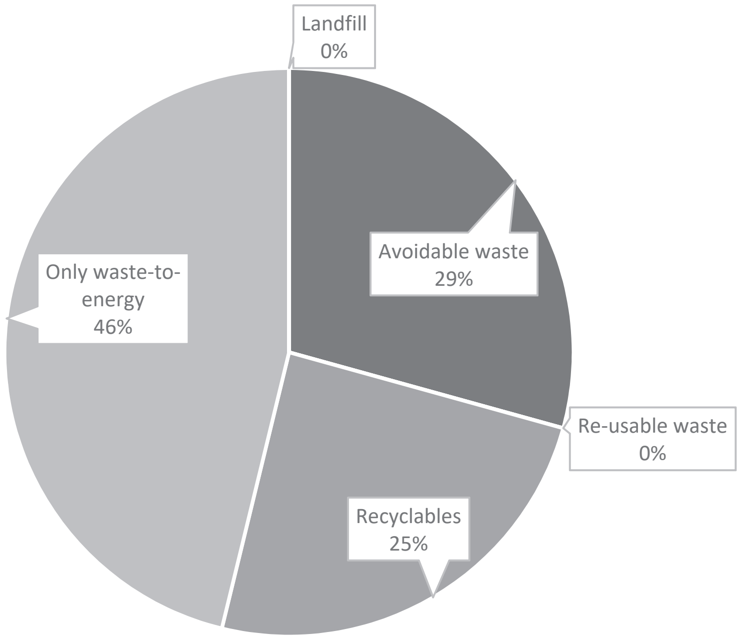

Figure 1: *Quality of LWP in Ljubljana*

In Table 2, the avoidable waste is presented for each source of origin. The percentage of total separately collected packaging waste is shown. Not properly sorted material at source includes electronics, bulky waste, medical materials, biodegradable waste, batteries, as well as textiles, nappies, and footwear. The residue after screening can be used only as in waste to energy process and is not meant to contain recyclables.

Table 2: *Not sorted material is presented as the percentage of total collected LPW from different sources in Slovenia*

Not properly sorted material source %	Sežana	Idrija	Ljubljana	Lenart
Electronics	0.1	0.2	1	0.3
Nappies	1.5	0.9	1.3	0.6
Textile	5.7	4.7	2.1	3
Footwear	2.1	0.9	0.9	0.4
Bulky waste	8.5	7	5.5	5.4
Medical materials	/	0.09	0.1	0.1
Candles	0.1	0.1	0.04	0.04
Batteries	0.1	0.1	0.2	0.03
Biodegradable waste	6.06	3.4	0.9	0.6
C&D waste	1.05	/	/	2.3
Residue after screening: 0–70 mm	/	/	17.3	/
Residue – mixed communal waste	10.9	9.4	/	/
Total	36.11	26.79	29.34	12.77

In Figure 2, the share of waste materials is also represented for Ljubljana. Bulky waste represents 5.5%. For sorting lines, the bulky waste and C&D waste are extremely dangerous from the technical point of view.

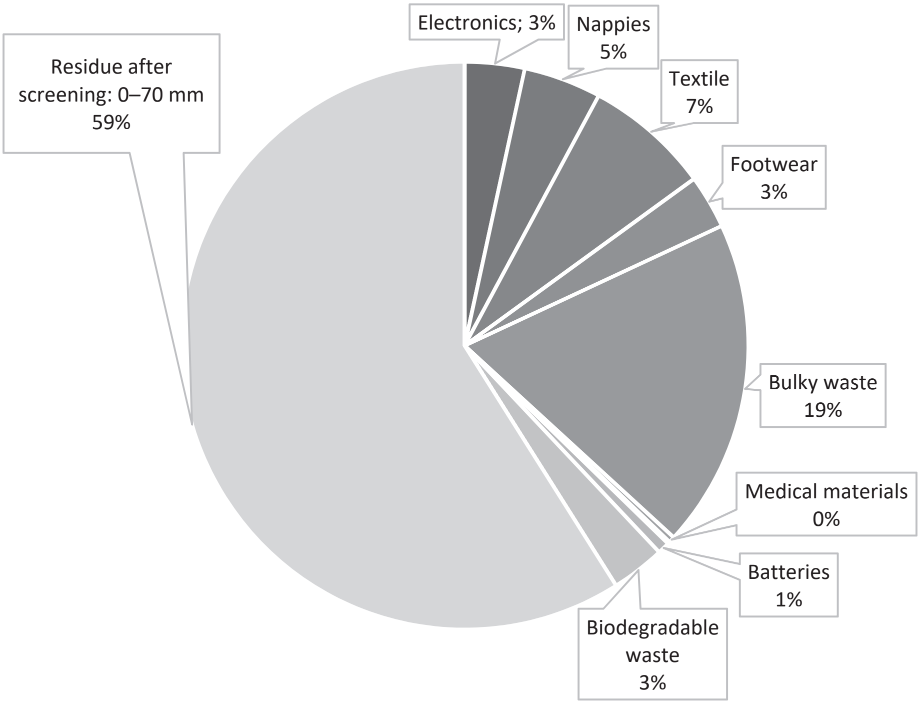

Figure 2: *Definition of avoidable waste from collected LWP in Ljubljana*

The analysis shows that the system of separated collection, without cleaning all the plastic to remove all the biological matter, causes a significantly lower share of valuable recyclables.

Manual or automatic sorting lines have recyclable losses due to machinery congestion caused by contamination.

When we estimate an extremely high separate collection share of household waste, we have high contamination accordingly. Consequently, only 30% of recyclables can be sorted out at sorting lines.

5.2 Analysis of mixed municipal waste

The analysis of mixed municipal waste in Table 3 reflects the separate collection system. As expected, as the share of recyclables is decreasing, so is the share of landfill material, as the law sets parameters that have to be abided by.

Avoidable waste is hard to recognize in the waste stream. The definition of avoidable waste in mixed municipal waste is a subjective matter. There is some share of waste that should be avoided, but this is a matter for different research. Furthermore, re-usable waste is difficult to determine without insight into the condition of the material before the owner defined it as waste. The share of recyclables was analysed during 2017 and recyclables represented only five per cent of waste in mixed municipal waste. It needs to be pointed out that these recyclables are dirty and can be traded only with a lower price.

Table 3: *Mass percentage of material in the analysed mixed municipal waste stream in Krško*

Municipal waste source %	Krško
Avoidable waste	0
Re-usable waste	0
Recyclables	5
Only waste-to-energy	93
Landfill	2

The municipality of Krško lies in eastern Slovenia. Households have been encouraged to separate waste for more than 20 years. According to success of separate selection the share of recyclables in mixed municipal waste is low, as represented in Figure 3.

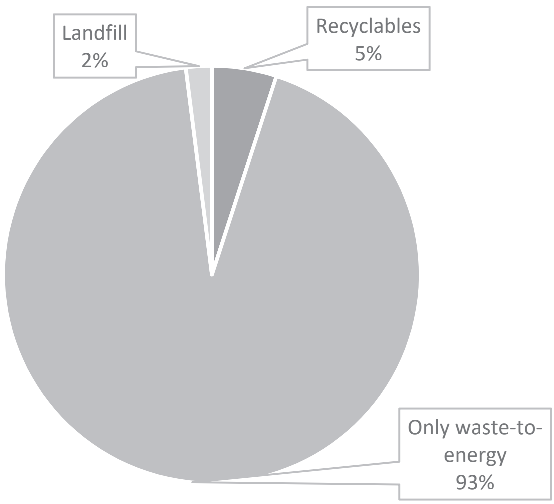

Figure 3: *Share of waste stream in mixed municipal waste collected in Krško*

5.3 Analysis of bulky waste

The analysis of bulky waste was performed through visualization. The bulky waste was checked and weighed when entering the waste management facility. The represented percentage of different sets of material in Table 4 shows the current situation in the Krško region. The recyclables in bulky waste such as metals, PP, and wood can be separated manually. Much of the bulky waste could have been processed through a system of repair and re-use, and some could have been avoided by proper sorting at source, or just proper use and treatment through its lifetime.

Table 4: *Mass percentage of material set in bulky waste in the Krško region*

Bulky waste source %	Krško
Avoidable waste	10
Re-usable waste	20
Recyclables	10
Only waste-to-energy	60
Landfill	0

6 CONCLUSION

Separate collection itself does not ensure recyclables. Also, separate collection itself does not ensure zero waste, as citizens believe.

What citizens can improve is the usage of the right packaging, making every-day decisions not to produce solid waste, clearing their shopping lists of unnecessary items. As long as we live in our modern society, we will generate waste, so zero waste is an ideology we should follow in order to minimize the problems, as we are and will be waste producers and accordingly we need to take responsibility for our actions.

The economy is based on market flow. The stream of material should not be stopped. The material stream should be properly guided. Directions are given but still not regulated within the laws and regulations to have a greater effect on minimising waste.

Zero waste is foremost a challenge for households and not for waste treatment facilities.

At the point at which waste is generated, there is an immediate need for technology to treat the waste properly. To use the best technology or system, to treat the waste according to waste structure, waste valorisation must be provided. Not all technology can be effective or optimal for all types and quantity of waste. Waste treatment needs the best optimization with energy consumption of the process to avoid needless costs for no result.

By following the necessary steps, at the end of the day, in some cases waste treatment causes unnecessary costs, energy consumption, and is environment-unfriendly.

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Journal of Energy Technology

JET Volume 12 (2019) p.p. 41-49
Issue 2, September 2019
Type of article 1.01
www.fe.um.si/en/jet.html

LIFT AND DRAG COEFFICIENTS FOR DIFFERENT MAGNUS ROTOR TYPES

KOEFICIENTI VZGONA IN UPORA ZA RAZLIČNE KONFIGURACIJE MAGNUSOVEGA ROTORJA

Marko Pezdevšek[ℜ]

Keywords: Magnus effect, lift coefficient, drag coefficient, Ansys CFX, endplates, aspect ratio

Abstract

In this paper, the results of numerical simulations for various Magnus rotor configurations are presented. For each configuration, a blocked structured mesh was designed in ICEM CFD. Numerical simulations were conducted using Ansys CFX. The influence of the aspect ratio on the lift and drag coefficients depending on the speed ratio was investigated, as was the influence of endplates on a Magnus rotor. From the obtained results, it was concluded that adding endplates to a Magnus rotor increases the lift and drag coefficients.

Povzetek

V prispevku so predstavljeni rezultati numeričnih simulacij različnih konfiguracij Magnusovega rotorja. Za vsako konfiguracijo smo s programom ICEM CFD izdelali blokovne strukturirane numerične mreže. Numerične simulacije so bile izvedene s programskim paketom Ansys CFX. Preučili smo vliv geometrijskega razmerja Magnusovega rotorja na potek koeficienta vzgona in upora v odvisnosti od hitrostnega razmerja. V nadaljevanju smo še preučili vpliv končnih plošč. Iz rezultatov simulacij je razvidno, da uporaba končnih plošč povečuje koeficient vzgona in koeficient upora.

[ℜ] Corresponding author: Marko Pezdevšek, University of Maribor, Faculty of Energy Technology, Hočevarjev trg 1, 8270 Krško, E-mail address: marko.pezdevsek@um.si

1 INTRODUCTION

The Magnus effect was named after Heinrich Magnus, a German physicist who described the effect in 1852 in his research in the deflection of projectiles from firearms. The Magnus effect is present with a rotating object moving through a fluid. A rotating object (in our case a cylinder) experiences a deflection that can be explained by the difference in pressure of the fluid on opposite sides of the spinning object. The direction in which the deflection happens is related to the direction (clockwise or counterclockwise) of rotation. The forces that act on a rotating cylinder are seen in Figure 1; the lift force is defined as a force that is perpendicular to the free stream velocity while the drag force is parallel to the free stream velocity.

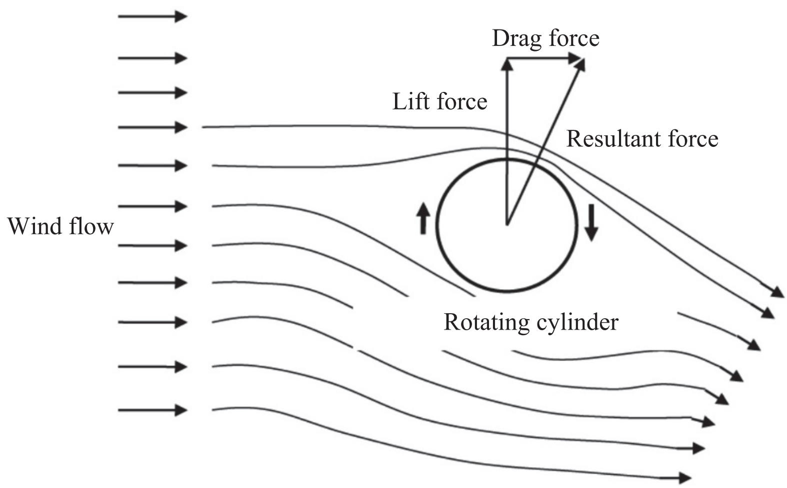

Figure 1: *Forces acting on a rotating cylinder*

The German engineer Anton Flettner was the first to build a ship that attempted to use the Magnus effect for propulsion. In 1924, he constructed the ship named “Backau”, which had two large cylinders each 15 m in height and 3 m in diameter driven by a 37 kW motor. The ship would later be renamed “Baden Baden” and was used to cross the Atlantic Ocean, *[1].*

In recent years, research in Magnus rotors has increased, and several authors have covered this topic. Mandar Gadkari, *[2]*, researched the Magnus effect using 2D numerical simulations. Niel Lopez, *[3]*, conducted numerical simulations for different Magnus rotor types; at different aspect ratios, he investigated the effect that spirals, bumps and humps have on the lift and drag coefficient. Seyed Ali Kazemi, *[4]*, used an airfoil geometry with rotating walls instead of the conventional cylinder shape; he conducted numerical simulations at various speed ratios and several angles of attack.

2 GEOMETRY, MESH, AND BOUNDARY CONDITIONS

2.1 Geometry

The aspect ratio (AR) is defined as the ratio between the height and diameter of a cylinder. Cylinders with aspect ratios of 2, 3, and 4 were modelled. Our goal was to investigate the dependency between AR and lift-drag coefficients. In the example in which we have AR=3, endplates were added to the cylinder. The diameter of the endplates was 2D. The size of the computational domain remained constant for all cases and was 1 m before, 2 m after, 1 m above and below the cylinder. The computational domain is shown in Figure 2.

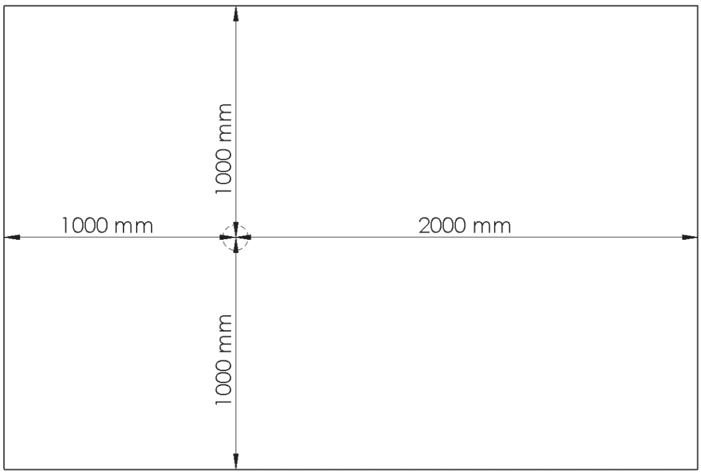

Figure 2: *Computational domain*

2.2 Mesh

For all the above-mentioned examples, a blocked structured mesh was created in ICEM CFD. The final mesh consisted of approximately 6 million elements. Figure 3 shows the mesh for AR=3; below the same figure, a section of the mesh is enlarged so we can better see the mesh distribution and size in the area near the cylinder walls.

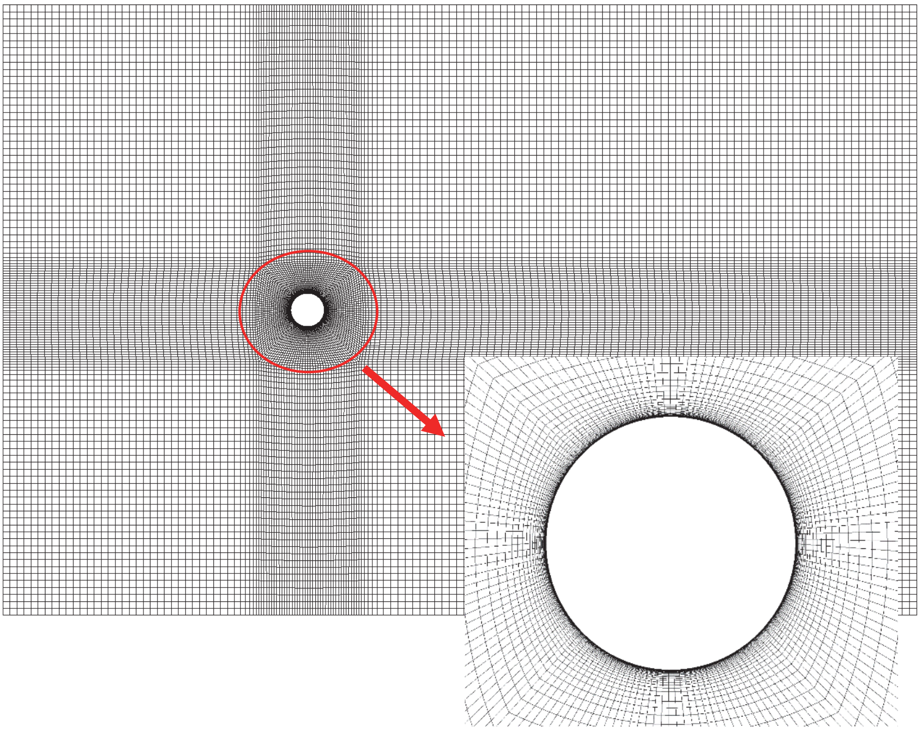

Figure 3: *Blocked structured mesh with the magnified section at the bottom*

The dimensionless value y+=1 was taken into account during the mesh design phase. The element size near the cylinder wall was adjusted accordingly. An O-grid was incorporated into the basic design of the mesh; the expansion ratio perpendicular to the wall surface was set to 1.15. The height of the cylinder was described with 120 elements. The cylinder surface was described with 33,150 elements. Simulations have shown that the maximum y+ is less than 4, which can be seen in Figure 4.

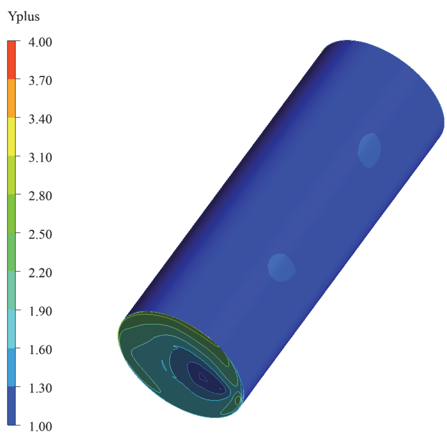

Figure 4: *y+ values*

2.3 Boundary conditions

The following boundary conditions were applied. The left surface was defined as an inlet where an inlet velocity of 10 m/s was defined. The right surface was defined as an opening where the average static pressure 0 Pa was applied. The top and bottom walls were defined as stationary no-slip walls. The cylinder walls were defined as a rotating no-slip wall where an appropriate angular velocity was defined. All the above-mentioned boundary conditions can be seen in Figure 5.

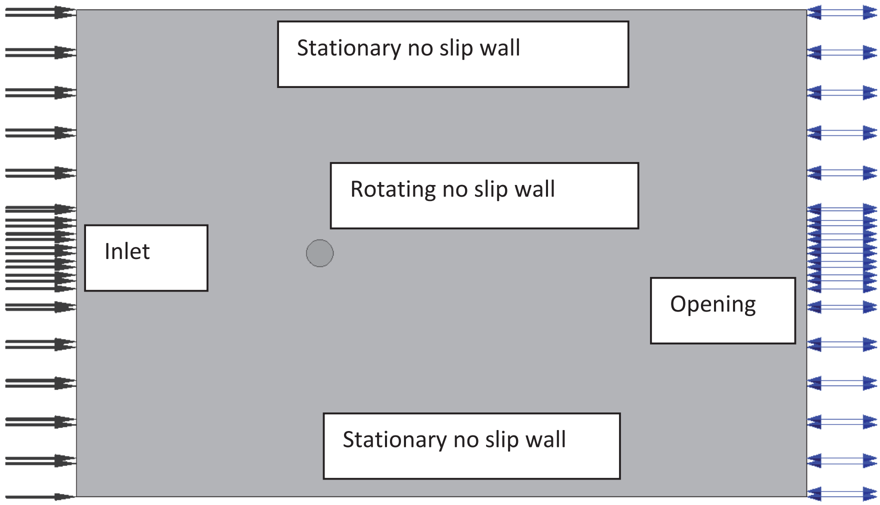

Figure 5: *Applied boundary conditions*

In Ansys CFX 17.1, we conducted steady-state simulations for speed ratios between 1 and 5 with a 0.5 step. The average RMS residuals were set at 10^-5. The SST turbulence model was used.

3 EXPERIMENT

The experimental measurements were completed in the wind tunnel of the Faculty of Energy Technology of the University of Maribor. The wind tunnel has a measuring cross-section of 2×2 m at which wind speeds of 25 m/s can be achieved. The general shape of the wind tunnel is a closed-loop design; at the bottom of the loop, there is a fan, while at the top of the loop there is the measuring section. The frame on which the whole structure (rotating cylinder, motors) is mounted to is bolted directly to the bottom surface of the wind tunnel. The horizontal axle is mounted with two bearings to the frame. The vertical shaft is powered by an electric motor, which is at the bottom of the shaft and is mounted in two places, which are seen in Figure 6. The cylinder is mounted to the vertical shaft. The experiment was conducted at a constant wind speed of 10 m/s. We changed the rpm of a cylinder with an AR=3 from 1000 rpm to 8000 rpm. The force was measured with an HBM U9C force gauge witch was positioned perpendicular to the airflow. The position of the drive motor and force gauge can be seen in Figure 6.

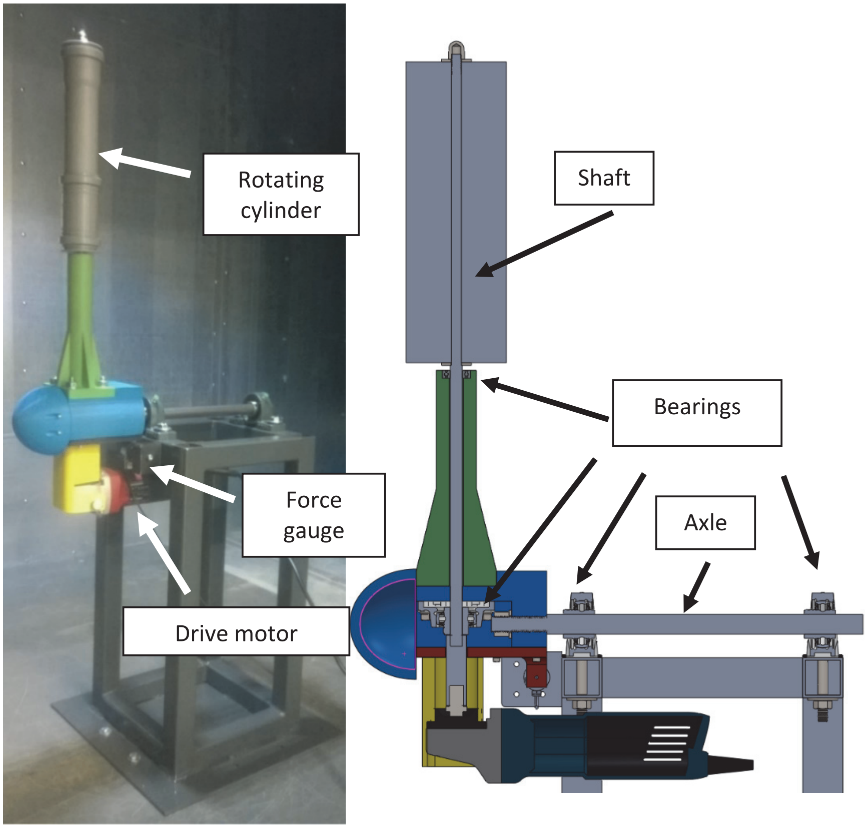

Figure 6: *Position of components for the experiment*

4 RESULTS

The lift coefficient is defined with the following equation:

$$C_l = \frac{F_l}{0.5\rho A v_\infty^{\ 2}} \tag{4.1}$$

Where:

F_l – lift force [N],
ρ – density [kg/m3],
A – area of the cylinder field [m2],
v_∞ – free stream velocity [m/s].

The drag coefficient is defined with the following equation:

$$C_d = \frac{F_d}{0.5\rho A v_\infty^{\ 2}} \tag{4.2}$$

Where:

F_d – Drag force [N].

The aspect ratio is defined as the ratio between height and diameter of a cylinder.

$$AR = \frac{h}{2R} \tag{4.3}$$

Where:

h – cylinder height [m],

R – cylinder radius [m].

The area of the cylinder field is defined as the height multiplied with the diameter:

$$A = h2R \tag{4.4}$$

The speed ratio is defined as the ratio between the circumferential velocity and absolute velocity:

$$\lambda_2 = \frac{\Omega R}{v_\infty} \tag{4.4}$$

Where:

Ω – angular velocity [rad/s].

Figure 7 shows the lift coefficient as a function of the speed ratio. The figure contains experimental results and the results of CFD simulations at AR=3. At λ_2<2, we can see that the CFD results generally show good agreement with experimental data. The results deviate the most at λ_2=2, where the lift coefficient in the case of CFD simulations is still increasing, while the experimental data show that the maximum is already reached. At λ_2>2, the CFD results show good agreement with experimental data.

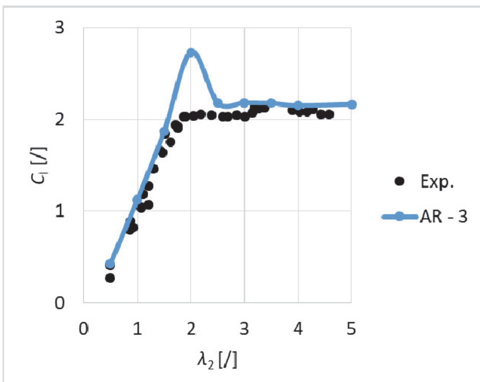

Figure 7: *Lift coefficient as a function of the speed ratio*

Figure 8 shows the lift coefficient (left) and the drag coefficient (right) as a function of the speed ratio. The figure contains the results of CFD simulation data at AR=2, 3, and 4. From Figure 8, we can conclude that the lift and drag coefficient increases with higher aspect ratios. At speed ratios higher than 3, we can observe that the lift coefficient remains constant, similarly as can be seen with the drag coefficient.

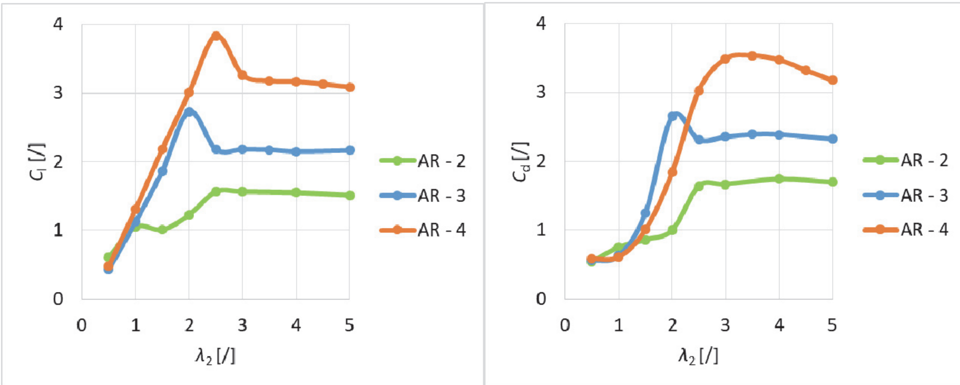

Figure 8: *Lift coefficient (left) and drag coefficient (right) as a function of speed ratio for different aspect ratios*

Figure 9 shows the lift coefficient (left) and the drag coefficient (right) as a function of the speed ratio. The figure shows the results of CFD simulations at AR=3, for the example with and without endplates. From the figure, we can see that with the use of endplates the lift and drag coefficient increases significantly. The maximum lift coefficient for the example without endplates is 2.8 at λ_2=2; with endplates, the coefficient rises to approximately 8 at λ_2=4. We can see a similar pattern with the drag coefficient which has a maximum value of 2.8 at λ_2=2 for the example without endplates. With the inclusion of endplates the maximum value rises to 9 at λ_2=5.

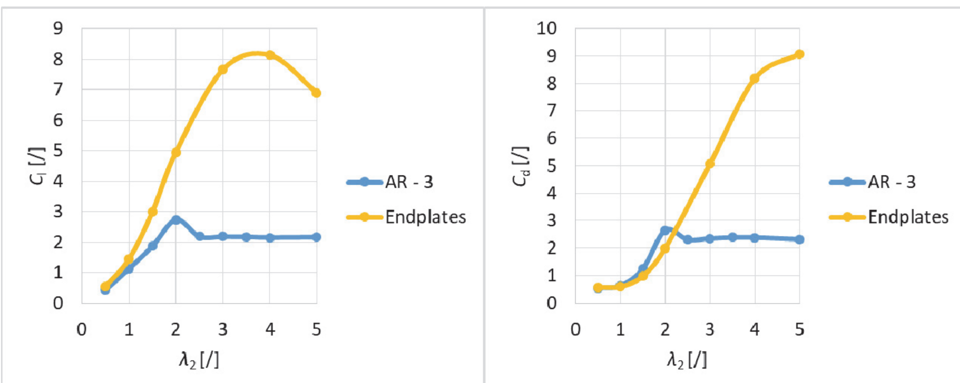

Figure 9: *Lift coefficient (left) and drag coefficient (right) as a function of speed ratio for example with endplates (blue) and without endplates (yellow)*

5 CONCLUSION

Several numerical simulations were performed for different Magnus rotor configurations. For each configuration, a blocked structured mesh in ICEM CFD was created. The simulations were conducted in Ansys CFX. We compared the results of CFD simulations for AR=3 to experimental data. At λ_2<2 and λ_2>2, the CFD results show good agreement with experimental data. At λ_2=2, the results deviate the most; in the case of CFD simulations, the lift coefficient is still increasing, while the experimental data show that the maximum is reached. We compared the lift and drag coefficient depending on the speed ratio for different aspect ratios. The results show that with increasing the aspect ratio, the lift and drag coefficients increase. For a cylinder with AR=3, we compared CFD results for an example with and without endplates. The results show that the lift and drag coefficients increase significantly with the inclusion of endplates. In future work, we hope to include more experimental data and different cylinder designs.

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Nomenclature

(Symbols)	(Symbol meaning)
C_l	lift coefficient
F_l	lift force
ρ	density
A	area of the cylinder field
v_∞	free stream velocity
C_d	drag coefficient
F_d	drag force
AR	aspect ratio
h	cylinder height
R	cylinder radius
Ω	angular velocity
λ_2	speed ratio

Inštitut za energetiko Institute of Energy Technology

Institute of Energy Technology

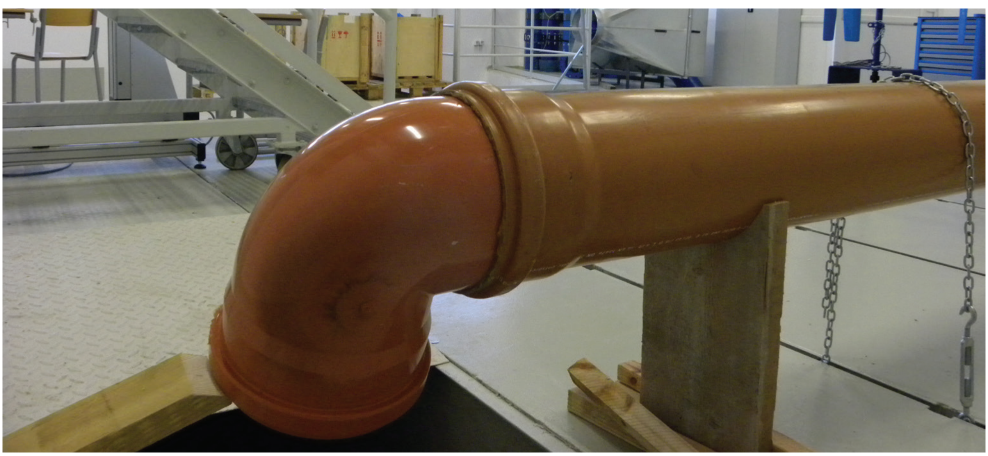
In addition to higher education, the Faculty of Energy Technology also carries out research in the field of energy technology. Most infrastructure and equipment required for research activities are available at the Institute of Energy Tehnology, where interdisciplinary research with a focus on research excellence is conducted. With the implementation of basic and applied research, new knowledge, new products, processes and services that raise the competitiveness of the economy are created. As part of its mission, the Institute for Energy contributes to the sustainable development of society.

Within Institute of Energy Technology, research is conducted by nine laboratories:

- Laboratory for Aero- and Hydro-Energy Technology (LAHET);
- Applied Electrical Engineering Laboratory (LAE);
- Laboratory of Ecology and Environment Protection (LEVO);
- Electric Machines and Drives Laboratory (LESP);
- Laboratory for Energy Conversion (LEP);
- Laboratory for Energy Management and Engineering (LABEMI);
- Nuclear Energetics Laboratory (LJE);
- Laboratory for Thermomechanics, Applied Thermal Energy Technologies and Nanotechnologies (LTTN);
- Laboratory for Virtual Engineering (CADER).

Laboratory for Aero- and Hydro-Energy Technology (LAHET)

The activities of LAHET are in the fields of science, development and applied research in following areas: mechanical and flow resonance issues, flow interactional problems, acoustic problems, developing and designing of wind technologies, hydraulic technologies and alternative energy technologies, all in accordance with the principles of an open thermodynamic approach.



Experimental model (physical models) tests on the (model-based) structure with air, water or simultaneously with both air and water flows are performed on the equipment available.

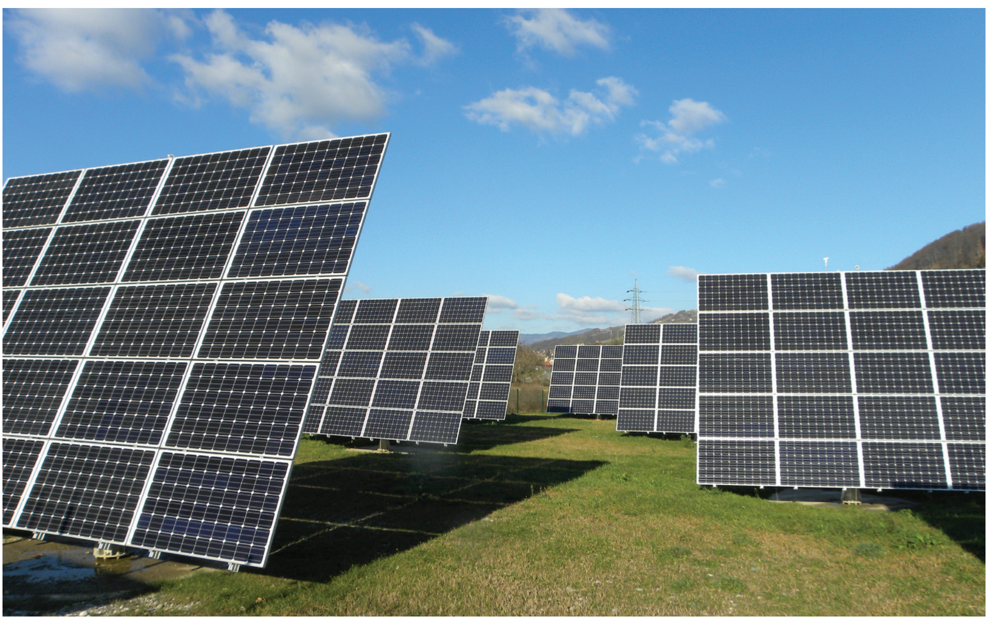
In the hydro part of the works, we can implement model-based testing of physical models of the entire hydroelectric power plant with its flow path (inlet/outlet channels, etc.). The simulation tests can be performed under practically all possible operating regimes, including flooding.

It is possible to implement model-based tests on scaled physical models of pipe ducts, conduits, junctions, conversion, both in the open as well as in closed ducts (tubes).

Applied Electrical Engineering Laboratory (LAE)

LAE offers comprehensive services in the context of scientific research, the development of different hardware and software solutions, special educations and training for industry in the following fields:

- Electromagnetic energy converters (magnetic nonlinear dynamic modelling and the development of advanced experimental methods and measurement systems);
- Renewable sources and technologies (with focus on the utilization of solar and hydropower energy);
- Energy efficiency in buildings and industrial processes (research on smart grids and energy management, the development of methodologies, technologies and software solutions for determining the efficiency of industrial processes);
- Advanced sensor and measurement systems (research on hardware and software for detecting the potential of renewable energy sources, telemetry and applications in Energy Engineering).



Laboratory of Ecology and Environment Protection (LEVO)

With its laboratory equipment, LEVO can review the living environment, which represents the ecosystem in which we live and that has a direct impact on our health.

Laboratory equipment includes instruments for measuring the turbidity of drinking and waste water, enabling the detection of organoleptic changes of water, and detecting changes in its composition.

Devices for the measurement of residual chlorine in drinking water directly monitor the quality of the water.

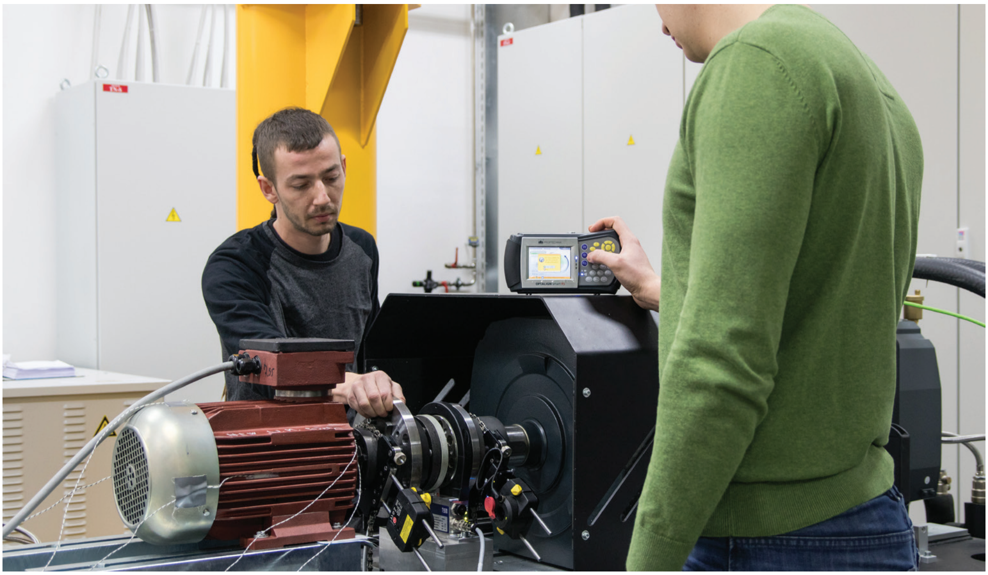
A spectrophotometer is used for the analysis of wastewater, drinking water, and water in cooling and heating systems.

A method for the rapid detection of bacteria in drinking and waste water is based on the verification of the enzymatic activity in living bacterial cells. This is a specific detection of the presence of bacteria and does not include other taxonomic groups.

With devices for measuring the quality of air and IR cameras, the quality of life and protecting the environment is improved.

Electric Machines and Drives Laboratory (LESP)

The LESP working group includes researchers working in the field of design, modelling, control and testing of different types of electric machines and drives. Research work for industry is focused on: energy conversion in electrical machines, development of new electrical machines topologies, electric machine diagnostics, magnetic field analyses, heating of electrical machines, prediction of electric machine characteristics, modeling of energy phenomena in nonlinear magnetic materials, energy efficiency improvement of electrical machines, development of calculation and experimen-

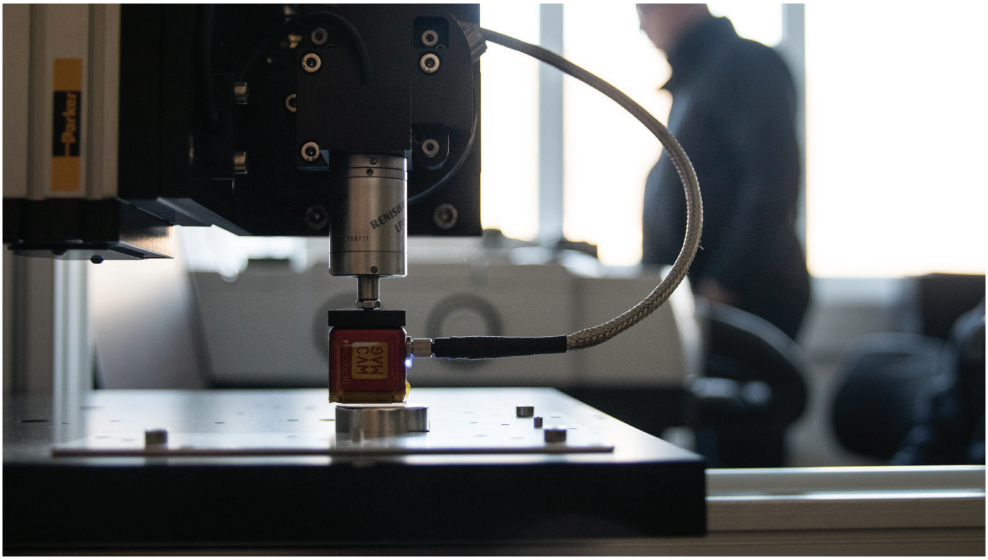


tal methods for the determination of electric machines parameters, measurements of load and efficiency characteristics and development of electric machine control. LESP is a reliable industrial partner for these applications: household appliances, industrial drives, electric propulsion for electric vehicles and vessels, electric traction drives, generators for wind energy conversion systems, drives for fans, compressors, and pumps.

Laboratory for Energy Conversion (LEP)

LEP carries out research in the field of:

- Design of electric machines:
  - Development of new software solutions for the design of electrical machines using analytical and numerical methods;
  - Measurement of the characteristics, local demagnetization and quality of permanent magnets using clips obtained by the scanner with a magnetic camera;
- Technologies for exploiting renewable energy sources:
  - Design of wind generators;
  - Design of solar power plants;
  - Biomass and renewable energy sources;



- Measurements in energy technology;
- NET metering - energy self-sufficiency:
  - Design and implementation of smart measurement systems in the energy sector;
- Design of energy control systems;
- Planning of energy policies;
- Optimization of power consumption;
- Application of genetic algorithms for optimization in energy systems;
- Design of electric vehicles;
- Elaboration of life cycle assessment for the evaluation of environmental impacts;
- Calculations of operating states of power systems.

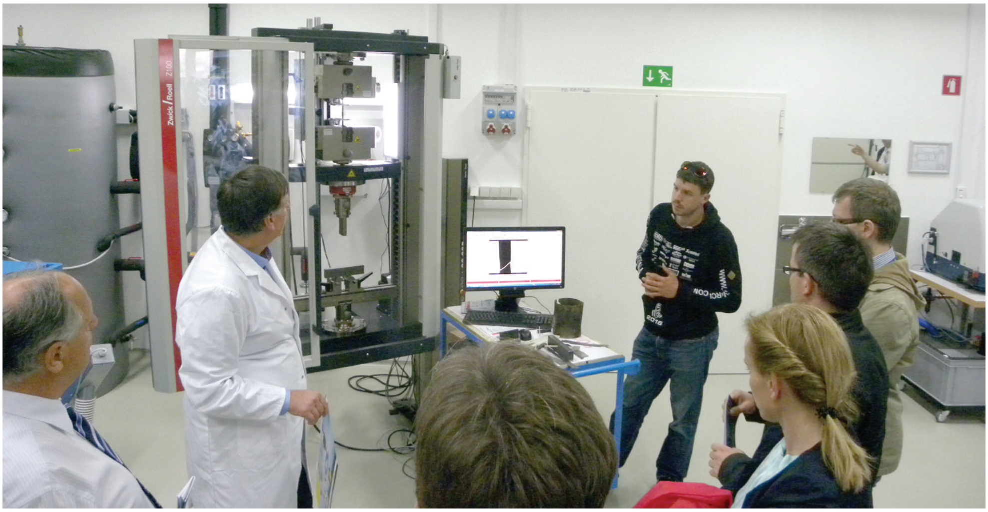
Laboratory for Energy Management and Engineering (LABEMI)

LABEMI carries out research in the field of:

- Energy engineering: developing pressure vessels, pipelines and reservoirs, making welding draft and processes, monitoring quality and execution of supervision at demanding welding applications, fracture mechanics of energy components;

- Biomass: consultancy, testing of new energy agriculture products, testing of all types of burners and biomass, co-generation-tri-generation with biomass combination and making of technical documentation with calculation for district heating;

- Energy-efficient buildings: consultancy for energy reconstruction of buildings, making and preparing of elaborate and rough outlines of energy solutions for zero- and low-energy buildings, making documentation of process, fire and explosive safety, thermography of buildings, preparing and issuing of energy certificates and energy audits of buildings, designing micro generators of heat for passive and low-energy buildings;



- Energy management: monitoring of energy consumption in buildings, consultancy with measures for efficient energy management, making of CNS for energy system with consumption optimization, energy project management.

Nuclear Energetics Laboratory (LJE)

The laboratory has equipment for radiation surveys of the working environment and also simple measurements of radioactivity. The sensitive scintillation gamma spectrometer and alpha spectrometer are intended for more demanding measurements and research work. This equipment enables us to participate in research and development related to future radwaste depository and existing nuclear facilities.

The laboratory also has equipment for the vacuum deposition of thin layers, which is supported with equipment for electrical characterization of structures. The system is capable of deposition of inorganic layers, as well as layers of organic semiconductors which could serve as a basis for different detectors of ionizing radiation. Based on the results of previous work, we expect that we will be able to make different organic semiconductor thin-layered structures that could be used for the detection and measurement of ionizing radiation.

Laboratory for Thermomechanics, Applied Thermal Energy Technologies and Nanotechnologies (LTTN)

LTTN deals with interdisciplinary problems in the research areas of thermodynamics, mechanics and electromagnetic effects. Within this laboratory educational, professional and scientific activities are carried out. The activity of the laboratory covers the following areas:

- Thermomechanics;
- Fluid mechanics;
- Nanotechnologies and microtechnologies in energy technology;
- Hydrogen and methanol technologies;
- Heat exchangers; heat converters and mass exchangers;
- Use of geothermal energy; biogas and biomass;
- Use of solar energy;
- Heating; cooling and air-conditioning systems;
- Maintenance of thermoenergetic devices.

Laboratory for Virtual Engineering (CADER)

CADER is an interdisciplinary service facility enabling access to the tools, expertise and collaborative opportunities needed to support high edge research, academic initiatives and innovative uses of technology in the general areas of:

- Teaching and learning;
- Modelling, animation and design;
- Visualization and simulation;
- Virtual and rapid prototyping, 3D printing;
- Application development.

The laboratory equipment consists of:

- a 3D visualization room with massive parallel computer support for analyses and simulation (Catia, SolidWorks, ANSYS) and use of real-time 3D rendering tools on a corner-cave visualization system (3.3×3.5m);
- High-end 3D printers: EnvisionTEC Xtreme, CubePro trio, TypeA Series1 with accessories for high-quality products from various materials. 3D printing and virtual reality can be used to help better visualization of products in three-dimensions, making them more tangible.

MAIN TITLE OF THE PAPER
SLOVENIAN TITLE

*Author[1], Author [2], Corresponding author*ℜ

Keywords: (Up to 10 keywords)

Abstract

Abstract should be up to 500 words long, with no pictures, photos, equations, tables, only text.

Povzetek

(Abstract in Slovenian language)

Submission of Manuscripts: All manuscripts must be submitted in English by e-mail to the editorial office at jet@um.si to ensure fast processing. Instructions for authors are also available online at http://www.fe.um.si/en/jet/author-instructions.html.

Preparation of manuscripts: Manuscripts must be typed in English in prescribed journal form (MS Word editor). A MS Word template is available at the Journal Home page.

A title page consists of the main title in the English and Slovenian language; the author(s) name(s) as well as the address, affiliation, E-mail address, telephone and fax numbers of author(s). Corresponding author must be indicated.

Main title: should be centred and written with capital letters (ARIAL bold 18 pt), in first paragraph in English language, in second paragraph in Slovenian language.

Key words: A list of 3 up to 6 key words is essential for indexing purposes. (CALIBRI 10pt)

Abstract: Abstract should be up to 500 words long, with no pictures, photos, equations, tables, - text only.

Povzetek: - Abstract in Slovenian language.

Main text should be structured logically in chapters, sections and sub-sections. Type of letters is Calibri, 10pt, full justified.

ℜ Corresponding author: Title, Name and Surname, Organisation, Department, Address, Tel.: +XXX x xxx xxx, E-mail address: x.x@xxx.xx

[1] Organisation, Department, Address

[2] Organisation, Department, Address

Units and abbreviations: Required are SI units. Abbreviations must be given in text when first mentioned.

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Chapter examples:

1 MAIN CHAPTER

(Arial bold, 12pt, after paragraph 6pt space)

1.1 Section

(Arial bold, 11pt, after paragraph 6pt space)

1.1.1 Sub-section

(Arial bold, 10pt, after paragraph 6pt space)

Example of Equation (lined 2 cm from left margin, equation number in normal brackets (section. equation number), lined right margin, paragraph space 6pt before in after line):

Equation (1.1)

Tables should have a legend that includes the title of the table at the top of the table. Each table should be cited in the text.

Table legend example:

Table 1: *Name of the table (centred, on top of the table)*

Figures and images should be labelled sequentially numbered (Arabic numbers) and cited in the text – Fig.1 or Figure 1. The legend should be below the image, picture, photo or drawing.

Figure legend example:

Figure 1: *Name of the figure (centred, on bottom of figure, photo, or drawing)*

References

[1] **N. Surname:** *Title,* Journal Title, Vol., Iss., p.p., Year of Publication

[2] **N. Surname:** *Title,* Publisher, Year of Publication

[3] **N. Surname:** *Title* [online], Publisher or Journal Title, Vol., Iss., p.p., Year of Publication. Available: website (date accessed)

Examples:

[1] **J. Usenik**: *Mathematical model of the power supply system control*, Journal of Energy Technology, Vol. 2, Iss. 3, p.p. 29 – 46, 2009

[2] **J. J. DiStefano, A.R. Stubberud, I. J. Williams**: *Theory and Problems of Feedback and Control Systems*, McGraw-Hill Book Company, 1987

[3] **T. Žagar, L. Kegel:** *Preparation of National programme for SF and RW management taking into account the possible future evolution of ERDO* [online], Journal of Energy Technology, Vol. 9, Iss. 1, p.p. 39 – 50, 2016. Available: http://www.fe.um.si/images/jet /Volume 9_Issue1/03-JET_marec_2016-PREPARATION_OF_NATIONAL.pdf (7. 10. 2016)

Example of reference-1 citation: In text *[1],* text continue.

Nomenclature

(Symbols)	(Symbol meaning)
t	time

JET

JET I Journal of Energy Technology I Vol. 12, Issue 2, September 2019 I University of Maribor, Faculty of Energy Technology

ISSN 1855-5748

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