



Fakulteta za  
industrijski inženiring  
Faculty of Industrial Engineering

**Razvoj industrijskega inženiringa (RII8):  
Priložnosti, potenciali, izzivi**

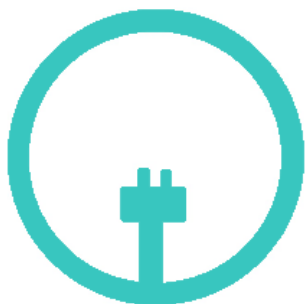
***Development of Industrial Engineering (RII8):  
Opportunities, Potentials, Challenges***

**Zbornik recenziranih povzetkov 8. mednarodne  
konference**

**Proceedings of Reviewed Abstract  
of 8th International Conference**

**TRAJNOSTNI VIDIK INDUSTRIJSKEGA INŽENIRINGA**

**SUSTAINABLE INDUSTRIAL ENGINEERING**







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Šmarješke Toplice, september 2023



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## KAZALO | TABLE OF CONTENTS

### **Predgovor**

### **Preface**

*Tomaž Savšek*

Aditivna proizvodnja lahkih kovin, kot je magnezij.....1 Additive manufacturing of light-weight metals like magnesium <i>Yasir Beeran Pottathara, Hanuma Reddy Tiyyagura, Nika Brili, Snehashis Pal, Igor Drstvenšek, Simon Muhič, Janez Povh</i>	1
Harnessing the High Pressure: Addressing the Energy Crisis through Innovative Techniques.....2 <i>Szymon Starzonek</i>	2
The lowest eigenfrequencies of a fluid-loaded elastic cylindrical shell.....3 <i>Hazel Yücel, Nihal Ege, Barış Erbaş, Julius Kaplunov</i>	3
A review of recent advances in Wire Arc Additive Manufacturing (WAAM).....4 <i>Damjan Klobčar, Mohammad Reza Ghavi, Janez Povh, Drago Bračun, Luka Selak, Mirza Imširovič, Uroš Trdan, Aljaž Ščetinec</i>	4
Problematika visokonapetostnih baterij po koncu življenjske dobe vozil na električni ali hibridni pogon .....5 The problem of high-voltage batteries at the end of the life of electric or hybrid vehicles <i>Tinkara Škulj Medved, Damjan Balabanič</i>	5
Bat2Life: Pametno upravljanje odjema in proizvodnje EE z uporabo baterije 2. življenjskega obdobja.....6 Bat2Life: Smart EE consumption and production management using the 2nd life cycle battery <i>Kristina Bogataj, Andrejček Pečjak, Janez Korošec, Žiga Hus, Tomaž Savšek</i>	6
Digitalizacija organizacijskega procesa.....8 Digitalisation of organisational process <i>Stefan Cvijanović</i>	8
Optimizacija proizvodnega procesa na rezalno-gubalni liniji.....9 Optimization of the production process on the cutting-forming production line <i>Špan Domen, Marica Prijanovič Tonkovič</i>	9
Obdelava podatkov za napovedovanje korekcij varilnih orodij s pomočjo umetne inteligence.....10 Data processing for prediction of welding fixture adjustments using artificial intelligence <i>Robert Strahinič, Jernej Klemenc, Vili Malnarič</i>	10
Razvoj koncepta naprave za izkoriščanja energije valovanja morja.....11 Developing a concept for a sea wave energy harvesting device <i>David Zalovič, Damir Vrančič</i>	11
PCB Production in Slovenia: Exploring Opportunities, Unleashing Potential, and Overcoming Challenges in the Green Transition.....12 <i>Samrah Mušič</i>	12
CAD in CAM tehnologije v procesu višjega strokovnega izobraževanja.....13 CAD and CAM technologies in the process of higher professional education <i>Mitja Muhič</i>	13
Geopolitični interesi in blagovni tokovi v evropski industriji.....14 Geopolitical interest and goods flow in European industry <i>Sašo Murtič, Ingrid Franko Uhernik, Šejla Murtič</i>	14

## **Predgovor**

Pred vami je zbornik recenziranih prispevkov 8. mednarodne konference o razvoju industrijskega inženiringa, s podnaslovom: Priložnosti, potenciali in izzivi, ki ga tradicionalno organizira Fakulteta za industrijski inženiring Novo mesto. Vabilu k sodelovanju na konferenci se je odzvalo veliko število avtorjev s skupaj 12 prijavljenimi povzetki.

Vsebina posameznih prispevkov je raznolika in obravnava sodobne metode in posamezne inovativne rešitve problemov na področju industrijskega inženiringa. Uvodoma se seznanimo z aditivna proizvodnja lahkih kovin, kot je magnezij. V nadaljevanju se soočimo z reševanjem energetske krize z inovativnimi tehnikami izkoriščanja visokega pritiska. Mednarodno priznani strokovnjaki nam bodo predstavili najnižje lastne frekvence s tekočino obremenjene elastične cilindrične lupine. Sledi pregled trenutnega napredka v aditivni proizvodnji z uporabo žičnih oblikov. Sledita dva zanimiva povzetka o problematiki visokonapetostnih baterij po koncu življenjske dobe vozil na električni ali hibridni pogon ter prikaz možnosti uporabe teh baterij v novih stacionarnih aplikacijah. V času digitalizacije je vsekakor pomembna digitalizacija organizacijskega procesa, ki bo predstavljena v nadaljevanju. Sledi predstavitev optimizacije proizvodnega procesa na rezalno-gubalni liniji in predstavitev obdelave podatkov za napovedovanje korekcij varilnih orodij s pomočjo umetne inteligence. Sledita dve zanimivi predstavitvi in sicer predstavitev razvoja koncepta naprave za izkoriščanja energije valovanja morja ter predstavitev proizvodnje PCB v Sloveniji v zelenem prehodu. Ob koncu spoznamo CAD in CAM tehnologije v procesu višjega strokovnega izobraževanja ter zaključimo z geopolitičnimi interesi in blagovnimi tokovi v evropski industriji.

Kot avtorji ali soavtorji posameznih prispevkov so se k sodelovanju na konferenci odzvali mednarodno uveljavljeni raziskovalci in eminentni visokošolski učitelji tako iz Slovenije kot tudi iz tujine, kar nas v programskem odboru navdaja z veseljem v pričakovanju izmenjave odličnega znanja in uspešnih praks.

Dr. Tomaž Savšek  
Predsednik programskega odbora

## **Preface**

Before you is a book of abstracts of the 8th International Conference on the Development of Industrial Engineering, with the subtitle: Opportunities, Potentials and Challenges, traditionally organized by the Faculty of Industrial Engineering Novo mesto. A large number of authors responded to the invitation to participate in the conference with a total of 12 submitted abstracts.

The content of individual contributions is diverse and deals with modern methods and individual innovative solutions to problems in the field of industrial engineering. In the beginning, we will learn about the additive manufacturing of lightweight metals, such as magnesium. In the following, we face the solution of the energy crisis with innovative techniques of high-pressure utilization. Internationally recognized experts will present the lowest eigenfrequencies of a fluid-loaded elastic cylindrical shell. The following is a review of recent advances in wire arc additive manufacturing. The following are two interesting abstracts about the issue of high-voltage batteries after the end of the life of electric or hybrid vehicles and a presentation of the possibility of using these batteries in new stationary applications. In the age of digitization, digitization of the organizational process is definitely important, which will be presented below. This is followed by a presentation of the optimization of the production process on the cutting-forming line and a presentation of data processing for prediction of welding fixture adjustments using artificial intelligence. Two interesting presentations follow, namely the presentation of the development of the concept for a sea wave energy harvesting device and the presentation of PCB production in Slovenia in the green transition. At the end, we learn about CAD and CAM technologies in the process of higher professional education and conclude with geopolitical interests and goods flows in European industry.

As authors or co-authors of individual papers, internationally renowned researchers and eminent professors from Slovenia and abroad responded to the conference, which fills us in the program committee with joy in anticipation of the exchange of excellent knowledge and successful practices.

Dr. Tomaž Savšek  
Chairman of the Program Committee



## Aditivna proizvodnja lahkih kovin, kot je magnezij

### Additive manufacturing of light-weight metals like magnesium

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#### Povzetek

Magnezij (Mg) in njegove zlitine so postali priljubljeni v industriji, zlasti v ortopediji. Proizvodnja ortopedskih izdelkov z uporabo Mg se še vedno sooča s številnimi izzivi, predvsem zaradi majhne teže in omejene prožnosti, ki izhaja iz visoke vnetljivosti in visoke toplotne prevodnosti magnezija. Postopki aditivne proizvodnje, kot je selektivno lasersko taljenje (SLM), nudijo zaščitno okolje med proizvodnjo izdelka, ki lahko zmanjša reakcijo s kisikom. Vendar pa lahka narava Mg povzroča različne težave, kot so brizganje prahu in staljenih materialov, letenje delcev prahu in zaščita pred laserskim sevanjem. Zato je komora SLM napolnjena s prahom v okolju inertnega plina, ki preprečuje, da bi laser prodrl in dosegel območje delovanja. S povečevanjem kroženja plina skozi filter prihaja posledično do povečanja letenja prahu v komori, zaradi česar prihaja do izgube materiala. Da bi odpravili te težave, je bilo izvedenih več poskusov, v katerih se je moč laserja spreminjala med 40 in 200 W v korakih po 10 W, medtem ko se je hitrost skeniranja spreminjala med 400 do 3000 mm/s v korakih po 100 mm/s. Upošteevane so dvoslojne debeline, in sicer 25  $\mu\text{m}$  in 50  $\mu\text{m}$ . Pretok kroženja plina se je spreminjal od 80 l/min do 300 l/min. Rezultati so pokazali, da predlagani proizvodni parametri pomembno vplivajo na premagovanje zgoraj omenjenih težav.

**Ključne besede:** magnezij; aditivna proizvodnja; lahke kovine; SLM; moč laserja

**Razvrstitev:** Znanstveni članek

#### Abstract

Magnesium (Mg) and its alloys have become popular for industrial applications, especially in orthopaedics. Orthopaedic product manufacturing using Mg still faces numerous challenges mainly due to the low weight and limiting flexibility which arises from the high flammability and high thermal conductivity of magnesium. Additive Manufacturing processes such as Selective Laser Melting (SLM) offer a protective environment during the manufacture of the product that can diminish the reaction with oxygen. However, the light-weight nature of Mg causes various problems such as spattering of powder and molten materials, flying of powder particles, and shielding of laser radiation. Therefore, the SLM chamber is occupied by the powders as dust in the inert gas environment that prevents laser from penetrating and reaching the action zone. Increasing the gas circulation through the filter also has the disadvantage of increasing powder fly, which causes the powder layer to lose the materials. To overcome these issues, several experiments have been conducted in which the laser power has varied between 40 to 200 W by 10W increment, while the scanning speed varied between 400 to 3000 mm/s by 100 mm/s increments. Two-layer thicknesses, namely 25  $\mu\text{m}$  and 50  $\mu\text{m}$ , has been considered. The flow rate of the gas circulation has varied from 80 l/min to 300 l/min. The results showed that the proposed manufacturing parameters have significant influences to overcome above mentioned issues.

**Keywords:** magnesium; additive manufacturing; light-weight metals; SLM; laser power

**Article Classification:** Scientific Paper





# Harnessing the High Pressure: Addressing the Energy Crisis through Innovative Techniques

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## Abstract

The global energy crisis poses significant challenges that extend beyond the realm of energy production. It impacts economic stability, geopolitical dynamics, and environmental sustainability. As we strive to address this crisis, it is essential to explore diverse avenues for renewable energy sources, such as solar, wind, hydro, and geothermal power. Investing in clean energy technologies and improving energy efficiency can help mitigate the effects of the crisis and pave the way towards a more sustainable future. By employing unique research methods, including high-pressure techniques, it becomes possible to modify the physical properties of amorphous materials or control the nanocrystallization process to obtain materials with enhanced mechanical parameters and electrical conductivity. Another important aspect of high-pressure research is the application of the barocaloric effect in heat exchange processes. All these application areas of high-pressure techniques may offer one of the solutions to the many challenges facing humanity in this era of multiple crises. Additionally, transitioning to electric vehicles and implementing smart grid systems can contribute to reducing our dependence on fossil fuels and optimizing energy distribution. Embracing energy conservation practices at both individual and societal levels is equally crucial. Encouraging sustainable behaviors, such as energy-efficient building designs, recycling, and responsible consumption, can lead to substantial energy savings.

**Keywords:** energy, high pressure, batteries, glassy materials, electric conductivity

**Article Classification:** Scientific Paper



## The lowest eigenfrequencies of a fluid-loaded elastic cylindrical shell

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### Abstract

Revisit of a classical problem in fluid-structure interaction is inspired by modern industrial applications, see [1-3]. An asymptotic approach, typical for the theory of elastic shells, is implemented to analyze the lowest vibration frequencies of a thin-walled elastic cylinder immersed in a compressible fluid, see, [4] and [5], also [6]. A two-term asymptotic formula is derived for the real parts of the lowest complex valued eigenfrequencies. The imaginary parts of these eigenfrequencies are also estimated. The main results may be outlined as

- i. the values of the lowest eigenfrequencies are asymptotically smaller than for a shell with traction-free faces (a dry shell)
- ii. the leading order term in the frequency expansion is not influenced by the shell inertia
- iii. the two-term asymptotic formula does not involve the effect of fluid compressibility.

The obtained results are illustrated numerically for steel and aluminum shells immersed in water, demonstrating that the imaginary parts of the frequencies are significantly small. As a result, they are generally ignored in comparison with the contribution of structural damping.

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**Keywords:** thin shell, fluid-loaded, asymptotic, eigenfrequencies

**Article Classification:** Scientific Paper



## A review of recent advances in Wire Arc Additive Manufacturing (WAAM)

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### Abstract

This article provides an overview of wire arc additive manufacturing (WAAM), which is the deposition of metal wire using an arc welding power source and CNC or robotic manipulator. The high deposition rate of WAAM justifies its use for manufacturing of large components compared to other AM methods. However, the use of wire as feedstock in the WAAM process has certain advantages and disadvantages which are explained in detail. The potential of WAAM process in material technology such as in-situ alloying and functionally graded materials (FGMs) by eliminating the complicated manufacturing process, is shown. The influence of the progress in artificial intelligence on the development of the next generation of WAAM is presented. Various sensors, path planning, process control and simulation of WAAM are discussed to reduce material and energy consumption. Post-processing techniques are also discussed as a method to improve the quality of the final product. Finally, future perspective of WAAM process is provided.

**Keywords:** additive manufacturing, wire arc additive manufacturing, welding, in-situ alloying, control, future prospects

**Article Classification:** Scientific Paper



## Problematika visokonapetostnih baterij po koncu življenjske dobe vozil na električni ali hibridni pogon

### The problem of high-voltage batteries at the end of the life of electric or hybrid vehicles

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#### Povzetek

Čeprav so električna vozila postala del našega vsakdana, pa njihov začetek sega v 19. stoletje, ko so patentirali prvo električno vozilo. Njihova priljubljenost se z leti močno povečuje, lahko bi rekli, da smo na vrhuncu razvoja električnih in hibridnih vozil. Avtomobilska podjetja so, skupaj s svetovnimi vladami, odločena, da klasičnih vozil na bencinsko in dizelsko gorivo po letu 2030 ne bodo več proizvajali. S tem bomo tako zmanjšali ogljični odtis, kot tudi hrup klasičnih vozil na fosilna goriva. Trg bomo preplavili z električnimi in hibridnimi vozili, ki so okolju veliko bolj prijazna, saj emitirajo manjše količine okolju škodljivih snovi ter ne povzročajo hrupa. Vozila lahko po vrnitvi iz službe preprosto priključimo na električno omrežje, jih napolnimo in so čez nekaj ur ponovno pripravljeni za uporabo. Vsa dejstva o električnih in hibridnih vozilih zvenijo obetavno, vendar se ne zavedamo potencialne nevarnosti visokonapetostnih industrijskih baterij, ki poganjajo vozila na električni ali hibridni pogon. Litij-ionska baterija ima v električnih in hibridnih vozilih pomembno vlogo shranjevanja električne energije, ki je potrebna za delovanje vozila. Vsako električno ali hibridno vozilo po približno desetih letih potrebuje zamenjavo litij-ionske baterije, saj njene zmogljivosti niso več ustrezne za normalno uporabo vozila. Podjetja veliko denarja in časa namenjajo odkrivanju novih tehnologij in izboljševanju lastnosti vozil, z odpadnimi baterijami, pa se ukvarja le peščica podjetij. Prav s to težavo smo se ukvarjali v naši raziskavi, v katerem smo predstavili začetke razvoja električnih in hibridnih vozil, njihovo sestavo in spoznali litij-ionsko baterijo, njeno delovanje ter poskusili odkriti, kaj vse lahko storimo z odpadnimi baterijami. Do sedaj smo spoznali veliko obstoječih metod recikliranja odpadnih baterij ter nekatere idejne rešitve za katere pričakujemo, da bodo kmalu prišle v širšo uporabo.

**Ključne besede:** električna vozila, hibridna vozila, litij-ionska baterija, okolje, onesnaževanje

**Razvrstitev:** Znanstveni članek

#### Abstract

Although electric vehicles have become a part of our everyday lives, their origins date back to the 19th century, when the first electric vehicle was patented. Their popularity has increased dramatically over the years, and it could be said that we are at the cutting edge of electric and hybrid vehicle development. Car companies, together with governments around the world, are determined to phase out conventional petrol and diesel vehicles after 2030. This will reduce both the carbon footprint and the noise of conventional fossil fuel vehicles. We will flood the market with electric and hybrid vehicles, which are much more environmentally friendly, emitting fewer pollutants and making less noise. They can simply be plugged in, recharged and ready for use again in a few hours. All the facts about electric and hybrid vehicles sound promising, but we are not aware of the potential dangers of the high-voltage industrial batteries that power electric or hybrid vehicles. In electric and hybrid vehicles, the lithium-ion battery plays an important role in storing the electricity needed to run the vehicle. Every electric or hybrid vehicle needs to replace its lithium-ion battery after about ten years, as its capacity is no longer adequate for normal vehicle use. Companies spend a lot of time and money on discovering new technologies and improving the performance of vehicles, but only a handful of companies deal with waste batteries. This is the problem that we have addressed in our research, which has looked at the origins of the development of electric and hybrid vehicles, their composition, the lithium-ion battery, how it works, and what we can do with waste batteries. So far, we have learnt about many existing methods for recycling waste batteries and some of the ideas we expect to see in widespread use soon.

**Keywords:** electric vehicles, hybrid vehicles, lithium-ion battery, pollution

**Article Classification:** Scientific Paper



## Bat2Life: Pametno upravljanje odjema in proizvodnje EE z uporabo baterije 2. življenjskega obdobja

### Bat2Life: Smart EE consumption and production management using the 2nd life cycle battery

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#### Povzetek

V prispevku predstavljamo prve rezultate projekta Bat2Life, ki predstavlja učinkovito povezavo dveh partnerjev in sicer visokotehnološkimi IKT podjetjem Solvera Lynx ter inovativnim Metron Inštitutom, ki sta osredotočena na prebojno inovacijo pametnega upravljanja odjema in proizvodnje električne energije z aplikacijo hranilnikov energije, proizvedenih iz baterij 2. življenjskega obdobja.

V okviru projekta razvijamo (1) tipiziran modul baterijskega shranjevalnika iz obnovljenih baterij iz električnih vozil, (2) programsko rešitev za upravljanje proizvodnje in odjema električne energije (EE), ki bo primerna za gospodinjstva in male poslovne odjemalce, ter (3) integrirano rešitev, ki bo na inovativen način združila na novo razviti lastnosti oziroma elementa ter nadgradila obstoječe rešitve na področju sistemov za proizvodnjo obnovljivih virov energije (OVE), v prvi vrsti s sončnimi in vetrnimi elektrarnami, ter napredne odjemalce, kot so polnilne postaje za električna vozila (EV). Končni izdelek bomo validirali in demonstrirali v operativnem okolju pri nosilnem partnerju, tako da bo izdelek potrjen v končni obliki in primeren za uporabo v realnem okolju.

V nove rešitve prenašamo bogato znanje in izkušnje na področju razvoja in implementacije fleksibilnih sistemov upravljanja proizvodnje in odjema EE, trajnostnega energetskega kroga, električne mobilnosti in avtomobilskih baterij. Razvijamo učinkovite rešitve, s katerimi se naslavljamo aktualne izzive na področju upravljanja z EE iz OVE ter ponovne uporabe delno izrabljenih baterij iz EV. Posledično se bo zmanjšala potreba po proizvodnji novih baterij za stacionarne aplikacije, kar bo vplivalo na zmanjšanje potreb po primarnih surovinah. V okviru programske rešitve razvijamo tudi aplikacijo za spremljanje karakteristik baterijskega sistema in zagotavljanje sledljivosti baterijskega sistema – potni list baterij.

**Ključne besede:** baterije električnih vozil, drugo življenjsko obdobje, upravljanje proizvodnje in odjema električne energije

**Razvrstitev:** Strokovni članek

#### Abstract

In this paper, we present the first results of the Bat2Life project, which represents the effective connection of two partners, namely the high-tech ICT company Solvera Lynx and the innovative Metron Institute, which are focused on the breakthrough innovation of smart management of electricity consumption and production with the application of energy storage devices produced from 2nd life cycle batteries.

In the framework of the project, we are developing (1) a typical battery storage module from recovered batteries from electric vehicles, (2) a software solution for managing the production and consumption of electrical energy (EE), which will be suitable for household and small business customers, and (3) an integrated solution, which will combine newly developed features or elements in an innovative way and upgrade existing solutions in the field of systems for the production of renewable energy sources (RES), primarily with solar and wind power plants, as well as advanced customers such as charging stations for electric vehicles (EV). We will validate and demonstrate the final product in an operational environment at a supporting partner, so that the product will be validated in its final form and suitable for use in a real environment.





In new solutions, we transfer rich knowledge and experience in the field of development and implementation of flexible management systems for production and consumption of EE, sustainable energy cycle, electric mobility and car batteries. We develop effective solutions that address current challenges in the field of managing EE from RES and reusing partially used batteries from EVs. As a result, the need to produce new batteries for stationary applications will decrease, which will affect the reduction of the need for primary raw materials. As part of the software solution, we are also developing an application for monitoring the characteristics of the battery system and ensuring the traceability of the battery system - the battery passport.

**Keywords:** *batteries of electric vehicles, second life cycle, management of production and consumption of electricity*

**Article Classification:** *Professional Paper*

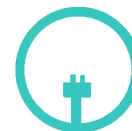
**Projekt Bat2Life** *Financira Evropska unija – NextGenerationEU*



REPUBLIKA SLOVENIJA  
MINISTRSTVO ZA GOSPODARSTVO,  
TURIZEM IN ŠPORT



Financira  
Evropska unija  
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## Digitalizacija organizacijskega procesa

## Digitalisation of organisational process

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### Povzetek

V večjih podjetjih se pogosto soočamo z izzivi obvladovanja posameznih aktivnosti, ki vključujejo sodelovanje različnih služb in zahtevajo povratne informacije o statusu. Predvsem je izziv obvladovati trenutno stanje aktivnosti in določati odgovornosti, ko gre za kompleksnejše naloge, ki vključujejo organizacijo več različnih timov in posameznikov. Za učinkovito obvladovanje aktivnosti je ključnega pomena komunikacija, status aktivnosti in transparentnost procesa. Z digitalizacijo organizacijskega procesa in vpeljavo novih organizacijskih pristopov smo prišli do rešitve, ki nam omogoča učinkovito obvladovanje aktivnosti, ki zahtevajo povezovanje služb znotraj podjetja. Nov organizacijski model nam omogoča hitro reševanje eskalacij in sistemsko vodenje aktivnosti. Z našo rešitvijo smo uspešno izboljšali organizacijo, zmanjšali število komunikacijskih kanalov in bistveno pohitrili proces obvladovanja.

**Ključne besede:** digitalizacija, obvladovanje aktivnosti, organizacijski model, povezovanje služb, komunikacija

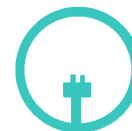
**Razvrstitev:** Strokovni članek

### Abstract

In larger companies, we are often faced with the challenge of managing individual activities that involve the collaboration of different departments and require status feedback. In particular, it is challenging to manage the current status of activities and assign responsibilities when it comes to more complex tasks involving the organisation of several different teams and individuals. Communication, status of activities and transparency of the process are key to effective activity management. By digitising the organisational process and introducing new organisational approaches, we have come up with a solution that allows us to effectively manage activities that require the integration of departments within the company. The new organisational model allows us to quickly resolve escalations and manage activities in a systematic way. With our solution, we have successfully improved the organisation, reduced the number of communication channels and significantly accelerated the management process.

**Keywords:** digitalisation, activity management, organisational model, integration of departments, communication

**Article Classification:** Professional Paper



## Optimizacija proizvodnega procesa na rezalno-gubalni liniji

### Optimization of the production process on the cutting-forming production line

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#### Povzetek

V proizvodnem procesu se ne moremo izogniti zastojem. Ti negativno vplivajo na poslovanje podjetja, hkrati pa vplivajo na povečan stres zaposlenih, ki delajo na nedelujočih strojih. Zato je potrebno zmanjšati zastoje na minimum, da teče proizvodni proces nemoteno. Poleg velikih zastojev se v proizvodnji pojavlja tudi veliko število mikro zastojev. Čeprav so slednji trenutno zanemarljivi, pa vplivajo v daljšem časovnem obdobju na potek proizvodnega procesa.

V raziskavi smo ugotavljali vpliv mikro zastojev na proizvodni proces in sicer na rezalno-gubalni liniji. Izračunali smo stroške in ugotovili, da se zaradi mikro zastojev lahko zmanjša količina proizvedenih izdelkov za 1,4 %. Izmed zbranih predlogov smo izbrali dva najbolj primerna predloga za testno implementacijo: omogočiti operaterju pogled v dvizni zalogovnik ter zmanjšanje premera luknje na lovilnih ščitih.

Z realizacijo navedenih predlogov je bilo ugotovljeno, da sta imeli optimizaciji neposreden vpliv na proizvodni proces. Tako smo na posameznem delovnem mestu v izmeni pridobili tudi do 350 kosov več mesečno. Dokazali smo, da je z vključitvami raznih izboljšav možno zmanjšati vpliv na mikro zastoje ter povečati produktivnost.

**Ključne besede:** rezalno-gubalna linija, preoblikovanje, cev, mikro zastoj, optimizacija, stroški

**Razvrstitev:** Strokovni članek

#### Abstract

In the production process we cannot avoid interruptions. These have a negative impact on the company's operations, and, at the same time, they increase the stress of employees who work on non-working machines. Therefore, it is necessary to reduce interruptions to a minimum so that the production process runs smoothly. In addition to major interruptions, there is also a large number of micro interruptions in production. Although the latter are currently negligible, they affect the course of the production process over a longer period of time.

In the research, we determined the impact of micro interruptions the production process, and namely on the cutting-forming line We calculated the costs and determined that the number of manufactured products can be reduced by 1.4 % due to micro interruptions. From the collected proposals, we selected two most suitable proposals for test implementation: allowing the operator to look into the lifting magazine and reducing the diameter of the hole in the catch shields.

With the realization of the proposals, it was established that the two optimizations had a direct impact on the production process. We obtained up to 350 pieces more per month at an individual workplace in a shift and we proved it that by incorporating various improvements, it is possible to reduce the impact on micro interruptions and increase productivity.

**Keywords:** cutting-forming line, reshaping, pipe, micro interruption, optimization, costs

**Article Classification:** Professional Paper



## Obdelava podatkov za napovedovanje korekcij varilnih orodij s pomočjo umetne inteligence

### Data processing for prediction of welding fixture adjustments using artificial intelligence

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#### Povzetek

V sklopu razvojne raziskave je bila analizirana možnost uporabe sistema umetne inteligence v procesu varjenja zvarjenca kompleksne oblike. Slednji je sestavljen iz večjega števila odpreškov kompleksne oblike, ki so izdelani iz visokotrnostnega jekla. Zaradi navedenega je pravilna nastavitve varilnih orodij še posebej zahtevna. Razviti sistem na podlagi vhodne geometrije oz. geometrije odpreškov vrne vrednost nastavitve orodij, s katerimi je dosežena ustrezna geometrija končnega zvarjenca. Raziskava se je delila na dva dela. V prvem delu je bilo potrebno prepoznati vplivne parametre v omenjenem procesu ter jih pretvoriti v obliko, ki omogoča uporabo v sistemu umetne inteligence. Izkazalo se je, da ima na končno geometrijo zvarjenca največji vpliv geometrija odpreškov oz. geometrija robov in površin, ki nastopajo v varu. Tukaj je bilo potrebno najti učinkovit način za opis njihove geometrije. Izkazalo se je, da je najbolj učinkovit način opis robov s pomočjo polinomov, kjer so slednji določeni s pomočjo Akaikevega informacijskega kriterija. Drugi del raziskave je zajemal postavitve modela zveze med končno geometrijo zvarjenca ter parametri procesa oz. geometrijo odpreškov. Postavljeni modeli so temeljili na dveh različnih topologijah nevronske mreže. Prva obravnavana topologija je bila večravninski perceptron, druga pa je bila nevronska mreža z eliptičnimi baznimi funkcijami. Slednja je bila tudi aplicirana, saj je takšno nevronska mrežo možno učiti adaptivno ter jo doučiti s poljubnim številom podatkov. V sklopu razvojne raziskave smo pokazali, da je z uporabo ustrezne topologije nevronske mreže mogoče napovedati ustrezne nastavitve varilnih orodij na podlagi geometrije odpreškov.

**Ključne besede:** umetna inteligence, nevronske mreže, aproksimacija, polinomi, korekcije varilnih orodij, Akaikevi informacijski kriterij

**Razvrstitev:** Strokovni članek

#### Abstract

As part of the development research, the possibility of using an artificial intelligence system in the process of welding a product of complex shape was analyzed. The latter consists of a large number of stamped parts of a complex shape, which are made of high-strength steel. Because of the above, the correct welding fixtures adjustments are particularly demanding. Developed system based on geometry of the stamped parts returns the value of the welding fixtures adjustments, which are used to achieve the appropriate geometry of the final welded product. The research was divided into two parts. In the first part, it was necessary to identify the influential parameters in the mentioned process and convert them into a form that enables use in the artificial intelligence system. It turned out that the geometry of the stamped parts or rather the geometry of the edges and surfaces of the stamped parts has the greatest influence on the final geometry of the welded product. Hence, it was necessary to find an efficient way to describe their geometry. It turned out that the most effective approach is to describe the edges using polynomials, where the latter are determined using the informational Akaike criterion. The second part of the research included setting up a model of the relationship between the final geometry of the welded product and geometry of stamped parts. The built models were based on two different neural network topologies. The first topology was a multi-layer perceptron, and the second was a neural network with elliptical basis functions. The latter was applied as a preferred choice since such a neural network can be trained adaptively with any amount of data. As part of the development research, we showed that application of the suitable topology of the neural network enables predicting the appropriate welding fixture adjustments of the welding tools based on the geometry of the stamped parts.

**Keywords:** artificial intelligence, neural networks, approximation, polynomials, welding fixtures adjustments, Akaike information criterion

**Article Classification:** Professional Paper



## Razvoj koncepta naprave za izkoriščanja energije valovanja morja

### Developing a concept for a sea wave energy harvesting device

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#### Povzetek

Rast in višanje življenjskega standarda prebivalstva med drugim povzroča večanje emisij škodljivih plinov in drugih onesnaževal, kot so ogljikov dioksid, metan, dušikovi oksidi, ozon, žveplov dioksid, amonijak, benzen, pesticidi, trdi delci v zraku in podobno. Omenjena onesnaževala v veliki meri prispevajo tako k splošnemu slabšanju zdravja prebivalstva, kot tudi k škodljivim podnebnim spremembam in zmanjševanju biotske raznolikosti. Podnebne spremembe v največji meri povzročajo toplogredni plini, ki v veliki meri nastajajo pri izgorevanju fosilnih goriv za potrebe mobilnosti ter pri segrevanju in ohlajanju bivalnih in delovnih prostorov. Zaradi omenjenih negativnih posledic toplogrednih plinov je nujno potrebno čimprej zmanjšanje emisij, ki ga lahko najučinkovitejše dosežemo z uporabo obnovljivih virov energije, kot so sončna energija (ki je primarni vir nekaterih ostalih energij ter pogonska sila celotnega ekosistema), vetrna energija, vodna energija (hidroenergija), energija biomase, pogojno obnovljiva geotermalna energija, nuklearna energija (ki ni zelena, temveč modra energija) ter energija morja in oceanov. Ker večino našega planeta prekrivajo morja oziroma oceani, smo sledili raziskovalcem in inženirjem, ki si že vrsto let prizadevajo izkoriščati energijo oceanov, saj so morski tokovi, plimovanja in valovi neizčrpen vir obnovljive energije. V ta namen bomo preizkusili koncept generatorja električne energije na osnovi vzbujanja valovanja, na podlagi tehnologije samodejnega navijanja oziroma polnjenja ročne ure. Gre za koncept električnega generatorja, ki bo kot vir energije izkoriščal mehansko energijo z valovanjem morja vzbujene rotirajoče ekscentrične mase. Rotirajoča masa bo zavrtela rotorski podslop v statorskem paketu na principu brezkrtačnega enosmernega motorja (BLDC) in tako vhodno vrtilno energijo generatorja spremenila v izhodno električno energijo. V prispevku bomo opisali, preizkušali, ter analizirali rentabilnost razvitega generatorja električne energije.

**Ključne besede:** električni generator, brezkrtačni motor, energija valovanja, ogljična nevtralnost, optimalni prenos energije

**Razvrstitev:** Strokovni članek

#### Abstract

Population growth and rising living standards are leading to an increase in emissions of greenhouse gases and other pollutants such as carbon dioxide, methane, nitrogen oxides, ozone, sulphur dioxide, ammonia, benzene, pesticides, airborne particles and other pollutants, to name a few. These pollutants are major contributors to the overall deterioration of public health as well as primary cause of climate change and loss of biodiversity. The main contributors to climate change are greenhouse gases, most of which are produced by burning fossil fuels for mobility and heating and cooling homes and workplaces. These negative impacts of greenhouse gases make it imperative to reduce emissions as quickly as possible, and the most effective way to do this is to use renewable energy sources such as solar energy (which is the primary source of some other energy and the driving force of the entire ecosystem), wind energy, hydropower, biomass energy, conditionally renewable geothermal energy, nuclear energy (which is not green energy but blue energy), and energy from the sea and oceans. Since most of our planet is covered by seas or oceans, we have followed the example of researchers and engineers who have been working for many years to harness ocean energy, because ocean currents, tides and waves are an inexhaustible source of renewable energy. To this end, we will test the concept of a wave excitation-based electricity generator based on the technology of automatically winding or recharging a wristwatch. This concept is a power generator that uses the mechanical energy of a rotating eccentric mass excited by ocean waves as an energy source. The rotating mass turns a rotor assembly in a stator pack based on the principle of a brushless DC motor (BLDC), converting the supplied rotational energy from the generator into electrical output energy. In this paper, we describe, test and analyse the functionality of the developed power generator.

**Keywords:** electric generator, brushless motor, wave energy, carbon neutrality, optimal energy transfer

**Article Classification:** Professional Paper





# PCB Production in Slovenia: Exploring Opportunities, Unleashing Potential, and Overcoming Challenges in the Green Transition

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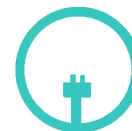
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## Abstract

This article delves into the opportunities, potential, and challenges associated with PCB (Printed Circuit Board) production in Slovenia within the context of the global green transition. Slovenia, a small yet vibrant European country, has emerged as a significant player in the PCB manufacturing industry. This article examines the country's current state of PCB production, highlights its green initiatives, and presents an analysis of the opportunities and challenges that lie ahead.

**Keywords:** PCB, green transition, industry, future, energy

**Article Classification:** Professional Paper



## CAD in CAM tehnologije v procesu višjega strokovnega izobraževanja

### CAD and CAM technologies in the process of higher professional education

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#### Povzetek

Računalniško modeliranje – CAD (Computer-aided design) in računalniško podprta proizvodnja – CAM (Computer-aided manufacturing) sta nepogrešljiva v današnji industriji in so pomemben del procesa digitalizacije in industrije 4.0. Uporabljamo jih za pomoč pri načrtovanju, modeliranju, izdelavi tehnične dokumentacije in izdelavi izdelkov od prototipov do velikoserijske proizvodnje.

Računalniško modeliranje – CAD je uporaba računalnikov in delovnih postaj za pomoč pri modeliranju, spreminjanju, analizi in optimizaciji izdelkov. Ta programska oprema se uporablja za povečanje produktivnosti, izboljšanje kakovosti, izboljšanje komunikacije prek dokumentacije in ustvarjanje baze podatkov za industrijo.

Računalniško podprta proizvodnja – CAM, je uporaba programske opreme za krmiljenje obdelovalnih strojev pri izdelavi izdelkov. Lahko se nanaša tudi na uporabo računalnika za pomoč pri vseh operacijah proizvodnega procesa, vključno z načrtovanjem, upravljanjem, transportom in skladiščenjem.

V prispevku je prikazan praktičen proces in primeri uporabe CAD in CAM tehnologij v procesu višjega strokovnega izobraževanja na študijskih programih strojništvo in mehatronika. CAD in CAM tehnologije uporabljamo pri predmetih Računalniško modeliranje, Računalniško podprta proizvodnja in tehnologije, Tehnično projektiranje in načrtovanje in predvsem pri projektnem delu in diplomskih nalogah. CAD in CAM tehnologije pomagajo inženirjem in podjetjem doseči večjo konkurenčnost, inovativnost ter izboljšanje funkcij in kakovosti izdelkov.

**Ključne besede:** računalniško modeliranje – CAD, računalniško podprte tehnologije, računalniško podprta proizvodnja – CAM, Višja strokovna šola

**Razvrstitev:** Strokovni članek

#### Abstract

Computer modeling - CAD (Computer-aided design) and computer-aided manufacturing - CAM (Computer-aided manufacturing) are indispensable in today's industry and are an important part of the digitalization process and Industry 4.0. We use them to help with planning, modeling, production of technical documentation and production of products from prototypes to mass production.

Computer Modeling - CAD is the use of computers and workstations to help model, modify, analyze and optimize products. This software is used to increase productivity, improve quality, improve communication through documentation and create a database for industry.

Computer-aided manufacturing - CAM is the use of software to control machine tools in the manufacture of products. It can also refer to the use of a computer to assist in all operations of the production process, including planning, management, transportation, and storage.

The paper shows the practical process and examples of CAD and CAM technologies in higher professional education in the mechanical engineering and mechatronics study programs. CAD and CAM technologies are used in Computer Modeling, Computer Aided Production and Technologies, Technical Design and Planning and especially in project work and diploma theses. CAD and CAM technologies help engineers and companies achieve greater competitiveness, innovation and improvement of product functions and quality.

**Keywords:** Computer-aided design – CAD, Computer-aided technologies, Computer-aided manufacturing – CAM, Higher professional education

**Article Classification:** Professional Paper



## Geopolitični interesi in blagovni tokovi v evropski industriji

### Geopolitical interest and goods flows in european industry

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#### Povzetek

Vajeni smo, da so spremembe v gospodarstvu in industriji stalnica, nanje še bolj vplivajo blagovni tokovi in geopolitični interesi sveta, ki narekujejo spreminjanje oblike in načina zagotavljanja surovin za proizvodnjo. Spremembam je podvržena tudi logistika in logistični procesi, ker mora slediti tehnološkemu razvoju in posodobitvi industrijske, istočasno pa je kot oskrbovalna močno vtisnjena med velike interese držav daljnega vzhoda in zahoda. Primerno blagovnim tokom se spreminjajo načini oskrbe proizvodnje, kar daje vtis vračanja industrijskega razvoja nekaj korakov nazaj. V povezavi z gibanjem blagovnih tokov primerjamo tudi oblike managementa, ki sega v področje, ki naj bi skozi iskanje novih rešitev omogočal uvajanje novih modelov, novih sistemov, novih paradigem, ki naj bi izboljšale proizvodnjo, produktne tokove in storitev, ki naj bi omogočali proizvodnjo in krožno gospodarstvo. Glede na vse večje globalne interese vzhoda in zahoda, se pogloblja gospodarska kriza, kar posledično vpliva na določene sisteme vodenja in upravljanja blagovnih tokov in industrijske proizvodnje. Pri vsem spoznavamo, da sodobne oblike vodenja proizvodnje z dobave surovin ob pravem času, na pravem mestu »Just in Time« ali model proizvodnje brez emocij »Ji joka« ne deluje, zaradi česar industrija, proizvodne in storitvene organizacije vse bolj razmišljajo o zagotavljanju večjih blagovnih rezerv, ki bi zagotovile proizvodnjo za pol leta ali celo za eno leto, kar naj bi za sodobno obliko proizvodnje pomenilo vračanje korak nazaj. Zbrani podatki v industriji, proizvodnji, storitvenih in drugih organizacijah nam sporočajo, da so nastale nove potrebe po blagovnih tokovih, na katere vplivajo geopolitični interesi vzhoda in zahoda, obenem je vojna v Ukrajini spremenila oblike zagotavljanja energije in surovin za evropsko industrijo.

**Ključne besede:** blagovni tokovi, oskrba, proizvodnja, geopolitični interesi, Evropa, industrija

**Razvrstitev:** Strokovni članek

#### Abstract

We are used to the fact that changes in the economy and the constant have an even greater impact on commodity flows and geopolitical interests of the world, which encourage changes in the forms and methods of providing raw materials for the manufacturing industry. The changes are also supported by logistics and logistics processes, because it has to follow technological development and renewed industry, and at the same time, as a supply station, it is strongly imprinted among the great interests of the countries of the Far East and the West. In line with commodity flows, the ways of supplying production are changing, which gives the impression of taking industrial development back a few steps. In connection with the movement of product flows, we also compare the forms of management, which reaches into the field that, through the search for new solutions, should enable the introduction of new models, new systems, new paradigms, which should improve production, product flows and services, which should enable production and circular economy. Given the increasing global interests of East and West, the economic crisis is deepening, which in turn affects certain systems of management and management of commodity flows in industrial production. In everything, we realize that modern forms of production management with the supply of raw materials at the right time, at the right place "Just in Time" or the model of production without emotions "Ji joka" do not work, which is why industry, production and service organizations are increasingly thinking about providing greater commodity reserves, which would ensure production for half a year or even for a year, which should mean taking a step back for the modern form of production. Collected data in industry, production, services and other organizations tell us that new needs have arisen for commodity flows, due to changes in the geopolitical interests of East and West, and at the same time, the war in Ukraine has changed the forms of providing energy and raw materials for European industry.

**Keywords:** commodity flows, supply, production, geopolitical interests, Europe, industry

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