Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

Fakulteta za strojništvo / Faculty of Mechanical Engineering

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Miha Brojan miha.brojan@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Mehanika / Mechanics

4. Opis raziskovalnega dela *(Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Delo je usmerjeno v raziskovanje vpliva stisljivosti na viskoelastično obnašanje materialov, kot so gume in številna biološka tkiva, ki jih običajno obravnavamo kot (skoraj) nestisljive. Cilj raziskave je modelirati odziv gume pri obremenitvah z zelo visokim hidrostatičnim tlakom (v območju 1000–5000 bar), kjer se sicer skoraj nestisljivi materiali začnejo obnašati kot stisljivi ter izkazujejo fazne transformacije v trdnem stanju. Takšno obnašanje je z vidika tehniške mehanike še v veliki meri neraziskano. Raziskovalec bo zato razvil teoretično formulacijo za opis ravnovesnih, snovnih in kinematičnih enačb pri velikih deformacijah ter dokazal, da takšen pristop omogoča zapis analitičnih in numeričnih rešitev mehanskih problemov s posebnimi simetrijami. Ker klasična predpostavka nestisljivosti numerično otežuje reševanje (npr. zaradi pojava »zaklepanja« končnih elementov oz. umetno povečane togosti) bodo razviti tudi posebni numerični algoritmi, ki bodo temeljili na ustreznih deformacijskih korekcijah. Razviti modeli bodo tudi eksperimentalno verificirani. Končni rezultati bodo prispevali k boljšemu razumevanju obnašanja (skoraj) nestisljivih materialov, kot so gume in biološka tkiva, ter omogočili zanesljivo modeliranje njihovega odziva pri izjemno visokih tlakih, kar je pomembno na primer pri razvoju tesnil in naprav, ki temeljijo na barokaloričnem efektu.

Eng.:

The research is focused on investigating the influence of compressibility on the viscoelastic behavior of materials such as rubber and various biological tissues, which are typically considered as (nearly) incompressible. The objective of the research is to model the response of rubber under very high hydrostatic pressures (in the range of 1000-5000 bar), where otherwise nearly incompressible materials begin to exhibit compressible behavior and undergo solid-state phase transformations. From the perspective of engineering mechanics, such behavior remains largely unexplored. The candidate will therefore develop a theoretical formulation describing the equilibrium, constitutive, and kinematic equations for large deformations and demonstrate that this approach enables analytical and numerical solutions of mechanical problems with specific symmetries. Since the classical incompressibility assumption significantly complicates numerical implementation (e.g. due to finite element “locking” and artificially increased stiffness) special numerical algorithms based on appropriate deformation corrections will be developed. The proposed models will also be experimentally validated. The final results will contribute to a better understanding of the behavior of (nearly) incompressible materials such as rubber and biological tissues and will enable reliable modeling of their response under extremely high pressures, which is important, for example, in the development of seals and devices that rely on the barocaloric effect.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):
  - diplomska listina / potrdilo o zaključku študijskega programa
    (diploma certificate / certificate of completion of the study programme)
  - priloga k diplomi / potrdilo o opravljenih obveznostih
    (diploma supplement / official transcript of records containing all grades obtained in the study programme)
- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):
  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
    (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Tomaž Katrašnik, tomaz.katrasnik@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

2.03.00 Energetika

4. Opis raziskovalnega dela *(Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.: Raziskovalno delo mladega raziskovalca bo usmerjeno v razvoj naprednega večfizikalnega in večdomenskega numeričnega modela za analizo delovanja gorivnih celic s poudarkom na transportnih pojavih v poroznih strukturah. Cilj raziskave je vzpostaviti fizikalno-kemijsko konsistenten 2D+1D model, ki bo omogočal računanje v realnem času in hkratno obravnavo tokovnih, tlačnih, toplotnih ter elektrokemijskih pojavov v sklopu realnih geometrij tokovnih polj. Upoštevanje prav slednjih, vključno z vzporedno, prepleteno in serpentinasto geometrijo kanalov, ter njihovo interakcijo s poroznimi plastmi (plast za difuzijo plinov, katalitski sloj, itd.) bo ključen raziskovalni izziv. Poseben poudarek bo namenjen tudi doslední sklopitvi med tlakom in hitrostnim poljem.

Na tej osnovi bo razvit napreden opazovalec, sposoben lokalne rekonstrukcije ključnih notranjih stanj, kot so porazdelitev električnega toka, tlačna, koncentracijska ter temperaturna polja, brez neposredne lokalne meritve. Pomemben del raziskave bo razvoj in implementacija koncepta elektrokemijske tlačne impedančne spektroskopije, ki bo omogočala analizo dinamičnega odziva sistema na tlačne perturbacije. Prav slednja bo omogočila razvoj novih modelsko osnovanih diagnostičnih metod.

Mladi raziskovalec bo deloval v mednarodnem raziskovalnem okolju, saj je laboratorij močno vpet v evropski raziskovalni prostor ter sodeluje na najprestižnejših raziskovalnih in aplikativnih projektih. To omogoča aktivno sodelovanje z vodilnimi tujimi univerzami in raziskovalnimi institucijami ter neposredno povezavo z industrijskim okoljem, kjer se razvite rešitve implementirajo v prakso.

Od kandidata se pričakuje:

- *dobra matematična in fizikalna podlaga (mehanika tekočin, prenos toplote),*
- *znanje numeričnih metod (FEM, FVM ali sorodnih pristopov),*
- *izkušnje s programiranjem (npr. Python, MATLAB, C++ ali sorodni jeziki),*
- *sposobnost samostojnega in skupinskega raziskovalnega dela in znanstvenega pisanja v angleškem in slovenskem jeziku,*
- *interes za razvoj naprednih modelov in virtualnih senzorjev.*

Prednost bodo imeli kandidati z izkušnjami na področju večfizikalnega modeliranja, numerične stabilnosti ter razvoja simulacijskih orodij.

Eng.: The research work of the young researcher will focus on the development of an advanced multiphysics and multidomain numerical model for the analysis of fuel cell operation, with emphasis on transport phenomena in porous structures. The objective of the research is to establish a physically and chemically consistent 2D+1D model capable of real-time computation and simultaneous treatment of flow, pressure, thermal, and electrochemical phenomena within realistic flow-field geometries. Particular attention will be devoted to the consideration of various channel configurations, including parallel, interdigitated, and serpentine geometries, and their interaction with porous layers (gas diffusion layer, catalyst layer, etc.), which represents a key research challenge. Special emphasis will also be placed on consistent pressure–velocity coupling.

Based on the model, an advanced state observer will be developed, capable of locally reconstructing key internal states, such as electric current distribution, pressure, concentration, and temperature fields, without direct local measurements. An important part of the research will be the development and implementation of the concept of electrochemical pressure impedance spectroscopy, enabling analysis of the dynamic system response to pressure perturbations. This approach will further enable the development of novel model-based diagnostic methods.

The young researcher will work in an international research environment, as the laboratory is deeply integrated into the European research space and participates in prestigious research and applied projects. This provides opportunities for active collaboration with leading international universities and research institutions, as well as direct engagement with industry, where the developed solutions are implemented in practice.

The candidate is expected to have:

- *a strong background in mathematics and physics (fluid mechanics, heat transfer),*
- *knowledge of numerical methods (FEM, FVM, or related approaches),*
- *programming experience (e.g., Python, MATLAB, C++, or similar languages),*
- *the ability to conduct independent and team-based research and to write scientific texts in English and Slovenian,*
- *an interest in the development of advanced models and virtual sensors.*

Preference will be given to candidates with experience in multiphysics modelling, numerical stability analysis, and the development of simulation tools.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):
    - diplomska listina / potrdilo o zaključku študijskega programa
      (diploma certificate / certificate of completion of the study programme)
    - priloga k diplomi / potrdilo o opravljenih obveznostih
      (diploma supplement / official transcript of records containing all grades obtained in the study programme)
- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):
    - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
      (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Andrej Kitanovski, andrej.kitanovski@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Procesno strojništvo in Energetika / podpodročje Hladilna tehnika in toplotne črpalke *Process and Energy Engineerng / subdomain: Refrigeration and heat pumps*

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Okvirni naslov: Zasnova in analiza delovanja miniaturnega uparjalnika in kondenzatorja, izdelanih s pomočjo aditivnih tehnologij

Upravljanje s toploto postaja zaradi vedno večje kompaktnosti naprav zahtevno. Dostopne in učinkovite rešitve upravljanja obsegajo aktivne hladilne metode s tekočinami, termoelektrično hlajenje in uporabo toplotnih cevi. V primerjavi z njimi parno-kompresijske tehnologije dosegajo največjo gostoto moči. Na tem področju je bilo več študij posvečenih miniaturnemu parno-kompresijskemu hlajenju: miniaturnim kompresorjem, miniaturnim uparjalnikom, kondenzatorjem in drugim vrstam mikro prenosnikov toplote. Večina raziskav je bila doslej usmerjena v različne rešitve toplotnih cevi ali mikro prenosnikov toplote za enofazne tekočine. Pregled literature mikro prenosnikov toplote kaže, da je bila do danes dosežena najvišja gostota moči 180 W/cm³ pri uporabi dvofaznega toka tekočine. Napredne rešitve uparjanja na površini omogočajo odvod toplote tudi do 550 W/cm². Dodatne izboljšave termohidravličnih lastnosti so možne z uporabo kompozitnih materialov, spremembo geometrije (posebne topografije, izdelane z aditivnimi tehnologijami), kot tudi z izbiro vrste dvofazne tekočine in tokovnih razmer.

Cilj doktorskega dela je raziskava novih vrst visoko-kompaktnih in učinkovitih miniaturnih kompozitnih uparjalnikov in kondenzatorjev za majhne parno-kompresijske sisteme, ki temeljijo na okolju prijaznih hladivih. Poudarek bo na konceptualnih rešitvah, ki temeljijo na aditivnih tehnologijah izdelave z implementacijo naprednih topografij. Delo bo obsegalo numerično modeliranje in simulacije ter eksperimentalno analizo in verifikacijo rezultatov.

Prednost bodo imele kandidatke in kandidati z znanjem strojništva ali fizike ter izkušnjami s področja vsebine doktorskega dela.

Eng.:

Working Title: Design and performance evaluation of miniature additively manufactured evaporators and condensers

Thermal management is becoming increasingly challenging due to the growing compactness of devices. Effective solutions include active liquid cooling, thermoelectric cooling, and heat pipes. Among these, vapour-compression technologies achieve the highest power density. Numerous studies have explored miniature vapour-compression cooling, focusing on miniature compressors, evaporators, condensers, and other micro-heat exchangers. Most research has targeted heat pipes or micro-heat exchangers for single-phase fluids. Literature on micro-heat exchangers shows that the highest power density achieved to date is 180 W/cm³ using two-phase flow. Advanced surface evaporation solutions enable heat dissipation up to 550 W/cm². Further enhancements in thermohydraulic performance are possible through composite materials, geometry modifications (such as specialised topographies via additive manufacturing), and optimised two-phase fluids and flow regimes.

The objective of this doctoral research is to investigate novel, highly compact and efficient miniature composite evaporators and condensers for small vapour-compression systems using environmentally friendly refrigerants. Emphasis will be placed on conceptual designs that leverage additive manufacturing with advanced topographies. The work will include numerical modelling and simulations, as well as experimental analysis and validation of results.

Preference will be given to candidates with backgrounds in mechanical engineering or physics, and experience relevant to the doctoral topic.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
    - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
    - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
    - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

☒ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Leon Kos leon.kos@lecad.fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Rekonstrukcija plazemskih parametrov z uporabo umetne inteligence pri sintetični diagnostiki merilnih sistemov ter magnetohidrodinamiko v fuzijskih reaktorjih

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.: Brezkontaktni merilni sistemi v fuzijsko relevantnih napravah (IR kamere, kamere v vidnem spektru, bolometri, ...) so ključni za razumevanje obnašanja plazme in nadzor termičnega obremenjevanja stene reaktorja v stiku s plazmo (ang. plasma-facing components). Pri kovinskih PFC-jih, ki definirajo steno tokamaka, se pojavljajo merilne motnje, kot so odboji s površin ter nepoznavanje emisivnosti in temperatur na steni, kar lahko oteži interpretacijo signalov in vpliva na varno delovanje reaktorja. Zaradi visokih stroškov eksperimentov se uveljavlja sintetična diagnostika, kjer z numeričnimi simulacijami izračunamo sintetične signale merilnih sistemov (npr. IR kamere) na osnovi odlaganja moči, termalnih modelov in optičnih simulacij sevanja ter odbojev. Pomemben del plazemskih scenarijev predstavlja magnetohidrodinamika (MHD), ki omogoča analizo stabilnosti plazme in dogodkov, ki lahko povzročijo hitre spremembe obremenitev na steni. Cilj doktorske naloge je priprava nabora simulacij za izračun sintetičnih signalov treh diagnostičnih sistemov v reaktorju ITER (bolometri, IR kamere in kamere v vidnem spektru) ter v drugi fazi uporaba umetne inteligence za rekonstrukcijo plazemskih parametrov iz teh signalov. Celoten pristop predstavlja korak k digitalnemu dvojčku plazemskih scenarijev in pripadajočih merilnih sistemov.

Eng.: Non-contact measurement systems in fusion-relevant devices (IR cameras, visible-spectrum cameras, bolometers, …) are essential for understanding plasma behavior and monitoring the thermal loading of plasma-facing components. With metallic PFCs defining the tokamak wall, measurement disturbances such as surface reflections and uncertainties in emissivity and wall temperature can complicate signal interpretation and impact safe operation. Due to the high cost of experiments, synthetic diagnostics is increasingly used to compute synthetic diagnostic signals (e.g., IR camera signals) from numerical simulations, combining power deposition, thermal wall models, and optical simulations of radiation and reflections. Magnetohydrodynamics (MHD) is a key part of plasma scenarios, enabling stability analysis and the study of events that can cause rapid changes in wall loading. The aim of the doctoral project is to prepare a set of simulations to compute synthetic signals for three ITER diagnostic systems (bolometers, IR cameras, and visible-spectrum cameras) and, in the second phase, to use artificial intelligence to reconstruct plasma parameters from these signals. Overall, the approach represents a step toward a digital twin of plasma scenarios and the associated diagnostics.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
  - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
  - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Franc Majdič, franc.majdic@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Strojništvo, konstruiranje, vzdrževanje, hidravlika

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

*Slov.: V okviru doktorskega študija bomo raziskovali **napovedno vzdrževanje hidravličnih sistemov z uporabo metod strojnega učenja**. Glavni cilj je razvoj modelov, ki na podlagi senzornih meritev in obratovalnih podatkov prepoznajo zgodnje znake degradacije komponent ter napovejo verjetnost oziroma čas do odpovedi ključnih komponent hidravličnih sistemov. Raziskava bo zajemala pripravo in analizo časovnih vrst, kot so tlak, pretok, temperatura, čistoča, dielektrična konstanta,... Obravnavala bo izzive realnih podatkov, kot so šum, manjkajoče vrednosti, ter primerjavo različnih pristopov, od klasičnih metod do modelov za časovne vrste. Poudarek bo tudi na robustnosti in razložljivosti napovedi, da bodo rezultati uporabni pri odločanju v vzdrževanju. Končni rezultat bo metodologija in prototipni postopek za zgodnje opozarjanje na okvare, optimizacijo servisnih intervalov in zmanjšanje nenačrtovanih zastojev, s čimer se izboljšata zanesljivost in ekonomika obratovanja hidravličnih sistemov.*

*Eng.: As part of our doctoral studies, we will investigate **predictive maintenance of hydraulic systems using machine learning methods**. The main objective is to develop models that, based on sensor measurements and operating data, recognize early signs of component degradation and predict the probability or time to failure of key components of hydraulic systems. The research will include the preparation and analysis of time series such as pressure, flow, temperature, cleanliness, dielectric constant, etc. It will address the challenges of real data, such as noise, missing values, and the comparison of different approaches, from classical methods to time series models. Emphasis will also be placed on the robustness and interpretability of predictions so that the results can be used in maintenance decision-making. The end result will be a methodology and prototype procedure for early fault detection, service interval optimization, and reduction of unplanned downtime, thereby improving the reliability and economics of hydraulic system operation.*

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):

- diplomska listina / potrdilo o zaključku študijskega programa
  (diploma certificate / certificate of completion of the study programme)

- priloga k diplomi / potrdilo o opravljenih obveznostih
  (diploma supplement / official transcript of records containing all grades obtained in the study programme)

- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):

  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
    (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☐ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo (*UL Faculty of Mechanical Engineering*)

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Alen Oseli, alen.oseli@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Tehnika, Mehanika, Polimeri (*Engineering sciences and technologies, Mechanics, Polymers*)

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.: Biološko-navdihnjeni piezo- in termo-odzivni nanostrukturirani poltrdni materiali

Nanostrukturirani poltrdni materiali predstavljajo nastajajoči razred biomimetičnih materialov, zasnovanih za posnemanje sklopljenih mehanskih (viskoelastičnost, fleksibilnost, itd.), senzoričnih (piezo- in termo-občutljivost, zaznavanje signalov, itd.), transportnih (dostava zdravil, transport ionov, itd.) ter drugih funkcionalnih značilnosti bioloških mehanizmov (koža, ionski kanali, itd.). Ti bio-navdihnjeni pametni materiali so ključni za posnemanje naravnih principov, procesov in sistemov, ki so skozi milijone let evolucije reševali kompleksne funkcionalne izzive. Posledično zagotavljajo osnovo za imitacijo teh mehanizmov, ki omogočajo pomembne inovacije v platformah nove generacij za zaznavanje in aktuacijo, inteligentnih sistemih, mehki robotiki ter številnih drugih aplikacijah na različnih industrijskih in znanstvenih področjih.

Eden glavnih izzivov je načrtovanje materialov, ki so sposobni reproducirati te sklopljene bio-navdihnjene funkcije. Takšno multifunkcionalnost je mogoče doseči z vgradnjo različnih nanopolnil (ojačitvenih, prevodnih, itd.) v polimerno matrico, s čimer ustvarimo sklopljene mehanske, senzorične ali druge funkcionalno-usmerjene odzive, ki zavisijo od narave polnila (ogljikova, naravna ipd.), njihove geometrije (krogle, palice ipd.), koncentracije ter širokega nabora drugih dejavnikov. Drugi izziv se nanaša na kinetiko strjevanja teh materialov, ki mora zagotavljati geomeetrijsko stabilne poltrdne snovi, kot tudi omogočiti njihovo preoblikovanje v fleksibilne nanostrukturirane sisteme. Tretji izziv pa se nanaša na učinkovitost in končno zmogljivost teh materialov, bodisi v poltrdni ali trdni obliki. Skupaj ti (trije) izzivi predstavljajo osrednjo temo predlagane raziskave.

Delo mladega raziskovalca bo osredotočeno na razvoj zgorajomenjenih bio-navdihnjenih pametnih materialov z vključevanjem multifunkcionalnih nanopolnil v polimerne matrice. Raziskava bo obravnavala nastanek omrežja, obliko morfologije in osnovne gradnike. Poseben poudarek bo namenjen kinetiki zamreževanja (utrjevanja) ter prehodu iz poltrdnih materialov v fleksibilne nanostrukturirane sisteme. Sistematično bodo proučene povezave med strukturo in lastnostmi s poudarkom na termičnih, termo-mehanskih in električnih analizah, kot tudi piezo- in termo-občutljivosti teh materialov, ter njihovi implementaciji v realne aplikacije. Vzporedno z eksperimentalnim delom in razvojem materialov pbo potekal tudi razvoj ter nadgradnja numeričnih in teoretičnih modelov za popis teh povezav. Takšni modeli so ključnega pomena za razvoj materialov naslednje generacije s prilagojenimi funkcionalnostmi, ki bodo ustrezale specifičnim zahtevam uporabe.

Raziskava bo potekala v prostorih Laboratorija za eksperimentalno mehaniko, kjer bodo uporabljene napredne procesne tehnike za izdelavo pametnih nanostrukturiranih materialov (mikro-mešanje, brizganje, itd.). Nastanek omrežja, njegova morfologija in gradniki ter kinetika zamreževanja bodo ovrednoteni z naprednimi reološkimi analizami in mikroskopskimi metodami (modularni kompaktni reometri, elektronska mikroskopija, itd.). Povezave med strukturo in lastnostmi pripravljenih nanokompozitov bodo karakterizirane z uporabo termičnih, termo-mehanskih, električnih ter drugih analiz (diferenčna dinamična kalorimetrija, dinamična mehanska analiza, elektrometri ipd.). Funkcionalne lastnosti bodo opredeljene z napredno univerzalno preizkuševalno platformo, sklopljeno z najsodobnejšimi električnimi napravami (univerzalni preizkuševalni stroj, elektromer, LCR-meter ipd.), preko katerih se bo vrednotila piezo- in termo-občutljivost bio-navdihnjenih materialov oziroma struktur.

Za uspešno izvedbo predlagane raziskave se od mladega raziskovalca pričakuje:

- tekoče znanje angleškega jezika (ustno in pisno),
- izkušnje z laboratorijskim delom (poznavanje vsaj nekaterih zgoraj navedenih naprav),
- zaželjeno znanje programskih jezikov (Phython in LabView)

Eng.: Bio-inspired Piezo- and Thermo- Responsive Nanostructured Semi-Solid materials

Nanostructured semi-solids represent an emerging class of biomimetic materials engineered to replicate the coupled mechanical (viscoelasticity, flexibility), sensory (piezo- and thermo-sensitivity, signal detection), transport (drug delivery, ion or neurotransmitter transport), and other functional characteristics of biological operations (skin, ion channels etc.). These bio-inspired smart materials are crucial for emulating nature’s design principles, processes, and systems which have solved complex functional challenges over millions of years of evolution. They provide a foundation for replicating those operations, enabling key innovations in next-generation sensing and actuation platforms, intelligent systems, soft robotics, and countless other applications across various industrial and scientific fields.

One of the primary challenges lies in designing materials capable of reproducing these coupled bioinspired functions. Such multifunctionality can be achieved by incorporating various nanofillers (reinforcing, conductive, etc.) into a polymeric matrix to generate coupled mechanical, sensory or any other performance-oriented responses, which depends on the nature of the fillers (carbon-based, organic, etc.), their geometry (spheres, rods, etc.), concentration as well as broad spectrum of other factors. The second challenge concerns curing-kinetics of these materials which must ensure geometrically stable semi-solids or facilitate their transition to flexible nanostructured system. The third challenge relates to the efficiency and ultimate performance of these materials, whether in semi-solid or solid form. Together, these three challenges represent the core focus of the proposed research.

The Young Researcher’s work will concentrate on the development of such bio-inspired smart material through the incorporation of multifunctional nanofillers in polymer matrices. The study will investigate particle network formation, its morphology and main building blocks. Within this research, particular emphasis will be placed on curing kinetics and the transition from semi-solid materials to flexible nanostructured systems. Structure–property relationships will be systematically examined, focusing on thermal, thermo-mechanical and electrical analysis, together with piezo- and thermo-responsive functionalities of these materials and their translation into real-world applications. In parallel with experimental research and material development, the study will also focus on development and refinement of numerical/theoretical models describing those relations. These models are of key importance to facilitate development of next generation materials with tailored functionalities to meet specific performance requirements.

The study will be conducted within the facilities of Laboratory for Experimental Mechanics, utilizing advanced processing techniques for the fabrication of smart nanostructured materials (micro-compounding, injection molding, etc.). Network formation, its morphology and building blocks, along with curing-kinetics of these, will be evaluated using advanced rheological analysis and microscopy methods (modular compact rheometers, electron microscopy, etc.). Structure-property relation within the prepared nanocomposites will be determined using thermal, thermo-mechanical, electrical tests along with analytical tools (differential scanning calorimetry, dynamic-dynamic mechanical analysers, electrometers, etc.). Finally, functional performance of these bioinspired materials or structures will be characterized by advanced testing platform coupled with electrical instruments (universal testing machine, electrometer, LCR meter, etc.) to capture their piezo- and thermo-responsive behaviour.

For the successful completion of the proposed research, Young Researcher is expected to have:

- Fluent knowledge of English (speaking and writing)
- Work experience within laboratory (familiar with some devices mentioned above)
- Knowledge in programming languages is highly appreciated (Python and LabView)

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):
    - diplomska listina / potrdilo o zaključku študijskega programa
      (diploma certificate / certificate of completion of the study programme)
    - priloga k diplomi / potrdilo o opravljenih obveznostih
      (diploma supplement / official transcript of records containing all grades obtained in the study programme)
- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):
    - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
      (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

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☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☐ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☒ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Tomaž Pepelnjak, tomaz.pepelnjak@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

2.10	Proizvodne tehnologije in sistemi / Manufacturing technologies and systems
2.10.02	Izdelovalna tehnologija / Manufacturing technology

4. Opis raziskovalnega dela (*Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Predlagana doktorska raziskava se osredotoča na razvoj hibridnega okvira digitalnega dvojčka (Digital Twin, DT) za preoblikovanje pločevine, ki povezuje nadzor proizvodnega procesa s programiranjem strukturnih mehanskih lastnosti ter izborom materiala. Tradicionalna optimizacija postopkov preoblikovanja je usmerjena predvsem v proizvodne kriterije, kot so omejevanje tanjšanja, preprečevanje gubanja in minimizacija in kompenzacija elastičnega izravnavanja. Sodobne lahke konstrukcije v različnih industrijskih vejah pa zahtevajo komponente, katerih performanse kot so togost, sposobnost absorpcije energije ali upogibna odpornost so lahko ciljno oblikovane že med samim proizvodnim procesom. Obstoječi pristopi digitalnega dvojčka v preoblikovanju so večinoma omejeni na napovedovanje napak in geometrijske točnosti. Pomembna raziskovalna vrzel ostaja v povezovanju lastnosti materiala, procesnih parametrov in strukturnih kazalnikov zmogljivosti izdelane komponente v enoten model.

Cilj raziskave je razviti in eksperimentalno validirati hibridni digitalni dvojček, ki združuje modeliranje v digitalnem okolju (MKE analize) in metode umetne inteligence (Artificial Intelligence, AI) ter omogoča napovedovanje tako proizvodnih kot tudi strukturnih ključnih kazalnikov uspešnosti (Key Performance Indicators, KPI) ob hkratnem eksplicitnem vključevanju izbora materiala. Sistem bo omogočal večkriterijsko optimizacijo strukturnih KPI v pogojih realne prilagodljivosti preoblikovalnega sistema ter tako klasično preoblikovanje pločevine nadgradil iz zgolj izdelovalnega procesa v kompleksno orodje za ciljno načrtovanje mehanske zmogljivosti preoblikovanega izdelka.

Praktična verifikacija razvitega sistema bo bazirala na trodimenzionalnem nesimetričnem globoko vlečenem modelnem izdelku. Geometrija modelnega izdelka bo določena v začetni fazi raziskave. Omogočati mora heterogene deformacijske poti med preoblikovanjem, občutljivost na anizotropijo materiala, učinke različnih napetostnih stanj na postavljene KPI kazalnike ter merljivo strukturno obnašanje. V začetni fazi raziskave bo izbran tudi omejen nabor pločevin z različnimi mehanskimi in preoblikovalnimi lastnostmi, ki bodo za potrebe nadaljnih analiz eksperimentalno ovrednotene. Identificirani konstitutivni parametri bodo uporabljeni kot vhodni parametri DT, kar bo omogočalo so-optimizacijo materiala in procesa ter modeliranje vpliva variacij materialnih lastnosti med različnimi serijami pločevin.

Raziskava bo temeljila na dvonivojskem hibridnem okviru KPI. Proizvodni KPI bodo vključevali tipične tehnološke parametre kot so največje tanjšanje, vrednotenje geometrijskih odstopanj zaradi elastičnega izravnavanja, težnjo h gubanju ter parametre poteka sile glede na gib pehala stiskalnice med preoblikovanjem. Strukturni KPI bodo obsegali upogibno togost, opredeljeno absorpcijo energije izdelane komponente, obremenitev pri začetku uklona ter razmerje togost/masa. Integracija obeh ravni KPI v enoten napovedni in optimizacijski model predstavlja osrednjo znanstveno novost in inovativni pristop pri nadgradnji izdelovalnih sistemov.

Metodološko bo raziskava združevala simulacije po metodi končnih elementov (Finite Element, FE), predvideno je programsko okolje Abaqus, ki se bo nadgrajevalo z nadomestnimi modeli, temelječimi na umetni inteligenci. Fizikalni nivo bo zagotavljal mehansko osnovo modela, medtem ko bodo večizhodni modeli strojnega učenja omogočali učinkovito napovedovanje KPI. Eksperimentalni podatki iz merilnikov med in po poteku preoblikovanja bodo uporabljeni za oceno stanja procesa in eventuelno variacijo materiala. Večkriterijski optimizacijski modul bo nato določal kombinacijo materiala in procesnih parametrov za doseganje ciljanih KPI izdelka z opredeljeno stopnjo zaupanja.

Pričakovani znanstveni doprinos raziskave vključuje strukturirano napovedovanje KPI, ki povezuje proizvodne in strukturne vidike, validiran hibridni model digitalnega dvojčka za preoblikovanje pločevine ter metodologijo so-optimizacije preoblikovanja in strukturnih lastnosti izdelka. Raziskava tako prispeva k razvoju nove paradigme preoblikovanja, kjer digitalni dvojček izdelovalnega procesa aktivno soustvarja mehanske in strukturne performanse izdelka neposredno med proizvodnjo.

Eng.:

The proposed doctoral research focuses on the development of a hybrid Digital Twin (DT) framework for sheet metal forming that integrates manufacturing process control with the programming of structural mechanical properties and material selection. Traditional optimization of forming processes primarily addresses manufacturing criteria such as limiting thinning, preventing wrinkling, and minimizing and compensating elastic springback. However, modern lightweight structures across various industrial sectors require components whose performance — such as stiffness, energy absorption capacity, or bending resistance — can be purposefully tailored already during the manufacturing process. Existing Digital Twin approaches in forming are mostly limited to defect prediction and geometric accuracy assessment. A significant research gap remains in linking material properties, process parameters, and structural performance indicators of the manufactured component within a unified model.

The objective of the research is to develop and experimentally validate a hybrid Digital Twin that combines modelling in a digital environment (Finite Element Method (FEM) analyses) with Artificial Intelligence (AI) methods, enabling prediction of both manufacturing and structural Key Performance Indicators (KPIs), while explicitly incorporating material selection. The system will enable multi-objective optimization of structural KPIs under conditions of real adaptability of the forming system, thereby transforming conventional sheet metal forming from a purely manufacturing process into an advanced tool for targeted design of mechanical performance of the formed product.

Practical verification of the developed system will be based on a 3D, non-symmetric, deep-drawn demonstrator component. The geometry of the demonstrator will be defined during the initial phase of the research. It must allow heterogeneous strain paths during forming, sensitivity to material anisotropy, the influence of different stress states on the defined KPIs, and measurable structural behaviour. In the initial phase, a limited selection of sheet metals with different mechanical and formability characteristics will also be chosen and experimentally characterized for further analyses. The identified constitutive parameters will be used as input parameters for DT, enabling co-optimization of material and process, as well as modelling the influence of material property variations between different sheet batches.

The research will be based on a two-level hybrid KPI framework. Manufacturing KPIs will include typical technological parameters such as maximum thinning, evaluation of geometric deviations due to elastic springback, wrinkling tendency, and force–stroke characteristics during forming. Structural KPIs will include bending stiffness, defined energy absorption of the produced component, load at the onset of buckling, and stiffness-to-weight ratio. The integration of both KPI levels into a unified predictive and optimization model represents the central scientific novelty and innovative approach toward advancing manufacturing systems.

Methodologically, the research will combine Finite Element (FE) simulations—using Abaqus as the primary software environment—with surrogate models based on Artificial Intelligence. The physics-based layer will provide the mechanical basis of the model, while multi-output machine learning models will enable efficient KPI prediction. Experimental data from various sensors obtained during and after forming will be used for evaluation of the process and potential material variation. A multi-objective optimization module will then determine the combination of material and process parameters required to achieve the targeted product KPIs with a defined confidence level.

The expected scientific contributions include structured KPI prediction linking manufacturing and structural aspects, a validated hybrid Digital Twin model for sheet metal forming, and a methodology for co-optimization of forming processes and structural product properties. The research thus contributes to the development of a new forming paradigm in which the Digital Twin of the manufacturing process actively co-creates the mechanical and structural performance of the product directly during production.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master’s degree (2nd Bologna level)):*
    - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
    - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji

(candidate who has not yet completed a Master's degree):

- potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
  (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

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☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo (UL Faculty of Mechanical Engineering)

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Primož Potočnik, primoz.potocnik@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Tehnološko usmerjena fizika (Tehnology driven physics)

4. Opis raziskovalnega dela (*Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Uvod

Raziskovalno delo bo potekalo na Fakulteti za strojništvo v Ljubljani v okviru Laboratorija za sinergetiko (LASIN), ki deluje na področju laserskih dodajalnih tehnologij, sistemov in procesov, ter inteligentnih sistemov vodenja procesov. Raziskave bodo usmerjene v laserske dodajalne procese (DED-LB), s poudarkom na direktni laserski depoziciji z žico (DLD-Wire), ter v integracijo metod strojnega učenja, nevronskih mrež in prediktivnega vodenja za optimizacijo procesa v realnem času. DLD-Wire predstavlja eno izmed najperspektivnejših tehnologij za izdelavo in obnovo kovinskih komponent zaradi visokega materialnega izkoristka, nizke poroznosti in možnosti obdelave zahtevnih materialov.

Eksperimentalno delo

Eksperimentalno delo bo potekalo v laboratoriju LASIN na naprednem robotiziranem sistemu za direktno lasersko depozicijo (DLD) kovinske žice, ki vključuje:

- 6-osnega industrijskega robota ABB,
- namensko programsko okolje za krmiljenje robota (RobotStudio),
- lastno razvito lasersko glavo z anularnim (obročastim) profilom žarka,
- podajalni sistem za kovinsko žico,
- integrirano procesno senzoriko za spremljanje dinamike taline in lastnosti nanosa.

Eksperimentalno delo kandidata bo obsegalo:

- tehnično nadgradnjo sistema za izvajanje raziskovalnih eksperimentov,
- razvoj in implementacijo procesne senzorike (optični, IR, temperaturni in drugi senzorji),
- razvoj regulatorja podajanja žice in sinhronizacije z laserskim virom,
- načrtovanje in izvajanje eksperimentov za sistematično analizo vpliva procesnih parametrov na stabilnost procesa in lastnosti nanosa,
- izdelavo testnih vzorcev z različno geometrijsko kompleksnostjo,
- analizo dimenzijske točnosti, mikrostrukture in mehanskih lastnosti izdelkov.

Cilji raziskovalnega dela

Osrednji cilj doktorskega raziskovanja je:

- razvoj inovativnih metod za izboljšanje stabilnosti procesa DLD,
- razvoj adaptivnega vodenja procesa v realnem času,
- izboljšanje dimenzijske natančnosti, ponovljivosti in metalurške kakovosti izdelkov.

Pri tem bo poseben poudarek na:

- podatkovno podprtem modeliranju procesa,
- razvoju digitalnega dvojčka procesa DLD,
- identifikaciji kritičnih procesnih parametrov,
- integraciji metod umetne inteligence v zaprtozančno regulacijo procesa,
- definiranju merljivih metrik stabilnosti in kakovosti procesa.

Glavne naloge doktorskega kandidata

- Raziskave, modeliranje in eksperimentalna validacija procesa direktne laserske depozicije z žico.
- Identifikacija ključnih procesnih spremenljivk ter razvoj sistema za njihovo sprotno merjenje in diagnostiko.
- Optimizacija procesnih parametrov (moč laserja, hitrost podajanja žice, hitrost gibanja robota, kavstika žarka ipd.) za doseganje stabilnosti procesa.
- Načrtovanje optimalnih poti nanašanja materiala glede na geometrijo izdelka ter zmanjševanje napak (prelivanje, poroznost, odstopanja).
- Razvoj metod strojnega učenja (regresijski modeli, nevronske mreže, hibridni fizikalno-podatkovni modeli) za napovedovanje stabilnosti in kakovosti nanosa.
- Implementacija prediktivnega / adaptivnega vodenja procesa v realnem času.
- Programiranje robotskega sistema (ABB, RAPID).
- Načrtovanje in izvedba eksperimentov ter analiza rezultatov.
- Priprava in objava znanstvenih člankov v mednarodnih znanstvenih revijah (najmanj dva članka v revijah Q1 ali Q2).
- Aktivno sodelovanje na mednarodnih konferencah in vključevanje v mednarodne raziskovalne projekte.

Zahtevane kvalifikacije

- Zaključen magistrski študij s področja strojništva, mehatronike, matalurgije, računalništva ali sorodnih tehničnih ved.
- Osnovno razumevanje laserskih dodajalnih procesov ali naprednih proizvodnih tehnologij.
- Poznavanje osnov metod strojnega učenja, numeričnega modeliranja ali regulacije sistemov.
- Zaželene izkušnje s programskimi orodji: Python, MATLAB, ANSYS, SolidWorks.
- Zaželene izkušnje z ABB RobotStudio in programiranjem v jeziku RAPID.
- Znanje obdelave eksperimentalnih podatkov in statistične analize.
- Aktivno znanje angleškega jezika (pisno in ustno).
- Visoka stopnja raziskovalne radovednosti, samostojnosti in analitičnega razmišljanja.
- Sposobnost znanstvenega pisanja ter priprave publikacij v mednarodnem okolju.

Eng.:

Introduction

The research will be conducted at the Faculty of Mechanical Engineering in Ljubljana, within the Laboratory of Synergetics (LASIN), which specializes in laser additive technologies, systems and processes, as well as intelligent process control systems. The focus of the research will be on laser-directed energy deposition (DED-LB) processes, with a particular emphasis on direct laser wire deposition (DLD-Wire), and on the integration of machine learning, neural networks, and predictive control for real-time process optimization. DLD-Wire is one of the most promising technologies for manufacturing and repairing metal components due to its high material efficiency, low porosity, and capability to process challenging materials.

Experimental Work

The experimental work will be carried out in the LASIN laboratory on an advanced robotic system for direct laser deposition (DLD) of metal wire, which includes:

- a 6-axis ABB industrial robot,
- a dedicated RobotStudio environment for robot control,
- an in-house developed laser head with an annular beam profile,
- a wire feeding system for metal wire,
- integrated process sensors for monitoring melt pool dynamics and deposition properties.

The candidate’s experimental tasks will include:

- technical upgrades of the system to support research experiments,
- development and implementation of process sensing (optical, IR, temperature, and other sensors),
- development of a wire-feeding controller and synchronization with the laser source,
- planning and conducting experiments for a systematic analysis of process parameter influence on process stability and deposition quality,
- production of test samples with varying geometric complexity,
- analysis of dimensional accuracy, microstructure, and mechanical properties of the manufactured parts.

Research Objectives

The main objectives of the doctoral research are:

- development of innovative methods for improving DLD process stability,
- development of adaptive real-time process control,
- improving dimensional accuracy, repeatability, and metallurgical quality of the products.

Special emphasis will be placed on:

- data-driven process modeling,
- development of a digital twin of the DLD process,
- identification of critical process parameters,
- integration of artificial intelligence methods into closed-loop process control,
- defining measurable metrics of process stability and quality.

Main Tasks of the Doctoral Candidate

- Research, modeling, and experimental validation of the direct laser wire deposition process.
- Identification of key process variables and development of a system for their real-time measurement and diagnostics.
- Optimization of process parameters (laser power, wire feed speed, robot travel speed, beam caustics, etc.) to achieve process stability.
- Planning optimal material deposition paths according to part geometry and minimizing defects (overdeposition, porosity, deviations).
- Development of machine learning methods (regression models, neural networks, hybrid physics-informed/data-driven models) for predicting process stability and deposition quality.
- Implementation of predictive/adaptive real-time process control.
- Programming of the robotic system (ABB, RAPID).
- Planning and execution of experiments and analysis of results.
- Preparation and publication of scientific papers in international journals (at least two papers in Q1 or Q2 journals).
- Active participation in international conferences and involvement in international research projects.

Required Qualifications

- Completed master's degree in mechanical engineering, mechatronics, metallurgy, computer science, or related technical fields.
- Basic understanding of laser additive processes or advanced manufacturing technologies.
- Knowledge of basic machine learning methods, numerical modeling, or systems control.
- Appreciated experience with software tools such as Python, MATLAB, ANSYS, SolidWorks.
- Appreciated experience with ABB RobotStudio and programming in RAPID.
- Skills in experimental data processing and statistical analysis.
- Proficiency in English (written and spoken).
- High level of research curiosity, independence, and analytical thinking.
- Ability to write scientific texts and prepare publications in an international environment.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
  - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
  - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*

- potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
  (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☒ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

FS

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Franci Pušavec (franci.pusavec@fs.uni-lj.si)

3. Raziskovalno področje (*Research field*):

Moderne proizvodne in izdelovalne tehnologije s poudarkom na pametnih procesih in okolijskih odtisih / Advanced manufacturing and production technologies with a focus on smart processes and environmental footprints

4. Opis raziskovalnega dela *(Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Napredne smernice v svetovni proizvodni industriji kažejo na pospešen razvoj k pametnim, digitalno podprtim ter okoljsko optimiziranim procesom. V tem okviru se raziskovalni program mladega raziskovalca usmerja na sledeča ključna področja:

1. Inteligentno odrezavanje z uporabo umetne inteligence in napredne senzorike
Sodobni trendi kažejo, da uporaba umetne inteligence za obdelavo velikega števila informacij/podatkov postaja potreba v industriji, saj algoritmi v realnem času in avtonomno lahko prilagajajo/kontrolirajo rezalne procese in s tem izboljšujejo ponovljivost, kakovost ter produktivnost. Mladi raziskovalec se bo tako lahko vključil v razvoj:

- metodologije karakterizacije obdelovalnosti s pametno senzoriko (Kistler, Dewesoft);
- sistemov za realno-časovno podporo odločanju na podlagi signalov (vibracije, sile, temperatura, akustika);
- modelov strojnega učenja za napoved obrabe orodja, stabilnosti procesa in optimizacijo kakovosti površine.

2. Digitalni dvojčki odrezovalnih procesov in strojev
Tematika postajaja hrbtenica sodobne proizvodnje in odrezovalnih procesov za napovedovanje in kontrolo procesov. Tako so možnosti za mladega raziskovalca sledeče:

- razvoj virtualnih modelov obdelovalnih procesov,
- vzpostavljanje povratne zanke med realnimi podatki (senzorji, visoko frekvenčni zajem) in simulacijo,
- raziskave kinematičnih, dinamičnih in toplotnih vplivov skozi digitalne dvojčke,
- vključevanje robotike in avtonomnosti procesov.

3. Hibridni in zeleni procesi odrezovanja z oceno okoljskih odtisov (LCA)
Industrija se usmerja v trajnostno proizvodnjo, zmanjševanje rabe hladilno-mazalnih sredstev, uporabo vodnih supermaziv, celo trend proti suhi obdelavi, ter oceno celotnega življenjskega cikla procesov. V okviru tega se raziskave usmerjajo proti:

- LCA modeli odrezovalnih procesov z vključitvijo meritev onesnaženosti zraka, trdih delcev, čistosti površin, porabe energije,
- razvoj metod za čisto (clean) in suho obdelavo,
- implementacija supermaziv na vodni osnovi in analiza njihovega vpliva na kakovost, trajnost in produktivnost,
- spremljanje vplivov na delovno okolje in operaterje.

4. Big data in visoko-frekvenčni zajem podatkov za inteligentno obdelavo
Eden ključnih trendov moderne proizvodnje je popolna preobrazba obdelovalne industrije v podatkovno vodeno, digitalno povezano ekosfero, kjer imajo glavno vlogo big data analitika, povezljivost in digitalna sledljivost procesov. Na tem področju so aktualne sledeče teme:

- integracija merilnih platform za združevanje mehanskih, toplotnih, električnih in ostalih podatkov s strojev,

- razvoj algoritmov za večmodalno analitiko podatkov,
- postavitev koncepta pametnih/avtonomnih/prilagodljivih obdelovalnih procesov v laboratorijskem okolju (povezljivost strojev, PLC, IoT, strojni vid).

Podpora raziskav s sodobno laboratorijsko opremo:
- CNC-struženje, frezanje, mikroobdelave, precizni EDM, AFM, robotika;
- napredna senzorika (vibracije, pospeški, sile, termovizija, pirometri);
- Dewesoft za sinhroniziran visoko-frekvenčni zajem signalov;
- oprema za meritve čistosti, kakovosti zraka, LCA parametrov;
- PLC Beckhoff za digitalno integracijo s stroji (prenos procesnih podatkov v digitalne dvojčke).

S predstavljenimi temami dajemo kandidatom integriran znanstveni okvir za prihodnjo generacijo odrezovalnih in proizvodnih procesov, ki združujejo:
- inteligentne odločitvene modele,
- digitalne dvojčke,
- robustne senzorske platforme,
- trajnostne in hibridne pristope,
- ter merljive okolijske kazalnike.

Eng.:

Advanced trends in the global manufacturing industry indicate accelerating shift toward smart, digitally supported, and environmentally optimized processes. Within this context, the research program for the young researcher focuses on key areas recognized as strategic for the future of machining and advanced manufacturing processes:

1. <u>Intelligent machining using artificial intelligence and advanced sensor systems</u>
The use of artificial intelligence to process large volumes of data is becoming a necessity in industry, as algorithms can autonomously process information in real time and enable adaptive process control. The young researcher will be able to participate in the development of:
- methodologies for machinability characterization using smart sensor systems (Kistler, Dewesoft),
- real-time decision-support systems based on signal monitoring (vibrations, forces, temperature, acoustics),
- machine-learning models for predicting tool wear, process stability, and surface-quality optimization.

2. <u>Digital twins of machining processes and machine tools</u>
This topic is becoming the backbone of modern manufacturing and machining for process prediction and control. Opportunities for the young researcher include:
- development of virtual models of machining processes,
- establishing feedback loops between real data (sensors, high-frequency data acquisition) and simulations,
- studying kinematic, dynamic, and thermal influences through digital twins,
- integrating robotics and autonomous processes.

3. <u>Hybrid and green machining processes with environmental-footprint assessment (LCA)</u>
Industry is moving toward sustainable production, reduction of coolant/lubricant consumption, the use of water-based super-lubricants, even trends toward dry machining, and full life-cycle assessment of processes. Research directions include:
- LCA models of machining processes, incorporating measurements of air contamination, particulate emissions, surface cleanliness, and energy consumption,
- development of methods for clean and dry machining,
- implementation of water-based super-lubricants and analysis of their impact on quality sustainability and productivity,
- monitoring effects on the working environment and machine operators.

4. <u>Big data and high-frequency data acquisition for intelligent machining</u>
One of the key trends in modern manufacturing is the complete transformation of the machining industry into a data-driven, digitally connected ecosystem, where big-data analytics, connectivity, and digital traceability of processes play central roles. Relevant topics include:

- integration of measurement platforms for combining mechanical, thermal, electrical, and other machine-related data,
- development of algorithms for multimodal analytics,
- establishing concepts of smart, autonomous, and adaptive machining processes in the laboratory environment (machine connectivity, PLC, IoT, machine vision).

Support for research through advanced laboratory equipment:

- CNC turning, milling, micromachining, precision EDM, AFM, robotics,
- advanced sensor systems (vibrations, accelerations, forces, thermography, pyrometry),
- Dewesoft for synchronized high-frequency data acquisition,
- equipment for measuring cleanliness, air-quality parameters, and LCA indicators,
- a Beckhoff PLC platform for digital integration with machine tools (transfer of process data into digital twins).

Through the topics presented, we provide candidates an integrated scientific framework for the next generation of machining and manufacturing processes, enhanced by:

- intelligent decision-making models,
- digital twins,
- robust sensor platforms,
- sustainable and hybrid approaches,
- and measurable environmental indicators.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):
    - diplomska listina / potrdilo o zaključku študijskega programa
      (diploma certificate / certificate of completion of the study programme)
    - priloga k diplomi / potrdilo o opravljenih obveznostih
      (diploma supplement / official transcript of records containing all grades obtained in the study programme)
- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):
    - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
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☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

Fakulteta za strojništvo / Faculty of Mechanical Engineering

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Janko Slavič janko.slavic@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Mehanika / Mechanics

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Mladi raziskovalec bo raziskoval tri-razsežno identifikacijo virov hrupa s pomočjo hitrih kamer. Danes ne obstajajo metode za prostorsko visoko natančno identifikacijo virov hrupa; načrtovana znanstvena raziskava ima potencial identifikacije strukturno rojenega hrupa z visoko prostorsko ločljivostjo.

Cilj doktorske raziskave bo določitev 3D nihajnih oblik celotnega polja z visoko natančnostjo in brez predhodnega poznavanja geometrije predstavlja preboj v eksperimentalni modalni analizi. Ti natančni podatki so temelj za vibro-akustično modeliranje, ki prvič na celovit način povezuje dinamiko strukture z emisijo zvočnega polja. Ker bi metoda temeljila na vizualnih podatkih, bi omogočala natančno identificirati vire hrupa v hrupnem okolju (kar s klasičnimi mikrofoni ni mogoče).

Doktorsko izobraževanje se bo začelo s prvo fazo, ki vključuje poglobitev temeljne teorije slikovne EMA in akustike ter natančno definiranje raziskovalne vrzeli za postavitev hipotez. V drugi, ključni, fazi bo kandidat razvijal znanstveni doprinos na področju tri-razsežne identifikacije hrupa s pomočjo meritev s hitro kamero; pričakujemo lahko razvoj lastnih algoritmov, izvajanje kompleksnih eksperimentalnih meritev in vzpostavljanje modelne povezave z vibro-akustično simulacijo. Zaključna faza je posvečena pisanju in objavi znanstvenih prispevkov ter pripravi in uspešnemu zagovoru doktorske disertacije.

Eng.:

The researcher will investigate the three-dimensional identification of noise sources using high-speed cameras. Currently, methods for high-precision spatial identification of noise sources do not exist; the planned scientific research has the potential to identify structure-borne noise with high spatial resolution.

The objective of this doctoral research is to determine full-field 3D mode shapes with high precision. Achieving this without prior knowledge of the geometry represents a breakthrough in Experimental Modal Analysis (EMA). These precise data points form the foundation for vibro-acoustic modeling, which, for the first time, comprehensively links structural dynamics with sound field emissions. Since the method is based on visual data, it would enable the accurate identification of noise sources even in noisy environments—a task that is impossible with conventional microphones.

The doctoral education will begin with the first phase, which includes deepening the fundamental theory of image-based EMA and acoustics, as well as precisely defining the research gap to establish hypotheses. In the second, key phase, the candidate will develop a scientific contribution in the field of three-dimensional noise identification using high-speed camera measurements; this stage is expected to involve the development of original algorithms, the execution of complex experimental measurements, and the establishment of a model link with vibro-acoustic simulation. The final phase is dedicated to writing and publishing scientific papers, and the preparation and successful defense of the doctoral dissertation.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
  - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
  - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

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☒ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

☐ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Prof. dr. Božidar Šarler, bozidar.sarler@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

2.13.01 Procesno strojništvo

4. Opis raziskovalnega dela *(Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.: Raziskovalna skupina se ukvarja z modeliranjem in simulacijo sosledja metalurških procesov od različnih načinov ulivanja, valjanja, iztiskanja, toplotnih obdelav do končnega polizdelka. Pri tem za rešitev makroskopskih modelov mehanike trdin, tekočin in elektromagnetnega polja uporablja originalno razvito in večkrat nagrajeno brezmrežno metodo. Modeliranje mezoskopskega nivoja mikrostrukture je izdelano na podlagi koncepta točkovnih avtomatov, mikroskopskega nivoja pa na podlagi metode faznega polja.

Mladi raziskovalec bo nadaljeval razvoj opisanega simulacijskega sistema. Pri tem bo za vsak pod-proces definiral indikatorje rabe energije, produktivnosti, lastnosti, kvalitete, varnosti in vpliva na okolje. Procese bo sklopil med seboj z manipulatorjem. Procesi bodo zaporedno povezani na podlagi izračunane mikrostrukture. Na podlagi manipulatorja bo možno optimizirati proizvodni proces glede na indikatorje. Pri tem bo možna optimizacija procesnih parametrov, ki dajo najbolj ugodne indikatorje polizdelka ali poiskanje takšnih procesnih parametrov, ki dajejo zahtevane karakteristike polizdelka.

Za optimizacijo bo fizikalne modele sosledja metalurških procesov povezal z evolucijskimi optimizacijskimi metodami - iterativnim pristopom, kjer se procesi postopno izpopolnjujejo na podlagi povratnih informacij iz fizikalnih modelov.

Dopolnjen simulacijski sistem bo validiral na podlagi strojneg učenja iz industrijskih podatkov.

Od kandidata pričakujemo dobro poznavanje numeričnega modeliranja ter programiranja ter veselje do opisanega področja raziskav.

Kandidati naj imajo magistrsko izobrazbo na področju strojništva ali metalurgije, lahko tudi drugih področij tehnike, fizike ali matematike.

Eng.:The research group is engaged in modelling and simulation of the sequence of metallurgical processes from various methods of casting, rolling, extrusion, heat treatment to the final semi-finished product. In doing so, it uses an originally developed and several times awarded meshless methods to solve macroscopic models of solid mechanics, fluids and electromagnetic fields. The modelling of the mesoscopic level of the microstructure is based on the concept of point automata, and the microscopic level is based on the phase field method.

The young researcher will continue the development of the described simulation system. In doing so, he will define indicators of energy consumption, productivity, properties, quality, safety and environmental impact for each sub-process. He will connect the processes to each other with a manipulator. The processes will be sequentially

connected based on the calculated microstructure. Based on the manipulator, it will be possible to optimize the production process according to the indicators. In this case, it will be possible to optimize the process parameters that give the most favourable indicators of the semi-finished product or to find such process parameters that give the required characteristics of the semi-finished product.
For optimization, physical models of metallurgical process sequences will be combined with evolutionary optimization methods - an iterative approach where processes are gradually improved based on feedback from physical models.
The developed simulation system will be validated based on machine learning from industrial data.
We expect the candidate to have good knowledge of numerical modelling and programming and a passion for the described field of research.
Candidates should have a master education in mechanical engineering or metallurgy, but also in other fields of engineering, physics or mathematics.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
  - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
  - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

☐ **nagrade –** univerzitetna Prešernova nagrada ali Prešernova nagrada članice Univerze v Ljubljani oz. druga enakovredna nagrada *(awards, e.g. Prešeren Prize of the University of Ljubljana, Prešeren Prize of a University of Ljubljana member and/or another equivalent award))*

☐ **bibliografija** *(bibliography)*

☐ **življenjepis** *(CV)*

☐ **motivacijsko pismo** *(motivation letter)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

Univerza v Ljubljani, Fakulteta za strojništvo (University of Ljubljana, Faculty of Mechanical Engineering)

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Domen Šeruga, domen.seruga@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Konstruiranje – Specialna razvojna znanja (Mechanical design – Special development know-how)

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Usposabljanje mladega raziskovalca bo vezano na obravnavo obnašanja magnezijevih zlitin pri obratovanju v realnih delovnih pogojih, ki vključujejo naključne mehanske obremenitve. Posledica takšnega obratovanja so kompleksna večosna napetostno-deformacijska stanja, s katerimi se gradivo odzove na obremenitev. Zaradi različnih deformacijskih mehanizmov, ki se v magnezijevih zlitinah pojavijo kot posledica njihove kristalne strukture, je napetostno-deformacijski odziv teh gradiv odvisen od načina obremenjevanja. Pri velikih amplitudah obremenitve, ki povzročijo elastoplastični odziv gradiva, se npr. napetostno-deformacijski odziv na natezno-tlačno obremenitev močno razlikuje od odziva na strižno obremenitev. Usposabljanje mladega raziskovalca bo kombinacija laboratorijskega dela in razvoja materialnega modela s pripadajočimi materialnimi parametri. Potrebna znanja bo mladi raziskovalec pridobil med samim usposabljanjem.

Usposabljanje bo potekalo tako, da se bo mladi raziskovalec najprej seznanil s širšim področjem problematike in se nato omejil na ožje področje obratovalne trdnosti magnezijevih zlitin, še posebej magnezijeve zlitine AZ31. Spoznal bo materialni model, ki v trenutni obliki omogoča simulacijo napetostno-deformacijskega odziva pri naključnem enoosnem natezno-tlačnem, strižnem in sofaznem obremenjevanju, in določitev materialnih parametrov na podlagi deformacijsko kontroliranih malocikličnih preizkusov. Ta del usposabljanja bo potekal preko opravljanja izpitov in seminarjev na doktorskem študiju UL-FS. S pridobljenimi znanji bo predlagal razširjen model obstoječega enoosnega materialnega modela na popis večosnih obremenitvenih stanj s pripadajočimi dodatnimi materialnimi parametri. Zasnoval bo preizkuse, s katerimi bo mogoče na gradivu izvajati različne vrste obremenitev in razdelal načrt eksperimentalnega dela, katerega cilj bo določitev dodatnih materialnih parametrov s pomočjo statističnih metod. Na izbranih naključnih obremenitvenih primerih bo z uporabo razširjenega materialnega modela simuliral obnašanje magnezijevih zlitin pri realnih pogojih obratovanja.

Med svojim usposabljanjem bo mladi raziskovalec napisal in objavil dva izvirna znanstvena članka in se udeležil vsaj ene mednarodne konference iz širše tematike usposabljanja.

The training of the young researcher will consider the behaviour of magnesium alloys during operation under realistic working conditions which involve variable mechanical loads. The material in such operation responds to the load by complex multiaxial stress-strain states. Due to the various deformation mechanisms that occur in magnesium alloys as a consequence of their crystal structure, the stress-strain response of these materials depends on the load type. For example, at high load amplitudes that cause an elastoplastic response of the

material, the stress-strain response to the tensile-compressive load differs significantly from the shear-load response. The training of the young researcher will be a combination of laboratory work and development of a material model with associated material parameters. The young researcher will acquire the necessary know-how during the training process.
The training will be carried out so that the young researcher first becomes acquainted with the broader area of the problem and then deepens their knowledge to the narrower field of the operational strength of magnesium alloys, especially magnesium alloy AZ31. They will learn about the material model, which in its current form enables simulation of the stress-strain response under variable uniaxial tensile-compressive, shear and in-phase loading, and about the determination of the material parameters gained from strain-controlled low-cycle fatigue tests. This part of the training will be carried out within the framework of courses and seminars at the Ph.D. study programme at UL-FME. With the acquired knowledge, the young researcher will propose an extended material model which will enable consideration of multiaxial loads using associated additional material parameters. Furthermore, the young researcher will design tests to allow for application of different types of loads and develop a plan of experimental work aimed at determination of additional material parameters using statistical methods. For selected variable load cases and using the extended material model, they will simulate the behaviour of magnesium alloys under realistic operating conditions.
During their training, the young researcher will write and publish two original scientific articles and participate at least at one international conference related to the field of training.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
    - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
    - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
    - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

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☒ **motivacijsko pismo** *(motivation letter)*

☐ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*

☐ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☒ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

Jaka Tušek jaka.tusek@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Mehanika / mechanics Toplotno tehnika / thermal engineering

4. Opis raziskovalnega dela *(Research work description*):
Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Slov.:

Raziskovalno delo je usmerjeno v razvoj naprednih trdninskih hladilnih tehnologij, ki temeljijo na multikaloričnem učinku, tj. kombinaciji elastokaloričnega in barokaloričnega pojava v aktivnih materialih. Osrednji cilj raziskave je razvoj in optimizacija multikalorične (elasto–baro) hladilne naprave, pri čemer bo raziskovalec proučeval mehansko in termodinamsko obnašanje elastokaloričnih cevk, izpostavljenih radialnemu obremenjevanju s hidrostatičnim tlakom (bodisi z notranje bodisi z zunanje strani), pri čemer bo barokalorični material uporabljen kot tlačni medij z namenom povečanja kaloričnega učinka. V prvem delu bo raziskovalec razvijal numerične modele za opis sklopljenega mehansko-termodinamskega odziva elastokaloričnih materialov (npr. zlitin z oblikovnim spominom) v cevni geometriji. Numerični modeli bodo omogočali primerjavo med notranjim in zunanjim tlačnim obremenjevanjem ter identifikacijo optimalnih obratovalnih pogojev z vidika kaloričnega odziva in uklonske stabilnosti. Eksperimentalni del raziskave bo zajemal načrtovanje in izdelavo preskusnega sistema za radialno obremenjevanje elastokaloričnih cevk s kontroliranim hidrostatičnim tlakom, pri čemer bo barokalorični material uporabljen kot tlačni medij, z namenom eksperimentalne validacije numeričnih modelov ter ovrednotenja multikaloričnega učinka. Na podlagi numeričnih in eksperimentalnih rezultatov bo raziskovalec oblikoval koncept multikalorične hladilne naprave, ki bo temeljila na cikličnem radialnem obremenjevanju cevk ter učinkovitem prenosu toplote med aktivnim materialom in toplotnima rezervoarjema. Raziskava bo prispevala k razvoju okolju prijaznih alternativ konvencionalnim hladilnim tehnologijam, saj multikalorični sistemi ne uporabljajo toplogrednih hladiv in omogočajo visoko energijsko učinkovitost. Delo bo tako pomembno prispevalo k razumevanju sklopljenih kaloričnih pojavov ter k praktični implementaciji trdninskih hladilnih rešitev naslednje generacije.

Eng.:

The research work is focused on the development of advanced solid-state cooling technologies based on the multicaloric effect, i.e., the combination of elastocaloric and barocaloric phenomena in active materials. The main objective of the project is the development and optimization of a multicaloric (elasto–baro) cooling device, in which the researcher will investigate the mechanical and thermodynamic behavior of elastocaloric tubes subjected to radial loading by hydrostatic pressure (applied either internally or externally), where a barocaloric material will be used as the pressure-transmitting medium in order to enhance the overall caloric effect. In the first phase, numerical models will be developed to describe the coupled thermo-mechanical response of elastocaloric materials (e.g., shape memory alloys) in tubular geometry. These models will enable comparison between internal and external pressure loading and the identification of optimal operating conditions with respect to the magnitude of the caloric response and buckling stability. The experimental part of the research will include the design and construction of a testing system for radial loading of elastocaloric tubes under controlled hydrostatic pressure, with the barocaloric material serving as the pressure-transmitting medium for the purpose of experimental validation of the numerical models and evaluation of the multicaloric effect. Based on the combined numerical and experimental results, a conceptual design of a multicaloric cooling device will be developed, relying on cyclic radial loading of tubes and efficient heat transfer between the active material and thermal reservoirs. The research will contribute to the development of environmentally friendly alternatives to conventional cooling technologies, as multicaloric systems eliminate the need for greenhouse refrigerants while enabling high energy efficiency. The work will significantly advance the understanding of coupled caloric phenomena and support the practical implementation of next-generation solid-state cooling solutions.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja) *(candidate who has completed a Master's degree (2nd Bologna level)):*
  - diplomska listina / potrdilo o zaključku študijskega programa *(diploma certificate / certificate of completion of the study programme)*
  - priloga k diplomi / potrdilo o opravljenih obveznostih *(diploma supplement / official transcript of records containing all grades obtained in the study programme)*
- kandidat, ki še ni zaključil študija na 2. stopnji *(candidate who has not yet completed a Master's degree):*
  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij *(official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)*

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☐ **bibliografija** *(bibliography)*

☒ **življenjepis** *(CV)*

☒ **motivacijsko pismo** *(motivation letter)*

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☒ **osnutek idejne zasnove raziskovalnega dela** *(preliminary research proposal)*

☐ **priporočilno pismo** *(letter of recommendation)*

☐ **druge priloge** *(other attachments):*

Opis raziskovalnega dela *(Research work description*)

1. Članica UL (*UL member)*:

UL Fakulteta za strojništvo

2. Ime, priimek in elektronski naslov mentorja/ice (*Mentor's name, surname and email*):

izr. prof. dr. Matevž Zupančič; matevz.zupancic@fs.uni-lj.si

3. Raziskovalno področje (*Research field*):

Prenos toplote in snovi

4. Opis raziskovalnega dela *(Research work description*):

Vključuje morebitne dodatne pogoje, ki jih mora izpolnjevati kandidat/ka za mladega raziskovalca/ko, ki niso navedeni v razpisu za mlade raziskovalce *(It includes any additional conditions that the candidate for a young researcher must meet, which are not listed in the call to tender for young researchers.)*.

Raziskovalno delo zajema študjo prenosa toplote in snovi s poudarkom na mehurčkastem vrenju v bazenu ter prisilnem konvektivnem vrenju.

Vrenje predstavlja enega najučinkovitejših mehanizmov odvajanja toplote in je ključno za razvoj naprednih hladilnih sistemov v energetiki, mikroelektroniki, vesoljski tehniki ter trajnostnih energetskih sistemih. Kljub več desetletjem raziskav ostajajo temeljni mehanizmi prenosa toplote in snovi na mikro- in mezoskali, zlasti med tekočo in parno fazo ter v bližini trdne grelne površine, še vedno nezadostno pojasnjeni.

Raziskovalno delo bo usmerjeno v:

- eksperimentalno karakterizacijo prenosa toplote in snovi pri rasti mehurčkov,
- analizo mehanizmov prenosa toplote na različnih velikostnih skalah,
- preučevanje vpliva lokalnega temperaturnega polja na dinamiko rasti mehurčka,
- analizo mehanizmov prenosa toplote na podlagi modela delitve toplotnih tokov,
- analizo ključnih parametrov vrenja,
- analizo koalescence med sosednjimi mehurčki pri višjih gostotah toplotnega toka,
- razvoj površin za izboljšan prenos toplote ter
- razvoj in uporabo naprednih diagnostičnih sistemov za karakterizacijo procesa vrenja.

Raziskave bodo temeljile na uporabi naprednih diagnostičnih metod, vključno z visokohitrostno vizualizacijo, infrardečo termografijo ter metodami merjenja temperature v delovnem fluidu. Poleg tega bodo vključevale implementacijo funkcionaliziranih površin in kompleksnih geometrij z uporabo laserskega teksturiranja, funkcionalnih premazov, različnih tehnik jedkanja ter 3D-tiska polimerov in kovin.

Pričakovani rezultati vključujejo poglobljeno razumevanje mehanizmov prenosa snovi pri fazni spremembi, izboljšanje modelov za napovedovanje procesa vrenja ter razvoj smernic za optimizacijo površin za aplikacije, ki zahtevajo odvajanje visokih gostot toplotnega toka.

The research work focuses on the study of heat and mass transfer, with particular emphasis on nucleate pool boiling and flow boiling.

Boiling represents one of the most efficient heat removal mechanisms and is essential for the development of advanced cooling systems in energy engineering, microelectronics, aerospace applications, and sustainable energy technologies. Despite several decades of research, the fundamental mechanisms governing heat and mass transfer at micro- and mesoscales, particularly at the liquid–vapor interface and in the vicinity of the heated solid surface, remain insufficiently understood.

The research activities will focus on:

- experimental characterization of heat and mass transfer during bubble growth,
- analysis of heat transfer mechanisms across different length scales,
- investigation of the influence of local temperature fields on bubble growth dynamics,
- analysis of heat transfer mechanisms based on the heat flux partitioning model,
- analysis of key boiling parameters,
- investigation of bubble coalescence at elevated heat flux conditions,
- development of surfaces for enhanced heat transfer, and
- development and application of advanced diagnostics for boiling process characterization.

The research will rely on advanced diagnostic techniques, including high-speed visualization, infrared thermography, and temperature measurements within the working fluid. In addition, it will involve the implementation of functionalized surfaces and complex geometries using laser texturing, functional coatings, various etching techniques, and 3D printing of polymers and metals.

The expected outcomes include a deeper understanding of mass transfer mechanisms during phase change, improved predictive models for boiling processes, and the development of design guidelines for optimizing surfaces in applications requiring high heat flux dissipation.

5. Priloge, ki jih je treba priložiti ob prijavi *(Documents required to be submitted with the application)*:

☒ **potrdilo o doseženi izobrazbi *(proof of completed education)***

- kandidat z zaključenim magistrskim študijskim programom (2. bolonjska stopnja)
  (candidate who has completed a Master's degree (2nd Bologna level)):

  - diplomska listina / potrdilo o zaključku študijskega programa
    (diploma certificate / certificate of completion of the study programme)

  - priloga k diplomi / potrdilo o opravljenih obveznostih
    (diploma supplement / official transcript of records containing all grades obtained in the study programme)

- kandidat, ki še ni zaključil študija na 2. stopnji
  (candidate who has not yet completed a Master's degree):

  - potrdilo o do sedaj opravljenih obveznostih z ocenami magistrskega študijskega programa, s katerim se bo kandidat prijavil na doktorski študij
    (official transcript of records listing all courses and grades obtained so far in the Master's degree programme on the basis of which the candidate will apply for enrollment in a doctoral degree programme.)

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☒ **bibliografija** *(bibliography)*

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