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*):

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

3. Raziskovalno področje (*Research field*):

Strojništvo (Mechanical 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.: Skoraj polovico svetovne končne rabe energije predstavlja ogrevanje in hlajenje, pri čemer velika večina te energije še vedno temelji na fosilnih gorivih. Poleg tega se približno polovica letne svetovne rabe energije nanaša na odpadno toploto, ki ostaja neizkoriščena. Za razogljičenje in tudi defosilizacijo ogrevanja in hlajenja je potrebno implementirati izboljšave energetske učinkovitosti naprav in sistemov, izrabiti razpoložljivo odpadno toploto ter povečati rabo obnovljivih virov energije. Najučinkovitejši način za dosego teh ciljev je mogoč z uporabo tehnologij toplotnih črpalk. Za uporabo v bivalnem okolju so še posebej zanimive tiste vrste tehnologij toplotnih črpalk, ki omogočajo obratovanje brez gibljivih delov, vibracij ali prekomerne ravni hrupa in uporabo takih hladilnih sredstev, ki ne predstavljajo nevarnosti izpusta v okolje. Eno takih tehnologij predstavljajo termoelektrične toplotne črpalke, ki pa imajo dokaj nizek izkoristek pretvorbe energije. Zato so potrebne rešitve, ki bi omogočale izboljšanje njihove učinkovitosti. Raziskovalno delo bo obsegalo konceptualno zasnovo, simulacije in eksperimentalno delo na medsebojno povezanih področjih prenosa toplote, Peltier učinka ter toplotnih črpalk. Skladno z nalogo bo potrebno zasnovati posebne topografije prenosnikov toplote, izdelanih s pomočjo aditivnih tehnologij in le te (optimizirano) kombinirati s specifično prilagoditvijo Peltier modulov. Integrirano toplotno črpalko bo potrebno implementirati v izbranem realističnem primeru ter demonstrirati njeno delovanje pri različnih pogojih.

Prednost bodo imele kandidatke ali kandidati z znanjem fizike, strojništva ali elektrotehnike. Močno je zaželeno celovito razumevanje principov prenosa toplote in sposobnost izvajanja numeričnih simulacij in eksperimentalnega dela. Praktične izkušnje na teh področjih so izjemnega pomena, saj bodo pomembno prispevale k raziskovalnim ciljem. Sposobnost kritičnega razmišljanja, reševanja kompleksnih problemov in prilagajanja izzivom na področju energetsko učinkovitih ogrevalnih in hladilnih sistemov bo ključna za uspeh raziskovalne naloge. Prav tako mora kandidatka ali kandidat izkazovati izrazito natančnost, zanesljivost, dobre komunikacijske veščine in sposobnost dela v timu.

Eng.: Nearly half of the world's final energy consumption is devoted to heating and cooling, with the vast majority still reliant on fossil fuels. Furthermore, approximately half of the world's annual energy use is dissipated as waste heat, remaining largely untapped. To decarbonize and transition heating and cooling away from fossil fuels, it is imperative to implement improvements in the energy efficiency of devices and systems, recover or harness available waste heat, and increase the utilization of renewable energy sources.

Heat pump technologies offer the most efficient pathway to achieving these objectives. For residential applications, there is particular interest in heat pump technologies that operate without moving parts, vibrations, or excessive noise levels, while using refrigerants that pose no environmental risk if released. Thermoelectric heat pumps represent one such technology; however, their relatively low energy conversion efficiency presents a significant challenge. Consequently, innovative solutions are needed to enhance their performance.

The proposed research work will encompass conceptual design, simulations, and experimental investigations in the interconnected fields of heat transfer, the Peltier effect, the additive manufacturing, and heat pump technology. A key aspect of the project will involve designing specialized heat exchanger topographies using additive manufacturing techniques and optimally integrating them with the specific adaptation of Peltier modules. The resulting integrated heat pump will be implemented in a selected real-world scenario to demonstrate its operational capabilities under various conditions.

Candidates with a strong background in physics, mechanical engineering, or electrical engineering will be given priority consideration for this position. The ideal applicant should possess a comprehensive understanding of heat transfer principles and demonstrate proficiency in conducting numerical simulations and experimental work. Practical experience in these areas will be highly valued, as it will contribute significantly to the research objectives. The ability to think critically, solve complex problems, and adapt to emerging challenges in the field of energy-efficient heating and cooling systems will be essential for success in this research endeavor. *The candidate must also demonstrate exceptional precision, reliability, strong communication skills, and the ability to work in a team.*

5. Priloge, ki jih kandidat priloži k prijavi *(Documents that the candidate submits with the application)*:

☒ **diplomska listina/potrdilo o zaključku študijskega programa** *(diploma certificate for study programme, with which the candidate has enrolled/ will enroll in a doctoral degree programme)*

☒ **priloga k diplomi/ potrdilo o opravljenih obveznostih (***official transcript of all the grades for study programme, with which the candidate has enrolled/will enroll in a doctoral degree programme)*

☒ **potrdilo o do sedaj opravljenih obveznostih z ocenami študijskega programa, s katerim se bo kandidat prijavil na študij** *(official transcript of all the grades the candidate has received so far for the study programme, with which the candidate will enroll to a doctoral degree programme)*

☒ **nagrade** *(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)*

☒ **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*):

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

3. Raziskovalno področje (*Research field*):

Strojništvo (Mechanical 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.: Skoraj polovico svetovne končne rabe energije predstavlja ogrevanje in hlajenje, pri čemer industrijski procesi doprinašajo polovico tega deleža. Od celotne rabe energije v industriji predstavlja procesna toplota kar tri četrtine, preostanek pa predstavljata mehansko delo in elektrika. Velika večina te energije še vedno temelji na fosilnih gorivih. Poleg tega se približno polovica letne svetovne rabe energije nanaša na odpadno toploto. Za razogljičenje in tudi defosilizacijo ogrevanja industrijskih procesov je potrebno implementirati izboljšave energetske učinkovitosti naprav in sistemov, izrabiti razpoložljivo odpadno toploto ter povečati rabo obnovljivih virov energije. Najučinkovitejši način za dosego teh ciljev je mogoč z uporabo tehnologij visoko-temperaturnih toplotnih črpalk. Od teh predstavlja parno-kompresijska tehnologija najbolj razširjen in energetsko najučinkovitejši način črpanja toplote do 200 °C. Slabost tehnologije predstavlja resna omejitev okoljskih, varnostnih zahtev in karakteristik hladiv. Naslednji problem predstavlja miniaturizacija naprav, saj danes najmanjše enote visoko-temperaturnih toplotnih črpalk dosegajo moči nad 20 kW. Hkrati je znano dejstvo, da nižanje moči in hkrati dimenzij vodi v dodatno znižanje energetske učinkovitosti naprav. Alternativno rešitev predstavljajo t.i. kalorične tehnologije, ki uporabljajo trdninska hladiva in teoretično dosegajo zelo visok eksergijski izkoristek. Ta je posledica reverzibilnosti procesov kaloričnih učinkov, ti pa so analogni procesom kompresije in ekspanzije. Med kaloričnimi tehnologijami predstavljajo tehnologije, ki temeljijo na elektrokaloričnem učinku, možnost izvedbe najbolj kompaktnih naprav in delovanje brez gibljivih delov. Posebno prednost pa predstavljajo razpoložljivi elektrokalorični materiali s faznimi prehodi pri visokih temperaturah, kar omogoča njihovo rabo v visoko-temperaturnih toplotnih črpalkah.
Cilj doktorskega dela je raziskati različne konceptualne rešitve visokotemperaturnih elektrokaloričnih toplotnih črpalk ter na podlagi analiz realizirati demonstracijsko napravo, s katero je moč eksperimentalno potrditi koncept in ovrednotiti delovanje pri različnih delovnih pogojih.

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

Eng.: Nearly half of the world's final energy consumption is dedicated to heating and cooling, with industrial processes accounting for half of this share. Within industry, process heat constitutes approximately three-quarters of total energy use, while the remainder is divided between mechanical work and electricity. A significant portion of this energy still relies on fossil fuels. Moreover, about half of the world's annual energy use is wasted as heat.

To decarbonize and transition industrial process heating away from fossil fuels, several measures are essential: improving the energy efficiency of devices and systems, harnessing available waste heat, and increasing the adoption of renewable energy sources. High-temperature heat pump technologies offer one of the most effective solutions to achieve these goals. Among these technologies, vapor-compression systems are the most widely used and energy-efficient method for pumping heat up to 200 °C. However, this technology faces challenges such as strict environmental and safety requirements, as well as limitations related to refrigerant properties. Another issue is miniaturization—current high-temperature heat pump units typically operate at powers exceeding 20 kW. Reducing power and size often results in a further decline in energy efficiency.

An alternative approach lies in caloric technologies, which utilize solid refrigerants and theoretically achieve exceptionally high exergy efficiency due to the reversibility of caloric effect processes). Among these, electrocaloric technologies stand out for their potential to create highly compact devices that operate without

moving parts. A notable advantage is the availability of electrocaloric materials with phase transitions at high temperatures, enabling their application in high-temperature heat pumps.

The objective of this doctoral thesis is to explore various conceptual designs for high-temperature electrocaloric heat pumps. Based on these analyses, the goal is to develop a demonstration device capable of experimentally validating the concept and assessing its performance under diverse operating conditions.

Preference will be given to candidates with knowledge of physics, mechanical engineering or electrical engineering and knowledge and experience in the research field of the doctoral thesis.

5. Priloge, ki jih kandidat priloži k prijavi *(Documents that the candidate submits with the application)*:

☒ **diplomska listina/potrdilo o zaključku študijskega programa** *(diploma certificate for study programme, with which the candidate has enrolled/ will enroll in a doctoral degree programme)*

☒ **potrdilo o do sedaj opravljenih obveznostih z ocenami študijskega programa, s katerim se bo kandidat prijavil na študij** *(official transcript of all the grades the candidate has received so far for the study programme, with which the candidate will enroll to a doctoral degree programme)*

☒ **življenjepis** *(CV)*

☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's existing research work, relevant to the research domain)*

☒ **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*):

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

3. Raziskovalno področje (*Research field*):

Fuzijske tehnologije (Fusion Technologies)

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.: Reakcija zlivanja lahkih jeder predstavlja potencialno rešitev človeške potrebe po velikih količinah čiste energije. Na poti do njenega koristnega izkoriščanja je še precej fizikalnih in inženirskih izzivov, ki se jih loteva tudi programska skupina Fuzijske tehnologije. Programska skupina je močno vpeta v dva glavna raziskovalna okvirja na področju fuzijske energetike in sicer Konzorcija EUROfusion, ki združuje evropske raziskave na tem področju, in organizacije ITER, katere cilj je izgradnja največjega fuzijskega eksperimentalnega reaktorja na svetu. Mladi raziskovalec se bo pri svojem delu ukvarjal predvsem s problematiko plazemske obremenitve prve stene fuzijskih naprav, ki predstavlja ključno omejitev pri načrtovanju reaktorjev in operativnih scenarijev. Pri svojem delu se bo spoznal z modeliranjem plazme in njene interakcije s steno, kjer se mešata naravoslovni in inženirski pristop. Tema doktorata bo povezana z razvojem in uporabo računalniških simulacijskih orodij potrebnih za izračun delčnih in toplotnih obremenitev komponent reaktorja, ki so v stiku s plazmo ter povezava z eksperimentom. Delo je izrazito mednarodno, saj je tematika pomembna za celotno svetovno fuzijsko srenjo. Poleg motivacije za raziskovalno delo je zaželeno tudi znanje programiranja in želja po nadaljnjem razvoju programerskega znanja, tudi v povezavi s superračunalništvom.

Eng.:The reaction of fusing of light nuclei represents a potential solution for human needs for large quantities of clean energy. There are still several physics and engineering related challenges on the path to nuclear power plants and some of them are addresses by the Fusion Technologies Programme. The Programme Group is strongly involved in the two main research frameworks in the field of fusion energy research, namely the EUROfusion Consortium, which brings together European research institutions in this field, and ITER, which aims to build the world's largest experimental fusion reactor. The junior researcher's work will focus on the issue of plasma loads of the first wall of fusion devices, which is a key constraint in reactor design and design of operational scenarios. His work will introduce him to modelling of plasma and its interaction with the wall, mixing the natural science and engineering approach. The topic of the PhD will be related to the development and use of computer simulation tools necessary to calculate the particle and thermal loads of reactor components in contact with plasma and the validation by the experiments. In addition to high motivation for research, programming skills are desired, as well as willingness to further develop programming skills, especially in relation to supercomputing.

5. Priloge, ki jih kandidat priloži k prijavi *(Documents that the candidate submits with the application)*:

☒ **potrdilo o do sedaj opravljenih obveznostih z ocenami študijskega programa, s katerim se bo kandidat prijavil na študij** *(official transcript of all the grades the candidate has received so far for the study programme, with which the candidate will enroll to a doctoral degree programme)* ☒ **življenjepis** *(CV)* ☒ **motivacijsko pismo** *(motivation letter)* ☒ **opis dosedanjega sodelovanja pri raziskovalnem delu** *(description of the candidate's research work)*