1. Raziskovalna organizacija (*Research organisation)*:

Univerza v Ljubljani, *Fakulteta za strojništvo*

2. Ime in priimek mentorja (*Name and surname of a mentor*):

Prof. dr. Igor Emri

3. Področje znanosti iz šifranta ARRS (*Primary research field*):

2.05 Tehniške vede/Mehanika

4. Kontaktni e-naslov mentorja (*Contact of a mentor)*:

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5. Kratek opis programa usposabljanja (*Short description of the program)*:

SLO

Poliamid 6 (PA6), znan tudi pod imenom »Najlon« je eden najbolj razširjenih materialov v tehniki in medicini, predvsem zaradi dobrih mehanskih lastnosti, odpornosti na obrabo, kemijske odpornosti in biokompatibilnosti. V sodelovanju z BASF je naša skupina pokazala, da ima sprememba porazdelitve molske mase PA6 izrazito ne-linearen vpliv na vedenje tega materiala. Pokazano je bilo tudi, da lahko s primerno izbrano porazdelitvijo molske mase materiala in natančno opredeljenimi temperaturno-tlačnimi procesnimi pogoji v fazi izdelave izdelkov možno izdelati izdelke z gradientno strukturo materiala.

To ne-linearno vedenje je mogoče razložiti s teorijo "prostega volumna". Prosti volumen je inherenten intermolekularni prostor, ki se tvori pri procesu ohlajanja pod temperaturo steklastega prehoda. Njegovo formiranje je odvisno od temperaturno-tlačnih pogojev pri prehodu iz tekočega v trdno stanje in kasneje tudi pri prehodu preko temperature steklastega prehoda. Pretekle raziskave so pokazale, da je mogoče z uporabo natančno določenih robnih pogojev narediti izdelke katerih mehanske lastnosti vzdolž izdelka se razlikujejo za več velikostnih razredov. Polimerni materiali z gradientno strukturo so zelo zanimivi v dentalni protetiki in ortopediji, kjer z gradientno strukturo lahko posnemamo strukturo kosti in zob.

Za določitev materialnih lastnosti gradientnih struktur so v uporabi (destruktivne) metode testiranja lokalnih mehanskih lastnosti, kot je naprimer nanoidentacija, na drugi strani pa so v uporabi klasične (nedestruktivne) merilne metode, kot je naprimer natezno-kompresijski test. Težava prvega pristopa je v tem, da je potrebno vzorce pripraviti in testirati v za to narejenih merilnih napravah, drug pristop pa nam podaja samo lastnosti celotnega vzorca (zgubimo informacijo o lokalnih lastnostih vzdolž vzorcev). Slednji pristop je možno nadgraditi z metodo korelacije digitalne slike (DIC – Digital Image Correlation), ki omogoča brezkontaktno merjenje lokalnega deformacijskega stanja vzorcev in s tem nedestruktivno merjenje gradientnosti izdelka.

CILJ USPOSABLJANJA in PRIČAKOVANI REZULTATI:

V sklopu projekta želimo uporabiti metodo korelacije digitalne slike (DIC – Digital Image Correlation) za določitev časovno-odvisnih mehanskih lastnosti gradientnih dentalnih in ortopedskih vsadkov.

Gradientna struktura materiala bo dosežena z izdelavo vzorcev, ki bodo izpostavljeni natančno opredeljenim temperaturnim in tlačnim robnim pogojem v fazi njihove izdelave. S pomočjo merilne metode DIC bodo določene časovno-odvisne materialne lastnosti na posameznem delu izdelanih vzorcev. V sklopu naloge bo potrebno razviti numerično zvezo med časovno-odvisnim deformacijskim stanjem, ki ga dobimo s pomočjo DIC metode in materialnimi funkcijami, ki popisujejo lokalno

časovno odvisnost implanta z gradientno strukturo.
V sklopu raziskovalnega programa bo potrebno raziskati:

1.) Kako robni pogoji (temperatura in tlak) pri izdelavi vzorcev vplivajo na gradientnost vzorcev?
2.) Kako lahko z uporabo DIC metode določimo lokalne materialne lastnosti na posameznem delu implanta z gradientno strukturo?
3.) Kako se meritve z uporabo DIC metode ujemajo z 'klasičnimi' destruktivnimi metodami testiranja (npr. nanoidentacijo)?

ANG
Polyamide 6 (PA6), known also under the name »Naylon«, is one of the most widely used materials in medicine and in technical science due to its good mechanical properties, resistance to wear, corrosion resistance and biocompatibility. In collaboration with BASF our group has shown that the change of distribution of molecular mass of PA6 has highly non-linear effect on the behavior of this material. It was also shown, that proper selection of distribution of molecular mass of material combined with precisely determined temperature-pressure processing conditions in the manufacturing phase results in a product with gradient structure. This non-linear behavior can be explained by "free-volume" theory. Free volume is a inherent intermolecular volume, that is formed in the process of cooling under the glass transition temperature. Its formation depends on temperature-pressure conditions at the transition from melt to solid and later also at the glass transition temperature. Past research have shown, that it is possible to obtain samples which properties change for orders of magnitude along the length of samples by using precisely determined boundary conditions. Very promising area for using polymeric materials with gradient structure are dental prosthetics and orthopedics, where gradient structure can mimic structure of bones and teeth.
For determination of mechanical properties of gradient structures local (destructive) testing methods are in use, such as nanoidentation. On the other hand, also classical (non-destructive) measuring methods are used, such as tension-compression test. The main issue of the first approach is that for testing special samples need to be prepare and tested in purposely build equipment, whereas the second approach gives us results only on properties of the whole sample (information on local properties along the length of the sample is lost). The latter approach can be upgraded using DIC method (Digital Image Correlation), which enables non-contact measurement of local deformation state of the sample and with this non-destructive measurement of guardiancy of the sample.

GOAL OF THE TRAINING and EXPECTED RESULTS:
Within the training we want to use DIC method for determination of time-dependent mechanical properties of gradient dental and orthopedic implants.
By exposing material to precisely determined temperature and pressure boundary conditions in the manufacturing phase gradient structure of material will be achieved. Using DIC method time-dependent properties will be determined in a particular part of the manufactured samples. Within the training, numerical methodology for correlating time-dependent deformation state obtained using DIC method and material functions which describe the local time-dependence of the implant with gradient structure needs to be developed.
As a part of the research the following needs to be investigated:
1.) How boundary conditions (temperature and pressure) at the manufacturing phase of sample preparation influence the guardiancy of samples
2.) How to determine local material properties using DIC method on samples with gradient structure
3.) How DIC measurements correlate with 'classical' destructive testing methods (i.e., nanoidentation)

Prof. dr. Igor Emri, mentor