

**Short thesis for the degree of Doctor of Philosophy
(PhD)**

**Development of patient-specific, lattice-
structured hip implant stems based on finite
element analysis and machine learning**

by Rashwan Alkentar

Supervisor: Dr. Tamás Mankovits



UNIVERSITY OF DEBRECEN

Doctoral School of Informatics

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Abstract

This doctoral dissertation focuses on optimizing hip implant design through the use of lattice structures, addressing the rising demand for implants and the need to reduce revision surgeries. A major biomechanical concern is ensuring proper implant fixation within human bone. Lattice topology optimization enhances osseointegration by mimicking bone-like structures. However, the variable properties of lattice structures based on design parameters make manufacturing complex. Machine learning, particularly linear regression, is used to predict mechanical properties efficiently, while additive manufacturing handles the intricate geometries. The research also evaluates the use of titanium alloy Ti6Al4V for its corrosion resistance and biocompatibility. The alloy's Young's modulus is assessed to ensure suitable elasticity for implants. The study examines three types of lattice structures with different unit cell shapes, analyzing their mechanical behavior through simulations. Computer-aided design is used in the early stages, and the porosity of the lattices is optimized to achieve the best mechanical and topological performance. After simulations, the structures are 3D-printed and subjected to laboratory compression

tests to validate the predicted results. Overall, the integration of lattice design, machine learning, and advanced manufacturing techniques contributes to creating more effective, customized, and durable hip implants.

Keywords: Optimization, lattice structures, machine learning, osseointegration, Finite Element Analysis, Direct laser metal sintering, additive manufacturing, compression testing, Linear Regression.

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Chapter 1: introduction

Research Motivation

This research investigates challenges in the integration of lattice structures into hip implants with the focus on material compatibility, optimal design, manufacturability, and long-term biocompatibility. By optimizing lattice topology on patient's anatomy, the study seeks to improve the osseointegration, enhance surgical success rates, increase implant durability, and improve the outcomes for hip arthroplasty patients.

Aims and objectives.

The dissertation optimizes hip implants via incorporating lattice structures to improve fixation, osseointegration, and biomechanical performance. Basically, it reviews biomaterials, uses CAD and FE simulations, and leverages additive manufacturing for patient-specific designs. Machine learning enhances the optimization process, aiming to develop durable, customized implants that can improve surgical outcomes and long-term reliability in the hip implants.

Contribution

While much research exists on hip implant optimization, most designs remain generic. This study focuses on creating personalized hip implants using lattice structures tailored to each patient's anatomy, enhancing fit, fixation, and performance. By pre-defining parameters like bone size, shape, and porosity, the research streamlines the customization process. Advanced computer modeling and simulation are employed to evaluate biomechanical properties and predict implant behavior under real conditions. This personalized approach aims to reduce complications such as loosening or wear, improve surgical outcomes, and extend implant lifespan, offering a more precise and effective alternative to standard hip replacement solutions.

Chapter 2: Thesis 1: Development of lattice structures to support bone ingrowth and reduce stress shielding for hip implant stem design.

Test specimens with the same porosity, designed using four different lattice structures (3D lattice infill, Double pyramid lattice with cross, Double pyramid lattice and face diagonals, Octahedral lattice) and developed for hip implant placement were printed using additive technology and Ti6Al4V raw material according to ISO 13314 standard. The cell sizes of the specimens were chosen to promote bone ingrowth for better fixation. Compression tests showed that the stiffness of the bulk material can be reduced by 90% using the investigated lattice structures. With this method, I developed lattice structures whose stiffness closely approximates the stiffness of the femur, thereby reducing the occurrence of stress shielding. The results for laboratory compression tests are shown in the next Figure 32. Young's modulus was calculated and shown on the graphs.

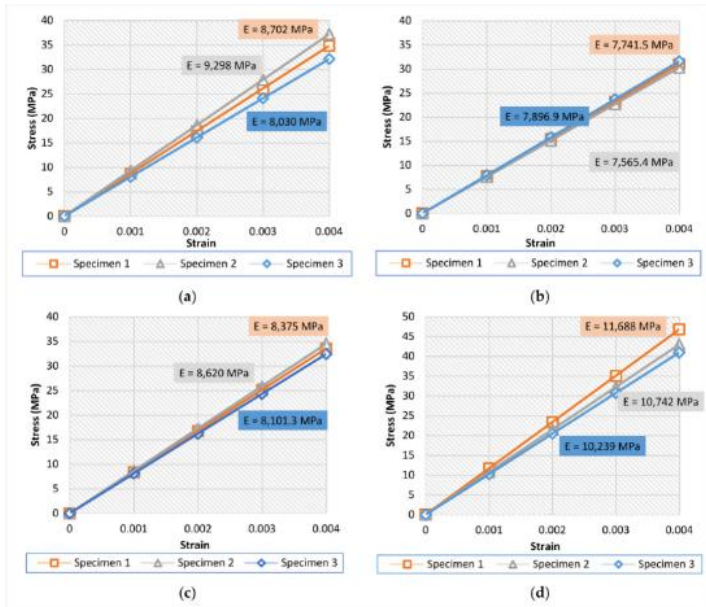


Figure 1. Stress–strain curves with the determined effective Young’s modulus: (a) 3D lattice infill pattern, (b) double-pyramid lattice with cross, (c) double-pyramid lattice and face diagonals, (d) octahedral lattice 2.

As a main result of the research, the stiffness of the structure was reduced to a range of 80-90% with the application of latticed optimization. During the experiments, the load applied on all the types was of the same value, and since they all have the same area under the load, the stress will be the same for all types. The difference in value of the Young’s modulus among all the types can be

explained by the change in the strain values, which comes since the reaction against the load for each type was unique and differs from the other. The “Octahedral lattice 2” type showed the highest value of Young’s modulus which nominates it to be the stiffest type among the other types. On the other hand, the lowest value among the structures was for the “Double Pyramid lattice with Cross” type.

Figure 33 shows the results of the FEM analysis for all types of lattice structures, whereas the deviation between the laboratorial results and FEM results was shown in Table 7.

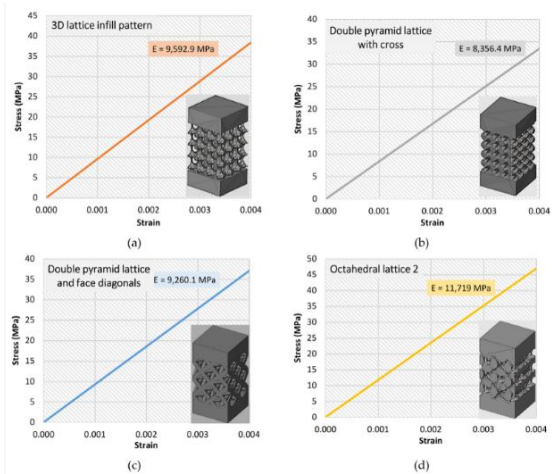


Figure 2. Stress–strain graphs and the effective Young’s modulus calculated via numerical analysis. (a) 3D lattice infill pattern, (b) Double pyramid lattice with cross, (c) Double pyramid lattice and face diagonals, (d) Octahedral lattice 2.

Table 1. Deviation in Young's modulus values between numerical analysis and laboratorial results

Cell type	Effective Young's Modulus (MPa) (measurement)	Effective Young's Modulus (MPa) (numerical analysis)	Deviation %
3D lattice infill pattern	8676.67	9592.9	9.6
Double pyramid lattice with cross	7734.60	8356.4	7.4
Double pyramid lattice and face diagonals	8332.00	9260.1	10.0
Octahedral lattice 2	10889.67	11719	7.1

The deviation detected among the structures' Young's modulus reached up to 10% in the maximum case that happened at the Double Pyramid lattice and Face Diagonals. The reasons behind such a deviation might be related to one of the following results: The quality of the 3D-printing, the quality of the metal powder used within the printing process, the accuracy of the 3D printer and the compression test accuracy considering how accurate the machine is.

Chapter 3: Thesis 2: Development of a surrogate finite element model for lattice-structured hip implant stem

Due to the complex geometry, finite element analysis of a hip implant stem designed with a lattice structure is extremely time-consuming. A surrogate finite element model has been developed for the hip implant stem to replace the lattice structures. This shortens the finite element pre-processing and reduces the computational cost by several orders of magnitude while maintaining the calculation accuracy in accordance with engineering practice. The developed surrogate model enables serial calculations for optimization tasks to be performed in a manageable amount of time, thus accelerating the hip implant design process.

FE simulations calculations were conducted to evaluate the compressive behavior of the hip implant using ANSYS Mechanical Workbench 2020 R2. The 3D CAD models were analyzed with taking the in-vivo conditions into consideration as regulated by the previously mentioned standards. Both models, geometrically latticed and the surrogate models, were examined during the analysis. Since

the compression machine usually records the vertical deformation of its compression plate, Figure 41 compares the resulting vertical deformation of these plates of the two models. The legends colored with black represent the absolute vertical deformation values, while the colorful legends provide insight into the implant's overall deformation behavior.

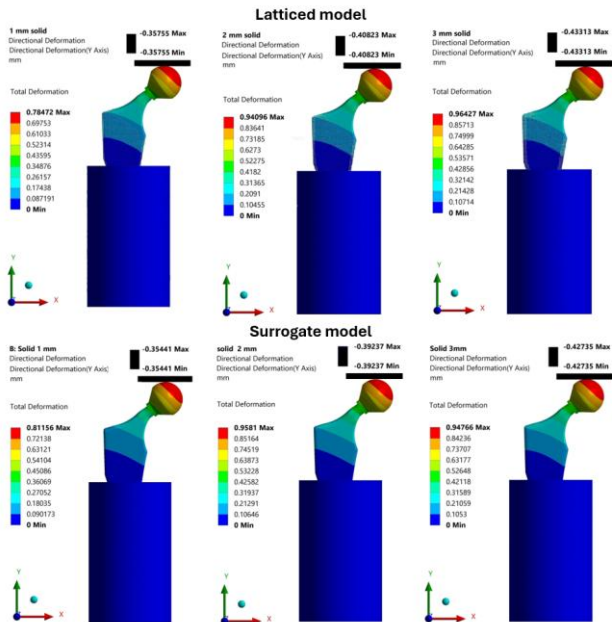


Figure 3. Compression plates' vertical deformation (Axis-Y) for latticed and surrogate models

Table 10 shows a comparison, in values, between using the geometrically latticed model and the surrogate model. The

deviation range among the results varies between 1-4% which is an acceptable range.

Table 2. Vertical deformation results deviation between latticed and surrogate models

Model	1 mm lattice	2 mm lattice	3 mm lattice
Vertical deformation mm			
Geometrically latticed model	0.357	0.408	0.433
Surrogate model	0.354	0.392	0.427
Deviation %	1	4	1

The accuracy of the results was assessed through conducting a mesh convergence study that analyzed vertical deformation in relation to the mesh element size as shown in Figure 42. The final mesh element size of 0.5 mm was selected, and a tetrahedral mesh type with patch-independent method were applied to the model. A convergence of 5% was achieved.

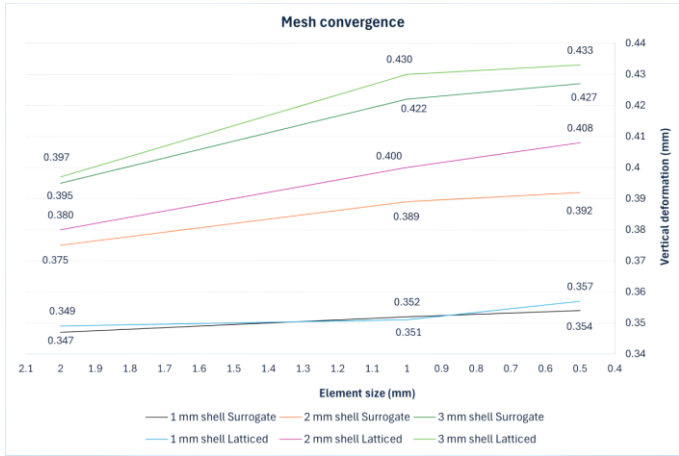


Figure 4. Convergence study

Therefore, the surrogate model can be a good replacement of the geometrically latticed model while still providing accurate results in numerical simulations. Table 11 shows a comparison of the two models in terms of solving time and the RAM usage in the operating system. The simulations were performed on a computer with four logical processors, four Intel® cores, and 16 GB installed physical memory (RAM).

Table 3. Deviations in computation results for Geometrically latticed model vs surrogate model

Model	1 mm lattice		2 mm lattice		3 mm lattice	
	Normal model	Surrogate model	Normal model	Surrogate model	Normal model	Surrogate model
Time (s)	1580	17	7363	20	9683	24
Maximum Memory used (MB)	1878	116	1924	124	2293	140

Using the surrogate model significantly reduces both computation time and RAM usage, leading to substantial time and cost savings in the simulation process. The computation time decreased from several thousand seconds to just a few seconds, while RAM usage was reduced from thousands to only a few hundred seconds.

The surrogate model can help facilitate the simulations performed on lattice structures where it can generate the resulting mechanical behavior almost with the same accuracy done on the normal model. Its ability to reduce computation time and capacity can greatly reduce the cost of the simulation process. Total hip implant's simulation will be performed using the surrogate model to experiment the implant reactions against everyday life loadings.

Chapter 4: Thesis 3: Porosity prediction of lattice structures using linear regression algorithm

Due to the complex design, geometric modeling of lattice structures is extremely time-consuming. The porosity of structures made of lattices depends primarily on the choice of the dimensions of the lattice length and lattice thickness. A linear regression algorithm was used to estimate the porosity of 3 different lattice structures (3D lattice infill, Double pyramid lattice and face diagonals, Octahedral lattice) as a function of lattice length and lattice thickness. The applied machine learning model is able to estimate the porosity of the lattice structure with 95% accuracy without time-consuming geometric modeling.

The machine learning models were done with good accuracy for all types of lattice structures. Table 4 exhibits accuracy values for all types. When checking the accuracy levels in each case, it is clear that a good accuracy level can be reached out of 81, 54, 54, learning points for 3D lattice infill, Double pyramid lattice and face diagonals and Octahedral lattice 2 respectively.

Table 4. Accuracy values for lattice types

Unit cell type	Case 1 Accuracy (%)	Case 2 Accuracy (%)	Case 3 Accuracy (%)
3D lattice infill	98	96	96
Double pyramid lattice and face diagonals	98	98	99
Octahedral lattice 2	98	99	99

Figure 5 shows the model results where actual porosity values are shown as scattered blue points, and the predicted porosity values for the feature space are shown as color-graded surface plots.

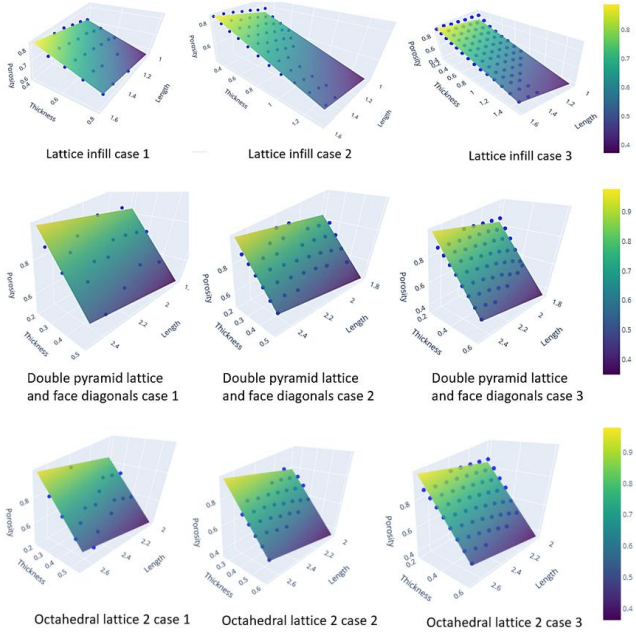


Figure 5. Machine learning models representations for all cases
 The models' accuracy for all models was also shown in Figure 6 using regression lines to visualize how accurate the models were.

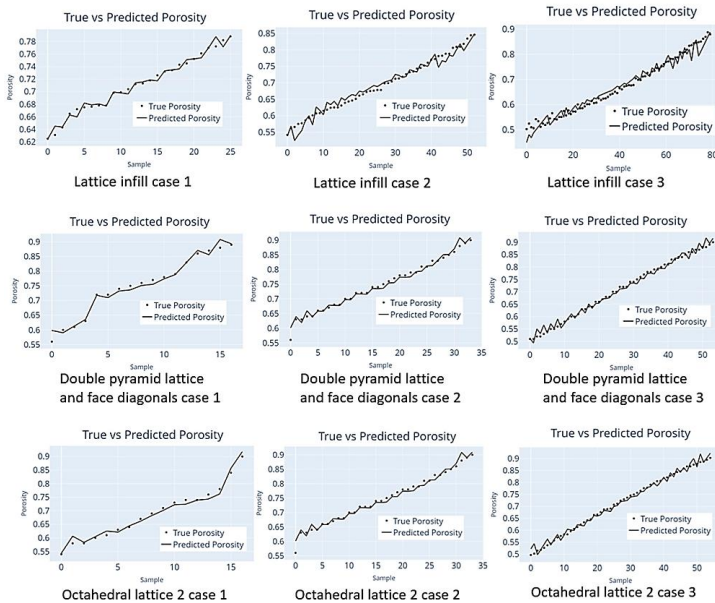


Figure 6. Prediction accuracy for all cases

The higher accuracy the model shows, the more efficient and productive the process will be for predicting porosity and saving time and effort by avoiding trial-and-error process to reach the desired optimum porosity for a specific hip implant design. Double pyramid lattice type and octahedral lattice type presented more accurate results,

and that is due to their inner structure being easier to predict and more mathematically conforming than the 3D lattice infill type. However, the accuracy level was over 96% for all three types, which is considered acceptable.

Chapter 5: Thesis 4: Development of a database for hip implant stem designed with lattice structure

A database for additively manufactured Ti6Al4V lattice-structured hip implant stem was developed depending on several cell parameters and designs. This considers the patient's weight and provides information about the mechanical response of the implant by simulating the implant environment. The database thus provides surgeons with the opportunity during the planning of hip implant surgery to select a partially patient-specific solution.

The regression learner application trained all kinds of models and showed the RMSE and MSE results for the validation and test set results. The four best results in terms of RMSE and R-squared value for total displacement U_{max} is shown in Table 5.

Table 5. Evaluation of the Total displacement U_{max} prediction model

Model	RMSE		R-squared	
	Training	Test	Training	Test
Neural Network (Wide NN)	0.26	0.31	0.96	0.96
Neural Network (Medium NN)	0.30	0.34	0.95	0.93

Neural Network (Bilayered NN)	0.40	0.42	0.91	0.90
Gaussian Process Regression (Matern 5/2 GPR)	0.51	0.62	0.85	0.76

While in Table 6 the best models for stress von Mises prediction are shown, and Table 7 shows the best four models for total strain energy.

Table 6. Evaluation of the Stress von Mises prediction model

Model	RMSE		R-squared	
	Training	Test	Training	Test
Gaussian Process Regression (Squared exponential GPR)	14.55	15.36	0.99	0.98
Gaussian Process Regression (Rational quadratic GPR)	14.64	15.95	0.99	0.96
Neural Network (Trilayered NN)	18.35	34.07	0.99	0.95
Tree (Fine tree)	20.69	47.77	0.99	0.90

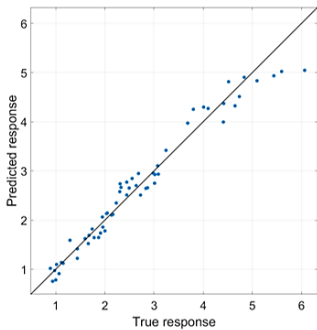
Table 7. Evaluation of the Total strain energy prediction model

Model	RMSE		R-squared	
	Training	Test	Training	Test
Neural Network (Trilayered NN)	0.34	1.06	0.99	0.97
Tree (Fine tree)	0.42	0.88	0.96	0.98

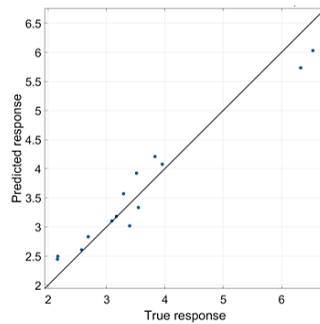
Neural Network (Wide NN)	0.42	0.99	0.95	0.94
Neural Network (Bilayered NN)	0.71	0.74	0.93	0.95

As can be seen from the above tables, the Gaussian Process Regression algorithm achieved the best results for all three outputs. However, different models of neural networks were suitable for each set of data.

Figure 7 shows the True vs Predicted response of the training and testing models for all three outputs.



a



b

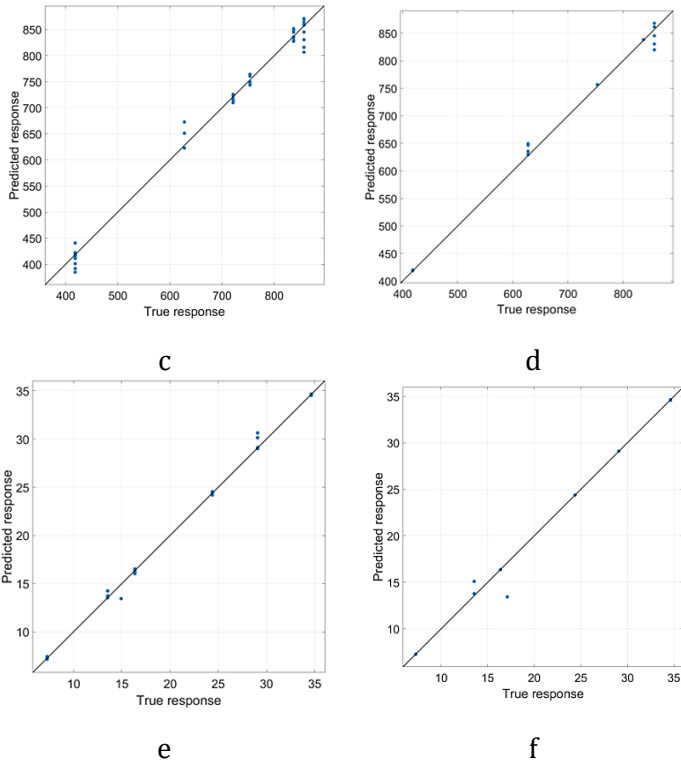


Figure 7. True vs Predicted response graph a) Maximum displacement training, b) Maximum displacement testing, c) von Mises stress training d) von Mises stress testing e) Total strain energy training f) Total strain energy testing

The models are performing well, however, there is noticeable deviation for higher true values, especially in stress and total energy cases, which suggests that models struggle a bit with the extreme cases. Overall, the models

have decent predictive accuracy with moderate variance and a slight bias for larger values.

For verification purposes, the total displacement was manually calculated via finite element analysis for a patient weighing 80 Kg where the forces and moments were calculated accordingly. The shell thickness was chosen to be 2 mm. 9 cases with 9 different values of lengths and thicknesses of the unit cell size were tested. The results were compared with the values calculated via the trained models. Table 8 shows the deviation between the two results. The model generalized well with accuracy over 90% but still suffered with extreme values where it generated results deviating up to 9% from the FEM analyzed ones.

The extreme cases take place when the difference between the values of Length and thickness is too big, such as 0.8 mm for length and 0.2 mm for thickness. These cases can be ignored because having a really small value for either of the two parameters makes manufacturing harder and more costly, as well as generating very big unit cell size which increases the porosity of the implant into undesirable level.

Table 8. FEM calculated cases vs Trained model calculated cases

				Regression model	FEM	
L (mm)	T (mm)	S (mm)	W (Kg)	Umax (mm)	Umax (mm)	Deviation %
0.4	0.2	2	80	3.094	2.896	6
L (mm)	T (mm)	S (mm)	W (Kg)	Umax (mm)	Umax (mm)	Deviation %
0.4	0.6	2	80	633.270	690.030	9
L (mm)	T (mm)	S (mm)	W (Kg)	Umax (mm)	Umax (mm)	Deviation %
0.6	0.4	2	80	11.651	10.638	9

The generated models were then exported into MATLAB and used to create a database for all possible cases of latticed implants variables. This database can be a reference for the surgeon to choose the suitable case for each specific patient. Models can now predict the behavior of the latticed implant against real life conditions without having to go through the simulation or the lab testing. The first and last fourteen values of the database are shown in the dissertation for reference. The database is composed of 2835 cases of latticed hip implants.

8.1 Conclusion and future work

A structural design flow was developed to ensure implants have an improved osseointegration, reduce volume and weight, and still remain manufacturable. Because of their biomedical advantages, lattices were used, and machine learning models were introduced to help predict hip implant properties such as porosity. A regression model was also developed to help assess the implant's mechanical behavior, helping surgeons in the selection process of most suitable implant. Future work aims at linking design variables with ANSYS APDL, which enables real-time adjustments and preview of lattice-optimized hip implant designs.

Theses:

This section shows the dissertation's relevant contributions, and the publications associated with the work done during the PhD stages.

Thesis 1:

Development of lattice structures to support bone ingrowth and reduce stress shielding for hip implant stem design

Test specimens with the same porosity, designed using four different lattice structures (3D lattice infill, Double pyramid lattice with cross, Double pyramid lattice and face diagonals, Octahedral lattice) and developed for hip implant placement were printed using additive technology and Ti6Al4V raw material according to ISO 13314 standard. The cell sizes of the specimens were chosen to promote bone ingrowth for better fixation. Compression tests showed that the stiffness of the bulk material can be reduced by 90% using the investigated lattice structures. With this method, I developed lattice structures whose stiffness closely approximates the stiffness of the femur, thereby reducing the occurrence of stress shielding.

This thesis is based on the following publications: (P1), (P5), (P7)

Thesis 2:

Development of a surrogate finite element model for lattice-structured hip implant stem

Due to the complex geometry, finite element analysis of a hip implant stem designed with a lattice structure is extremely time-consuming. A surrogate finite element model has been developed for the hip implant stem to replace the lattice structures. This shortens the finite element pre-processing and reduces the computational cost by several orders of magnitude while maintaining the calculation accuracy in accordance with engineering practice. The developed surrogate model enables serial calculations for optimization tasks to be performed in a manageable amount of time, thus accelerating the hip implant design process.

This thesis is based on the following publication: (P4)

Thesis 3:

Porosity prediction of lattice structures using linear regression algorithm

Due to the complex design, geometric modeling of lattice structures is extremely time-consuming. The porosity of

structures made of lattices depends primarily on the choice of the dimensions of the lattice length and lattice thickness. A linear regression algorithm was used to estimate the porosity of 3 different lattice structures (3D lattice infill, Double pyramid lattice and face diagonals, Octahedral lattice) as a function of lattice length and lattice thickness. The applied machine learning model is able to estimate the porosity of the lattice structure with 95% accuracy without time-consuming geometric modelling.

This thesis is based on the following publication: (P6)

Thesis 4:

Development of a database for hip implant stem designed with lattice structure

The study developed a comprehensive database for latticed implant stems, that includes the applied materials properties, additive manufacturing properties, cell-specific parameters, cell structure, and patient's weight. The developed database enables the simulation of the implant environment to help facilitate predicting the mechanical behavior of the hip implant. Consequently, the proposed system offers surgeons the ability to select patient-specific implant solutions, yet within certain limitations.

This thesis is based on the following publication: (P3)

Publications

(P1) Alkentar, R.; File, M.; Mankovits, T. Use of Compression Test to Determine the Young's Modulus of the Titanium Alloy Ti6Al4V Manufactured via Direct Metal Laser Sintering. *Int. Rev. Appl. Sci. Eng.* 2023, 14 (2), 256–262. <https://doi.org/10.1556/1848.2022.00536>.

(P2) Alkentar, R.; Mankovits, T. A Study on the Shape and Dimensional Accuracy of Additively Manufactured Titanium Lattice Structures for Orthopedic Purposes. *Period. Polytech. Mech. Eng.* 2022, 66 (4), 336–343. doi:10.3311/PPme.20382

(P3) Alkentar, R.; Manó, S.; Huri, D.; Mankovits, T., “Development of Patient-Specific Lattice Structured Femoral Stems Based on Finite Element Analysis and Machine Learning,” *Crystals*, vol. 15, no. 7, 2025, doi: 10.3390/cryst15070650.

(P4) Alkentar, R.; Mankovits, T. Development of Surrogate Model for Patient-Specific Lattice-Structured Hip Implant Design via Finite Element Analysis. *Appl. Sci.* 2025, 15 (7). <https://doi.org/10.3390/app15073522>.

(P5) Alkentar, R.; Kladovasilakis, N.; Tzetzis, D.; Mankovits, T. Effects of Pore Size Parameters of Titanium Additively Manufactured Lattice Structures on the

Osseointegration Process in Orthopedic Applications: A Comprehensive Review. *Crystals* 2023, 13(1), 1–16. doi:10.3390/cryst13010113.

(P6) Alkentar, R.; Mankovits, T. Optimization of Additively Manufactured and Lattice-Structured Hip Implants Using the Linear Regression Algorithm from the Scikit-Learn Library. *MDPI Cryst.* 2023, 13 (10). doi:10.3390/cryst13101513.

(P7) Alkentar, R.; File, M.; Mankovits, T. Investigation of the Performance of Ti6Al4V Lattice Structures Designed for Biomedical Implants Using the Finite Element Method. *Materials* 2022, 15(18), 1–14. doi:10.3390/ma15186335.

(P8) Alkentar, R.; Huri, D.; Mankovits, T. Numerical Investigation of 3D Lattice Infill Pattern Cellular Structure for Orthopedic Implant Design. In *KOD 2021: International Conference on Machine and Industrial Design in Mechanical Engineering*. Maja, C., Radivoje, M., Milan, R., Eds.; Springer International Publishing Ag: Berlin, 2022; pp 467-472 PG – 6. doi:10.1007/978-3-030-88465-9_45.

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(P10) Alkentar, R. Use of ANSYS Software for the Acetabular Cup Structure Analysis out of the Hip Implant. International Journal of Engineering and Management Sciences 2020, 5(2),1–6. doi:10.21791/IJEMS.2020.2.1.

(P11) Alkentar, R. Topology optimization and rim design. International Journal of Engineering and Management Sciences 2019, 4(4), 92–101. doi:10.21791/IJEMS.2019.4.10.

(P12) Zhang, L.; Alkentar, R.; Manó, S.; Szabó, J.; Mankovits, T.; Csernátóy, Z. Biomechanical Comparison of the Roof Step Cut Technique with the Bulk Bone Graft Technique During Total Hip Arthroplasty for Hip Dysplasia: A Finite Element Analysis. Acta Chir. Orthop. Traumatol. Cech. 2023, 90 (5).

(P13) Alkentar, R., Mankovits, T.: Design of Patient Specific Femoral Stem Using Lattice Structures. In: 8th International Scientific Conference on Advances in Mechanical Engineering (ISCAME 2022) / szerk, Homolya Márton, Mankovits Tamás, Department of Mechanical Engineering, Faculty of Engineering, University of Debrecen, Debrecen, 11-12, 2023. ISBN: 9789634904489



Registry number: DEENK/491/2025.PL
Subject: PhD Publication List

Candidate: Al Kentar Rashwan
Doctoral School: Doctoral School of Informatics
MTMT ID: 10076735

List of publications related to the dissertation

Foreign language scientific articles in Hungarian journals (2)

1. **Rashwan, A. K.**, File, M., Mankovits, T.: Use of compression test to determine the Young's modulus of the titanium alloy Ti6Al4V manufactured via direct metal laser sintering.
Int. rev. appl. sci. eng. 14 (2), 256-262, 2023. ISSN: 2062-0810.
DOI: <http://dx.doi.org/10.1556/1848.2022.00536>
2. **Rashwan, A. K.**, Mankovits, T.: A Study on the Shape and Dimensional Accuracy of Additively Manufactured Titanium Lattice Structures for Orthopedic Purposes.
Period. Polytech. Mech. Eng. 66 (4), 336-343, 2022. ISSN: 0324-6051.
DOI: <http://dx.doi.org/10.3311/PPme.20382>
IF: 1.3

Foreign language scientific articles in international journals (5)

3. **Rashwan, A. K.**, Manó, S., Huri, D., Mankovits, T.: Development of Patient-Specific Lattice Structured Femoral Stems Based on Finite Element Analysis and Machine Learning.
Crystals. 15 (7), 1-19, 2025. EISSN: 2073-4352.
DOI: <http://dx.doi.org/10.3390/cryst15070650>
IF: 2.4 (2024)
4. **Rashwan, A. K.**, Mankovits, T.: Development of Surrogate Model for Patient-Specific Lattice-Structured Hip Implant Design via Finite Element Analysis.
Appl. Sci.-Basel. 15 (7), 1-14, 2025. ISSN: 2076-3417.
DOI: <http://dx.doi.org/10.3390/app15073522>
IF: 2.5 (2024)
5. **Rashwan, A. K.**, Kladovasilakis, N., Tzelis, D., Mankovits, T.: Effects of Pore Size Parameters of Titanium Additively Manufactured Lattice Structures on the Osseointegration Process in Orthopedic Applications: A Comprehensive Review.
Crystals. 13 (1), 1-16, 2023. EISSN: 2073-4352.
DOI: <http://dx.doi.org/10.3390/cryst13010113>
IF: 2.4





6. **Rashwan, A. K.**, Mankovits, T.: Optimization of Additively Manufactured and Lattice-Structured Hip Implants Using the Linear Regression Algorithm from the Scikit-Learn Library.
Crystals. 13 (10), 1-12, 2023. EISSN: 2073-4352.
DOI: <http://dx.doi.org/10.3390/cryst13101513>
IF: 2.4
7. **Rashwan, A. K.**, File, M., Mankovits, T.: Investigation of the Performance of Ti6Al4V Lattice Structures Designed for Biomedical Implants Using the Finite Element Method.
Materials. 15 (18), 1-14, 2022. ISSN: 1996-1944.
DOI: <http://dx.doi.org/10.3390/ma15186335>
IF: 3.4

List of other publications

Foreign language international book chapters (1)

8. **Rashwan, A. K.**, Huri, D., Mankovits, T.: Numerical Investigation of 3D Lattice Infill Pattern Cellular Structure for Orthopedic Implant Design.
In: KOD 2021: International Conference on Machine and Industrial Design in Mechanical Engineering. Eds.: Cavic Maja, Mitrovic Radivoje, Rackov Milan, Springer International Publishing Ag, Berlin, 467-472, 2022. (Mechanisms and Machine Science, ISSN 2211-0984 ; 109.) ISBN: 9783030884659

Foreign language scientific articles in Hungarian journals (3)

9. Abdon, S. C. F. I., **Rashwan, A. K.**, Bortolini, M. D. M. A., Gurbanov, O., Lima, J. M. D. C.: Finite element analysis of cellular structures using Ansys.
Int. J. Eng. Manag. Sci. 6 (2), 197-204, 2021. EISSN: 2498-700X.
DOI: <http://dx.doi.org/10.21791/IJEMS.2021.2.16>
10. **Rashwan, A. K.**: Use of ANSYS Software for the Acetabular Cup Structure Analysis out of the Hip Implant.
Int. J. Eng. Manag. Sci. 5 (2), 1-6, 2020. EISSN: 2498-700X.
DOI: <http://dx.doi.org/10.21791/IJEMS.2020.2.1>
11. **Rashwan, A. K.**: Topology optimization and rim design.
Int. J. Eng. Manag. Sci. 4 (4), 92-101, 2019. EISSN: 2498-700X.
DOI: <http://dx.doi.org/10.21791/IJEMS.2019.4.10>





Foreign language scientific articles in international journals (1)

12. Zhang, L., **Rashwan, A. K.**, Manó, S., Szabó, J., Mankovits, T., Csernátóny, Z.: Biomechanical Comparison of the Roof Step Cut Technique with the Bulk Bone Graft Technique During Total Hip Arthroplasty for Hip Dysplasia: a Finite Element Analysis.
Acta Chir. Orthop. Traumatol. Cech. 90 (5), 301-313, 2023. ISSN: 0001-5415.
DOI: <https://www.doi.org/10.55095/achot2023/036>
IF: 0.4

Foreign language abstracts (1)

13. **Rashwan, A. K.**, Mankovits, T.: Design of Patient Specific Femoral Stem Using Lattice Structures.
In: 8th International Scientific Conference on Advances in Mechanical Engineering (ISCAME 2022) / szerk, Homolya Márton, Mankovits Tamás, Department of Mechanical Engineering, Faculty of Engineering, University of Debrecen, Debrecen, 11-12, 2023. ISBN: 9789634904489

Total IF of journals (all publications): 14,8

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The Candidate's publication data submitted to the Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

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