

РАМКОВА ПРОГРАМА ЄВРОПЕЙСЬКОГО СОЮЗУ З ДОСЛІДЖЕНЬ
ТА ІННОВАЦІЙ «ГОРИЗОНТ ЄВРОПА»

Історії успіху в Програмі «Горизонт Європа». Проект EffectFact – 101008140



Effective Factorisation techniques for matrix-functions: Developing theory, numerical methods and impactful applications

Ефективні методи факторизації для матричних функцій: розробка теорії, чисельних методів та ефективних додатків

Волчок Денис, доктор технічних наук, завідувач кафедри експлуатації та ремонту машин, координатор проекту від ННІ ПДАБА УДУНТ

<https://horizon2020.imaps.aber.ac.uk/effectfact.html>



Horizon Europe

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	Effective Factorisation techniques for matrix-functions: Developing theory, numerical methods and impactful applications
Research Area	MSCA-RISE-2020 - Research and Innovation Staff Exchange
Project Reference	EffectFact , Grant agreement ID: 101008140
Coordinator	Professor Gennady S. Mishuris
Project Funding	1 821 600 euro
Contract Type	MSCA-RISE: academic and non-academic sectors (SMEs) from EU/AC & outside Europe (third countries)
Start Date	2021-09-01
Duration	54 months
Project Description	Funded by the Marie Skłodowska-Curie Actions programme, the EffectFact project aims to develop advanced factorisation and Wiener-Hopf methods as well as methods for Riemann-Hilbert problems to solve time-dependent boundary value problems in complex discrete and continuous domains. The newly developed techniques could find use in biomechanics (DNA replication), medicine (surgical resection), metamaterials, artificial intelligence, and environmental and civil engineering. Bringing together partners from across the world, the project will strengthen the access of EU academic institutions and SMEs to international research, lead to tangible and impactful results, while building a strong base of robust, independent researchers who could expand the scope of the project in the future.

<https://horizon2020.imaps.aber.ac.uk/effectfact.html>



Partners
EU/AC:

Beneficiary 1 (Coordinator):

Aberystwyth University – Department of Mathematics

<https://www.aber.ac.uk/en/>

United Kingdom



Horizon Europe

AU leader and the project coordinator:

[Prof. Gennady Mishuris](#)

Beneficiary 21:

ESI Prydniprovsk State Academy Of Civil Engineering And Architecture, USUST

<https://pgasa.dp.ua/en/>

Ukraine



Director of the ESI PSACEA

USUST:

[Prof. Vlad Danishevskyy](#)



Project coordinator of the ESI PSACEA

USUST:

[Prof. Denys Volchok](#)

https://horizon2020.imaps.aber.ac.uk/effectfact_partners.html

Partners EU/AC:

Beneficiary 2:

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<https://www.keele.ac.uk/>
United Kingdom
KU leader: [Dr Michael Nieves](#)

Beneficiary 3:

University of Manchester
<https://www.manchester.ac.uk/>
United Kingdom
UoM leader: [Dr Anastasia Kisil](#)

Beneficiary 4:

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de Chimie Industrielles de la ville
de Paris
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ESPCI leader: [Prof. Lev Truskinovsky](#)

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Beneficiary 10:

Multiwave Technologies Ag
<https://www.multiwave.ch/>
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Beneficiary 11:

Multiwave Imaging
<https://www.multiwave.ch/projects/multiwave-imaging>
France

Beneficiary 12:

Multiwave Technologies Sas
<https://www.multiwave.ch/projects/multiwave-imaging>
France

Beneficiary 13:

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Horizon Europe

Partners

EU/AC:

Beneficiary 16:

Sami Shamoon College Of Engineering

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Israel

SSCE leader: [Dr Vladimir Frid](#)

Beneficiary 17:

C3M

<http://www.c3m.si/>

Slovenia

Beneficiary 18:

Geo Prospect

http://www.geo-prospect.com/en-GB/c/The_Company_history

Israel

Beneficiary 19:

Caemate Srl

<https://caemate.com/>

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Beneficiary 22:

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ONU leader: [Prof. Nataliya Vaisfeld](#)

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Third Country Partner:

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Peking University

China

PU leader: [Prof. Xun Huang](#)

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List of work packages

WP1 Development of analytical techniques for matrix-function factorization

WP2 Utilization of analytical techniques in effective numerical methods for WH and RH problems

WP3 Applications of MF techniques in biomechanics and medicine

WP4 Applications of MF techniques in metamaterials and related problems

WP5 Application of MF techniques in Artificial Neural Networks

WP6 Application of FTs to analyze fast dynamic and thermal effects in discrete structures

WP7 Enhancing civil, structure and environmental engineering by using FTs

WP8 ToK, Training, Communication and Outreach

WP9 Dissemination, Exploitation & Management

WP10 Ethics requirements

Our contribution to the project

From the simple to the complex

Propagation of uncertainties using simple formulas

$$\begin{aligned}
 Q = a + b &\Rightarrow \Delta Q = \Delta a + \Delta b \\
 Q = a - b &\Rightarrow \Delta Q = \Delta a + \Delta b \\
 Q = a + b - c &\Rightarrow \Delta Q = \Delta a + \Delta b + \Delta c \\
 Q = ab &\Rightarrow \frac{\Delta Q}{Q} = \frac{\Delta a}{a} + \frac{\Delta b}{b} \\
 Q = \frac{a}{b} &\Rightarrow \frac{\Delta Q}{Q} = \frac{\Delta a}{a} - \frac{\Delta b}{b} \\
 Q = \frac{ab}{c} &\Rightarrow \frac{\Delta Q}{Q} = \frac{\Delta a}{a} + \frac{\Delta b}{b} - \frac{\Delta c}{c} \\
 Q = a^n &\Rightarrow \frac{\Delta Q}{Q} = n \frac{\Delta a}{a} \\
 Q = \sqrt[n]{a} &\Rightarrow \frac{\Delta Q}{Q} = \frac{1}{n} \frac{\Delta a}{a}
 \end{aligned}$$

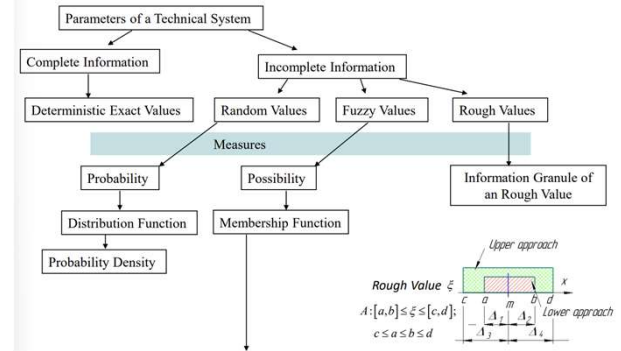
The case of more complex mathematical formulas

The function $z = f(x, y)$ is a function of two variables x and y . Now let Δx represent a small change in x , Δy a small change in y and Δz a small change in z .

$$\begin{aligned}
 \Delta z &= f(x + \Delta x, y + \Delta y) - f(x, y) \\
 \Delta z &= [f(x + \Delta x, y + \Delta y) - f(x, y + \Delta y)] + [f(x, y + \Delta y) - f(x, y)] \\
 \Delta z &= [f(x + \Delta x, y + \Delta y) - f(x, y + \Delta y)] \Delta x + [f(x, y + \Delta y) - f(x, y)] \Delta y \\
 \Delta z &\approx \frac{\partial f}{\partial x} \Delta x + \frac{\partial f}{\partial y} \Delta y
 \end{aligned}$$



Types of Data on Engineering System Parameters



Basic concepts of fuzzy set theory used in the work

Definition 1. A set (space) X is called a universal set (universe) if all subsets considered in a given class of problems are formed from its elements.

$$A \subseteq X$$

Definition 2. A fuzzy set A in a non-empty space X is called a set of ordered pairs (tuples).

$$A: \{\mu_A(x); x \in X\}$$

Definition 3. The degrees of membership can be:

$$\mu_A(x) = 0 \quad 0 < \mu_A(x) < 1 \quad \mu_A(x) = 1$$

A fuzzy set A is written as:

$$A = \frac{\mu_A(x_1)}{x_1} + \frac{\mu_A(x_2)}{x_2} + \dots + \frac{\mu_A(x_n)}{x_n} = \sum_{i=1}^n \frac{\mu_A(x_i)}{x_i}$$

The arithmetic symbols $+$ and \sum indicate the operation of pairing union.

$$\left\{ \frac{\mu_A(x)}{x} \right\}$$

For the case when X is considered with an infinite number of elements, a fuzzy set is symbolically written as

$$A = \int \frac{\mu_A(x)}{x}$$

Definition 4. The support of a fuzzy set A is the set of elements in the space X for which the condition $\mu_A(x) > 0$ holds, and it is denoted as

$$Supp A = \{x \in X; \mu_A(x) > 0\}$$

Definition 5. The height of a fuzzy set A is defined as the maximum value of the membership function $\mu_A(x)$, that is:

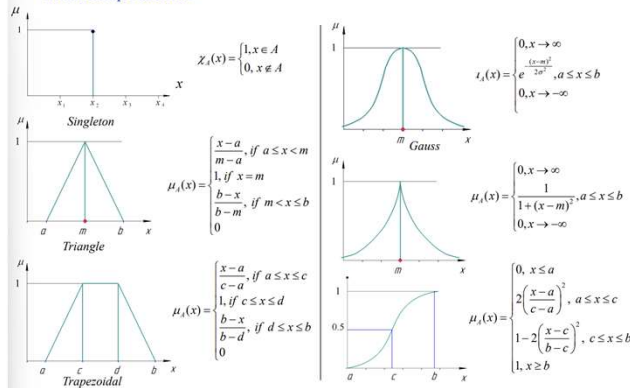
$$h = \max_{x \in X} \mu_A(x)$$

Definition 6. The relation $\mu_A^h(x) = \frac{\mu_A(x)}{h(A)}$ allows for the normalization of a fuzzy set.

Definition 7. A fuzzy set A is contained in a fuzzy set B (denoted as $A \subseteq B$) if and only if:

$$\mu_A(x) \leq \mu_B(x) \quad \forall x \in X$$

Membership Functions



Basic concepts of fuzzy set theory used in work

Definition 8. A fuzzy set $A \subseteq R$ (where the universe R is the set of real numbers) is called convex if and only if for any $x_1 \in R, x_2 \in R, \lambda \in [0,1]$ the following condition holds:

$$\mu_A(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_A(x_1); \mu_A(x_2)).$$

Definition 9. We will call α -level (or alpha-cut) of the fuzzy set $A \subseteq X$ such a crisp set A_α for which the condition $\mu_A \geq \alpha$ for $\alpha \in [0,1]$ is satisfied

$$A_\alpha = \{x \in X; \mu_A(x) \geq \alpha\}$$

The set A_α is defined by the characteristic function

$$\chi_{A_\alpha}(x) = \begin{cases} 1, & \mu_A(x) \geq \alpha \\ 0, & \mu_A(x) < \alpha \end{cases}$$

Some operations on fuzzy sets

Definition 10. The decomposition operation refers to the representation of a set $A \subseteq X$ as a collection of crisp sets A_α

$$A = \bigcup_{\alpha \in [0,1]} A_\alpha$$

where αA_α represents a fuzzy set, with elements assigned corresponding degrees of membership

$$\mu_{\alpha A_\alpha} = \begin{cases} \mu_A, & x \in A_\alpha \\ 0, & x \notin A_\alpha \end{cases}$$

The reverse statement is also true. If there is a set of subsets of some universal set X and a set of numbers from $[0,1]$, it is possible to synthesize a fuzzy set in X . This is an important property of fuzzy set theory, as it allows the formation of fuzzy sets of multiple outcomes based on the extension principle.

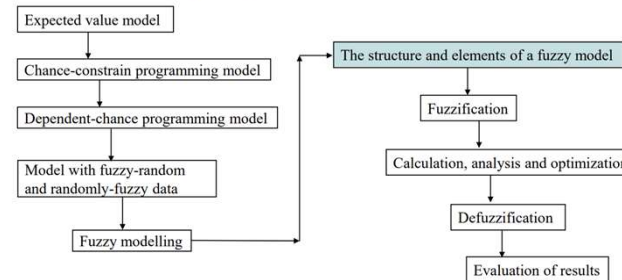
Definition 11. The intersection operation of two fuzzy sets $A \subseteq X$ and $B \subseteq X$ is a fuzzy set $C = A \cap B$ with a membership function

$$\mu_C(x) = \min(\mu_A(x); \mu_B(x)); \quad \forall x \in X$$

Definition 12. The union (sum) operation of two fuzzy sets $A \subseteq X$ and $B \subseteq X$ is a fuzzy set $C = A \cup B$, defined by the following membership function.

$$\mu_C(x) = \max(\mu_A(x); \mu_B(x)); \quad \forall x \in X$$

Models of Uncertain Programming



Basic concepts of fuzzy set theory used in work

Definition 13. The Cartesian product of two fuzzy sets $A \subseteq X$ and $B \subseteq Y$ is a fuzzy set $C = A \times B$, whose elements are calculated according to the following formula.

$$\mu_C(x, y) = \min(\mu_A(x); \mu_B(y)).$$

Let's present the expanded notation

$$A = \sum_{i=1}^n \frac{\mu_A(x_i)}{x_i}; \quad B = \sum_{j=1}^m \frac{\mu_B(y_j)}{y_j}$$

$$C = \sum_{(x_i, y_j)} \frac{\min(\mu_A(x_i); \mu_B(y_j))}{(x_i, y_j)}$$

Definition 14. Let f be a crisp one-to-one mapping from space X to space Y

$$f: X \rightarrow Y$$

Let A be a fuzzy set defined in X ; $A \subseteq X$

$$A = \sum_{i=1}^n \frac{\mu_A(x_i)}{x_i}$$

Let the set B be generated by mapping f and defined in the space Y .

$$B = f(A) = \sum_{i=1}^n \frac{\mu_A(x_i)}{f(x_i)}$$

or

$$B = f(A) = \sum_{j=1}^m \frac{\mu_B(y_j)}{y_j}; \quad y_j = f(x_i); \quad x_i \in X,$$

$$\begin{cases} \sup_{x \in X} \mu_A(x), & f^{-1}(y) = \emptyset \\ \mu_B(y) = x = f^{-1}(y) & \\ 0, & f^{-1}(y) = \emptyset \end{cases}$$

where \emptyset is the empty set of elements, and the f^{-1} inverse transformation $y = f(x)$

$$f^{-1}: Y \rightarrow X$$

So-called "principle of generalization" (or "extension") allows transferring (extending) various mathematical operations from distinct to fuzzy sets.

Basic concepts of fuzzy set theory used in work

Definition 15. The principle of extension on the Cartesian product is called obtaining a fuzzy set B formed by mapping f

$$f: X_1 \times X_2 \times \dots \times X_n \rightarrow Y,$$

$$X_1 \subseteq X; \quad X_2 \subseteq X; \quad \dots; \quad X_n \subseteq X$$

Let the set A_i be a subset of X_i ; $A_i \subseteq X_i$; $i = 1, 2, \dots, m$ then

$$B = \sum_{i=1}^m \frac{\mu_{A_i}(y_i)}{f(x_1, x_2, \dots, x_n)}$$

$$y_i = f(x_1, x_2, \dots, x_n); \quad x_i \in A_i; \quad i = 1, 2, \dots, m$$

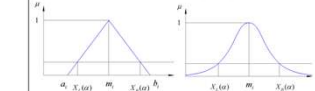
$$\begin{cases} \sup \min(\mu_{A_1}(x_1); \mu_{A_2}(x_2); \dots; \mu_{A_m}(x_m)) & \\ \mu_B(y) = \sum_{(x_1, x_2, \dots, x_n) \in f^{-1}(y)} & \\ 0, & f^{-1}(y) = \emptyset \end{cases}$$

Determination of the boundaries of sets α -levels

For the most common membership functions, consider the definition of the boundaries of sets

So, the first will be the membership function of the triangular form, where a, b , is the boundaries of the α -level, m is the modal value. In order to obtain the limits $X_1(\alpha), X_2(\alpha)$ we will use the α level section of the function by solving the equation $\mu(x) = \alpha$

If we consider the membership function of the Gaussian type, then the level points $\alpha=0$ for the membership function of this type are not considered. In this case, it is necessary to start the solution from the level for which we have: $\alpha = \Delta\alpha = 1/N$



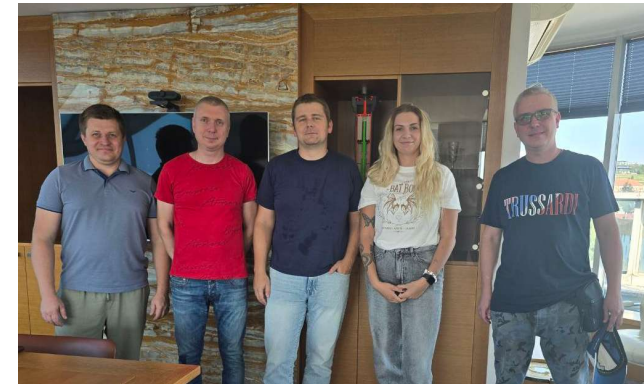
$$\begin{aligned}
 X_1(\alpha) &= m\alpha + (1-\alpha)a & X_1(\alpha) &= m - \sigma\sqrt{-2\ln\alpha} \\
 X_2(\alpha) &= m\alpha + (1-\alpha)b & X_2(\alpha) &= m + \sigma\sqrt{-2\ln\alpha} \\
 \alpha &\in [0,1] & 0 &< \alpha \leq 1
 \end{aligned}$$



Workshop

Artem SOPILNYAK Kostiantyn DIKAREV

Mathematical modelling in solids and structures with applications to engineering systems



In house ammonia technology

- In-house design (complete) and manufacture of new ammonia reactor & internals 500 tons NH3 / day, and startup whole unit Q1 2023
- Concept of Modular Ammonia Container - ammonia as a carrier of green hydrogen

Company ROEZ, s.r.o.

Flat floor structures

It is advisable to print the coating structure with holes along it, the cross-section should look like a lattice.

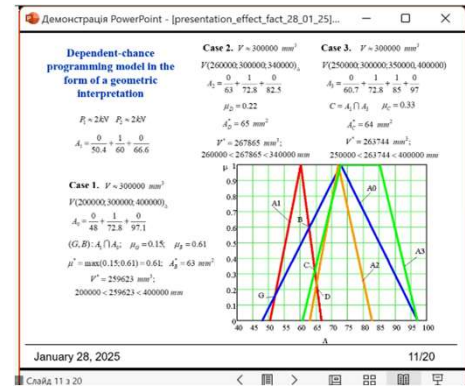
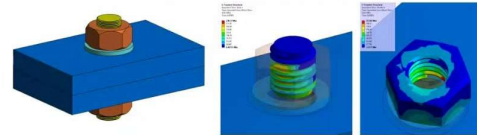
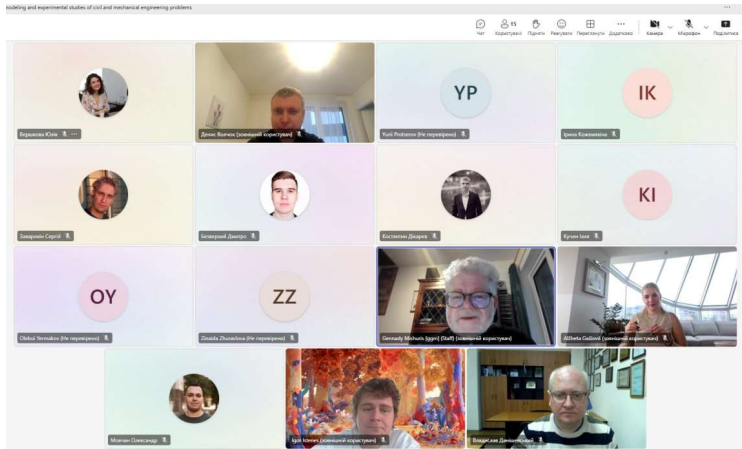
Print sequence:

- Bottom shelf of a flat floor structure: printing of the first layer (across the slab) - laying of reinforcing wire in the longitudinal and transverse directions - printing of the second layer (along the slab)
- Grating of a flat floor structure: the grating is printed in the longitudinal direction
- Top shelf of a flat overlap design: printing of the top shelf is similar to printing of the bottom shelf

LAYER-COMPOSITE STRUCTURE MODELLING IN ANSYS

- Cell size: 2x1 x1 m;
- Number of cells: 50;
- Load: 1000 N;
- Base: fixed support;
- Longitudinal faces: frictionless support;

The scientific and practical conference «Mathematical modeling and experimental studies of civil and mechanical engineering problems»



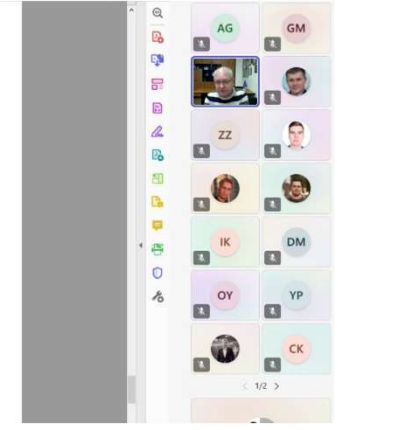
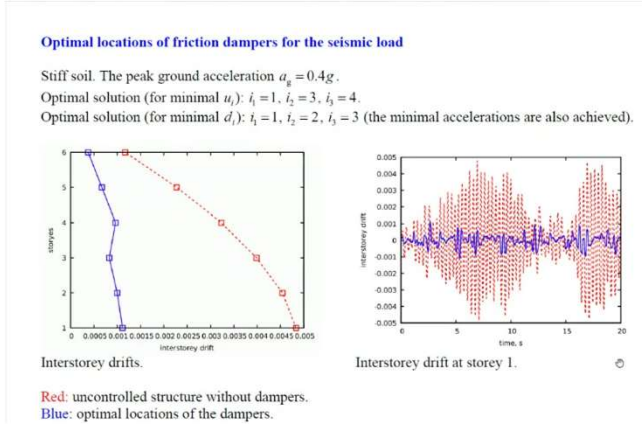
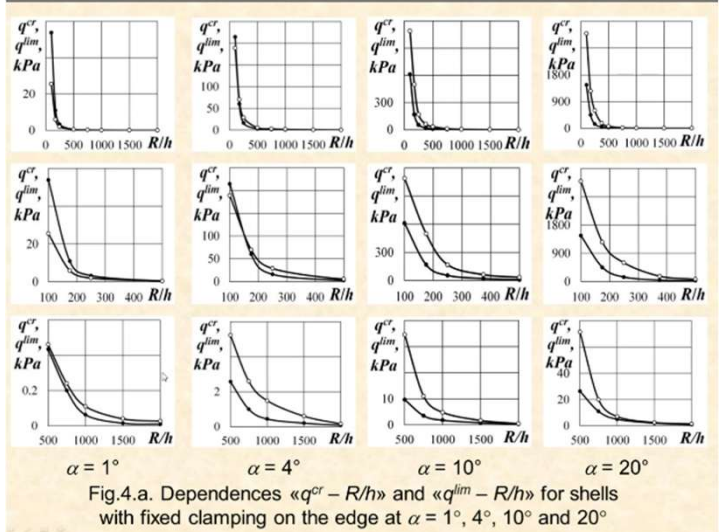
The solution for the subcase of soft contact conditions between the layers

$$u_1(r, h - 0) - u_1(r, h + 0) = k \frac{\partial u_1}{\partial z} \Big|_{z=h} \quad (1)$$

$$v_1(r, h - 0) - v_1(r, h + 0) = \mu_1 \frac{\partial v_1}{\partial z} \Big|_{z=h} - \mu_1 \frac{\partial u_1}{\partial z} \Big|_{z=h} = 0, K_1 = -\mu_1 \mu_2^* h \quad (2)$$

$$u_1(r, z) = \frac{A_1 r^2}{\mu_1 (K_1 - K_2)} \beta_1 \cos \beta_1 H \left[K_1 \frac{\partial v_1(z, 0)}{\partial z} - \right. \\ \left. - (\mu_1 - \mu_2) \mu_2^* G_{11}(z, h) \right] + \mu_1^* \sum_{n=1}^{\infty} \rho_n \left[\frac{A_1 r^2 z^2}{r_1^2 \beta_1^2 H^2} - \right. \\ \left. - K_1 \frac{\partial G_{11}(z, 0)}{\partial z} - (\mu_1 - \mu_2) \mu_2^* G_{11}(z, h) \right] \frac{\text{ch} \beta_1 h}{\beta_1} \frac{K(\lambda_n, z)}{[K(\lambda_n, r)]^2}, \kappa = 1, 2 \quad (3)$$

$$N_{1z}^* = \text{ch} \beta_1 H - \text{sh} \beta_1 (H - h) [K_1 r_1^2 \text{ch} \beta_1 h - (\mu_1 - \mu_2) \mu_2^* \text{sh} \beta_1 h] \\ N_{1r}^* = \cos \beta_1 H - \sin \beta_1 (H - h) [K_1 \beta_1 \cos \beta_1 h - (\mu_1 - \mu_2) \mu_2^* \sin \beta_1 h]$$



Venn diagram of scientific fields



Yuliia
VERSHKOVA



Viacheslav
CHABAN

This research area focuses on the experimental, analytical, and numerical investigation of sandwich panels subjected to static and dynamic loading. Special attention is given to the numerical modeling of structural joints, including the study of their angular stiffness, with the aim of developing a classification system for different types of joints. The research contributes to enhancing the structural performance and reliability of sandwich panel systems in engineering applications.



Denys
VOLCHOK

Improvement of the parameters of curvilinear motion of vehicles and road trains through the use of mechatronic systems with autonomous control. Development and enhancement of trajectory planning algorithms for autonomous vehicles. Optimization of the geometric parameters of the steering drive to achieve optimal steering angles of the controlled wheels. Solid-state modeling of active steering control systems, and development of new design solutions for unmanned vehicles.



Oleksandr
LYKHODII



Viktor
MALYI



Vladyslav
DANISHEVSKYY



Illia
KUCHYN



Dmytro
BEZVERKHYY

The concept of using material heterogeneity and spatial arrangement to guide and diffuse vibrational and seismic waves, aiming to develop a passive framework that leverages contrasting elements to attenuate destructive energy without relying on active modification methods.



Oleksii
KARASOV



Andrii
UZHELOVSKYY

This research area explores the development of a new type of hybrid system with controllable magnetic flux regulation. It also addresses the design and implementation of a fully electric differential, aimed at improving the efficiency, performance, and control capabilities of advanced electric and hybrid powertrains.

Current publications:

Volchok D., Danishevskyy V., Slobodianiuk S. & Kuchyn I. **Fuzzy sets application in the problems of structural mechanics and optimal design.** Acta mechanica. 2023. Vol. 234. P. 6191–6204. (Scopus) Q2

Andrianov I.V., Danishevskyy V.V., Kaplunov J. **Low-frequency vibrations of a high-contrast orthotropic lattice.** Mechanics Research Communications, 2025, 144, 104386. (Scopus) Q2

Ready for submission publications:

Denys Volchok, Yuliia Vershkova, Marina Babenko **Investigation of node flexibility in rod systems of steel structures under bending loads**

Alexander Oleynik, Denys Volchok, Marcus Stoffel, Serhii Panchenko **The stiffness characteristics of femoral head in a healthy state and at the aseptic necrosis**

Denys Volchok, Yuliia Vershkova, Artur Zbiciak **Assessment of the stress-strain state of a statically indeterminate beam under conditions of fuzzy information**

Yuliia Vershkova, Denys Volchok, Viacheslav Chaban, Artur Zbiciak **Determination of the load-bearing capacity of flat sandwich panels (laboratory tests)**

Publications in the preparation process:

Artur Zbiciak, Denys Volchok, Zofia Kozyra, Rafał Michalczyk, Nassir Al Garssi **Fuzzy-Modulus-Based Layered Elastic Analysis of Asphalt Pavements for Enhanced Fatigue Life Prediction**

ДЯКУЮ ЗА УВАГУ!