DOI 10.18372/2786-5487.1.20256
УДК 629.3

Oleksandr Rudyk
Ph.D., Associate Professor,
Khmelnytskyi National University,
Khmelnytskyi, Ukraine
yuhymovych@gmail.com
Mykhailo Poberezhnyi
PhD student,
Khmelnytskyi National University,
Khmelnytskyi, Ukraine
antanta2015@gmail.com
Pavlo Kaplun
Doctor of technical sciences, Professor,
Khmelnytskyi National University,
Khmelnytskyi, Ukraine
kaplunpavel@gmail.com
Volodymyr Gonchar
Ph.D., Associate Professor
Khmelnytskyi National University,
Khmelnytskyi, Ukraine
rogervova@gmail.com

USING SOLIDWORKS SIMULATION AS AN INNOVATIVE TECHNOLOGY WHEN CALCULATING OF PERFORMANCE OF DETAILS

Annotation. *The method of finite elements based on SolidWorks Simulation was applied to determine the dependence of the minimum coefficient of safety margin of the driven gear of the drum gear block of the vacuum spraying unit UVN-74 on the parameters of the finite element grid.*

Key words: *SolidWorks Simulation, finite element method, gear block, driven gear, safety factor.*

Анотація. *Застосовано метод скінченних елементів на базі SolidWorks Simulation для визначення залежності мінімального коефіцієнта запасу міцності веденої шестерні блоку шестерень барабана установки вакуумного напилення УВН-74 від параметрів скінченно-елементної сітки.*

Ключові слова: *SolidWorks Simulation, метод скінченних елементів, блок шестерень, ведена шестерня, коефіцієнт запасу міцності.*

Introduction. In today's conditions of technological development, it is no longer possible to imagine high-quality higher technical education without comprehensive use of modern automated design systems. One of the leading systems today is the SolidWorks software complex, which is widely used at machine-building enterprises around the world [1; 2].

SolidWorks solutions help in daily work by providing a user-friendly integrated three-dimensional design environment that covers all aspects of product development and helps to increase the productivity of design work [3; 4].

SolidWorks Simulation is a structural analysis system that is fully integrated with SolidWorks. SolidWorks Simulation and provides stress analysis, loss of stability, optimization, as well as frequency and thermal analysis on a single screen. Equipped with fast solving programs, SolidWorks Simulation makes it possible to quickly solve large tasks using the user's personal computer [5].

The software uses the finite element method, which is a numerical method for the analysis of technical structures. It is accepted as a standard method of analysis due to its versatility and suitability for work on computers. The finite element method divides the model into many small parts of simple shapes (elements), effectively replacing a complex problem with several simple ones that must be solved together. Elements have common points (nodes). The process of dividing the model into small parts is called creating a grid [6; 7].

SolidWorks Simulation determines the size of the element for the model, taking into account its volume, surface area, and other geometric characteristics. The size of the created grid (the number of nodes and elements) depends on various parameters. In the early stages of structural analysis, where approximate results may be appropriate, a larger element size is specified for faster resolution. A smaller element size may be required for a more accurate solution [8].

For a mesh on a solid, numerical accuracy is best achieved with a mesh with identical perfect tetrahedral elements whose edges are equal in length. It is impossible to create a grid of perfect tetrahedral elements for the entire shape. Due to small edges, curved shape, thin-walled elements and sharp corners, some edges of some created elements are longer than others. When the edges of the element are very different in length, the accuracy of the results decreases. On very sharp or curved boundaries, placing middle nodes on the actual shape can result in distorted elements with intersecting edges. It is recommended to set the "At nodes" parameter for the Jacobian check for solving static problems [5].

Analysis of the latest research. For example, the authors of [9; 10] evaluated the impact of mesh quality on the accuracy of detail calculations. For this, a high-quality grid based on curvature was used, and for the Jacobian check, the «At nodes» parameter was set with the selection of the optimal number and size of finite elements.

In [11], the dependence of the nodal stress on the number of finite elements of the model was determined. It is established that in order to build a mesh of optimal size, the number of finite elements must be gradually increased. Starting with a certain number of them, the value of the sought value will change slightly, which will determine the optimal grid size.

The aim of the article. The purpose of this study: to determine the dependence of the minimum coefficient of safety margin of the driven gear (fig. 1) of the gear unit of the drum of the UVN-74 vacuum spraying unit on the parameters of the SolidWorks Simulation finite element mesh.

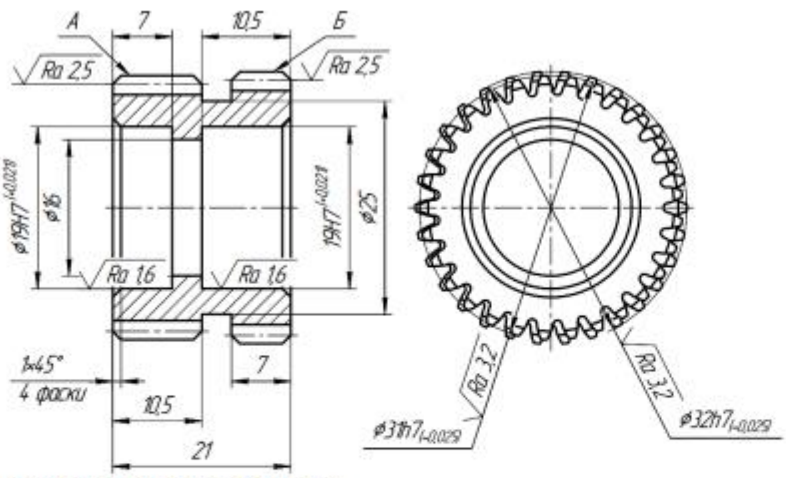


Fig. 1. Drawing of a block of gears

Research Methodology. The study was conducted using SolidWorks solid graphics software and the SolidWorks Simulation strength calculation module built into it.

First, a sketch is drawn in SolidWorks, the base is created, and then numerous elements are added to the model. When creating models, work with separate geometric elements (bumps, cutouts, holes, rounding, chamfers, etc.). As elements are created, they are inserted directly into the projected model.

The finite element analysis algorithm includes the following steps [12]:

– installation of fasteners in the faces or edges of the model, which remain functionally immobile during the operation of the part;

– application of load to the faces or edges of the model;

– generation of a mesh of finite elements with given parameters;

– carrying out a static calculation and viewing the results.

Research results. The general method of building a solid-state model of a gear block in SolidWorks is shown in fig. 2.

Fig. 2. Solid-state model of the gear blockper

The SolidWorks Simulation software module was used to determine the strength parameters of the gear unit model: static analysis was selected as the type of study of its stress-strain state.

The material from which the gear block is made is selected from the SolidWorks library – steel 1.4541 (X6CrNiTi18-10) - fig. 3.

Properties	
Name:	1.4541 (X6CrNiTi18-10)
Model type:	Linear elastic isotropic
Default strength criterion:	Maximum tension von Mises
Yield strength:	4e+08 N/m^2
Tensile strength:	6e+08 N/m^2
Modulus of elasticity:	2e+11 N/m^2
Poisson's ratio:	0,28
Mass density:	7 900 kg/m^3
Shear modulus:	7,9e+10 N/m^2
Thermal expansion coefficient:	1,1e-05 /Kelvin

Fig. 3. Assignment of the gear block model of steel properties X6CrNiTi18-10

The attachment points of the gear unit model (fixed geometry) were selected and external loads were applied to it (fig. 4).

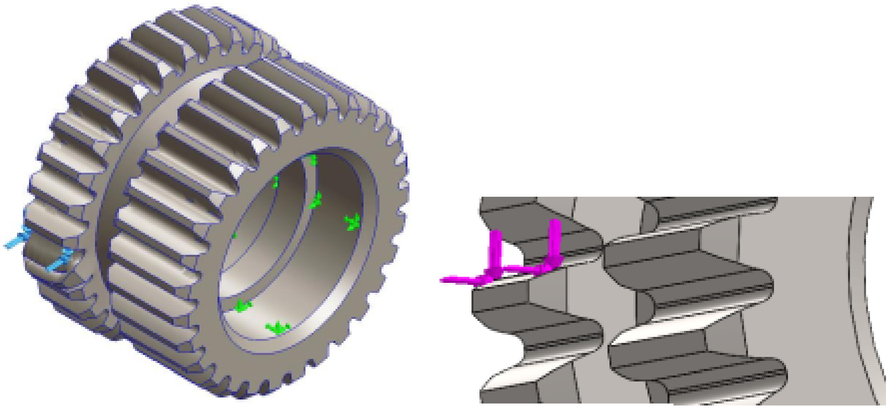

a b

Fig. 4. Fixing the gear block model (a) and forming the load pattern (b)

In order to determine the dependence of the minimum margin of safety of the driven gear of the gear unit on the parameters of the finite element grid, standard grids based on curvature with different values of Jacobian points and density were created (table 1).

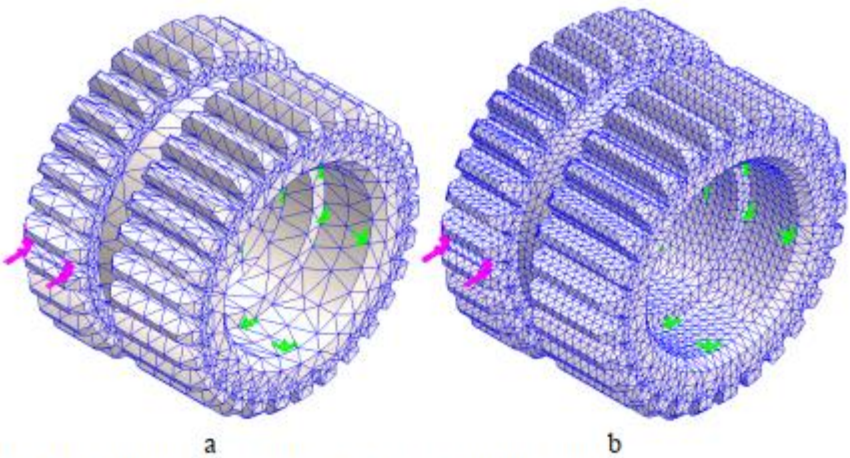
Table 1

Dependence of the minimum margin of strength n_{min} on the parameters of the finite-element grid

Jacobian points	4	4	4	16	29	At nodes
Grid density	Rude	By default	High	High	High	High
Element size, mm	2,4695	1,9756	0,9878	0,9878	0,9878	0,9878
Tolerance, mm	0,1235	0,0988	0,0494	0,0494	0,0494	0,0494
n_{min}	2,567	1,761	1,601	1,601	1,601	1,601

The created mesh on the model of the gear block is shown in fig. 5.

The resulting forces and moments of reaction acting on the gear unit are determined. A stiffness matrix was constructed and a finite element model of the gear block from its individual elements was synthesized.



a b

Fig. 5. Displaying the mesh on the gear block model:

a – element size 2.4695 mm;

b – element size 0.9878 mm

The resulting system of algebraic equations was solved and the components of the stress-strain state of the gear block were determined: maximum Von Mises stress σ = 2.499e+08N/m^2 (node 80734); the maximum resulting movement of URES h = 2.165e-03 mm (node 7739 – fig. 5); maximum equivalent strain ESTRN δ = 9.442e-04 (element 11719). At the same time, the minimum safety margin n = 1.601e+00 (node 80734), which is more than the permissible $[n_{min}]$ = 1,5.

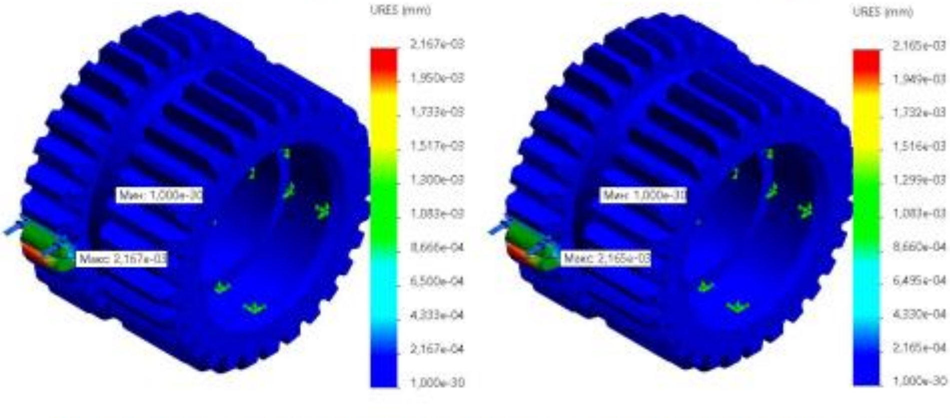


Fig. 6. Calculation results of total deformations ESTRN of the gear block model: a – element size 2.4695 mm; b – element size 0.9878 mm

Conclusions. It was established that the minimum margin of safety of the driven gear when using a high-quality grid does not depend on the number of Jacobian points (4, 16, 29, in nodes) under the given research conditions.

References

1. Рудик О. Ю., Диха О. В. SolidWorks як інноваційний засіб вивчення дисциплін автомобільного профілю. Системні технології. 2020. № 3(128) С. 21-35. URL: https://journals.nmetau.edu.ua/index.php/st/article/view/178/92 (last accessed: 2025/02/15).

2. Rudyk O., M. Barnych, O. Humeniuk, V. Shchur. SolidWorks as an innovative means of researching automotive engineering. *Actual problems in the system of education:general secondary education institution – pre-university training – higher education institution* 2023. № 3. С. 130-141. URL: https://jrnl.nau.edu.ua/index.php/APSE/article/view/17688/24992 (last accessed: 2025/02/15).

3. Rudyk O. Yu., Vasyura Yu. Yu. The use of computers in scientific research / *Integration of Education, Science and Business in the Modern Environment: Winter Debates: abstracts of the 1st International Scientific and Practical Internet Conference*, February 6-7, 2020. Dnipro: WayScience. P.3. Pp. 123-127. URL: http://www.wayscience.com/wp-content/uploads/2020/02/TOM-3-Zbirnik-1-mizhnarodna-nauk-prakt-int.-konf-Winter-Debates-1.pdf (last accessed: 2025/02/15).

4. Rudyk Oleksandr. Application of innovative technologies when researching the performance of road transport / Oleksandr Rudyk, Roman Kovalenko, Andrii Lavrenchuk, Daniil Hromov. *Actual problems in the system of education: general secondary education institution – pre-university training – higher education institution. 2024.* № 4. P. 78-90. URL: https://jrnl.nau.edu.ua/index.php/APSE/article/view/18723/25987 (last accessed: 2025/02/15).

5. Основні принципи SolidWorks Simulation. **URL:** http://help.solidworks.com/2013/russian/SolidWorks/cworks/c_SolidWorks_Simulati

on_Fundamentals.htm?id=1296116dbaf6478c8a4fbf6e7aa9bd48#Pg0 (last accessed: 2025/02/15).

6. Рудик О. Ю. Застосування SolidWorks у навчальному процесі / О. Ю. Рудик Н. С. Маріїн, С. І. Ярощук . *Матеріали IV Всеукраїнської науково-практичної Інтернет-конференції «Ресурсно-орієнтоване навчання в «3D»: доступність, діалог, динаміка»* / укл. Н. В. Кононец, В. О. Балюк. Полтава : КУЕП ПДАА, 2020. С. 96-100. URL: http://acup.poltava.ua/wp-content/uploads/2020/02/Збірник-2020-0203.pdf (last accessed: 2025/02/15).

7. Рудик О., Каплун П., Гончар В. Застосування SolidWorks для підготовки висококваліфікованих фахівців. *Актуальні проблеми в системі освіти: заклад загальної середньої освіти – доуніверситетська підготовка – заклад вищої освіти*. 2022. № 2. С. 699-706. URL: https://jrnl.nau.edu.ua/index.php/APSE/issue/view/879 (last accessed: 2025/02/15).

8. Рудик О. Ю. SolidWorks – CAD/CAE-система технічних вузів / О. Ю. Рудик, П. В. Каплун. *Science, society, education: topical issues and development prospects. Abstracts of the 2nd International scientific and practical conference. SPC «Sci-conf.com.ua»*. Kharkiv, Ukraine, 2020. P. 249-253. URL: http://sci-conf.com.ua/ii-mezhdunarodnaya-nauchno-prakticheskaya-konferencziya-science-society-education-topical-issues-and-development-prospects-20-21-yanvarya-2020-goda-harkov-ukraina-arhiv/ (last accessed: 2025/02/15).

9. Rudyk O. Yu., Gonchar V. A. The impact of the SolidWorks Simulation network quality on the accuracy of the calculations. *Eurasian scientific congress. Abstracts of the 1st International scientific and practical conference*. Barca Academy Publishing. Barcelona, Spain, 2020. P. 185-188. URL: http://sci-conf.com.ua/i-mezhdunarodnaya-nauchno-prakticheskaya-konferencziya-eurasian-scientific-congress-27-28-yanvarya-2020-goda-barselona-ispaniya-arhiv/ (last accessed: 2025/02/15).

10. Диха О. В., Рудик О. Ю. Застосування SolidWorks Simulation для підготовки фахівців автомобільного профілю. *Збірник тез доповідей ІІ-ї Міжнародної науково-технічної конференції «Перспективи розвитку*

машинобудування та транспорту – 2021»: Збірник тез. Вінниця : ВНТУ. 2021. С. 484-485. URL: http://elar.khnu.km.ua/jspui/handle/123456789/10992 (last accessed: 2025/02/15).

11. Трасковецька Л. М., Рудик О. Ю. , Бірюков О. В. .Математичне моделювання працездатності деталей методом скінченних елементів *Інформатика, інформаційні системи та технології: тези доповідей шістнадцятої всеукраїнської конференції студентів і молодих науковців.* Одеса, 19 квітня 2019 р. Одеса : ОНУ. С. 96-97. URL: http://elar.khnu.km.ua/jspui/handle/123456789/8467 (last accessed: 2025/02/15).

12. Псьол Сергій. Застосування комп'ютерного моделювання для розрахунків автомобільного транспорту / Сергій Псьол, Олександр Диха, Олександр Рудик, Костянтин Голенко. *Збірник наукових праць Національної академії Державної прикордонної служби України. Серія: педагогічні науки* / гол. ред. О. В. Діденко. Хмельницький : Вид-во НАДПСУ, 2023. № 1(32). С. 148-170. – URL: https://periodica.nadpsu.edu.ua/index.php/pedzbirnyk/article/view/1322 (last accessed: 2025/02/15).