Impact Factor:

ISRA (India)	= **6.317**	**SIS** (USA)	= **0.912**	**ICV** (Poland)	= **6.630**
ISI (Dubai, UAE)	= **1.582**	**РИНЦ** (Russia)	= **3.939**	**PIF** (India)	= **1.940**
GIF (Australia)	= **0.564**	**ESJI** (KZ)	= **8.771**	**IBI** (India)	= **4.260**
JIF	= **1.500**	**SJIF** (Morocco)	= **7.184**	**OAJI** (USA)	= **0.350**

Issue Article

SOI: 1.1/TAS DOI: 10.15863/TAS

International Scientific Journal

Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2023 **Issue:** 07 **Volume:** 123

Published: 11.07.2023 **http://T-Science.org**

Maruf Farhadovich Saibov
Navoi state mining and technological university
Assistant teacher of the department Mechanical engineering

Ulugbek Yunusovich Ochilov
Navoi state mining and technological university
Assistant teacher of the department Mechanical engineering

Khisrav Khurshid ugli Ashurov
Navoi state mining and technological university
PhD student of the department Mechanical engineering

TOPOLOGICAL LEVERAGE OPTIMIZATION IN SOLIDWORKS

Abstract*: The design and optimization of mechanical components play a crucial role in improving the efficiency and performance of various engineering systems. This paper presents a scientific investigation on the topological optimization of lever systems by weight using the SolidWorks software package. Lever systems are widely employed in a myriad of applications, ranging from simple tools to complex machinery. The objective of this study is to explore the possibilities of enhancing the lever's performance by employing topological optimization techniques. The focus is specifically on weight reduction while maintaining structural integrity and load-bearing capabilities. SolidWorks, a renowned computer-aided design (CAD) software, offers advanced tools and functionalities for topology optimization, enabling engineers to efficiently create and optimize mechanical designs.*

Key words*: topological optimization, mass reduction, additive production, SolidWorks.*

Language*: English*

Citation: Saibov, M. F., Ochilov, U. Yu., & Ashurov, Kh. Kh. (2023). Topological leverage optimization in solidworks. *ISJ Theoretical & Applied Science, 07 (123)*, 69-74.

Soi: http://s-o-i.org/1.1/TAS-07-123-10 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2023.07.123.10

Scopus ASCC*: 2200.*

Introduction

To achieve the research objective, the study begins with a comprehensive review of lever systems, their applications, and the importance of weight optimization. Subsequently, the fundamental principles of topological optimization are discussed, emphasizing its significance in achieving optimal structural designs. SolidWorks is introduced as the chosen software platform for implementing the optimization process due to its robust capabilities and user-friendly interface.

The methodology involves the formulation of an optimization problem by defining design parameters, constraints, and objectives. The lever's geometry is modeled within the SolidWorks environment, and the optimization algorithm is executed to iteratively determine the optimal distribution of material within the lever structure. The analysis includes stress analysis, factor of safety evaluation, and weight reduction assessment.

The results demonstrate the effectiveness of topological optimization in significantly reducing the weight of the lever while maintaining its structural integrity. The optimized lever designs exhibit improved mechanical performance, reduced material consumption, and enhanced efficiency. The findings of this study provide valuable insights into the benefits of incorporating topological optimization techniques within the design process of lever systems.

Methodology

Designers frequently encounter the task of enhancing established designs or conceiving novel parts within spatial constraints, aiming to achieve lightweight and robust solutions. In situations where the designer possesses only a general notion of the desired part's appearance, the conventional approach involves utilizing predetermined parameters for parametric optimization. However, an alternative method, known as topological optimization (T.O.), offers a distinct strategy wherein the initial design begins as a material array, allowing optimization algorithms to determine both the shape and size of the object. This paper presents a scientific exposition on topological optimization, elucidating its fundamental principles and its utilization in generating optimal material distributions for enhanced structural rigidity under specified loading conditions. The initial design of the proposed part takes the form of a solid-state model constructed within the SolidWorks software system (Fig. 1).

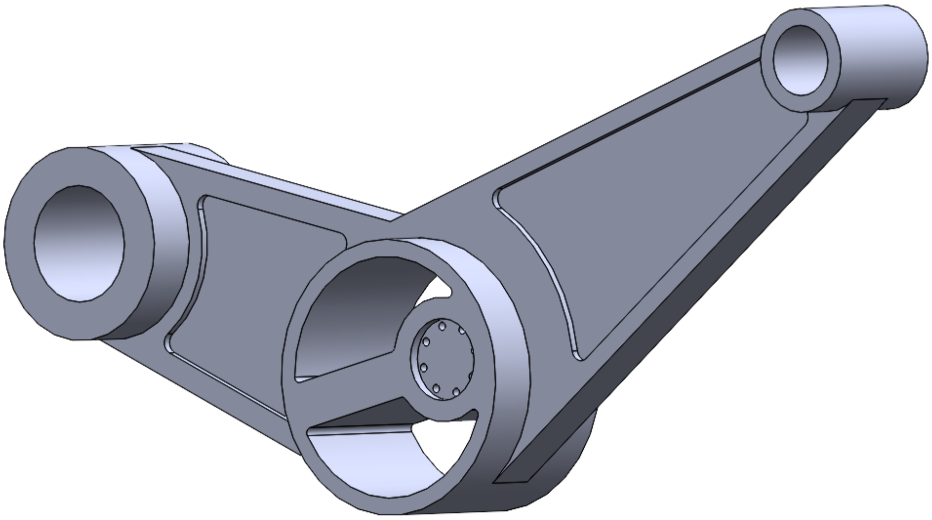

Fig. 1. The original design

In the Static Structural module, a static calculation is conducted with the following specifications: the material used is Structural Steel, a grid is created, and boundary conditions are defined. The boundary conditions consist of a Fixed Support with a hard termination and a Force applied to both the x and z components, each having a magnitude of 3000 N. The calculation model is depicted in Figure 2.

The performance criterion for the structure is defined as ensuring that the stresses experienced do not exceed the yield strength of the material. The distribution of equivalent stresses is illustrated in Figure 3. After performing the static calculation, the mass of the structure is determined to be 3.2564 kg.

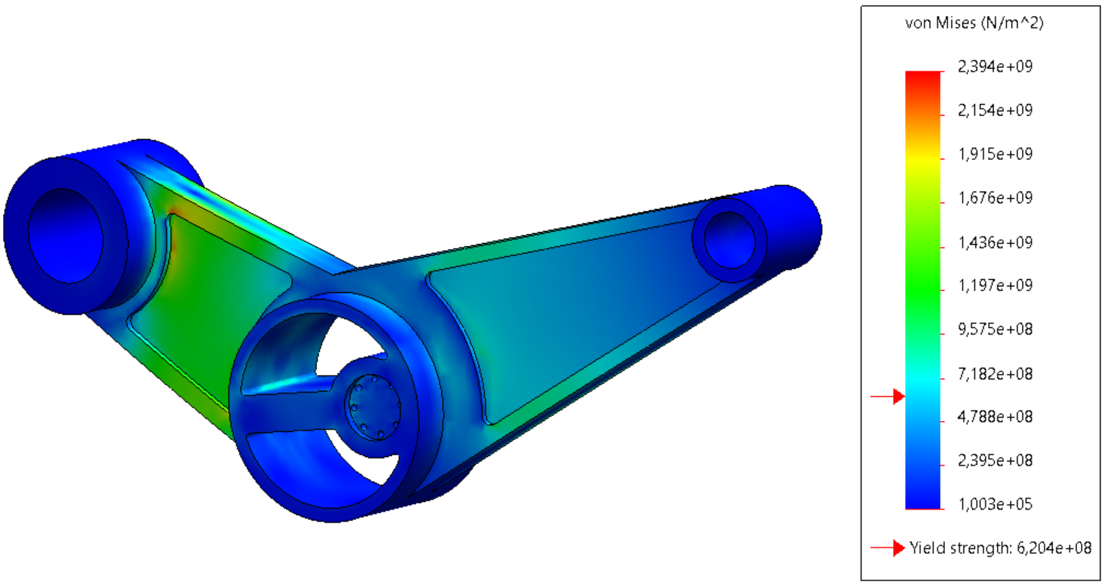

Fig. 2. The calculation model

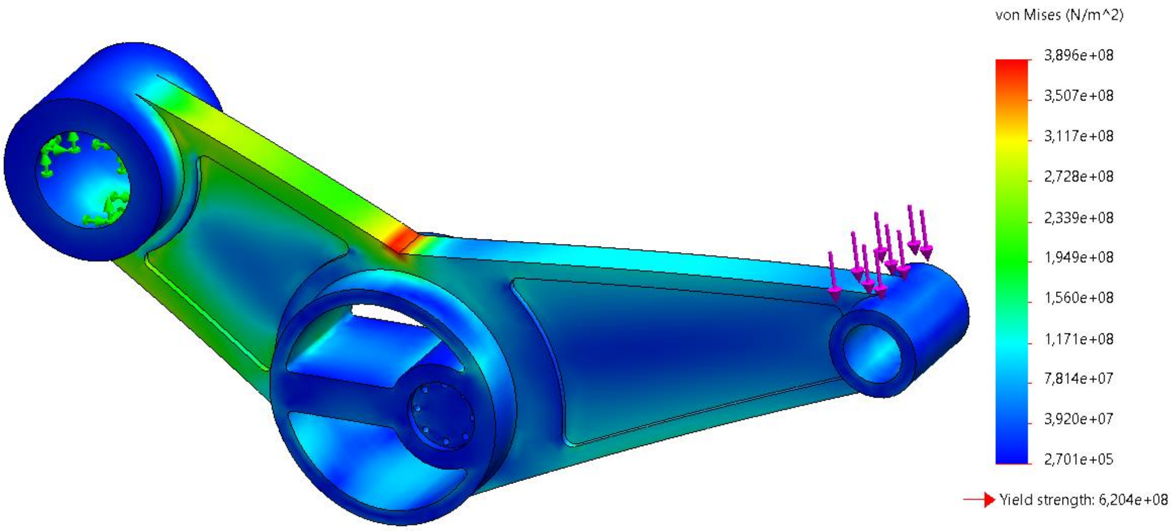

Fig. 3. Distribution of equivalent stresses

Now we proceed directly to the optimization. We edit the original structure so that it is more suitable for maintenance. We remove the grooves that serve the same purpose that we are pursuing - the reduction of mass in order to give more “freedom” to the solver. We add the Topology Optimization module, again we will set the same material, grid and GU parameters to the new design model. The mass of the resulting structure is 3.6647 kg. Topology Optimization includes the following items:

1. Analysis Settings (analysis parameters) - here are the familiar settings for the convergence of the solution to the TO problem, the maximum number of iterations, etc.

2. Optimization Region (optimization area) - setting areas that fall under optimization, and areas that optimization should not concern. We will consider the whole body as a design area, but inside this area we define bodies that will not be subject to optimization. By default, exceptions are those geometric objects to which the GU is attached. Change the Exclusion Region exceptions from the Boundary Condition to the Geometry Selection and manually select those bodies that do not need to be optimized.

3. Objective (the objective function) - the default is Compliance → Minimize (decrease in compliance - maximize stiffness). You can add additional target functions (Mass, Volume). Leave by default.

4. Response Constraint (PG) - the default is Mass - a certain percentage of the mass that should remain in an optimized design. In addition, there are options for Volume, Global Von-Mises Stress, Local Von-Mises Stress, Displacement, Reaction Force, Natural Frequency. Here you can also set production constraints, for example, to make the design symmetrical, or to represent a certain section elongated in a given direction, etc. This is used to adapt the result to one or another production method. We use a weight limit of 40%.

We carry out the solution of the maintenance problem. In the process of solving in real time, you can see the iteration number, the convergence graph, and also in the Solution Information branch the object - Topology Density Tracker, showing the structure being calculated. As a result of solving the problem, a graph was obtained, constructed in units of pseudo-density — the value responsible for the presence / absence of material in the calculation domain; is in the range from 0 to 1, where 0 is the complete absence of material, 1 is the place where the material must be. All that is between 0 and 1 is the effect of solving a problem, which is desirable to keep to a minimum. The graph is made in 3 areas of pseudo-densities having their own colors and signatures.

Extreme variants of the optimized design can be evaluated using the Topology Density tool by moving the Retained Threshold slider, which shows which part of the material we are removing, to the extreme positions (0.01 - on the left; 0.99 - on the right) (Fig. 4).

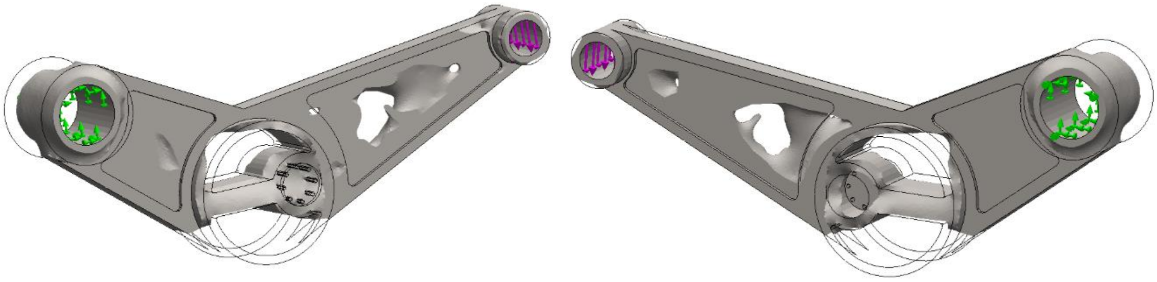

Fig. 4. Extreme optimized design options

Let's choose the option proposed by default (Retained Threshold –0.5), shown in Fig. 5. This design must be edited for verification calculation. To do this, right-click on the Results item of the Topology Optimization module in the project schematic and select Transfer to Design Validation System. A copy of the preliminary calculation appears, but with the geometry taken from the TO result. We fix gross errors of STL geometry with the Auto Fix command. Smaller errors are fixed with the Shrinkwrap tool, which "covers" STL geometry with a new layer of STL mesh. We improve the smoothness of the object with the help of two operations: Smooth (smoothing) and Reduce (significantly reducing the number of facets on the STL geometry while maintaining its shape). Repeat several times the combination of the last three commands to obtain satisfactory smoothness. Create a Solid Model from STL.

We perform verification calculations in Static Structural: we set the same material and GU, when creating the mesh, we use the Patch Independent method so that the surface faces are not taken into account. The threshold value of the ignored features should be less than the estimated sizes of the elements. The picture of equivalent stresses is presented below (Fig. 5).

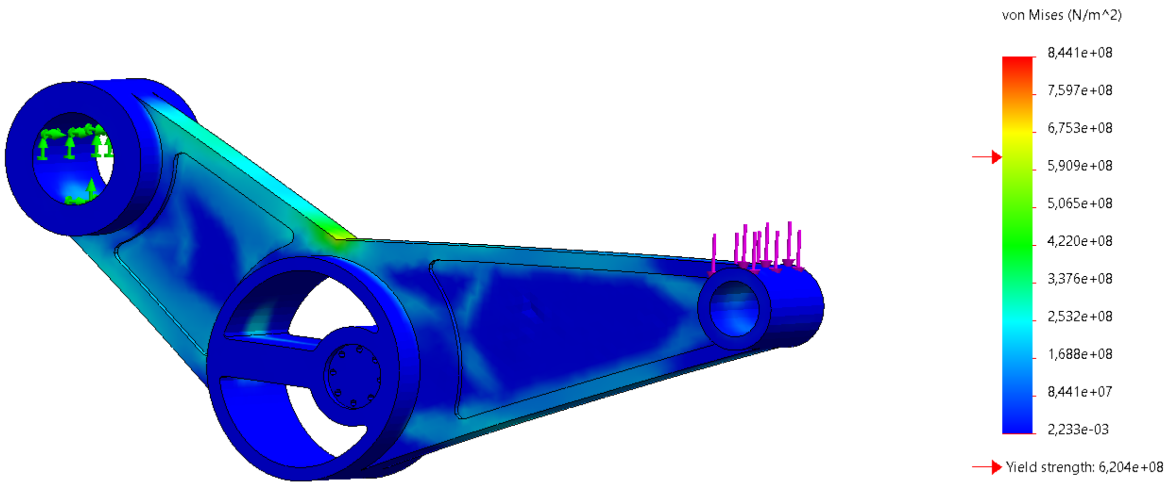

Fig. 5. Distribution of equivalent stresses with topological study

According to the results, it is clear that the resulting construction has lost strength, but in the wrong place, which, in the first calculation, probably, the link was slightly thinned. Nevertheless, the maximum stresses are much less than the yield strength, and, according to these rules, the design is quite functional. The mass of the structure is 2.8697 kg. At the same time, the resulting design can be produced mainly using 3D printers. We will improve the design and make it possible to manufacture it in a more classical way.

Fig.6. Mesh body with recommended parts to be removed

We will carry out its verification. When building a mesh, the Patch Independent method is no longer needed, because the number of surfaces is not so large. The distribution of equivalent stresses is presented below. The mass of the structure is 2.9548 kg. By analyzing the calculation results, the design is lighter than the original, but the maximum voltage is greater. It is worth noting that the maximum stresses act in the same place as in the original model. However, although the stresses are greater, they are still much less than the yield strength.

Conclusion

As a result of topological optimization, two different options were obtained, with masses of 2.8697 kg and 2.9548 kg, with maximum equivalent stresses of 140.73 MPa and 117.52 MPa, respectively. The mass and equivalent stresses of the initial design are 3.6647 kg and 79.87 MPa, respectively. Thus, two workable options with reduced weight were obtained, however, the latter option is preferable due to the possibility of production in more classical ways.

References:

1. Egamberdiev, I. P., et al. (2020). Research of vibration processes of bearing units of mining equipment. *International Journal of Advanced Trends in Computer Science and Engineering,* 2020, T. 9, №. 5, pp. 7789-7793.
2. Akhmedov, K. I., et al. (2020). Influence of integrated machining on the cutting capacity of fast-cutting steel R6M5. *Theoretical & Applied Science,* 2020, №. 9, pp. 322-327.
3. Fedorov, S. V., et al. (2021). Synthesis of refractory phases during surface micro-alloying with the use of a wide-aperture electron beam. Strategija sovremennogo nauchno-tehnologicheskogo razvitija Rossii: problemy i perspektivy realizacii, (pp. 32-35).

4. Ataullayev, A. O., & Sabov, M. F. (2020). Metalloobrabatyvajyshhie proizvodstvennye predprijatija, bazirujyshhiesja na stankah s chpu. *Theoretical & Applied Science*, 2020, №. 9, pp. 301-306.
5. Ataullayev, A. O., & Sabov, M. F. (2020). Metalworking manufacturing enterprises based on CNC machines. *ISJ Theoretical & Applied Science*, 09 (89), 2020, pp. 301-306.
6. Shamieva, O. R., Ishankulova, G. R., & Saibov, M. F. (2019). Pedagogical characteristics of independent work and its role in forming professional competences of students-engineers-engineers. *Theoretical & Applied Science*, 2019, №. 11, pp. 617-620.
7. Ahmedov, H. I., et al. (2017). Analiz drobil`nogo agregata kak linejnaja staticheskaja sistema. *Luchshaja studencheskaja stat`ja 2017*, pp. 73-75.
8. Yaxshiyev, S. N., Ashurov Kh. K., & Mamadiyarov, A.J. (n.d.). Dynamics of Spindle Assembly of Metal-Cutting Machine. *International Journal of Engineering and Advanced Technology (IJEAT)*, ISSN 2249-8958.
9. Karimov, N. K., et al. (2020). Povyshenie udarnoj vjazkosti konstrukcionnyh stalej termociklicheskoj obrabotkoj. *Estestvennye i tehnicheskie nauki: problemy transdisciplinarnogo sinteza*, pp. 40-43.
10. Ibragimov, A. A., et al. (2017). Interval`no-analiticheskie metody reshenija polnoj i chastichnoj problemy sobstvennyh znachenij. *Sovremennye tehnologii: aktual`nye voprosy, dostizhenija i innovacii*, pp. 16-22.
11. Jegamberdiev, I. P., Jahshiev, Sh. N., & Mamadijarov, A. Zh. (2021). *Prognozirovanie tehnicheskogo sostojanija podshipnikovyh opor metallorezhushhih stankov po spektral`nym harakteristikam.* Sostav redakcionnoj kollegii i organizacionnogo komiteta, 2021.
12. Egamberdiev, I., Sharafutdinov, U., & Ashurov, K. (2021). *Investigation of the possibility of increasing the durability of steel castings 110G13L.* Glavnyj redaktor: Ahmetov Sajranbek Mahsutovich, d-r tehn. nauk; Zamestitel` glavnogo redaktora: Ahmednabiev Rasul Magomedovich, kand. tehn. nauk; Chleny redakcionnoj kollegii, (p. 27).
13. Juraev, A., et al. (2021). *Modification of the structure of the Bitter separator machine.* Strategija sovremennogo nauchno-tehnologicheskogo razvitija Rossii: problemy i perspektivy realizacii, (pp. 12-16).
14. Kulmuratov, N. R., et al. (2020). Various issues in the field of setting nonstationary dynamic problems and analyzing the wave stress state of deformable media. *Theoretical & Applied Science*, №. 9, pp. 365-369.
15. Ashurov, K., et al. (2020). Applications metallographic and X-ray structural analysis. *Studencheskij vestnik*, №. 20-14, pp. 19-21.
16. Jahshiev, Sh. N., et al. (2021). *Formirovanie vibroakusticheskogo signala v podshipnikovyh oporah metallorezhushhih stankov*. European science forum, 2021, (pp. 19-23).
17. Ulug’Ov, G. O., et al. (2021). Investigation of the possibility of increasing the durability of steel castings 110G13L. *Universum: tehnicheskie nauki*, №. 11-6 (92), pp. 27-34.
18. Jegamberdiev, I. P., et al. (2021). Ocenka vyhodnoj tochnosti shpindel`nogo uzla tokarnogo stanka NT-250 I. *Innovacionnyj diskurs razvitija sovremennoj nauki*, 2021, pp. 103-107.