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APPLICATION OF COMPUTER SIMULATION AND ANALYSIS TO PROFESSIONAL EDUCATION

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Abstract. The application of SolidWorks Simulation is considered for calculations of the static strength and possible loss of stability of the bushing of the bushing of the outer balance of the carriage of the running gear of the tractors.

Keywords: bushing, stop, SolidWorks, static strength, durability.

Education is one of the most important subsystems of the social sphere of the state. It provides a process for citizens to obtain systematic knowledge, skills and competences. The purpose – their effective use in professional activity. Therefore, graduates must not only demonstrate good training but also fully meet the requirements of modern life. In this regard, professional education in today's reality is of particular importance: the use of computer simulation tools by researchers and

engineers is more relevant than ever before and demonstrates a high level of professionalism. Such modeling has an advantage over other types – it is more convenient for visual perception: the graphical model makes it possible to avoid compiling a verbal description.

In addition, computer simulation tools increase the ability to set learning tasks and control the process of their completion. They involve students in the learning process. At the same time their abilities are revealed, mental activity is activated.

The introduction into the subjects of the technical (engineering) cycle of modern techniques allows us to move from the traditional methods of teaching design to modeling using CAD systems, with subsequent application of CAD/CAE automated complexes. One of them is a 3D system of hybrid computer aided design, engineering analysis and production preparation for SolidWorks products [1].

This versatile system allows you to create flexible parametric models of products of any complexity and get an accurate picture of the stress-strain state of the model. Its tools give the designer ample opportunity to independently determine the parametric basis of the product and to establish the structure of relationships between parameters.

The system has two levels of functional dependencies: the first provides the relationship between the model parameters when recalculating their values, the second - the connection with CAD-systems when restoring the product in accordance with the obtained values of the parameters. The combination of these two types of dependencies allows for extraordinary results: it does not in fact limit the flexibility of the resulting model.

For the convenience of navigating the model and specifying the relationships between parameters, tools are provided for assistive visualization. The parametrization system has a sufficient set of tools to assemble any complex parametric model and obtain a product based on it with the necessary values of dimensions, design, physical and other parameters.

SolidWorks is: designing parts and assemblies of any complexity and purpose, sheet metal products, welded structures, tooling (molds, dies, electrodes); industrial

design; difficult surfaces; check of working capacity of the developed structures; production of drawings in accordance with the requirements of ESCD; work with large assemblies; direct editing of geometry; designing on the basis of knowledge bases; expert project systems; analysis of manufacturability of products (machining, casting); creating animations based on 3D models; SolidWorks Toolbox standard libraries; interactive documentation (creation of photorealistic images, WEB pages and animations based on 3D models; pipeline design; dimension chain analysis in 3D assembly model.

One of the applications of this program is SolidWorks Simulation: calculations for the strength of structures in the elastic zone [2]; setting and solving contact problems; calculations of assemblies; determination of own forms and frequencies of oscillations; calculations of structures for durability [3]; fatigue calculations; fall simulation; thermal and nonlinear calculations (contact problems, consideration of nonlinear material properties and load); analysis of fatigue stresses and determining the life of structures; linear and nonlinear dynamics of deformed systems.

Consider the use of SolidWorks for modeling and analysis on the example of solid-state design and subsequent verification of the loss of resistance of the bushing of the emphasis of the outer balance of carriages of the running gear of the tractors (fig. 1), a static study of which is highlighted in [4].

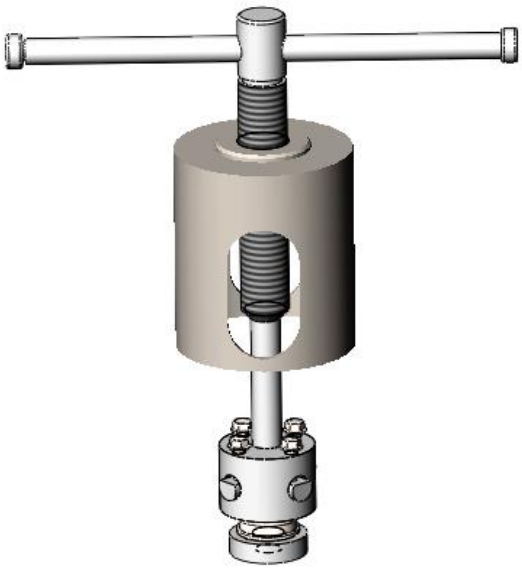
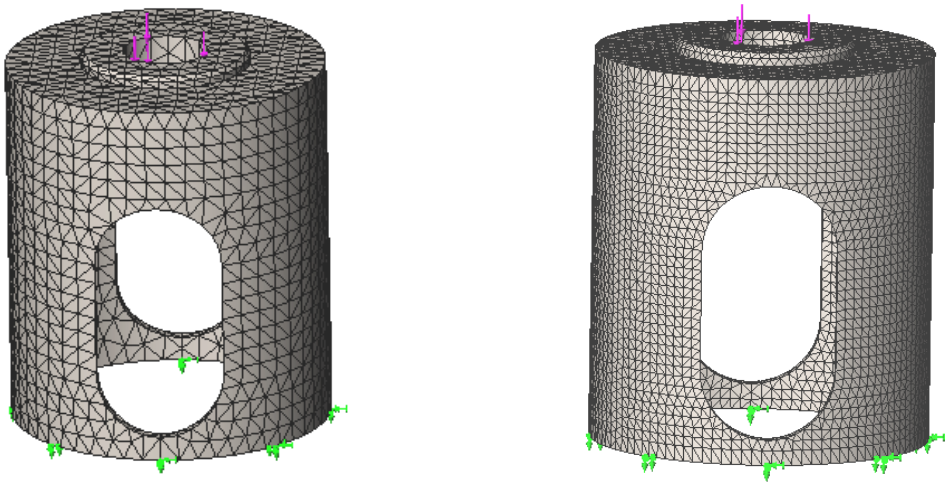


Fig. 1. Solid-state model of the puller

First of all, check the accuracy of the study [4]. It calculates the emphasis model with a coarse grid density (fig. 2, a). To increase the accuracy of the calculation, we create a grid with a large number of small elements (fig. 2, b) and repeat the calculation (other boundary conditions are the same with option [4]).

Study name	Static analysis (-Default-)
Grid type	Solid grid
Partition used	Standard grid
Auto grid compaction	Turned off
Jacobian points	4 points
Item size	8.09253 mm
Tolerance	0.404627 mm
Grid quality	High
Total nodes	16927
Total elements	9269
Maximum aspect ratio	6.1668
Percentage of elements with aspect ratio <3	98.4

Study name	Static analysis (-Default-)
Grid type	Solid grid
Partition used	Standard grid
Auto grid compaction	Turned off
Jacobian points	4 points
Item size	4.04627 mm
Tolerance	0.202313 mm
Grid quality	High
Total nodes	98730
Total elements	61322
Maximum aspect ratio	4.301
Percentage of elements with aspect ratio <3	99.9

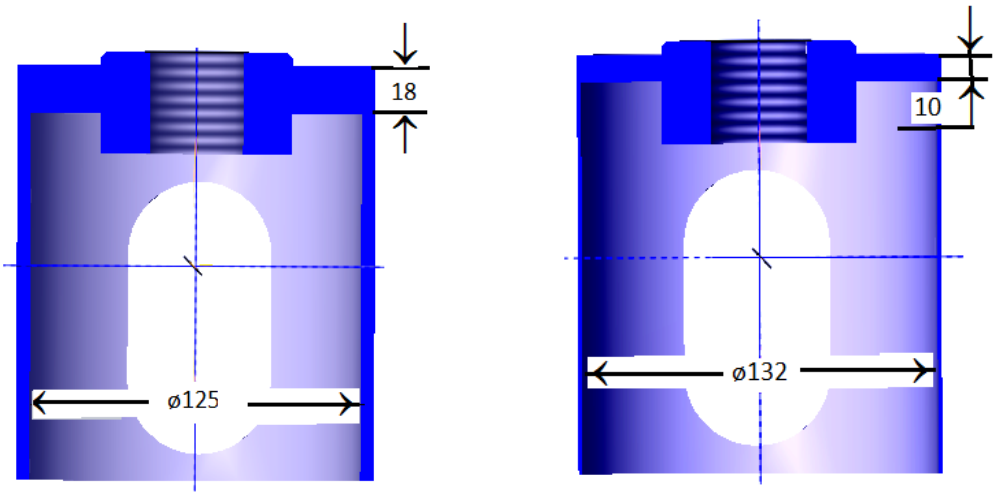


a b

Fig. 2. Grid parameters and finite element model with coarse density (a) and many small elements (b)

As a result of the finite element analysis, it is established that in the case of a grid with a large number of small elements, the minimum safety factor is n = 20,4736, and for a coarse grid density n = 20,9353 [4]. So, our calculation gives more accurate data, but in both cases, the emphasis is able to work on the criterion of strength. Therefore, it is possible to continue the study according to the

recommendations [4]: optimization of the dimensions of the emphasis towards reducing them (fig. 3) with the next stage – determining the stability of the emphasis.



a (mass *m* = 4.18346 kg) b (mass *m* = 2.32427 kg)

Fig. 3. Solid state models of the emphasis before (a) and after optimization (b)

As a result of optimizing the size of the stop, its weight has decreased by 1.8 times. But the next mandatory step (before determining durability) is how the emphasis on static strength will be affected: the results of the calculations are given in table. 1.

Table 1

The value of the node stresses VON, the resulting displacements URES, equivalent deformation ESTRN, the coefficient of safety margin optimized emphasis

Type	Min.	Max.
VON: Tension Von Mises	223 664 N/m^2. Node: 16 521	4,70733e+007 N/m^2. Node: 6 126
URES: The resulting displacement	0 mm. Node: 145	0,0315216 mm. Node: 8 091
ESTRN: Equivalent deformation	9,66409e-007. Element: 4 784	0,000162598. Element: 5 728
Strength margin	7,46858. Node: 6126	1 571,87. Node: 16521

Since the minimum strength factor optimized emphasis $n = 7{,}46858 > [n] = 1{,}5$, it is possible to continue the study.

Thin-walled parts loaded in the axial direction are bent under relatively small axial loads. Such structures may fail due to loss of resistance, although the voltage is well below the critical levels. For such structures, the critical longitudinal load becomes a critical design factor.

Loss of stability of a part occurs at some definite value of the load acting on it. It is called critical. In many cases, the loss of stability of individual elements causes the structure to collapse. Therefore, in addition to the strength calculation, the specified parts require a stability check.

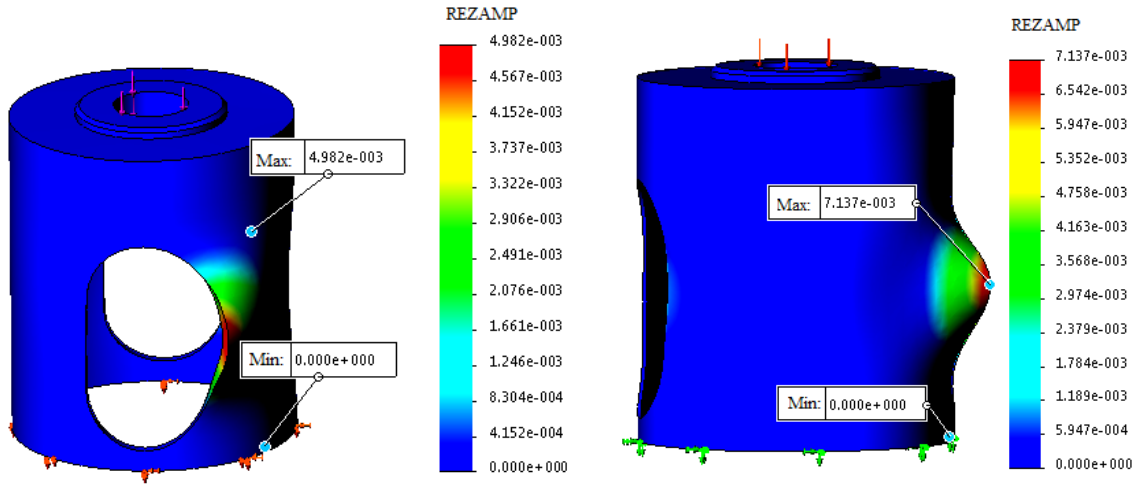
The stability of the shell – the ability to maintain its initial equilibrium position at a given load. The equilibrium position is called unstable if the shell does not possess this ability. The stable equilibrium position is characterized by small consequences at small initial perturbations, and the unstable equilibrium position is characterized by large consequences [5].

Stability loss is defined as the sudden deformation that occurs when the stored membrane (axial) energy is converted to bending energy without changing the applied external loads. Mathematically, when there is a loss of stability, the rigidity becomes degenerate. The linearized stability method used here solves the eigenvalue problem. The aim is to evaluate the critical coefficients of stability loss and the corresponding forms of stability regime [5].

The model can bend in different shapes under loads of different levels. The form that the model takes in the event of a loss of stability is called the form of the loss mode, and the load is called "critical" or "critical longitudinal loading."

With the help of SolidWorks Simulation it is established that the safety margin with a possible loss of resistance to optimization is $k = 565{,}4613$ (fig. 4, a), and after - $k = 43{,}5819$ (fig. 4, b), which in both cases is less than the allowable $[k] = 5$. That is, the loss of stability of the emphasis does not occur.

Name	Type	Min.	Max.
Amplitude for optimization	REZAMP: resulting amplitude Chart - for oscillation form: 1 (Load factor = 565,4613)	0 Node: 276	0,00498247 Node: 235
Amplitude after optimization	REZAMP: resulting amplitude Chart - for oscillation form: 1 (Load factor = 43,5819)	0 Node: 149	0,00713665 Node: 6083



a b

Fig. 4. Resulting amplitude and strength stock at loss of stability before (a) and after (b) optimization

Thus, SolidWorks Simulation provides a methodology for using computer simulation and analysis tools to design mechanisms and gadgets, with subsequent verification of their parts.

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