

APPLICATION OF COMPUTER MODELING TO DETERMINE THE WORKABILITY OF THE CAR PARTS REMOVAL PULLER OF CAR

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Abstract

Computer modelling considers the stress-strain state of solids using the SolidWorks computer-aided design and engineering analysis system. The SolidWorks Simulation application predicts the behaviour of a part in a real situation. To do this, the digital model is analysed using the finite element method. The object of the study is the water pump of the cooling system of the ZAZ "Tavria" car, in which the driven pulley and impeller are pressed onto the shaft with tension. To disassemble the water pump, a puller was designed and the performance of its most critical part, the gripper, was calculated, which operates under conditions of difficult tensile and bending resistance. Therefore, it is manufactured with a safety margin of $n \geq 3$ to prevent deformation during operation. At the same time, the option of violating safety precautions when disassembling the water pump with a puller was adopted – the entire load for removing its parts is taken by one gripper due to the possible skewing of the puller. To conduct a static analysis, a geometric model of the gripper was created in SolidWorks, its material (steel 45) was selected, the gripper was defined and the load applied to it, and a finite element model was created. For this purpose, the finite element method was used, which made it possible to bypass complex manual calculations of the strength of the variable cross-section gripper with the material resistance formulas. The SolidWorks Simulation software developed algebraic equations, taking into account the connections between the elements. They relate the reaction to the material property, constraint, and load. After organizing the equations into a large joint system, the stresses, displacements, equivalent strain, and safety factor of the gripper were found. Since the established minimum safety factor of the 45-steel gripper is less than the permissible one, 35HGSA steel was used for its manufacture. Its heat treatment regime is as follows: *isothermal*

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quenching at a temperature in the furnace $t = 350-370$ °C, cooling in a mixture of potassium and sodium nitrate with $t = 300$ °C, the exposure time in saltpeter until complete transformation into lower bainite $\tau = 30-40$ minutes, and medium tempering at $t = 400$ °C for $\tau = 1-1.5$ hours with cooling in air, after which the final structure is formed – tempered lower bainite. After repeated calculations, the minimum safety factor became greater than the permissible one, which ensures the gripper's operability.

Keywords

Computer modelling, SolidWorks, ZAZ "Tarvia", water pump, disassembly, SolidWorks Simulation, puller, gripper, operability.

Introduction

Computer modelling considers the stress-strain state of solids using the SolidWorks 3D computer-aided design (CAD) and engineering analysis (CAE) system, which is designed to solve the following tasks [1, 2, 3]: hybrid parametric modelling, design of parts, assemblies and products taking into account the specifics of manufacturing (sheet material, dies and molds, welded structures); express analysis (mass-inertial characteristics, strength and kinematics); import/export of geometric models, drawing design.

A SolidWorks application is SolidWorks Simulation, which predicts the behaviour of a part in a real-world situation. To do this, the digital model is analysed by the finite element method (FEM), which allows [4]:

- calculate alternative design options for the part;
- shorten the development cycle by optimizing design solutions;
- determine stresses, displacements, deformations, safety margins, and other parameters at the early stages of part and assembly development.

The basic idea of FEM is that any continuous quantity (temperature, pressure and displacement, etc.) can be approximated by a discrete model based on a set of piecewise continuous functions. In general, the continuous variable is not known in advance, and it is necessary to determine its value at some internal points of the domain.

In SolidWorks Simulation [2]:

- isotropic, orthotropic, and anisotropic materials are assigned;
- uniform or non-uniform pressures in any direction, forces with variable distribution, gravitational and centrifugal loads, support and distance forces are applied to the parts;
- an optimal solution is found that meets the constraints of geometry and behaviour; if the assumptions of linear static analysis are not applicable, nonlinear analysis is used;

- the effect of temperatures on different parts of the part is applied (heat transfer conditions: temperature, convection, radiation, heat output and heat flux; the temperature profile is automatically read and thermal stress analysis is performed);

- calculations of critical forces and forms of loss of stability, assemblies using contact elements are performed [5, 6];

- eigenforms and frequencies are determined; fatigue analysis evaluates the effect of cyclic loads in the model, identifying fatigue events with constant and variable amplitude;

- when analysing the shock load test, the dynamic problem is solved (an epure is created and a graph of the model's response is plotted in the form of a time dependence);

- longitudinal force diagrams, results for reaction forces, loss of stability forms, resonant vibration forms, temperature distribution results, temperature gradients and heat flow are plotted;

- analyses of contacts in friction assemblies, tension fit or hot fit, thermal contact resistance analyses.

The mandatory elements of research in SolidWorks Simulation are [7]: selecting the SolidWorks Simulation application and steps in it; assigning the type of research (static analysis) of the model; selecting the material of the part from the SolidWorks material library; selecting the fastening of the part; applying a load to certain planes, faces, or elements of the part; creating a FEM mesh; the influence of mesh quality on the accuracy of calculations.

SolidWorks Simulation allows you to replace the material of the part and save it based on the analysis of the stress state of the model; probe the stresses at critical points of the part; determine the maximum load that the modelled part can withstand without failure, at a given safety factor; determine the impact of part fasteners on their performance, etc.

Research object and methods

The object of the study was the water pump of the cooling system of the ZAZ "Tavria" car, in which the driven pulley 2 and impeller 5 are pressed onto the shaft with tension (fig. 1). To disassemble the water pump (i.e. removing the pulley and impeller from the shaft), it is necessary to design the puller and calculate the performance of its components.

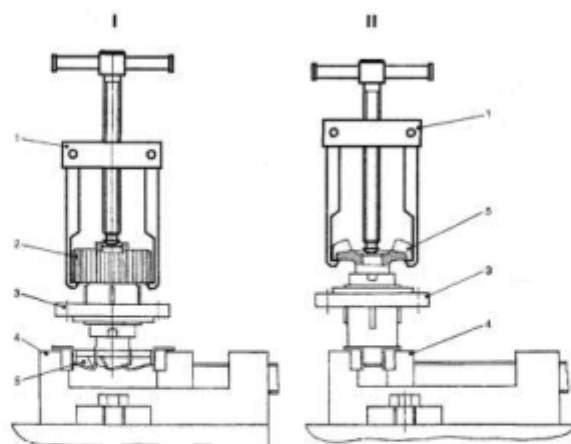


Fig. 1. Disassembling the water pump, removing with a puller: I – water pump pulley, II – water pump impeller; 1 – puller, 2 – water pump pulley, 3 – body, 4 – vise, 5 – impeller

The main requirement of the disassembly technology is the safety of the parts that communicate with the shaft, as well as the shaft itself, if it is new or suitable for further work (or can be repaired and restored). In cases where the pulley or impeller is completely destroyed and cannot be used in the future, it is necessary not to take special precautions when removing them from the shaft seat (however, the parts of the assembly connected to the shaft should be protected from damage).

Calculations have established that the force for removing the pulley is 7740 N, and for removing the impeller – 11610 N.

Despite the fact that a large number of repair operations are mechanized (electric and pneumatic wrenches, presses, etc.) are used, the share of manual labor in disassembly and assembly operations is still large. Even in large repair enterprises, the level of mechanization during disassembly sometimes does not exceed 12%, and during assembly – 5% of the volume of all disassembly and assembly works [8].

The main condition for high-quality and fast disassembly of machines is the provision of workplaces with correctly selected tools and devices (pullers) necessary for this purpose. In cases where the use of pullers is caused by production necessity, then, when choosing them, the following is taken into account [9, 10]:

1. The design of the puller should be such that during operation it does not cause damage to the parts it will come into contact with and provides sufficient pressing force.

2. Installation of the puller on the part should not cause the need for additional work (drilling new holes or reaming existing holes, etc.).

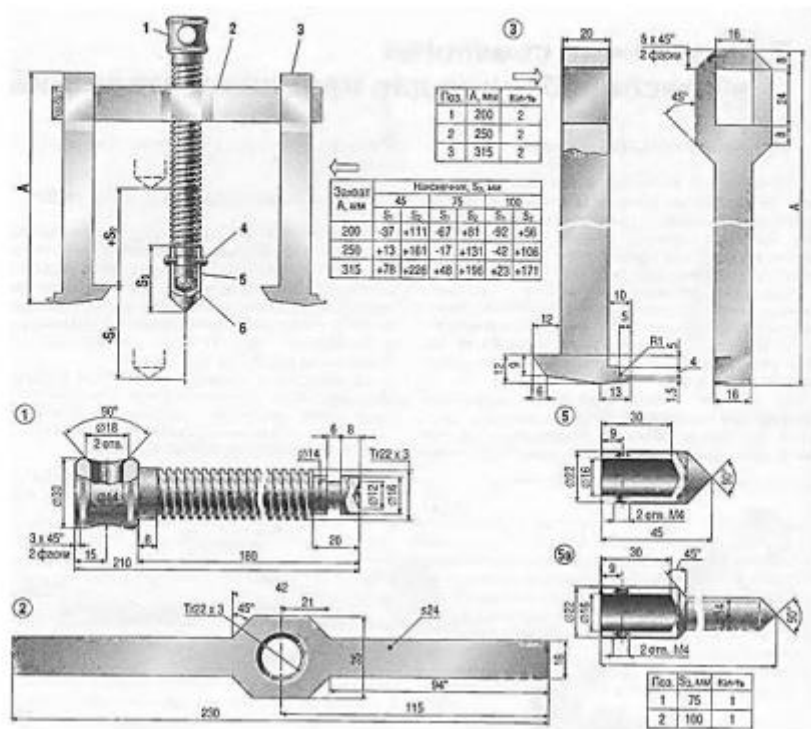
3. The puller must be stable in operation and centered in a symmetrical position relative to the part to be captured. Otherwise, it may fall off the part during operation and cause injury to the worker.

Setting the task

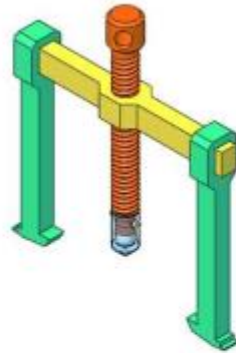
The risk of safety violations when using the puller is associated with insufficient strength of its parts. Therefore, you need to make the appropriate calculations using the SolidWorks computer-aided design system and its SolidWorks Simulation application.

Results and their discussion

The design of the pullers is very diverse, as the parts that can be disconnected with their help have different shapes and sizes. However, despite the wide variety of designs, all pullers have components and parts that are common in purpose and often in shape [10, 11]. Let us consider the puller (fig. 2), the most important parts of which are the grippers (pos. 3 in fig. 2, a), the ends of which end with a hook that compresses the driven pulley or impeller. The puller grips operate under conditions of difficult tensile and bending resistance, i.e., under conditions of eccentric tension. Therefore, they are manufactured with a safety margin $n \geq 3$ to prevent deformation during operation [12].



a



b

Fig. 2. Puller: a – assembly drawing (1 – screw; 2 – traverse; 3 – gripper; 4 – M4-5 screw; 5 – tip; 5a – tip variant; 6 – ball $\varnothing 16$ mm); b – 3D-model

The process begins with creating a geometric model of the gripper in SolidWorks (fig. 3, a). The next step is to select the material from which it is made from the SolidWorks library – an analog of steel 45 – DIN 1.1191 (C45E – fig. 3, b).

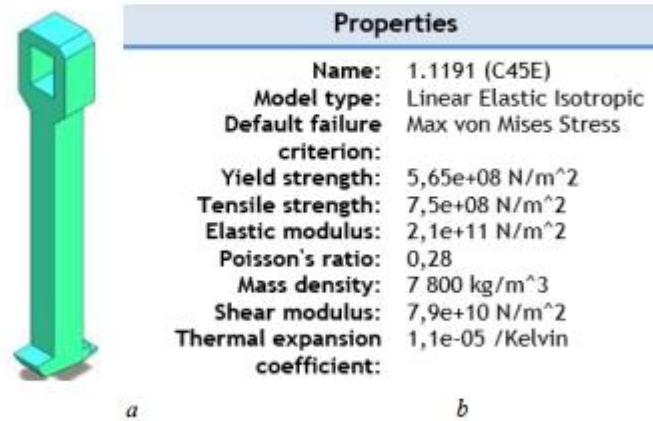


Fig. 3. 3D model of the gripper (a) and characteristics of C45E steel (b)

To conduct a static analysis, we defined the gripper hooks (fig. 4, a) and the load applied to it (fig. 4, b). In this case, we accept the option of violating safety precautions when disassembling the water pump with a puller - the entire load for removing the impeller (11610 N) is perceived by one gripper due to a possible skew of the puller.

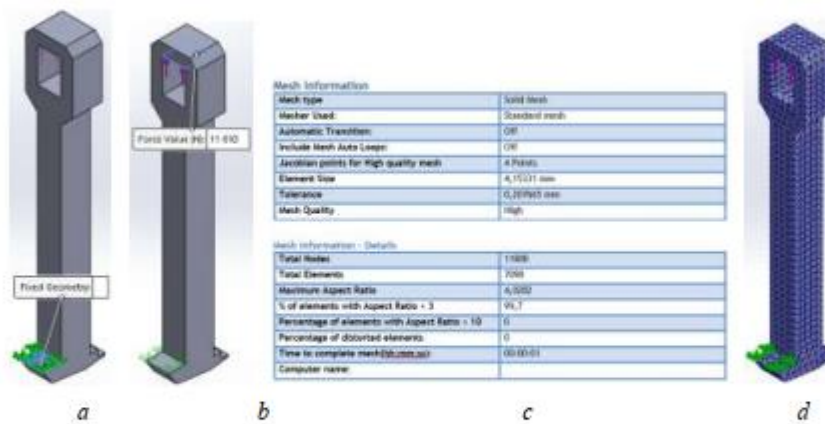


Fig. 4. Fixing the gripper hook (a), applying a load to its support (b), mesh parameters (c), its reflection on a solid (d)

The next step was to determine the contact interactions and create a finite element model of the gripper (fig. 4, c, d). To do this, we used the FEM, which allowed us to bypass complex manual calculations of the strength of a variable-section gripper by using the formulas of material resistance [13]. SolidWorks Simulation software, taking into account the connections between elements, develops algebraic equations. They relate the reaction to a material property, constraint, and load. After organizing the equations into a large joint system, the unknowns are found (fig. 5).

Name	Type	Min	Max
Stress1	VON: von Mises Stress	9,928e+04N/m ² Node: 11362	4,512e+08N/m ² Node: 11777

a

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000e+00mm Node: 1	9,003e-01mm Node: 178

b

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2,763e-07 Element: 1917	1,965e-03 Element: 6815

c

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	1,252e+00 Node: 11777	5,691e+03 Node: 11362

d

Fig. 5. Von Mises stress (a), displacement URES (b), equivalent strain ESTRN (c) and safety factor FOS (d) determined for a gripper made of steel 45

Since the minimum coefficient of the safety of the gripper made of steel 45 ($n = 1,252$ – see fig. 5, d) is less than the permissible $[n] = 3$, it is necessary to use another material for its manufacture. Therefore, we accept the following gripping material – steel 35HGSA with custom settings (elastic modulus, Poisson's ratio, mass density, tensile strength, yield strength - Fig. 6). Heat treatment mode – isothermal quenching at a temperature in the furnace $t = 850-870$ °C, cooling in a mixture of potassium and sodium nitrate with $t = 300$ °C, the exposure time in saltpeter until complete transformation into lower bainite $\tau = 30-40$ minutes, and medium tempering at $t = 400$ °C for $\tau = 1-1.5$ hours with cooling in air, after which the final structure is formed – tempered lower bainite.

Default failure criterion:	Max von Mises Stress
Description:	35HGSA
Source:	
Sustainability:	Undefined Select...

Property	Value	Units
Elastic Modulus	216000	N/mm ²
Poisson's Ratio	0.29	N/A
Shear Modulus	84000	N/mm ²
Mass Density	7850	kg/m ³
Tensile Strength	1570	N/mm ²
Compressive Strength		N/mm ²
Yield Strength	1410	N/mm ²

Fig. 6. Characteristics of 35HGSA steel

The results of the static analysis of the gripper after repeated calculations in SolidWorks Simulation are displayed as a colour gradient, which shows the distribution of the calculated parameters by changing the colour: The maximum Von Mises stresses are $\sigma = 4,476$ MPa (node 11777), the maximum resulting displacement URES h = 8,744e-01mm (node 178), and the maximum equivalent strain ESTRN $\delta = 1,898$ e-03 mm (element 6815), i.e., they do not exceed the permissible values (fig. 7). At the same time, the minimum safety factor FOS is $n = 3,150$ (node 11777), which is higher than permissible.

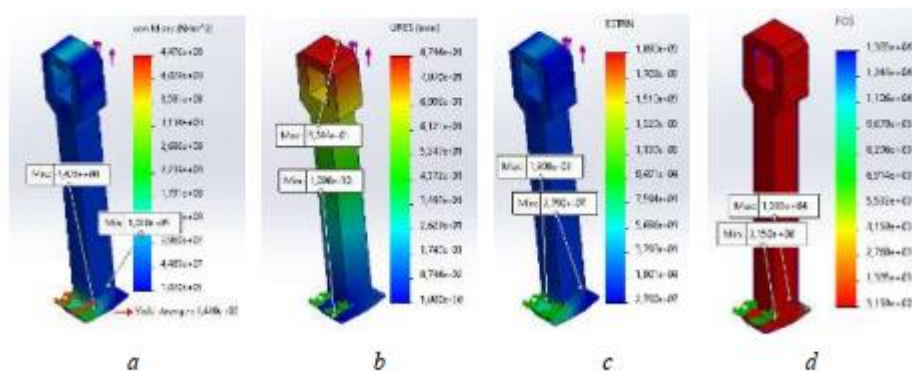


Fig. 7. Plots of maximum stresses VON (a), maximum resultant displacements URES (b), maximum equivalent deformations ESTRN (c), minimum safety margin FOS (d) of the gripper model made of 35HGSA steel

The diagram of the distribution of equivalent stresses according to the Mises criterion revealed an area with localization of maximum stresses and a reduced safety margin. A probing tool was used to accurately assess the stress state in this area (Fig. 8).

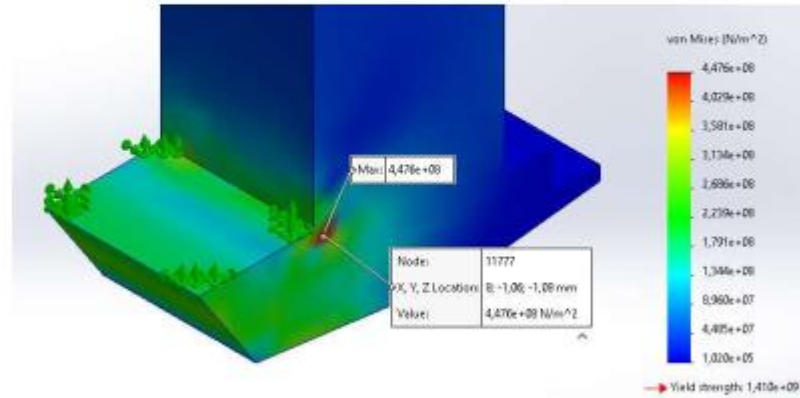


Fig. 8. Stress probing in a dangerous section

Conclusions

Thus, the strength parameters of the gripper, one of the most heavily loaded parts of the designed puller, ensure its performance. But to make a final conclusion, it is necessary to perform similar calculations for other parts.

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ДОСЛІДЖЕННЯ ПРОЦЕСУ ЛИТТЯ ПІД ТИСКОМ З АРМУВАННЯМ ВОЛОКНИСТИМИ НАПОВНІЮВАЧАМИ ЗАСОБАМИ SOLIDWORKS SIMULATION

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Анотація

У роботі досліджено процес лиття під тиском взуттєвої підкови із суміші полімерного матеріалу та армуючих волокон. Основну увагу приділено впливу орієнтації волокон і ліній спаю на експлуатаційні властивості виробу. За допомогою SolidWorks Simulation проведено моделювання заповнення прес-форми та аналіз розподілу і орієнтації волокон. Дослідження показали, що розташування впускних каналів впливає на міцність та втому витривалість підкови, а отже й на її

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