OPTIMIZATION OF THE STRUCTURE OF A MULTIFUNCTIONAL SOIL TILLAGE EQUIPMENT IN AGRICULTURAL HOLDINGS

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Abstract: *The heavy operating conditions exposed, raise very severe restrictions and require a rigorous selection of the components of the hydraulic systems that correspond to the requirements imposed on them. The paper analyzes the calculation and selection algorithm according to the standard of the "secondary" component of the hydraulic drive system - the linear hydraulic motor. The dimensioning and resistance calculations of the piston rod are elementary calculations for the optimization of a linear hydraulic motor within the multifunctional soil tillage equipment in agricultural holdings. This system of cylinders has been added to optimize the structure by modifying the center of gravity and reducing the occurrence of the buckling at the connection between the tie rods of the tractor and the equipment.*

Keywords*: Predimensioning, resistance calculation, tensile test*

1. Introduction

Usually solution of different engineering problems requires design of various objects or systems. Basically, there are three general approaches to solving engineering problems: an experimental approach, a computational approach and a computational-experimental approach, which combines both of the mentioned. Each of the first two approaches has advantages and disadvantages, while the last one joins the advantages and avoids the disadvantages of the other two. In this work will be performed a computational approach. When selecting the most suitable computational code for solving a problem, it is obligatory to mind that each computational code is based on a mathematical model of the governing physical processes, expressed in the form of a set of equations derived from physical laws, including semi-empirical and empirical constants or relationships. Consequently, an appropriate method for solving these equations is also required.

For problems which solution is based on Finite Volume Method (FVM) the equations of the mathematical model aresolved in a discrete form on a computational mesh. The solution of the mathematicalproblem is obtained with a certain degree of accuracy, depending on the method ofdiscretising the differential and/or integral equations and on the method of solving theobtained discrete equations. Of course, the solution also depends on the introduced initialdata. It is known that higher accurate solution requires finer computational mesh, providedthrough rather substantial computer memory and CPU time. [1]

2. Pre-dimensioning the linear hydraulic motor

The heavy operating conditions exposed, raise very severe restrictions and require a rigorous selection of the components of the hydraulic systems that correspond to the requirements imposed on them. The paper analyses the calculation and selection algorithm according to the standard of the "secondary" component of the hydraulic drive system - the linear hydraulic motor. Hydraulic motors are used for energy conversion purposes hydrostatic fluid in mechanical energy. In order to approach the calculation of a hydraulic system, namely the hydraulic motor, we must take into account the technical-functional characteristics of the hydraulic cylinder.[2].The hydraulic cylinder subjected to dimensioning, theoretical simulation with Flow Simulation from SolidWorks and resistance calculations using finite element analysis is part of the multifunctional soil working equipment in agricultural operations, fig.1.

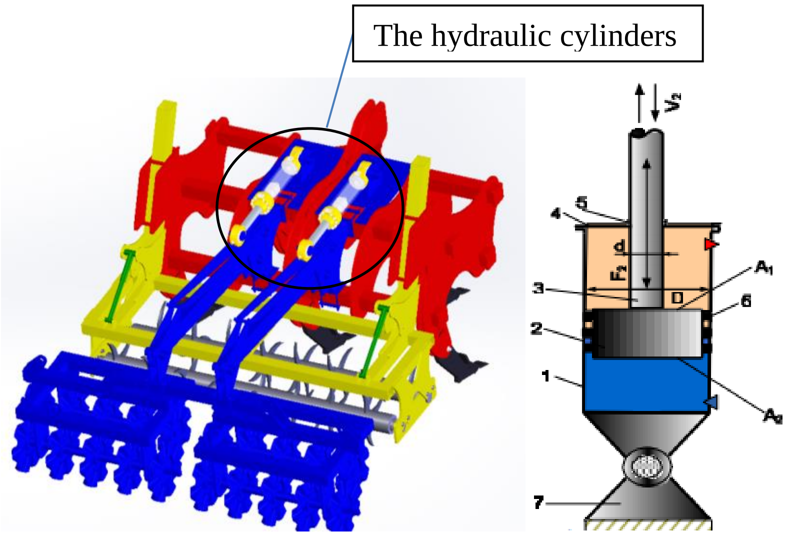


Fig. 1. The multifunctional soil working equipment in agricultural operations, with the highlight of the cylinder who will be analysed (1 - cylinder; 2 - piston; 3 - single or bi-lateral rod; 4 - the lid cylinder; 5 - sealing the piston rod to the cap; 6 - segments of piston seal; 7- cylinder clamping system)

Dimensional characteristics: L = mounting length; S = the maximum race; Lmax = the maximum length; A1 = the piston surface (cm^2).; A2 = small surface of piston (cm^2).

Functional characteristics: pn = the nominal pressure; Pmax = maximum pressure; p_0 = working pressure (210 bar).

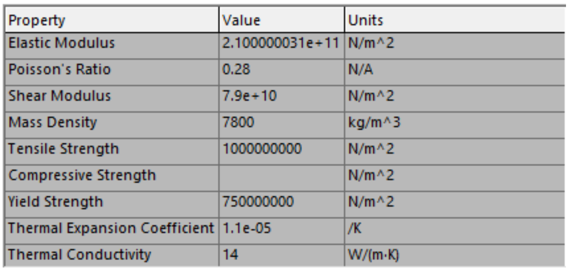
For hydraulic cylinders with double effect and unilateral rod, the theoretical forces developed by them, for the two senses of displacement of the piston, are:

$$F_1 = A_2 \cdot p_0 = \frac{\pi \cdot D^2}{4} \cdot p_0, \qquad \text{[daN]} \tag{1}$$

$$F_2 = A_1 \cdot p_0 = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot p_0, \qquad \text{[daN]} \tag{2}$$

From the given forums resulted F_1=299450 and F_2= 514970 N.

The material used in the construction of the rod is 42CrMo with its properties specified in fig. 2.



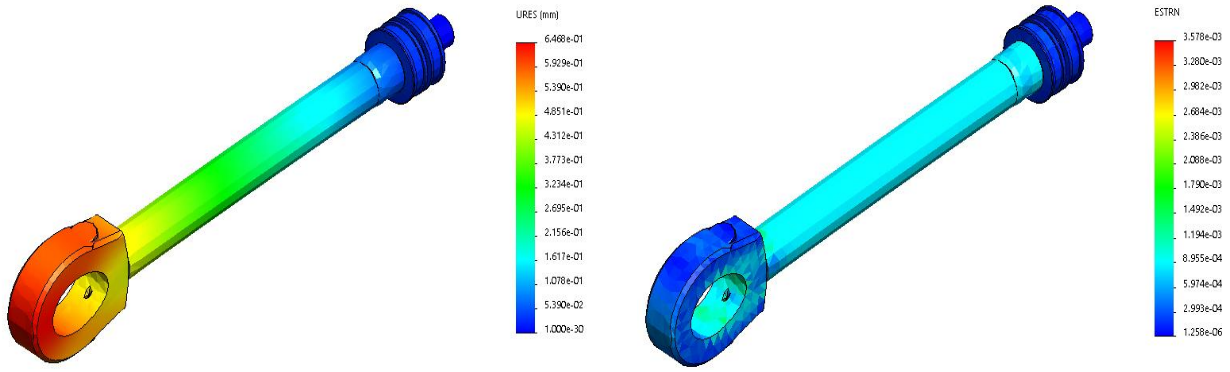
Property	Value	Units
Elastic Modulus	2.100000031e+11	N/m^2
Poisson's Ratio	0.28	N/A
Shear Modulus	7.9e+10	N/m^2
Mass Density	7800	kg/m^3
Tensile Strength	1000000000	N/m^2
Compressive Strength		N/m^2
Yield Strength	750000000	N/m^2
Thermal Expansion Coefficient	1.1e-05	/K
Thermal Conductivity	14	W/(m·K)

Fig. 2. Properties of the material from which the rod of the hydraulic cylinder is subjected to FEM analysis

3. Traction test of the piston rod material

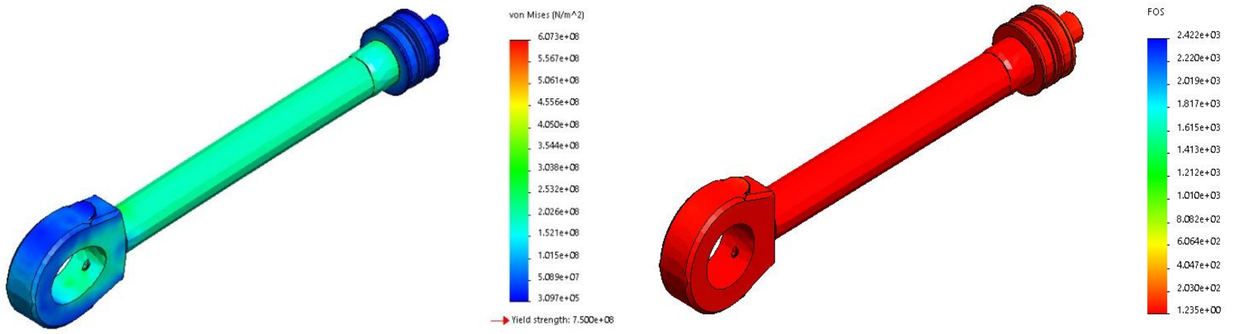
The tensile test is performed by applying the calculated axial force to the rod, after application, being a very small assembly, the interferences were checked and they do not exist, after this step the boundary conditions (the support of the structure) and their loading with the axial force F_2 and pressure of 210 bar (21 N / mm^2) in different directions for observing the results of the linear-elastic structural analysis: the values of the reactions in the supports, the distribution of the vector field of the relative-resultant displacement in the structure, the distribution of the tensor fields of the specific deformation and the Cauchy tension in the same structure. Also, an important result for the safety of the structure is the distribution of the safety factor; these results are presented in table 1.

Table 1: Results of structural linear elastic analysis



a) The distribution of the values of the resulting relative displacement field on the structure boundary

b) Distribution of total specific deformation field values on the structure boundary



c) Representation of the von Mises Stress on the structure boundary

d) Distribution of the safety factor at the border of the structure

At the maximum value of the force calculated according to the dimensions of the cylinder and the working pressure, a safety factor of 1.2 can be observed. As the force acting within the system is much smaller than the mass of the structure being 1044 kg, it turns out that the cylinder rod will have no problems and the cylinder is over dimensioned and can be optimized in order to choose an optimal cylinder for our structure. As the operating parameters cannot be changed, the optimization will be carried out in the two dimensions D and d. When the force exerted by the real system was introduced, a safety factor of 7.8 was obtained (fig. 3). An optimization will be done to reach a safety factor of 1.2 with this force.

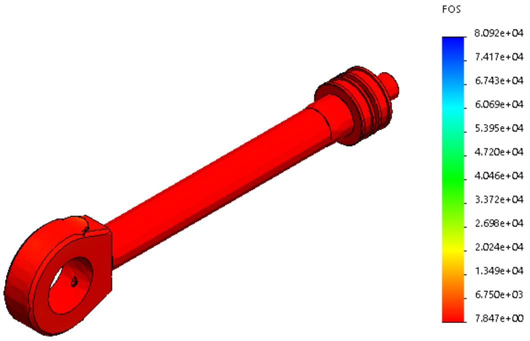


Fig. 3. The safety factor at the actual force of the studied system

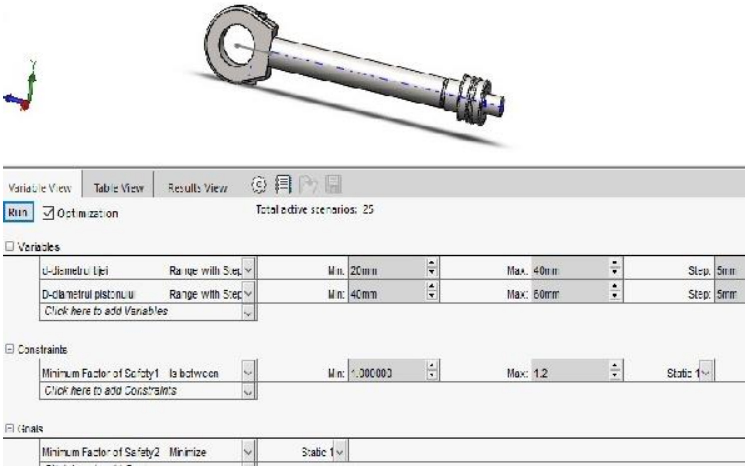
An *objective* in optimization is a parameter of the design that the designer seeks to optimize (i.e., either minimize or maximize).

The objective is usually not a parameter the designer can control directly. Instead, it is a function of the design variables that the designer specifies or controls directly. Examples of objective:

- mass, volume, surface area, stress, cost, etc. (for minimization)
- usable container volume, surface area, natural frequency, etc. (for maximization)

You can define only one objective in SW Simulation optimization analysis.

The objective is a function of the design variables; that is, changing the values of the design variables leads to change of value of the objective. In fact, this is the very point of optimization – *change things under your control (design variables) to achieve an objective that is not directly under your control (Factor of Safety).The settings for performing the optimization were made according to figure 4, with the constraint that the safety factor should be between 1 and 1.2 according to the settings from the previous simulation (Static 1).*



☑ Optimization

Total active scenarios: 25

☐ Variables

D-diametrul tijei	Range with Step	Min: 20mm	Max: 40mm	Step: 5mm
D-diametrul pistonului	Range with Step	Min: 40mm	Max: 60mm	Step: 5mm
Click here to add Variables				

⊟ Constraints

Minimum Factor of Safety1	Is between	Min: 1.000000	Max: 1.2	Static 1
Click here to add Constraints				

⊟ Goals

Minimum Factor of Safety2	Minimize	Static 1

Fig. 4. The settings made to optimize the piston rod

After making the settings, the optimization analysis was run and resulted for the actual force introduced into the system by the weight of the assembly, from the point of view of the safety factor a rod thickness of even 20 mm can be used, the piston diameter remaining the same. it will not yield to this force and to the pressure of 210 bar in the cylinder, as F_2 is inversely proportional to d, the cylinder will generate a maximum force greater than the previous one.

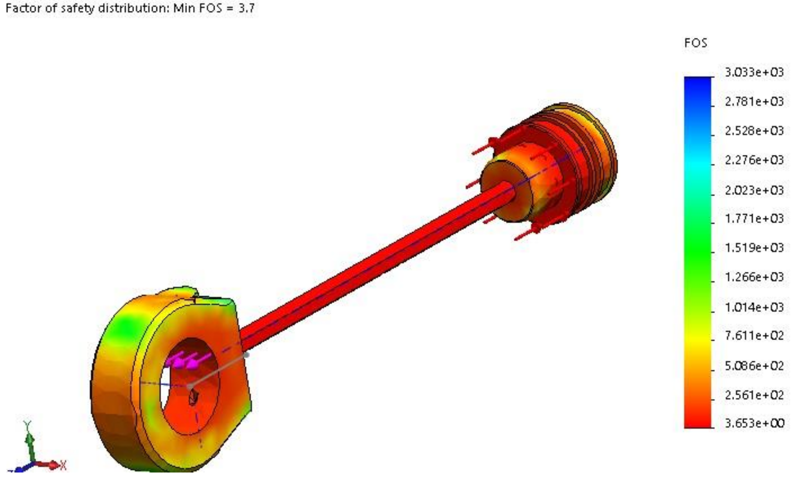


Fig. 5. The safety factor from FEM analysis for d = 20.

Conclusions

Following this first structural study on the cylinder within the equipment, some important conclusions can be drawn for further investigations.

For a normal request, calculated according to the criteria set out in the work, the load-bearing structure of the hydraulic cylinder, is overestimated, abstraction making of possible accidents in the ground, of a use in improper conditions or of shocks produced in transport

Given the maximum values of the equivalent voltage, there is no danger of yielding the structure material.

The high value of the safety coefficient (7.8), compared to its usual values in the practice of designing and manufacturing hydraulic cylinders, shows that the choice in the first phase of the execution of the experimental model was wrong and this will be remedied by the execution of the prototype for cost reduction of production.

Acknowledgments

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