NUMERICAL SIMULATION OF STEEL PLOUGHSHARE

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Abstract: The text presents information about the sphere of a steel ploughshare structural design. Blade is designed as a part of the fire–recovery track vehicles. Main advantage is a general range of application in various severe conditions. The article explains the basic principles of a design proposal that are subsequently verified by a numerical simulation. The authors made two types of simulations. The first one is a calculation, when the ploughshare is under standard load created by working conditions. Second case is, when the ploughshare is under critical load. The main message of the text is present basic know-how, how to design the steel ploughshare and evaluate the plastic zone at blade, which was created by under critical load.

1 Introduction of steel construction

A method of designing a steel structure is a difficult process that may be affecting a number of factors. Primary instances which must be considered at the beginning of the proposal are:

- manufacturability,
- ability for long-term operations,
- easy maintenance for a construction elements,
- economical aspects,
- safety for users [5].

The primary effort is to develop steel construction of low-weight and high load capacity. This leads to, that a shape, a dimensions and a load conditions allow a loss of the primary stable equilibrium position (fixed), what is in terms of functional ability of the structure unacceptable. The loss of stability and shapes exists, when the conditions are created for transition from a stable equilibrium position to a unstable equilibrium position. This transition is characterized by changing the shape of the body. A loss of stability of elastic bodies occurs most frequently in the case of long thin rods, thin-walled construction a wherever at last one dimension of the body is very small in relation to other [4].

Design in order to determine the optimal solution is a complex process and consisting of determining the operating conditions of construction, rational selection of active scheme shape structural materials and components that ensure the efficiency of construction with regard to price and technology [6]. For more information about buckling problem and theory about design the steel structures see the publications [2], [4], [5], [7] and [8].

1.1 Introduction of ploughshare

Ploughshare is universal working tool applied for pushing, moving and storing the material on construction site. They paramount technical parameters are:

- geometrical characteristics,
- angle setting of the working mode,
- angle of blade cutting edge.

The blade shape is intended by operating condition and types of blades are illustrated in Figure 1.We can assume, that our proposed ploughshare will be used in hard working conditions. That means, the base of soil is formed by stones, sand, root age system and along with the peat. Therefore is design intentionally oversizers according to rigid construction in positive way (increase a tool lifetime).Now is time for question: how is increase the weight of the ploughshare if we increased its own stiffness??? Good outcomes provide us the mathematical optimization methods. Where can user with reliable and desired mathematical approaches to get a very accurate usable result [1].

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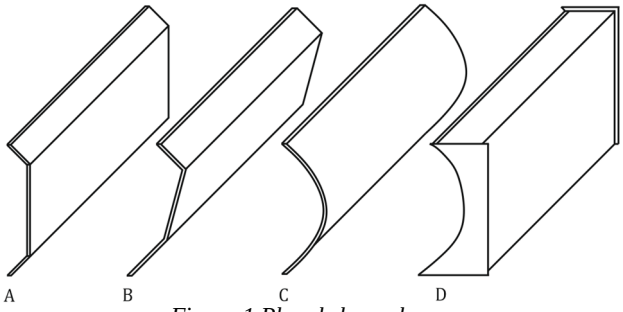

Figure 1 Ploughshare shapes

Introduction of ploughshares typology:

- A - type for small dozers,
- B - type for medium dozers,
- C - type for large dozers,
- D - thin-walled ploughshare.

1.2 Determination of working load

Consider the theory of cutting the soil, which was written by author [1]. It is assumed, that the separated material will be clipped from soil with blades part of ploughshare. Thus released material, which is pushed in vertical direction along ploughshare, is marked by number 1 in Figure 2. If the rising current reached some height level, than coherence of the soil is decreased and clipped materials starts falling down front of the ploughshare. This status is marked by number 2 in Figure 2.

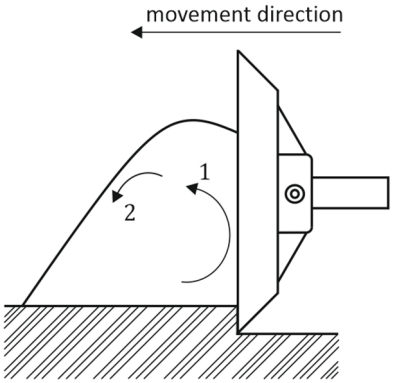

Figure 2 Working condition

So, it is possible to envisage composition of forces, which are redistributed in ploughshare during the working cycle. Based on this a forces redistribution, it can be calculate a working force and next step, according to this working force, is make a dimensioning construction, strength calculation and others operations, which are necessary for correct proposal. Redistribution of forces is in Figure 3.

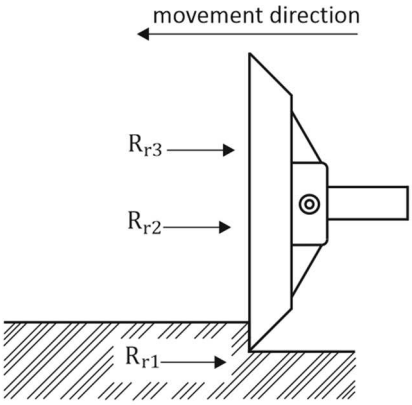

Figure 3 Redistribution of forces

Introduction:

- R_{r1} - cutting resistance of soil,
- R_{r2} - pushing resistance of soil,
- R_{r3} - friction resistance of soil.

A rigorous mathematical treatment for working force R_{rc} is given below:

$$R_{rc} = a.b.K + G_z.f_{zp} + G_z.f_{zr}.cos^2\gamma \quad (1)$$

Introduction:

- a - depth of cutting (m),
- b - width of cutting (m),
- K - the nominal resistance against cutting (kPa),
- G_z - gravity of pushing soil (N),
- f_{zp} - coefficient of friction of cutted material on the soil (-),
- f_{zr} - coefficient of friction of soil on the ploughshare (-),
- γ - inclination angle of the ploughshare (°).

Our determined of the R_{rc} value is R_{rc}= 34,9 kN.

2 Finite element method

The basic idea of the finite elements method is very simple. Mathematical functions, which we are looking at a particular area, we are interpolated so, that the region divide into sub-areas called finite elements. Within each analyse with finite element function is approximated appropriately chosen function clearly defined values in the fixed function and selected points called nodes. Instead of search function is a complex task with practically impossible, we are looking for now only a value in the nodes. The problem is thus discretized, the task is now to find it just a set of numbers. In classical mechanics of rigid bodies, this procedure leads to solving the system of linear algebraic equations of the type:

$$\boldsymbol{K\,d = R} \quad (2)$$

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Introduction:

- ***K***- stiffness matrix,
- ***d***- is a column matrix containing the searched values shifts in nodes,
- ***R*** - column matrix containing the external forces applied to the body [8].

2.1 Numerical simulations

For a numerical calculation was used Solidworks 2012 software. For a first necessary step we have set the correct boundary conditions at 3D model and a simplified mathematical model. It means that all 3D components of ploughshare that are not necessary for the correct calculation are removed and replaced with boundary conditions that reflect reality. This step is dramatically reducing the number of equations entering to the calculating. Advantages of this step are, reducing time used for solving equations. Thus, we have created a mathematical description of the areas to simplify the blade itself without arms (we assume, that a pushing arms are super rigid), bolts, and other structural members. Our monitored parameters for the simulation have the following values. Maximum tension generated in the material caused by working load force R_{rc} is σ_{max} = 190 MPa and for deformation δ_{max} = 3,84 mm. We have used a classical construction material with yield strength R_e =275 MPa. Redistribution of induced stress at ploughshare is in Figure 4 and Figure 5.

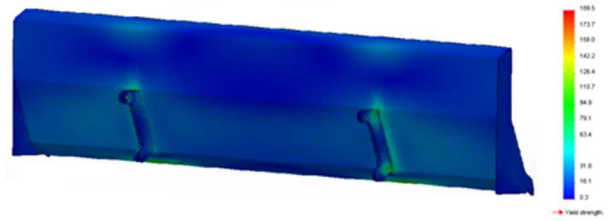

Figure 4 Redistribution of induced stress

It can be seen, that stress is created and manifests itself only at areas with the ploughshare handles. As was previously mentioned, the initial proposal blade is intended oversizers due to blade life time. The simulation No. 2 explores, what would happen if the ploughshare is overloaded. The blade is subjected by critical force. Information about this type of the simulation is in chapter bellow.

Figure 5 Redistribution of induced stress

2.2 Calculation with critical force

For this type of task, we have used a nonlinear calculation, the same steel material and the critical load is R_{rc2} = 50 kN. The maximum induced stress is σ_{max} = 277,5 MPa and induced deformations are δ_{max} = 5,51 mm. As can be seen, the watched value of the yield strength, have been exceeded about 22.5 MPa. This excess of yield strength causes a created plastic material in critical areas. After unloading, it is a state, when the blade ceases to operate the critical loads and system is returned to equilibrium state position, areas with a plastic materials have a same positions and what is only changing is a induced stress from σ_{max} = 277,5 MPa to σ_{odl} = 12,8 MPa (Figure 6).

Thus, it is possible to make a conclusion. If a critical load value reached maximum (σ_{max} = 277,5 MPa), the ploughshare is not seriously damaged due to a permanent plastic deformations created in areas, which are not affected the main design nodes and residual stress has a minimum value (σ_{odl} = 12,8 MPa).

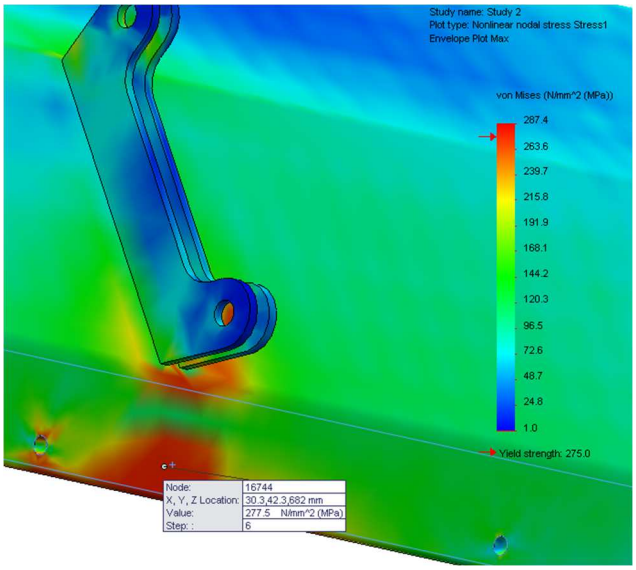

Figure 6 Areas with plastic material

It is appropriate to mention that such a state should be more thoroughly investigated and not to be really on the outcome of one simulation. For this reason, it has been made two independent simulations for confirmed the correctness of the first calculation with same results. Construction design of ploughshare is shown in Figure 7. The marks indicate the number of structural parts.

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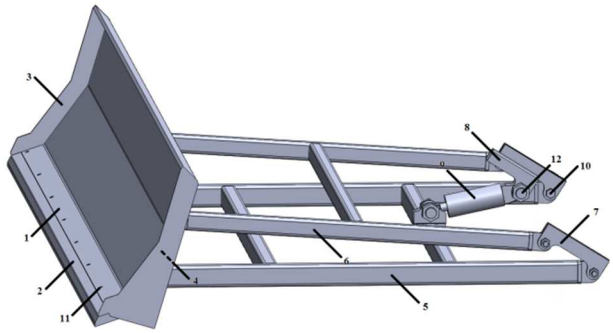

Figure 7 Ploughshare

Conclusion

Ploughshare is a tool for vehicles, which are used for working with soil. Developing process of a blade is very difficult in which the amount of unknown figures, which may negatively affect the reliability of the tool. We have presented the theoretical model of ploughshare to draw attention to areas of proposal, which have help to reader to understand this problematic.

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