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The influence of pressure to the stresses inside the plough body

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ABSTRACT

Purpose: The aim of the study was to examine the structure of the plough body and determining areas most susceptible to damage.

Design/methodology/approach: The analysis was performed using Finite Element Analysis (FEA) in AutoDesk Inventor Professional 2015. Characteristics of the materials that make up the individual parts correspond to the materials used for the production in the AGRO-MASZ company.

Findings: Studies have shown the greatest stress distribution in the mouldboard shin, mouldboard and leg. Highest stresses on mouldboard occur in the area, which is also the most exposed to the abrasive wear.

Research limitations/implications: It seems important to carefully examine the areas of the largest abrasive wear analysed plows bodies.

Practical implications: FEA analysis allows pre-testing of the properties of the part before manufacturing. Creating a model and adding forces and pressures to it allows for huge savings for companies. It is possible to find weaknesses in designed products before they cause problems. In the production of bodies for ploughs critical is the selection of suitable material and then subjecting it to specialist heat treatment.

Originality/value: Article allowed the estimation of the plow body stress of AGRO-MASZ company, the analysis of which has not yet been published. The studies allow for the continuous improvement of the quality of ploughs.

Keywords: Mouldboard design; Plough design; FEM analysis; Stress analysis

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ANALYSIS AND MODELLING

1. Introduction

Agriculture is an important sector of the economy. In order to produce food takes a lot of processes using dedicated machines. One such machine is the plough. Its construction has changed over the centuries [1]. Many research centres and companies conduct continuing studies to improve the construction of ploughs [2-9]. It is important to reduce the cost of fuel during plowing [10-12]. One of the important parts of the plow is a mouldboard. One of the important parts of the plow is mouldboard. Its shape [13-18] and tribological properties [19] have a great influence on the work of the plough.

In this paper the influence of pressure directed at the working surfaces of the plough body to the stresses inside the structure was analysed. The analysis was performed using Finite Element Analysis (FEA) in AutoDesk Inventor Professional 2015 [20]. FEA analysis allows pre-testing of the properties of the part before manufacturing. Creating a model and adding forces and pressures to it allows for huge savings for companies. It is possible to find weaknesses in designed products before they cause problems.

Characteristics of the materials that make up the individual parts correspond to the materials used for the production in the AGRO-MASZ company after suitable heat treatment.

The construction of the plough body shown in Figure 1.

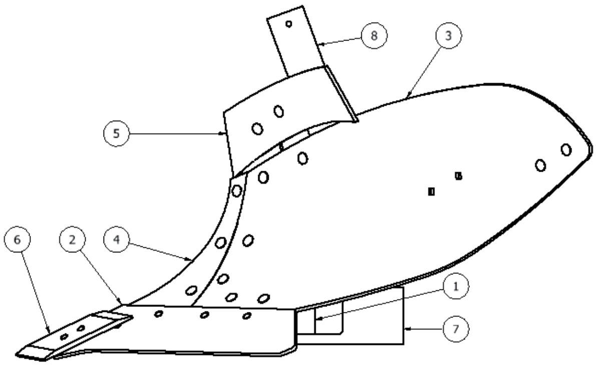

Fig. 1. Plough body parts: 1 – frog, 2 – share, 3 – mouldboard, 4 – mouldboard shin, 5 – trashboard, 6 – reversible point, 7 – landside, 8 – leg

2. Research

In order to perform FEA analysis should be done a discretization of the model. The model is divided into 347.880 nodes, of which were built 203.464 elements.

Figures 2 to 7 show detail six types of views including the mesh.

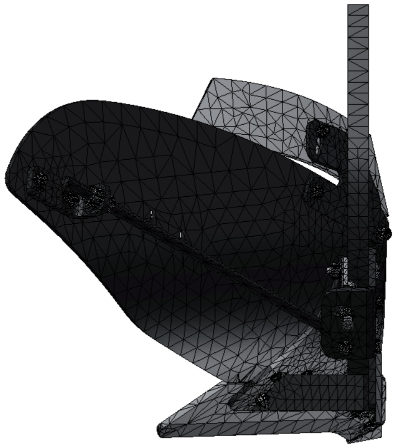

Fig. 2. Rear view with mesh

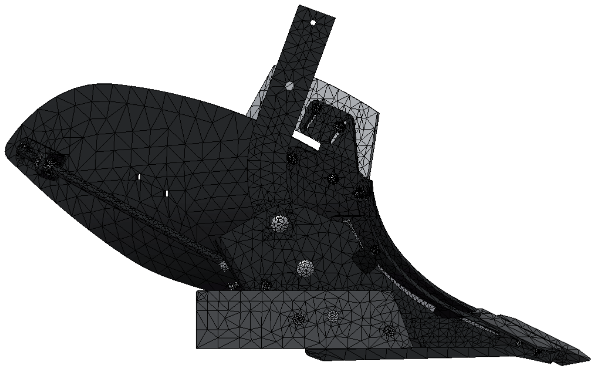

Fig. 3. Left view with mesh

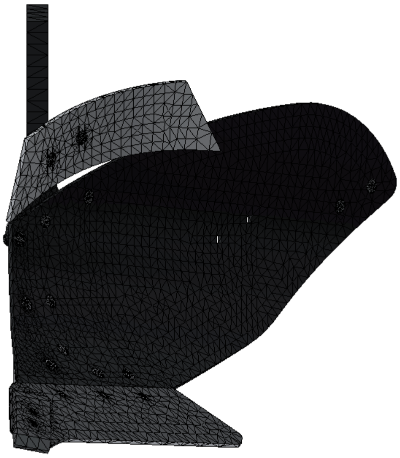

Fig. 4. Front view with mesh

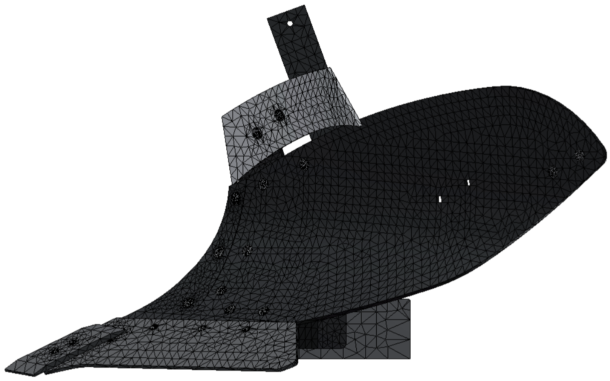

Fig. 5. Right view with mesh

Fig. 6. View from the top with mesh

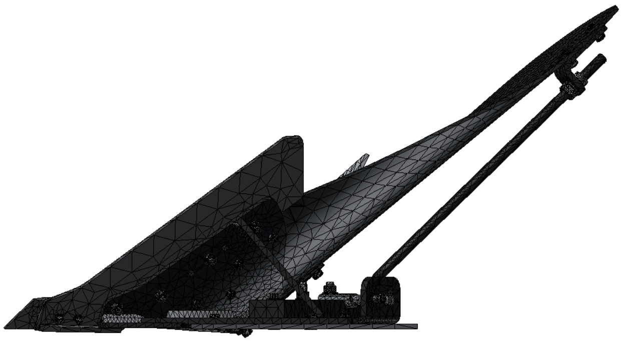

Fig. 7. View from the bottom with mesh

The physical properties of the part designated in Inventor: mass: 75.9 kg, area 208 dm^2, volume 9.7 dm^3.

Examined were three cases in which the pressure applied to the working surfaces was as follows: 0.1 MPa, 0.2 MPa and 0.4 MPa. The aim of the study was to examine the structure of the plough body and determining areas most susceptible to damage. Figure 8 shows the areas to which pressure was applied. The model was locked on upper part of the leg.

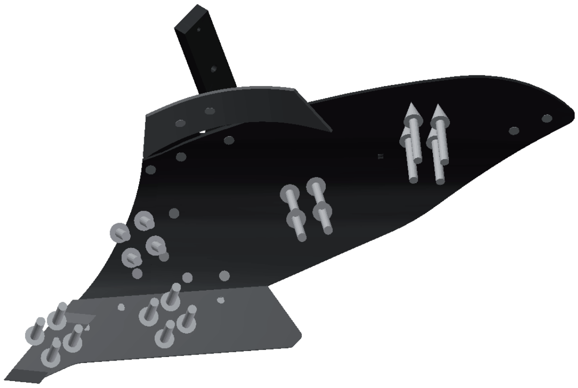

Fig. 8. The arrows show the surface to which pressure was applied

The results obtained are summarized in Tables 1-4 and in Figures 9-23 for all examined pressure values. In Figures 9-11, 14-16 and 19-21 was the same scale in order to better illustrate the stress distribution.

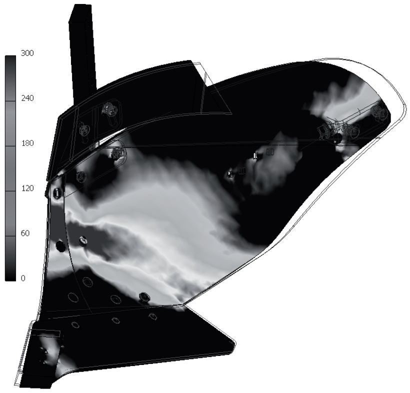

Fig. 9. Right view of 1st Principal Stress for pressure 0.1 MPa

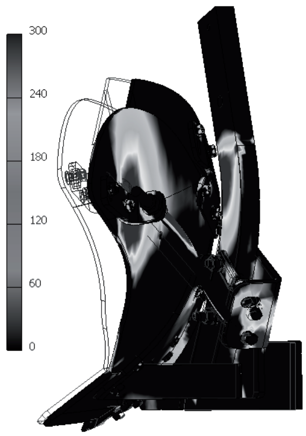

Fig. 10. Rear view of 1st Principal Stress for pressure 0.1 MPa

Table 1.
The results of the plow body FEA analysis for a pressure of 0.1 MPa

Name	Minimum	Maximum
Von Mises Stress	0.00111796 MPa	11060.7 MPa
1st Principal Stress	-4093.05 MPa	9408.58 MPa
3rd Principal Stress	-15840.9 MPa	2332.06 MPa
Displacement	0 mm	37.9313 mm
Safety Factor	0.0187149 ul	15 ul
Stress XX	-12781.1 MPa	7823.97 MPa
Stress XY	-2473.66 MPa	3243.68 MPa
Stress XZ	-3187.68 MPa	3381.45 MPa
Stress YY	-6528.48 MPa	4705.33 MPa
Stress YZ	-2757.78 MPa	2323.73 MPa
Stress ZZ	-6251.99 MPa	7396.35 MPa
X Displacement	-0.211971 mm	26.9386 mm
Y Displacement	-12.6234 mm	0.905911 mm
Z Displacement	-25.8247 mm	5.62695 mm
Equivalent Strain	0.00000000462042 ul	0.049333 ul
1st Principal Strain	-0.000105087 ul	0.0402426 ul
3rd Principal Strain	-0.0598534 ul	0.0000600632 ul
Strain XX	-0.0421203 ul	0.0331196 ul
Strain XY	-0.014336 ul	0.0187986 ul
Strain XZ	-0.018474 ul	0.019597 ul
Strain YY	-0.0271679 ul	0.0117117 ul
Strain YZ	-0.0159826 ul	0.0134671 ul
Strain ZZ	-0.0204245 ul	0.0237859 ul
Contact Pressure	0 MPa	9231.91 MPa
Contact Pressure X	-8154.72 MPa	8552.38 MPa
Contact Pressure Y	-7408.73 MPa	6385.79 MPa
Contact Pressure Z	-8179.27 MPa	7860.82 MPa

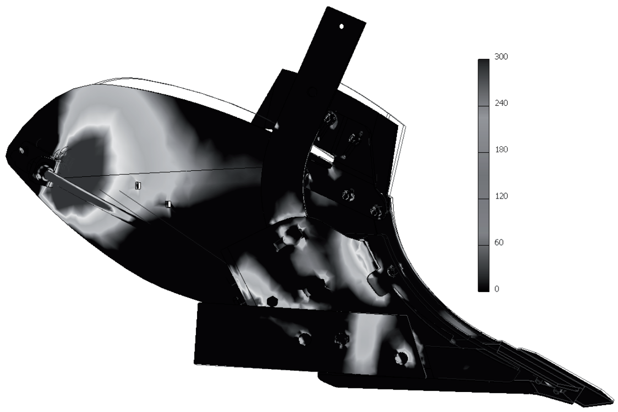

Fig. 11. Left view of 1st Principal Stress for pressure 0.1 MPa

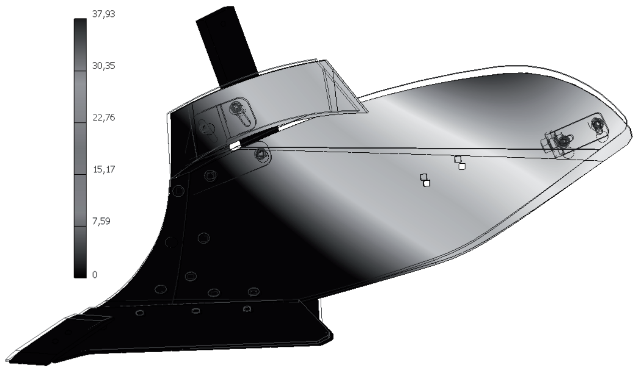

Fig. 12. Right view of displacement for pressure 0.1 MPa

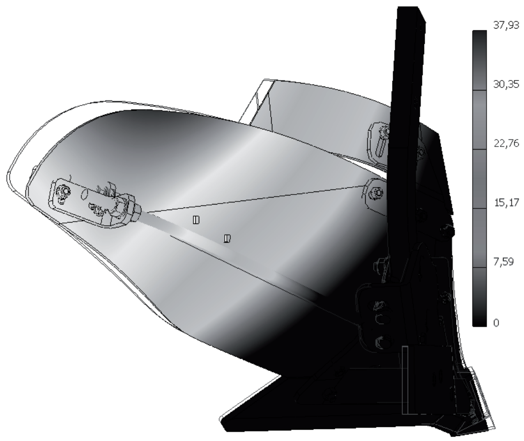

Fig. 13. Rear view of displacement for pressure 0.1 MPa

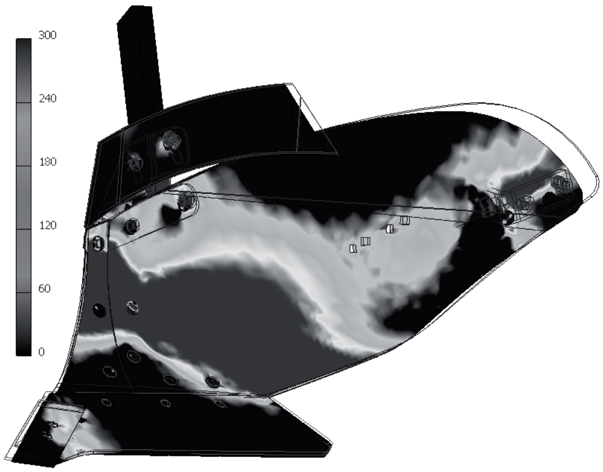

Fig. 14. Right view of 1st Principal Stress for pressure 0.2 MPa

Table 2.
The results of the plow body FEA analysis for a pressure of 0.2 MPa

Name	Minimum	Maximum
Von Mises Stress	0.00271526 MPa	22127.5 MPa
1st Principal Stress	-8189.83 MPa	18819.9 MPa
3rd Principal Stress	-31691.4 MPa	4665.42 MPa
Displacement	0 mm	75.8626 mm
Safety Factor	0.00935487 ul	15 ul
Stress XX	-25571 MPa	15646 MPa
Stress XY	-4947.42 MPa	6488.74 MPa
Stress XZ	-6375.82 MPa	6765.04 MPa
Stress YY	-13060.8 MPa	9411.29 MPa
Stress YZ	-5515.62 MPa	4646.96 MPa
Stress ZZ	-12507.7 MPa	14795.9 MPa
X Displacement	-0.423957 mm	53.8772 mm
Y Displacement	-25.2467 mm	1.81182 mm
Z Displacement	-51.6493 mm	11.254 mm
Equivalent Strain	0.0000000131427 ul	0.0986941 ul
1st Principal Strain	-0.000210462 ul	0.0804768 ul
3rd Principal Strain	-0.119742 ul	0.00012052 ul
Strain XX	-0.0842711 ul	0.0662338 ul
Strain XY	-0.0286725 ul	0.0376052 ul
Strain XZ	-0.0369508 ul	0.0392065 ul
Strain YY	-0.0543324 ul	0.0234245 ul
Strain YZ	-0.0319655 ul	0.0269312 ul
Strain ZZ	-0.0408497 ul	0.0475843 ul
Contact Pressure	0 MPa	18464 MPa
Contact Pressure X	-16329.3 MPa	17103.1 MPa
Contact Pressure Y	-14818.1 MPa	12772.9 MPa
Contact Pressure Z	-16355.4 MPa	15718.8 MPa

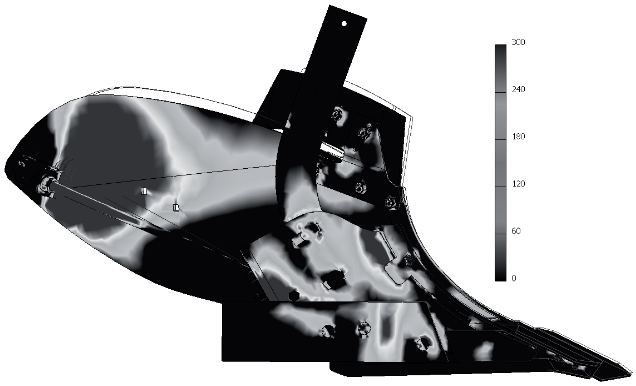

Fig. 16. Left view of 1st Principal Stress for pressure 0.2 MPa

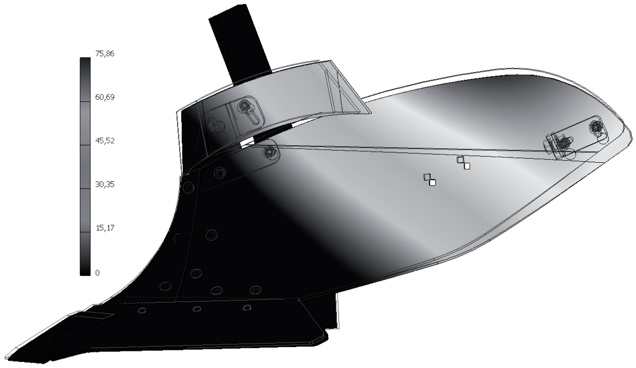

Fig. 17. Right view of displacement for pressure 0.2 MPa

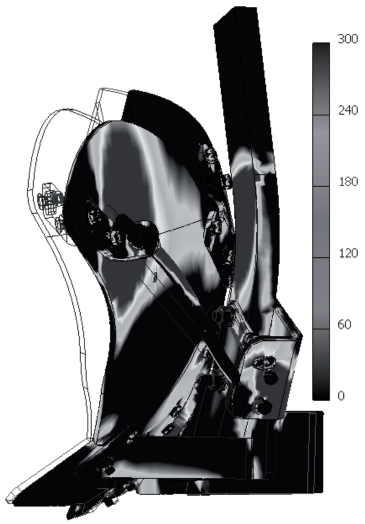

Fig. 15. Rear view of 1st Principal Stress for pressure 0.2 MPa

Fig. 18. Rear view of displacement for pressure 0.2 MPa

Table 3.
The results of the plow body FEA analysis for a pressure of 0.4 MPa

Name	Minimum	Maximum
Von Mises Stress	0.00543192 MPa	44255 MPa
1st Principal Stress	-16379.6 MPa	37639.8 MPa
3rd Principal Stress	-63382.7 MPa	9330.84 MPa
Displacement	0 mm	151.725 mm
Safety Factor	0.00467744 ul	15 ul
Stress XX	-51141.9 MPa	31292 MPa
Stress XY	-9894.84 MPa	12977.5 MPa
Stress XZ	-12751.6 MPa	13530.1 MPa
Stress YY	-26121.6 MPa	18822.6 MPa
Stress YZ	-11031.2 MPa	9293.96 MPa
Stress ZZ	-25015.3 MPa	29591.8 MPa
X Displacement	-0.847914 mm	107.754 mm
Y Displacement	-50.4934 mm	3.62364 mm
Z Displacement	-103.299 mm	22.508 mm
Equivalent Strain	0.0000000262533 ul	0.197388 ul
1st Principal Strain	-0.000420922 ul	0.160954 ul
3rd Principal Strain	-0.239483 ul	0.00024107 ul
Strain XX	-0.168542 ul	0.132468 ul
Strain XY	-0.0573451 ul	0.0752104 ul
Strain XZ	-0.0739015 ul	0.0784128 ul
Strain YY	-0.108665 ul	0.046849 ul
Strain YZ	-0.0639311 ul	0.0538627 ul
Strain ZZ	-0.0816994 ul	0.0951686 ul
Contact Pressure	0 MPa	36928.1 MPa
Contact Pressure X	-32658.3 MPa	34206.3 MPa
Contact Pressure Y	-29636.3 MPa	25545.8 MPa
Contact Pressure Z	-32710.9 MPa	31437.7 MPa

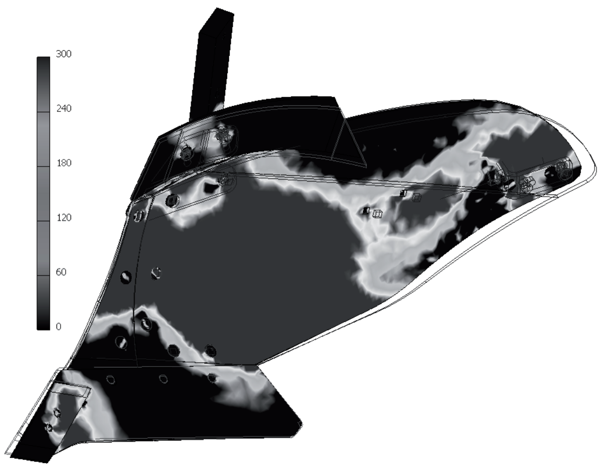

Fig. 19. Right view of 1st Principal Stress for pressure 0.4 MPa

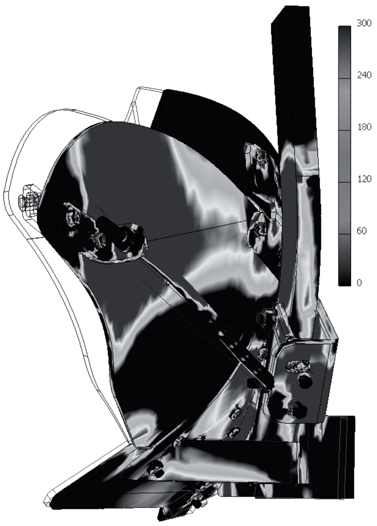

Fig. 20. Rear view of 1st Principal Stress for pressure 0.4 MPa

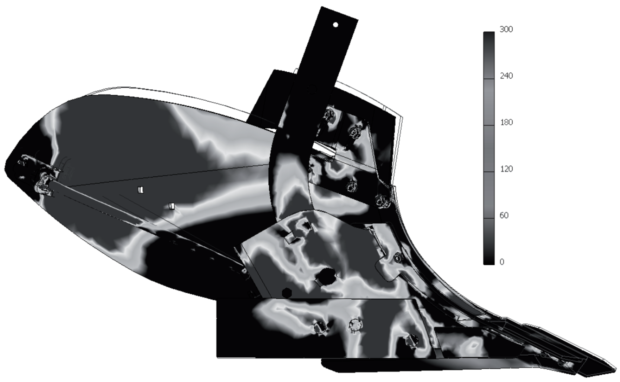

Fig. 21. Left view of 1st Principal Stress for pressure 0.4 MPa

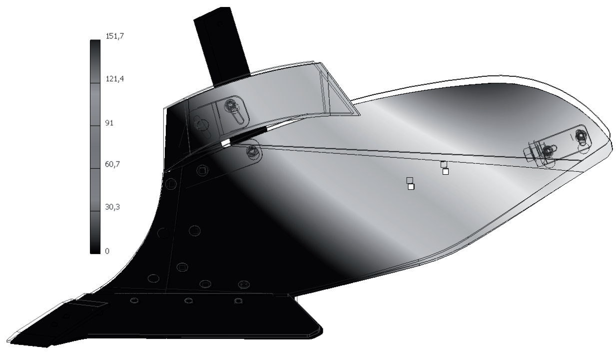

Fig. 22. Right view of displacement for pressure 0.4 MPa

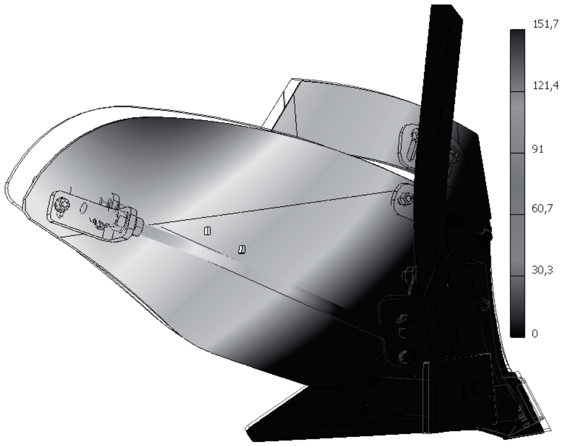

Fig. 23. Rear view of displacement for pressure 0.4 MPa

Table 4.
Reaction Force and Moment on Constraints

Pressure, MPa	Reaction Force, kN		Reaction Moment, kNm	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
0.1	39.9	-23.6	14.2	-9.7
		12.0		-4.3
		29.8		-9.4
0.2	79.9	-47.1	28.4	-19.4
		24.0		-8.6
		59.7		-18.8
0.4	159	-94.3	56.5	-36.7
		48.0		-14.5
		119.3		-40.4

3. Conclusions

Studies have shown the greatest stress distribution in the mouldboard shin, mouldboard and leg. Mouldboard deformation is proportional to the applied pressure. Highest stresses on mouldboard occur in the area, which is also the most exposed to the abrasive wear. In the production of bodies for plows, particularly mouldboard, critical is the selection of suitable material and then subjecting it to specialist heat treatment.

FEA analysis allowed to determine the largest stress areas where it is necessary to use high-quality steel subjected to specific heat treatment process allows to obtain a material with the highest: hardness toughness and resistance to abrasive wear.

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