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Evaluation of the Moldboard Structure Resistance of the Grader Equipment

In this paper, the author presents a method for evaluation of the moldboard structure resistance of the motor-graders. Usual grader model was chosen to be analyzed by the FEM. Horizontal force of the blade was estimated using the classical soil mechanics theories for cutting soil proposed by McKyes. The simulation results can be useful for structural performance evaluation of these machine used in construction and agricultural fields.

Keywords: *grader, moldboard, analysis, FEM*

1. Introduction

The motor graders are technological equipments specialized for different tasks developed at construction or agricultural fields, such as: grading, levelling, profiling, and other activities that require fine control over the placement of soil transported land. The working tool of the grader consists on a blade which is characterized by higher manoeuvrability at horizontal, vertical and lateral directions.

Several researchers [6, 7] have found that working tools acting on the soils encounter vibrations which are excited by the soil resistance to cutting process with frequencies until 10 Hz function by the velocity of machine motion.

In this paper, the author investigated the frequencies range of the grader blade and the response to the actions applied on its surface in grading operation, assuming that the soil resistance do not has the periodical fluctuation. In addition, the impact of the blade with the rigid obstacle will be studied.

2. Evaluation of the resistance forces to the cutting soil

McKyes [2] established some assumptions regarding the piling action in front the blade, as follows:

a) the pile action in the OY axis can be considered as normal pressure applied on the soil wedge;
b) the normal pressure is distributed uniformly on the blade;
c) the soil bulk is pushed by the equipment of earthmoving machine and slides above the surface of the ground;
d) the horizontal force caused by the traction system of the technological equipment is influenced by the soil proprieties (internal friction and cohesion).

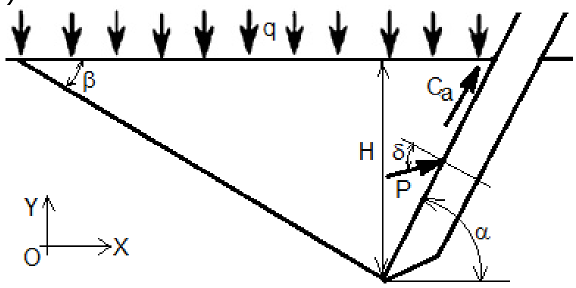


Figure 1. Model of McKyes for cutting soil

The passive force developed by the soil pile in front of the grader blade can be estimated as:

$$P = \left(\gamma H K_p + C_a K_{ca} + C K_c + q K_q\right) H l \tag{1}$$

where *H* is the cutting depth; *l* – width of the blade; γ - weight density of the soil; *C* – the cohesion of the soil; C_a – the cohesion at blade-soil interface; α - the inclination angle of the blade; β - the failure angle; *q* – the surface pressure; F_m – pushing force of the grader moldboard; *G* – weight of the blade.

The coefficients K_p, K_{ca}, K_c, K_q represent a function by the next parameters:

$$K_p, K_{ca}, K_c, K_q = f(\alpha, \beta, \varphi, \delta) \tag{2}$$

where φ is the soil friction angle; δ - the soil-blade friction angle.

The soil properties are: c=20 000 N/m^2, φ=30° and γ=1800 kg/m^3.

The force that is applied on the blade in working phase can be projected at two directions and result the horizontal and vertical forces with the following expressions:

$$\begin{aligned} F_x &= F_m + P\sin(\alpha+\delta) + C_a l H \cos\alpha, \\ F_y &= W + P(\alpha+\delta) - C_a l H. \end{aligned} \tag{3}$$

Shmulevich [5] estimated the surface pressure *q* and the horizontal force F_m applied on the moldboard by function of the displacement *d* of the motion of the blade, by the next expressions (3):

$$q = 0.5\gamma g d \frac{tg\alpha tg\beta}{(tg\alpha + tg\beta)}, \quad (4)$$

$$F_m = 0.5\gamma g d l tg\varphi . \quad (5)$$

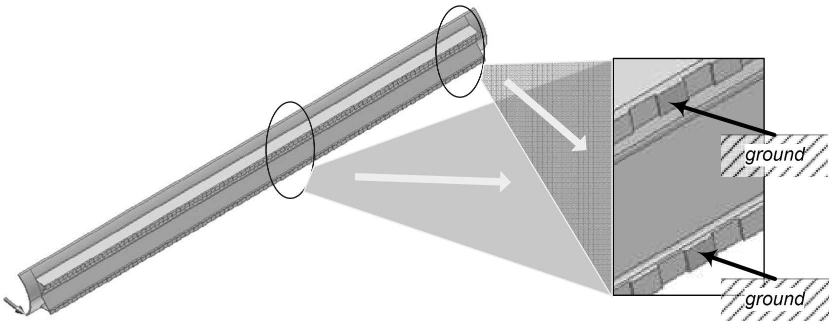
In the following, for qualitative estimation of quasi-static states of blade behavior, basic numerical analysis technique such as the finite element method (FEM) will be used.

3. FEM analysis of the grader blade.

To calculate the resistance structure of the moldboard will consider that the grader carries out levelling earthmoving, accidentally, very rigid blade obstacle. For obstacle passing over, the blade is pressed down until full sliding wheels and wheel lift axle on the ground earlier.

A typical constructive solution for moldboard grader in Figure 2 a) is presented. The loads and the spatial configuration of grounded constraints points for blade in Figure 2 b) were shown.

a) the grader equipment;



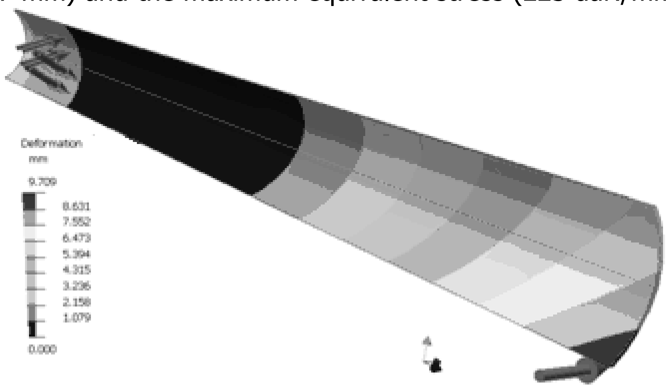
b) the modelling of the blade with loads and constraints.

Figure 2. Modelling of the grader blade.

The zones where grounded constraints were placed derived from the montage configuration according with linkage system between the blade and the drawbar. It has to be mentioned that the constraints of the blade was placed with simplified configuration of the application area such as plane surface in respect with interface area between moldboard and drawbar arm(s) [1]. After 3D blades generating, the authors studied the blade behavior under the soil passive resistance (F_x = 7 kN distributed on the all blade) concomitantly with the impact of a rigid obstacle materialized by a resistance R_x = 3,5 kN applied on a blade corner. Numerical simulation of blade with section area 400 mm x 15 mm and length 4200 mm, to the action of previous forces was carried out [3,4]. It has been assumed that the blade are made by a material with isotropic properties (Young's modulus: 200000 N/mm^2; Poission's ratio: 0.27; density: 7890e-9 kg/mm^3).

The results of FEM analysis was depicted in Figure 3. The parameters which defined the resistance of the metallic structure of the blade consist on: maximum deformation (9.7 mm) and the maximum equivalent stress (223 daN/mm^2).

a)



b)

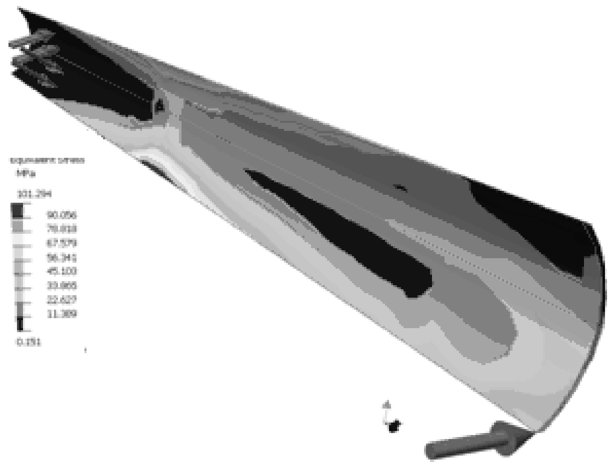


Figure 3. Results of FEM analysis:
a) deformation; b) equivalent stress.

In Table 1 are given the natural frequencies for the first ten vibration modes of the grader blade.

Table 1.

Vibration modes	Natural frequency [Hz]
1	24.10
2	53.36
3	100.25
4	148.03
5	248.87
6	287.14
7	315.44
8	336.24
9	380.59
10	424.06

It can be observed that values obtained for the natural frequencies are greater that 10 Hz, different by frequencies of vibrations induced by the soil resistance to cutting process.

4. Conclusion

In this paper, the FEM was used to simulate the response of the grader blade under the external loads induced to the impact with the rigid obstacle. Over the all blade acting the resistance to cutting soil and only at the corner blade acting resistance force of the obstacle

Excessive operational stresses can develop both structural damages of some equipment parts, and certain precision deviation of working technological parameters. The major purpose of this analysis results from the fact that the blade with its linkage system at the drawbar is an important part of the equipment ensemble.

New models of the graders have automatic grade control devices mounted to the blades that allow for control of the technological parameters developed in the grading operation in view of diminishing the deviation on the technical requirements imposed.

An optimal correlation between constructive parameters of the blade, in fact the moldboard, soil characteristics and velocity of the pushing pile will be able to supply a proper evolution of grader equipment structure during the working cycle and to assure regulated values of precision of technological parameters by avoiding the appearance of the resonance.

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