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COMPARATIVE ANALYSIS BETWEEN OPERATIONAL PERFORMANCES OF MOTOR GRADER EQUIPMENTS

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ABSTRACT

This paper generally deals with technological equipments for construction and agricultural works, and evaluated the operational performances for motor-grader equipments. Starting from a large review of modern motor-grader equipments provided by various companies in the world, this study was developed on two cases of grader blade with different structural and functional configurations. Analysis reveals both static and dynamic working regime information, with the most relevant exploitation cases for each type of blade. According to the experimental data and based on the comparative computational study, it results that the operational performances analysis of the grader structure with the entire equipment configuration frames the first necessary step of a correct design procedure.

KEYWORDS: motor-grader, functional capacity, FEM-FEA

1. INTRODUCTION

The motor graders are technological equipment working bodies in the shape of blade with which to dig at low depth, levelled, profiled, and transported land (Fig.1).

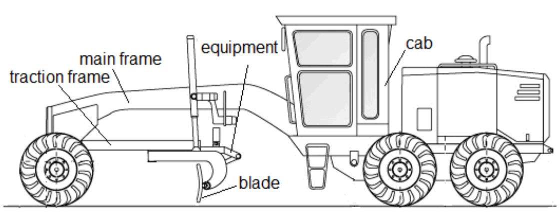


Fig. 1. The main grader's components

These types of machines are characterized by a better handling of an actively working body (blade) that is oriented horizontally, vertically and laterally displaced. The manoeuvrability of the blade and the development of the needed force for the blade to penetrate the soil are the main requirements imposed for ensuring operational performance of the motor grader.

2. EVALUATION OF DYNAMIC LOADS IN THE GRADER'S STRUCTURE

To calculate the resistance structure of the metal construction grader we will consider two unfavourable working hypotheses:

a) hypothesis 1: while working towards the end of digging, due to the vertical blade pressed, the machine reaches the limit of adhesion of the rear wheels and the front driven becomes detached from the ground;
b) hypothesis 2: whilst grader carries out levelling earthmoving, accidentally, very rigid blade snags. For obstacle passing over, the blade is pressed down until full sliding wheels and wheel lift axle on the ground earlier.

In this paper will be considered the dynamic loads that are transmitted in metallic construction of a grader induced by sudden changes in speed, with negative acceleration due to collision with a rigid obstacle appeared on the grader blade (hypothesis 2).

The motion equation of the equipment with the blade on terrain has the following form:

$$m^{*}\ddot{x} = F_t - (F_f \pm mg\sin\theta) - W_x \qquad (1)$$

where: m^* is the total reduced mass; m - total mass of the machine in translational motion; F_t –traction force; F_f - global rolling resistance; $\ddot{x}$- instantaneous acceleration; η_m- total efficiency of the transmission engine - drive wheels; W_x – terrain resistance at the blade.

In this paper, only the blade’s response to loads action will be dealt with. The static and dynamic behavior of the blade’s grader can be evaluated either by experimental measurements or by simulation. Thus, for hard graders that are digging in homogeneous heavy soils (type IV), the linear specific resistance values on the blade are given in Table 1.

Table 1. Values of the resistances [3]

Cutting resistance, in kN/m^2	Resistance on the blade, in kN/m	
	Calculus	Tests
170	50-125	75

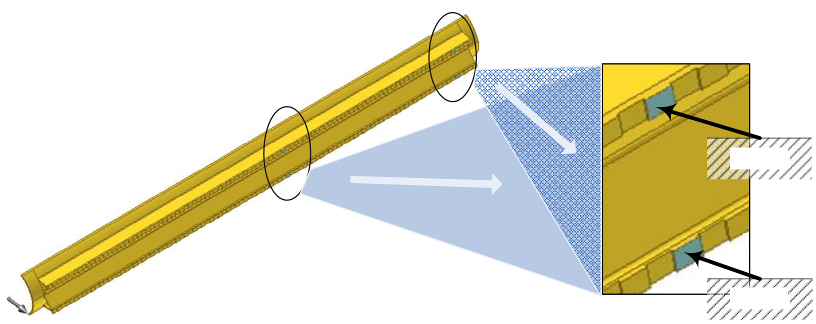
For estimation of static and dynamic states of the blade’s behavior, it is recommended a common numerical analysis technique such as the finite element method – FEM [1,2].

3. MODELING AND ANALYSIS OF GRADER’S BLADE

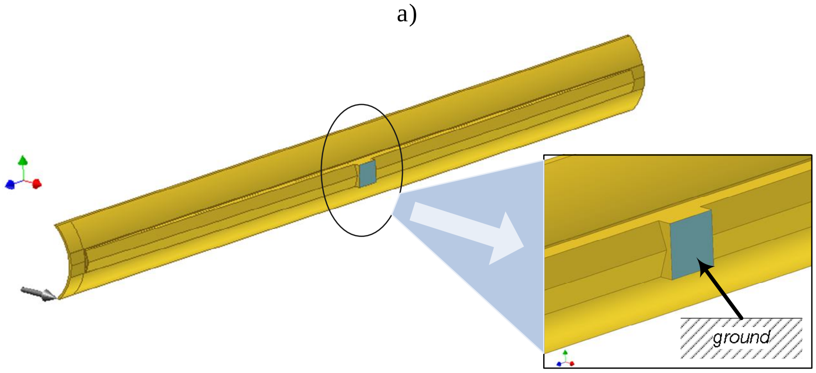
Some existing constructive solutions for the grader blade are presented in Figure 2.

Fig. 2. Constructive solutions for the grader’s blade (Caterpillar, Volvo, John Deere models)

In this paper, two different types of blades (type A and B) were selected by the authors for the comparative analysis between the operational performances. In Fig.3 it was depicted the spatial configuration of grounded constraints points for the two types of blade.



a)



b)

Fig.3. Grounded constraints position
a) on type A blade; b) on type B blade.

The zones where grounded constraints were placed derived from the montage configuration according to the linkage system between the blade and the drawbar. It has to be mentioned that for both blade types the constraints were placed with simplified configuration of the application area such as plane surface in respect with interface area between moldboard and drawbar arm(s). After 3D blades generating, the authors studied the static and dynamic blade's behavior under external forces produced by the impact of a rigid obstacle.

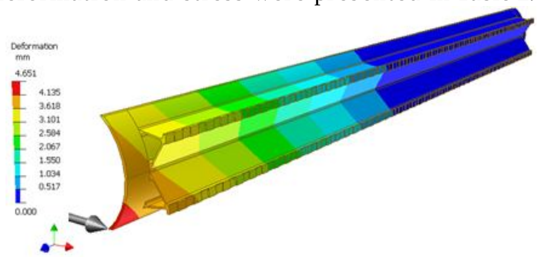
Two cases will be analyzed in this section:

a) scenario 1: the blade type A is subjected to the action of an obstacle materialized by a force F = 5 kN applied on a blade's corner;
b) scenario 2: blade type B is subjected in the same way as in scenario 1 (first case study). For the second case study, it was considered the concomitant external forces on the blade: a force of 5 kN on a blade's corner, a force of 2 kN in the median plane of the blade and a force uniformly distributed (represented cutting resistance) equal to 170 kN/m^2.

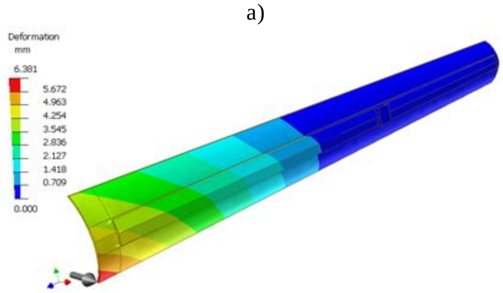
Numerical simulation of two blades with section area of 400 mm x15 mm and length of 4200 mm, to the action of impact force was carried out using FEM. It has been assumed that the blades are made from a material with isotropic properties as follows:

- Young's modulus: 200000 N/mm^2;
- Poission's ratio: 0.27;
- Density: 7890e-9 kg/mm^3.

The results of FEM analysis were depicted in Fig.4-6, and the maximum values of deformation and stress were presented in Table 2.

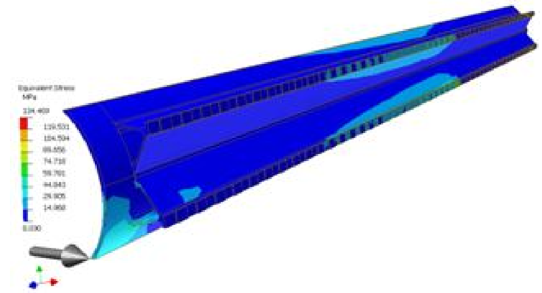


a)

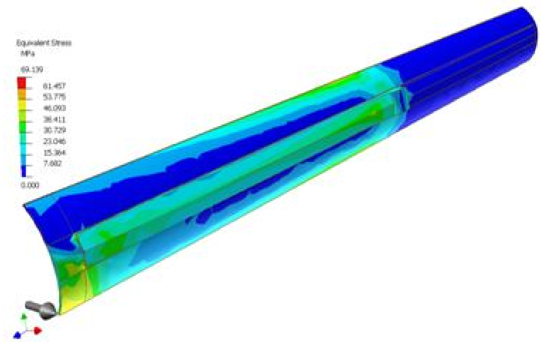


b)

Fig. 4. Deformations of the two blades
a) type A; b) type B.

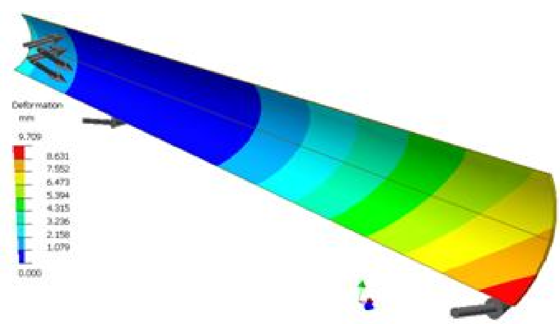


a)

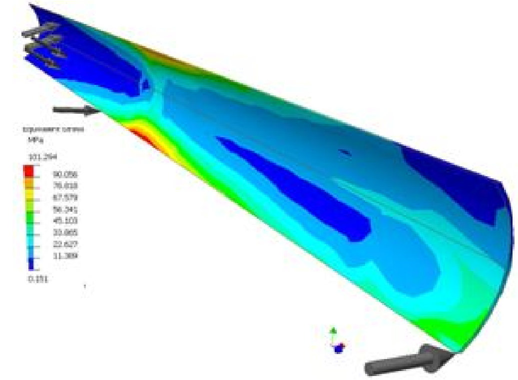


b)

Fig. 5. Equivalent stress into the material of the two blades
a) type A; b) type B (first case study).



a)



b)

Fig.6 Analysis of the second case of scenario 2
a) deformation; b) equivalent stress

Table 2 Results of FEM analysis

FEM / Blade	Type A	Type B	
		Case 1	Case 2
Deformation max., in mm	4.6	6.3	9.7
Equivalent stress max., in daN/mm^2	234	69.1	201.2

In Table 3 were presented the values of natural frequencies for the first ten vibration modes, for both types of blade. A global view of these data reveals low frequency range for both cases. This comparative analysis shows that even if the first natural mode has roughly the same values, the other modes acquire different trends for each blade type.

Table 3 Values of the natural frequencies

Blade's vibration modes	Natural frequency [Hz]	
	Type A	Type B
1	24.10	26.56
2	53.36	31.92
3	100.25	42.92
4	148.03	64.99
5	248.87	101.52
6	287.14	108.58
7	315.44	148.45
8	336.24	165.44
9	380.59	218.91
10	424.06	226.12

The comparative diagram depicted in Fig.7 highlighted these trends. Hereby, from the quantitative point of view, the type A blade provides roughly double values compared to the type B.

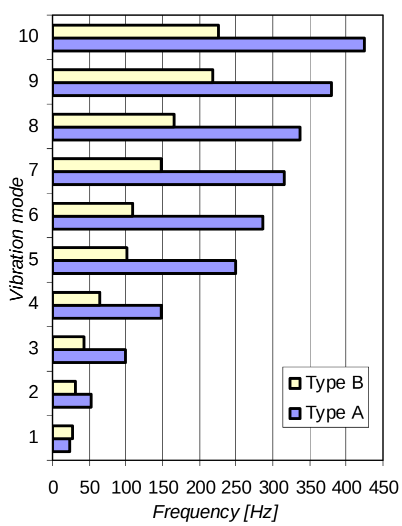


Fig.7. Comparative analysis of natural frequencies for the two types of blade

Structural configuration of the linkage system for type A blade leads to high stiffness of this solution and obviously to higher values of natural frequencies. Simplified linkage solution for type B blade provides a considerable reduction in stiffness and of course in natural vibration mode frequencies. These changes of natural frequencies appear even if the grounded point distributions for both type show that the free length of the type A blade is bigger than the type B (supposing the case of cantilever beam with bevel force acting on the free end).

The major purpose of this dynamic analysis results from the fact that the blade with its linkage system at the drawbar is an important part of the equipment ensemble. Hereby the blade dynamics actuates on the other parts and can bring these to a resonant working regime with harmful influences on the entire equipment ensemble including the hydraulic driving system. Because of these facts, the dynamic effects can produce both structural damages to some equipment parts, and a certain precision deviation to the main technological parameters. The correlation between the blade's parameters, in fact the moldboard, and the other parts of the grader equipment will be able to supply a proper evolution of the grader equipment structure during the working cycle and to ensure regulated values of precision of technological parameters.

4. CONCLUSIONS

The main conclusive remark of this study reveals the opportunity and the necessity of a correlated analysis between the working body and the passive structure for one of the most versatile equipment of construction and agricultural works, namely the motor-grader. In the first instance this is a qualitative computational analysis based on experimental data and on nowadays experience of different top suppliers for this kind of equipments. Quantitative values of essential parameters were used exclusively for comparative evaluations. Obviously the next step has to be a dedicated study, both computational, and "in situ" so that these estimative remarks change to a clear and particular final conclusions.

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