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DETERMINATION DYNAMIC CHARACTERISTICS OF ROADHEADERS BOOM WITH CUTTING HEAD

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ABSTRACT

Roadheaders are the primary excavating machines of many mines also called as continuous miner machines. Their structure is exposed to a complex interaction of the dynamic forces that cause vibrations and shocks. This leading to excessive wear of individual components of the device. The paper shows new methodology of designing main components of roadheader. Innovative solutions of a boom with cutting head was chosen to show design process by using advanced computer methods. The simulation study takes into account the kinematics and dynamics of the boom and its influence on the dynamic characteristics of the supporting structure.

Keywords: mining, roadheader, finite element method, modal analysis.

INTRODUCTION

The roadheaders boom with cutting head is a one of the most exposed machine component to the dynamic forces. Therefore there is a need to determine dynamic characteristics of that structure by using available mathematical and numerical tools. The study was to concentrate on dynamic response of structure by using finite element method. The geometrical model of roadheader boom was parameterized for further optimization process. The most critical points in methodology were determining initial boundary condition and identifying forces from interaction between cutting head and longwall.

THE MODELED SYSTEM

The modeled roadheader boom has a innovative type of transmission mechanical power to cutting head. In conventional solution main motors are usually located in arm and the mechanical power is transmitted by shaft to the main gear unit. In the considered solution the main gear unit is connected to PMSM electric motors located inside in the cutting head. This new concept allows to reduce cross-section of arm through less requirements for structure stiffness and minimized weight of the whole roadheader.

The geometrical model of roadheader boom with cutting head was shown in Figure 1. The structure consist of boom with two rotational joints, first one for providing rotation and second one for hydraulic actuator which force motion of cutting head along longwall. The cutting head is composed of three rotational steel drum with cutting tools. While cutting head is usually rotating approximately 50 rpm, each cutter react with rocks and produce torsional moment along cutting head axis. That dynamic process cause vibrations and transfer loads to the whole structure.

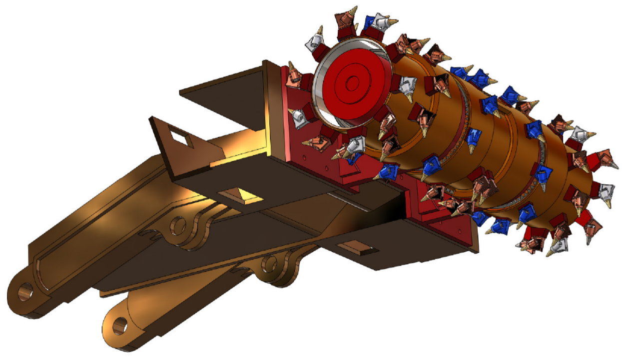


Fig. 1 The geometrical CAD model of roadheader boom.

THE NUMERICAL MODEL

The numerical model of roadheader boom was developed in LS-PrePost software and MATLAB environment. Appropriate script was created in aim of parameterized geometrical model of boom. The finite element model was shown in Figure 2.

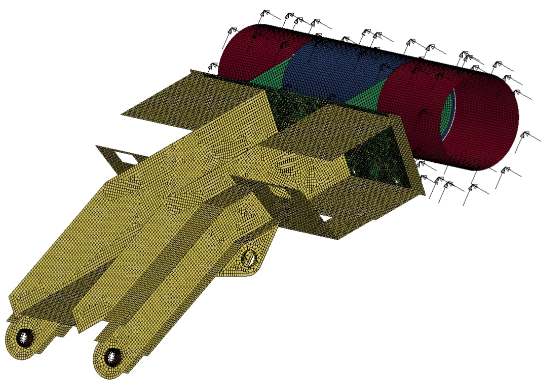


Fig. 2 The numerical FEM model of roadheader boom.

The lay-out of cutter was presented on surface development – Figure 3. The particular forces from individual cutter are recalculated to resultant torque. The spacing between cutters produce different excitation frequencies. This is the most undesirable load which may cause resonance of whole structure. Therefore there is a need to precisely determine boundary and initial conditions during roadheader cutting process.

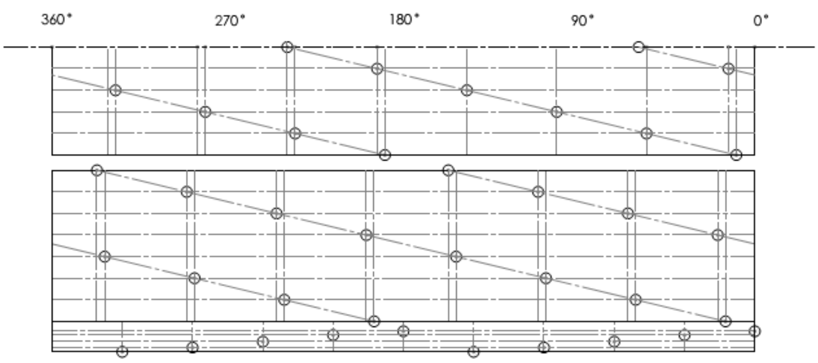


Fig. 3 The surface development of cutting head.

The starting point for the analysis is rotational speed of cutting head during the cutting process. The assumption for numerical analysis is variable value of cutting head angular velocity from 0 rpm to 60 rpm. In this case dynamic loads are the most unfavorable because excitation frequencies are time-dependent and may cause interaction with natural frequencies of structures in specific frequency range. For example the excitation loads at constant angular velocity (50 rpm) was shown Figure 4. The resultant torque and FFT of this signal cause five frequencies excitation in range from 0 Hz to 6 Hz.

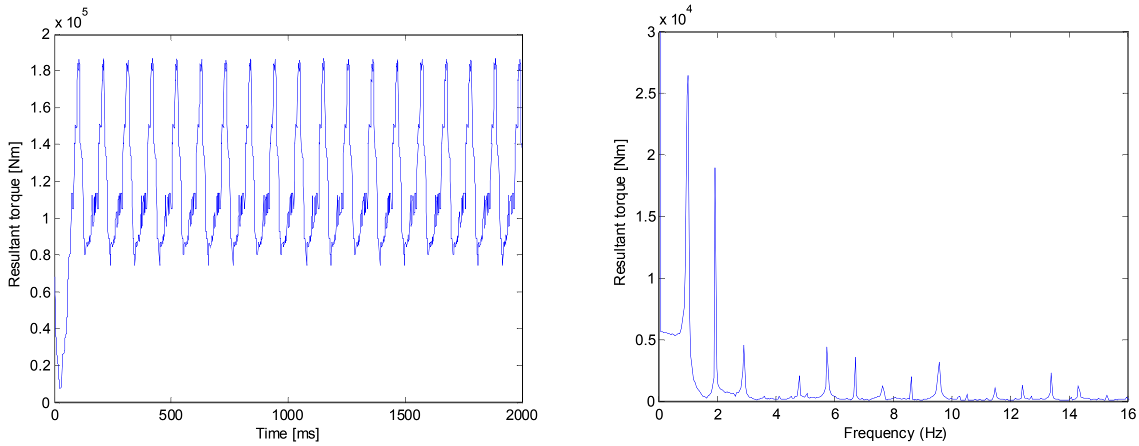


Fig.4 The resultant torque excitation signal.

The boundary condition was applied by four rotation joint in body boom. The considered kinematics of model had two degree of freedom. The first is related to boom motion and the second to cutting head rotation. This boundary condition was presented in Figure 5.

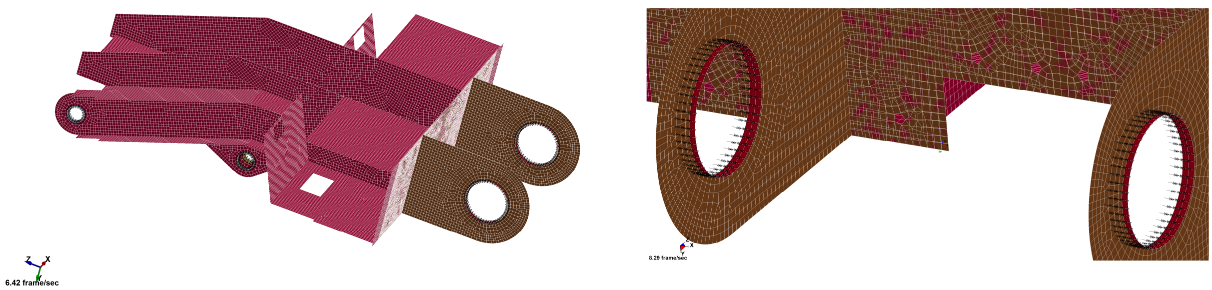
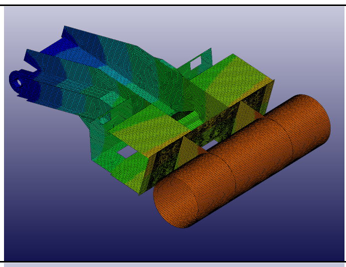
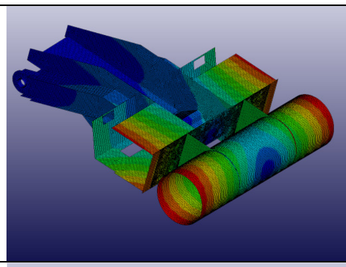
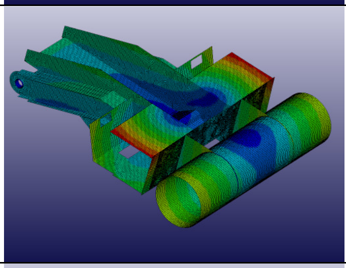
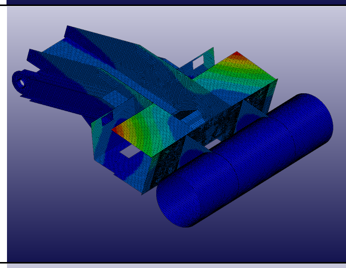
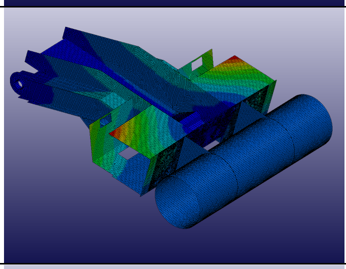
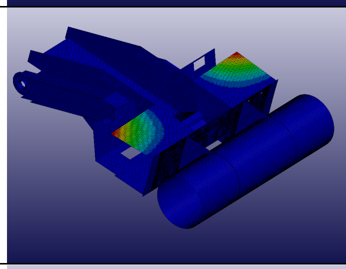
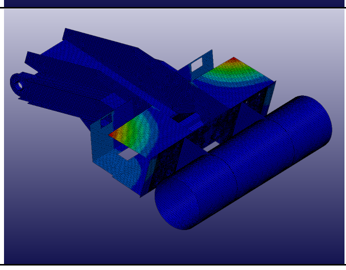
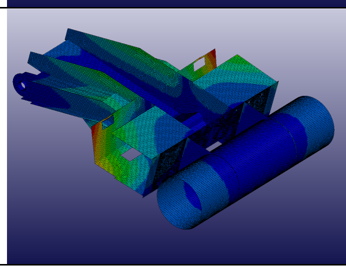


Fig.5 The numerical model and boundary condition.

THE MODAL ANALYSIS

The first step to determine dynamic characteristics of structure was numerical modal analysis. The results of first eight mode shapes were presented in the Table 1. This process allows to determine specific angular velocities of cutting head, where increased vibration and related stresses can be expected.

Table 1 The mode shape and natural frequencies of roadheader boom.

No.	Mode shape	Frequency value	No.	Mode shape	Frequency value
1		7,78 Hz	2		8.72 Hz
3		30,39 Hz	4		41,24 Hz
5		45,69 Hz	6		48,88 Hz
7		50,96 Hz	8		59,83 Hz

THE EXPLICIT DYNAMICS

The full explicit transient dynamic analysis was done in LS-Dyna solver. During analysis 5 seconds of cutting process were simulated. For further analysis four nodes were selected and location of them was shown in Figure 6.

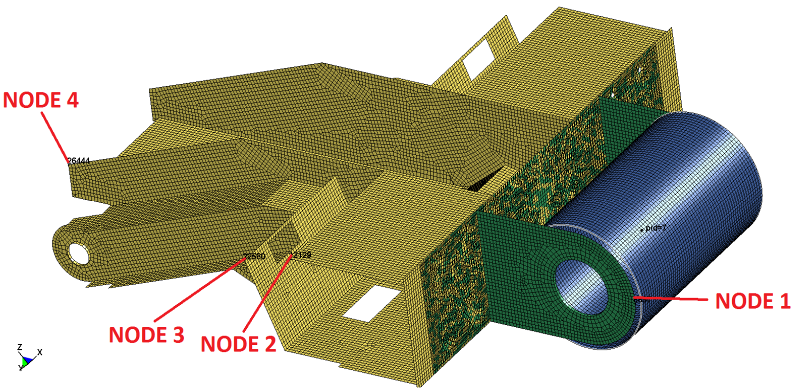


Fig.6 The nodes selected to acquiring acceleration.

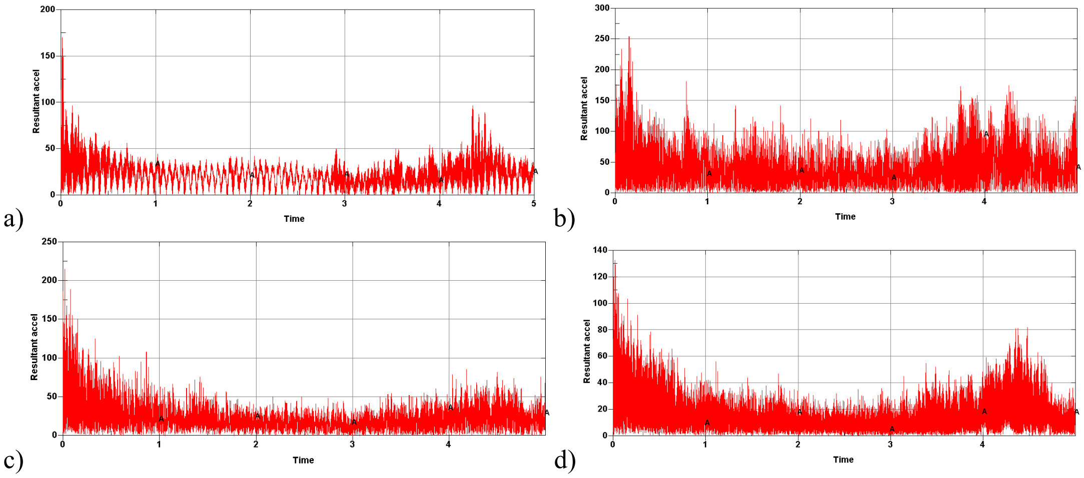


Fig.7 The time-depended resultant acceleration result a) for node 1 b) for node 2 c) for node 3 d) node 4

The time-dependent charts allows to recognize time points were increased resultant acceleration of structure can be seen. The first time range of increased acceleration is from start to 0.9 [s] and it is related to angular velocity equal approximately 1 [rad/s]. The second time range is from 3.5 [s] to 4.5 [s] and it is related to angular velocity from 4 [rad/s] to 5.5 [rad/s]. The maximum resultant accelerations is in time equal 4.42 [s] and the resultant Von Misses stress and acceleration maps for this time was shown of Figure 8.

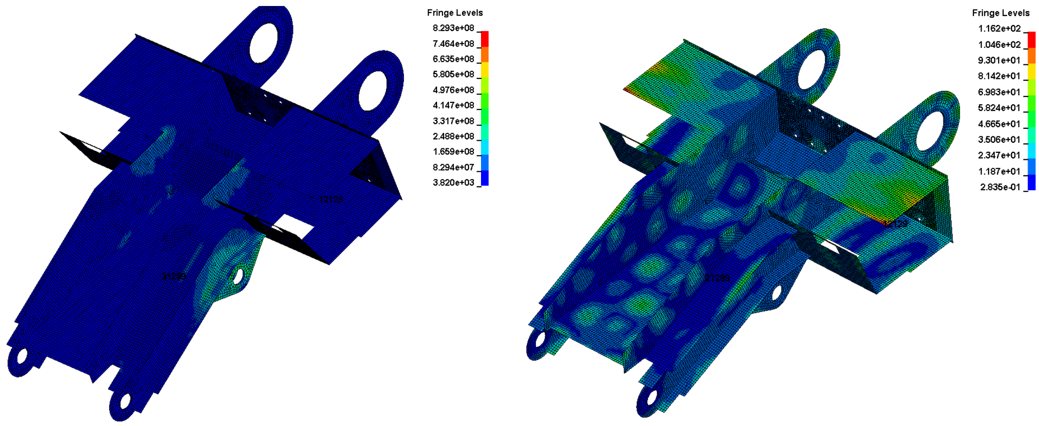


Fig.8 The resultant stress Von Misses (left) and acceleration (right) distribution for time 4.42 [s].

The increased resultant acceleration were related to transition between first, second and third natural frequencies while cutting head increased angular velocity. There was noticed that there is a danger of occurrence of resonance in normal roadheader cycled work at rotational speed equal 50 rpm.

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