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The identification of the vibration control system parameters designed for continuous miner machines

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A R T I C L E I N F O

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A B S T R A C T

The Continuous Miner machines are exposed to time dependent loads during normal operation of the rock cutting process. These loads cause vibrations, which have a negative influence on the whole structure of the machine. This phenomenon can be eliminated by applying passive or active vibration control systems (VCS). Generally these systems are coupled with additional elements, which provide dispersion or transfer energy. The energy thus acquired can also reinforce the intended function such as rock cutting operation in the case of mining machines. The objective of this paper is to present the method of numerical identification of VCS parameters for Continuous Miner machines. The main function of the presented system is to reduce displacement of cutting drum by using elastic element joined to machine chassis and applying appropriate algorithm of control of the angular velocity of cutting drum. The method described improves efficiency of mining and increases durability of machine. In order to determine mechanical and control parameters of VCS the genetic algorithm optimisation method conjugated with numerical modal analysis was used. Finally the transient dynamic analysis was performed for the full-scale model of Continuous Miner in order to verify VCS in normal working condition.

1. Introduction

The cutting system in the boring or mining machines is responsible for generating forces and dynamic torques, which – on the one hand – enable the crushing of rocks, and – on the other – negatively affect the entire structure of the machine [1] and environment [2]. Therefore, it is extremely important to improve the dynamic parameters of the cutting system, thereby making it possible to minimise the unfavourable vibrations in the selected nodes of the machine, while ensuring proper conditions for the mining process [3–7]. One of the many possibilities presented in literature [8–11] is to optimally control the kinematic parameters of the drive system in order to actively reduce vibrations. The vibration control system, proposed by the authors of the paper [12,13], as per the patent application no. P.410713 (see Fig. 1), contains an additional spring elements (3 and 5) with stiffness ***K1*** and ***K2*** mounted in the support structure (chassis) of the drive system (6). The vibrations may be minimized through an appropriate change in the rotational speed $\boldsymbol{\omega}$ of the cutting drum (1) during the cutting process. This change should cause a shift in the excitation frequency for which the mode shapes obtained shall have nodes in the critical points of the machine's structure, while maintaining an increased effect on the mined wall. This process requires a detailed analysis of the entire system and the selection of natural frequency that guarantees the desired cutting effect, while ensuring low vibration levels of the machine. By appropriately controlling the angular velocity of the drive motor [14], it is possible to induce resonance phenomena for the indicated natural frequency.

2. Calculation methodology

In the literature many methods of analysis nonlinear vibrating systems can be found [15–19]. The calculation methodology adopted by the authors presented in Fig. 2 is based on the application of genetic algorithms for the optimisation of kinematic parameters of the drive system [20].

The first step of this process involves identification of the mode shapes ensuring the reduction of vibrations in appropriate constructional nodes of the machine. This is done through a numerical modal analysis. The eigenvectors and eigenfrequency thus selected are the input values for the objective function developed. The implemented analytical model of the cutting process enables determination of the excitation frequency in the rotational speed function of the cutting drum and the distribution of the individual blades on the perimeter of the cutting drum. On that basis, the optimisation algorithm determines

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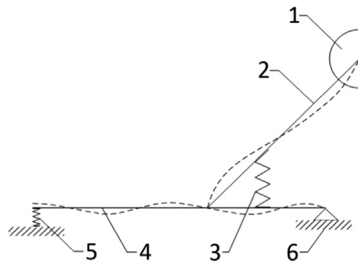

Fig. 1. A schematic model of the optimised structure 1 – cutting drum, 2 – boom arm, 3 – hydraulic cylinder with spring component, 4 – main frame, 5 – anchoring systems with spring component with, 6 – anchoring systems.

the values of decision variables related to the kinematic parameters of the drive system of the cutting drum. In order to verify the results, the last stage involves a dynamic analysis for complete identification of the dynamic characteristics of the structure and for determination of the benefits of changing the nature of the excitation.

3. Identification of cutting drum forces

The interacts between cutting tools and rocks have strongly non-linear characteristics. The finite element method (FEM) model was prepared to obtain characteristics of cutting force during excitation.

Cutting block presented in Fig. 3 is a concrete with unconfined compression strength 60 MPa, density 2 320 kg/m^3 and maximum aggregate size 19 mm. For simulation in LS Dyna was selected material model *MAT_CSCM_CONCRETE with applied contact eroding surface option. For this model parameters was taken from literature, where authors are presenting good agreement with experiments [27,28]. The depth of cutting material in presented results was 10 mm. The results of simulation for single bit cutting process was presented in Fig. 4.

However FEM simulation are time consuming methods and can't be directly used in real-time simulation or genetic algorithms methods. Therefore was developed simplified numerical model, which was used to identification process of stiffness components parameters. The model combine electric driveline system with permanent magnet synchronous machines (PMSM) model and mathematical model of cutting force characteristics.

The mathematical model of system with PMSM can be written by equation:

$$J\frac{d\omega_w}{dt} + b\omega_w = M_e - M_o$$

where:

ω_w – angular velocity of rotor
J – PMSM rotor moment of inertia,
b – damping factor,
p – number of pole pairs,
M_e – electromagnetic torque,
M_o – load torque,

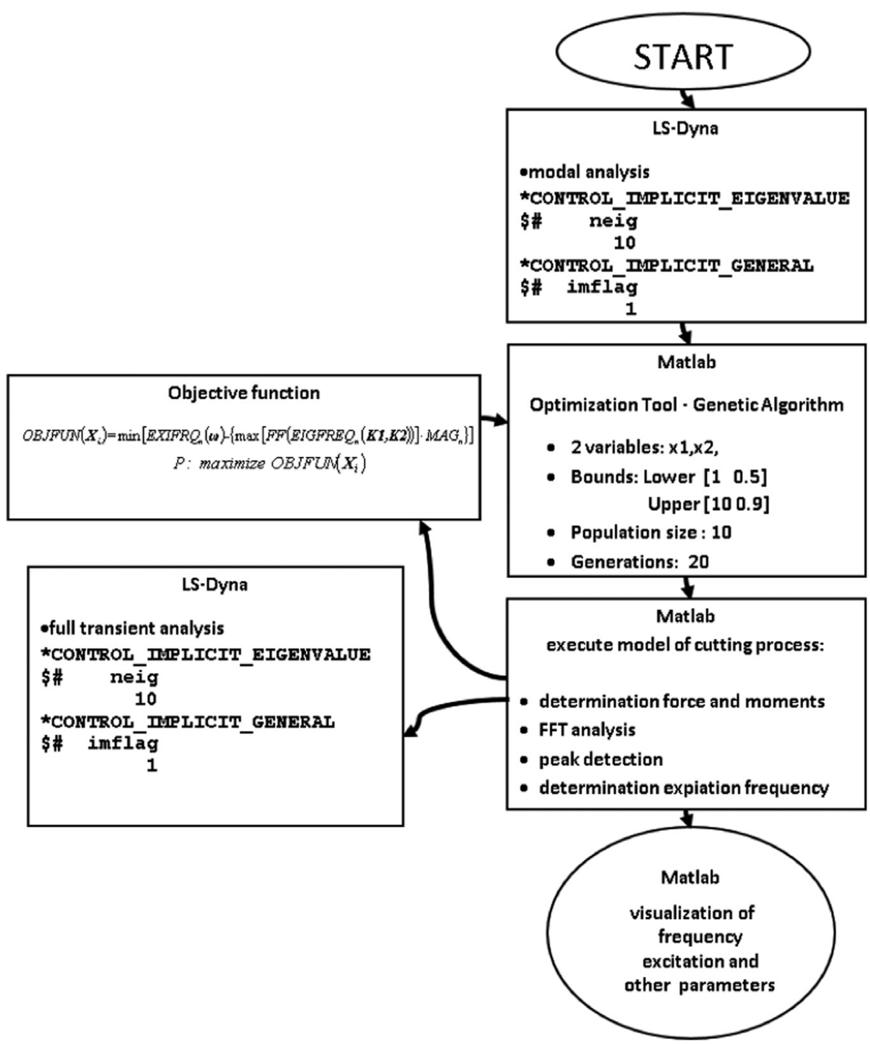

Fig. 2. The method adopted for the optimisation of cutting parameters.