Testing of the Laboratory Screen Prototype Operating under Parametric Resonance Conditions

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Abstract: In this paper the experimental studies of the screen working in the parametric resonance condition are discussed. The investigations are conducted for laboratory parametric resonance screen. The measuring test is performed for four cases of tension force values. The full sheet metal instead of the sieve is used. For each considered case the natural frequency of the plate and the parameter modulation frequency are determined. It is shown that the highest sieve plate amplitude is obtained when the parameter modulation frequency is two times larger than natural frequency of the sieve plate. This parametric resonance vibration was observed only for tension force equal to 4000 N because of the rotational speed limits of electrical vibrators.

Keywords: vibrating screen, parametric resonance, natural frequencies

1 INTRODUCTION

Screening is the basic process in separating mineralogical components. All of screens are based on method of screening, which is schematically shown in figure 1. The material is being fed onto the sieve and next is transported along the sieve during which the feed is segregated into the oversize and undersize material. In the screening process two types of resistances are distinguished: the layer resistance and the sieve resistance. Resistance of the layer has a significant impact on the screening of material thick layers. This kind of resistance is typical for the screening of a fine grade material. It is taken as difficulty of segregating layer. A difficulty of grain transition through the sieve mesh called as sieve resistance, has smaller effect. To minimize the layer resistance impact, and increase the efficiency of the screening process the proper motion of the screen should be established. This is the challenge for engineers [7]. The rapid progress of screening techniques and screen design was observed in 19th and 20th century. Nowadays the development of screen is stabilized and most of equipment produced by various machines companies is very similar [8]. In spite of this, there is always a need to improve the performance of screens. Increase capacity and efficiency of screening process on the one hand, and reducing its ecological footprint are the main goals of development of new screening equipment.

Vibro-impact mechanisms, such as screeners and drilling/cutting devices, are usually designed to operate in a resonance regime (RR). Then the most powerful energy flux can be achieved from the exciter to the vibrating component, and high oscillation amplitude of the target structure can be obtained using excitation of a relatively low intensity. Parametric resonance PR is the state of oscillating instability which can arise under periodic disturbance of a parameter of the structure, for example, under periodic variation of the pendulum length or the tensile force in a beam, plate or a flexible screen.

The problem of the parametric resonance in mechanical systems is studied by numerous researches and development centres [1-5]. This phenomenon is described by Hill and Mathieu and can be found as the fundamental theory related to the vibration of the slender structures and the parametric resonance phenomenon (the so-called Hill or Mathieu equation [3]). The analysis of parametric vibration in the beam system with constant transverse loading is presented by Osiński [5]. The numerical method, based on a finite element discretization, is proposed to solve the parametric resonance problem of shell structures by Başar et al. [1]. In some cases the parametric resonance phenomenon allows to achieve higher performance processing. A good example of confirmation, can be vibratory machines for screening and transport of aggregate [2, 5].

This paper continues the recent authors investigations concerning the vibration of screen systems [2]. The aim of these investigations is to determine the natural frequencies of the sieve and the parameter modulation frequencies (the excitation frequencies) as a function of the sieve tension force.

2 THE LABORATORY SCREEN DESCRIPTION

The laboratory screen (Fig. 1) is made in accordance to the project based on the GEPARD-2 screen. GEPARD-2 screen was formerly designed by V.
Slepyan from Loginov Partnership Mining Company in Kiev. The screen system consists of a sieve which is mounted between two beams. Complete screening system is suspended on the frame by tension springs. The frame is composed of square profiles welded together. The excitation force is generated by two electrical vibrators.

The screen was equipped with measurement sensors. The function of the sensors is to measure the vibration rate of the sieve, the sieve tension and rotational speed of electrical vibrators (force frequency):
- Vibration measurement is realizing by using small, high frequency, quartz shear ICP accelerometer (PCB 353B14). The sensor is connected to measurement card by device which condition the signal (Fig. 3). This device gives in the output acceleration and velocity signal.

- Rotational speed measurement - is performing by using the laser speedometer with resolution 1 rpm. This measurement enables to determine the inductors force frequency.
- High speed camera - this device is necessary to analyze the sieve natural modes and sieve deformation. It also is helpful to check what happens during the sieving process. The movie can be capture with frame rate 3000-5000 fps and very good resolution.
- Sieve tension measurement - to obtain the request resonant frequency it is necessary to adjust properly the sieve tension. This force can be measured by determining the force on the beam suspension (Fig. 4). The tension force is measured by using the strain gauge sleeves, which are mounted on the suspension bolt. The tests of this measurement device show sufficient accuracy (±25 N) and very similar results comparable with the analytical calculations for string tension (LPMC, Victor Slepyan) and numerical simulations. The tests were performed for plate without cut-outs.

The data collected during the measurement are presented in figure 5. The regions with high amplitude value represent the resonance appearing. The response of the plate was obtained for following screen parameters:
- springs stiffness: 2114 N·mm⁻¹,
- springs tension: 5134 N,
- excitation frequency: 52 Hz,
- excitation force (one site): ± 1500 N.

The discrete fourier transform (DFT) of the signal was performed in the MATLAB software to define the frequency of sieve vibration. The results are presented in figure 6.
As it is visible the spectral graph includes a lot of noise. Nevertheless, a distinct spectral peak occurs at 31.56 Hz (Fig. 7). The behavior of the 31.56 Hz signal can be clarified by bandpass filtering by using MATLAB software. The time/acceleration data were bandpass filtered from 21 Hz to 40 Hz (Fig. 8).

**CONCLUSION**

The numerical investigation for the screen system shows that the plate natural frequency should be nearly 25.9 Hz when the first natural mode occurs and 35.4 for second mode. The experimental investigation shows differences in comparison with numerical results. The plate vibrates with frequency equal to 31.56 Hz (except noise frequencies) which was shown by the analysis of collected acceleration data (Fig. 7). This value is close to second mode natural frequency from the numerical simulation (35.4 Hz). The parameters of the screen system (sieve tension, material properties and boundary conditions) in both cases (numerical and experimental) was the same. To prove and confirm that this effect occurs, the simultaneous measurement on two accelerometers have to be done. When accelerometers will be placed in opposite site on the plate, then signal from first accelerometer will be translated with time T/2 comparing with second one. For visualization the pictures with high speed camera also have to be made.

According to the theoretical description for parametric systems [4] i.e. Hill's equation and Mathieu equation, the primary parametric resonance should occur when the frequency of parameter change ($\omega_p$) (for example stiffness change) is twice bigger than the natural frequency of the system ($\omega$). In general, parametric resonance can occur when $\omega_p = 2\omega/k$ (for $k = 1, 2, 3, ...$) which was shown in figure 9. By taking the $\omega = 31.6$ Hz as resonant frequency of the sieve and $\omega_p = 52$ Hz as a parameter change frequency, the ratio of $\omega_p/\omega$ is equal to 1.64. In considered case the dumping influence and the depth of modulation may have an important effect on the final result, what will be analyzed in further research.

![Frequency spectrum graph](image1)

![Frequency spectrum graph](image2)

![Filtered data](image3)

![Stability-instability regions of solution of Hill equation](image4)
will be done in further investigation. In the beam theoretical model there is also possibility to take into account the load on the sieve [6]. The experimental investigation on the real model will be still carried out.

Acknowledgment

This work was supported by the European Research Agency - FP7-PEOPLE-2011-IAPP - Marie Curie Industry-Academia Partnerships and Pathways, grant agreement No. 284544.

REFERENCES


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