Effect of Exciting Force Amplitude on Occurrence of Parametric Resonance Phenomenon in Vibrating Screen

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Abstract

The paper considers the effect of exciting force amplitude on occurrence of parametric resonance phenomenon in vibrating screens by using experimental methods. The measuring test is performed for three cases of excitation force levels. For each force level sieve parametric vibrations are excited by using proper excitation frequency. It is shown that an increase of the excitation force results in an increase in the sieve vibration amplitude. The dependence between excitation force and sieve parametric vibrations is nonlinear. The value of excitation force has an effect on the sieve vibration mode shape. Two vibration mode shapes are detected. It is found that the excitation frequency influenced the vibration amplitude. An increase of sieve preload has no effect on the amplitude level, however it results in an increase of the sieve vibration frequency.

Keywords: vibrating screen, parametric resonance, natural frequencies

1. Introduction

In many physical, engineering, electrical and biological systems appearance of parametric resonance in the system is of great interest. Parametric oscillations are the case of system oscillatory motion caused due to time varying (periodic) parameters of the system. These parameters can be stiffness or inertia. Parametric resonance appears when the external excitation is equal to integral multiple of natural frequency of the system. Parametric oscillations for the first time were described by Hill and Mathieu. They elaborated the fundamental theory related to parametric resonance phenomenon (so called Hill's and Mathieu equations). The problem of parametric oscillations was investigated in numerous researches. Many of them are connected with simple structures (e.g. beams or rods) [4, 5, 7, 12]. Bolotin [4] well documented the elementary problems of parametric instability in elastic systems. He also described the damping influence on the regions of stability. Parametric oscillations of preloaded Bernoulli beam with constant transverse load was presented by Osiński [7]. In this research he also considered the case of the beam with periodically changing length. For analysis of parametric vibrations of the beam system, Hagedorn and Koval [5] considered Timoshenko theory. In work of Yang and Chen [12] parametric stability is presented for the beam with periodical axial load. They considered Newton's second law and Boltzmann superposition theorem. A lot of authors have studied the parametric resonance problems for plates and cylindrical shapes by using both analytical and numerical methods. Nguyen [6] presents the parametric resonance problem in simply-supported plate with parametric excitation. In this paper Karman large deflection theory and governing equation are considered. For computation of finite element discretization method is proposed. Dynamic stability analysis of axially moving viscoelastic plates is presented by Tang and Chen [11]. Here the time-dependent speed of plate moving on parametric resonance is investigated.

Most investigations on parametric resonance are carried out to predict the response of the system. Periodic changes of system parameters may result in rapid amplitude grow and lead to fatigue and damage. The examples are gear wheels cooperation, axially loaded slender structures or rolls of ships. However, in some cases the target excitation of resonance brings measurable effects. This is especially in the case of vibrating screens and conveyors, where operation in conditions of resonance can significantly increase the process efficiency. The application of parametric resonance in the screen construction was proposed by Slepyan et al. [8]. In works [9-10] they presented the simplify dynamic screen system consisted of two masses connected by a string. The analytical and numerical analysis of natural vibration of the screen is presented in work [2]. The experimental analysis of the parametric resonance occurrence in screen operation is carried out by Bąk et al. [3]. In this paper the plate without cut-outs is used instead of the sieve. In presented papers the screen system operating in parametric resonance conditions is included.

The paper deals with experimental investigation of the vibrating screen operation in parametric resonance conditions. The changes of the excitation force and the excitation frequencies are executed to measure of their effect on the sieve vibration amplitude.

2. Laboratory parametric resonance screen

The laboratory parametric resonance screen construction (Fig. 1a) is based on the first PR screen designed by Slepyan et al. [8]. The screen system consists of two beams connected by a sieve. The sieve is a simple sheet metal plate with rectangular cut-outs (Fig. 2) made from spring steel grade 1.8159. The rubber pads between the sieve and the beam are applied to limit the bending stresses concentration. Screening surface dimensions are 750 mm length and 500 mm width. This system is suspended on the base frame by set of sixteen springs with stiffness equal to 275 N each one, and the whole machine weight is equal to approx. 200 kg. Excitation force is generated by two electrical vibrators screwed down to the beams. The nominal value of excitation force is equal to 2972 N (for 2954 rpm vibrators rotational speed). This force can be adjusted with 10 % step of its nominal value. Rotational speed of electrical vibrators was read by using laser speedometer. Hence, the excitation frequency has been calculated. The suspension assembly (Fig. 1b) is supplied with strain gauges sleeves, that enable sieve preload measurement. Two piezoelectric accelerometers with the range up to ±1000 g are used for measurement of sieve vibration amplitude and frequency. They are located in two opposite sides of the sieve.

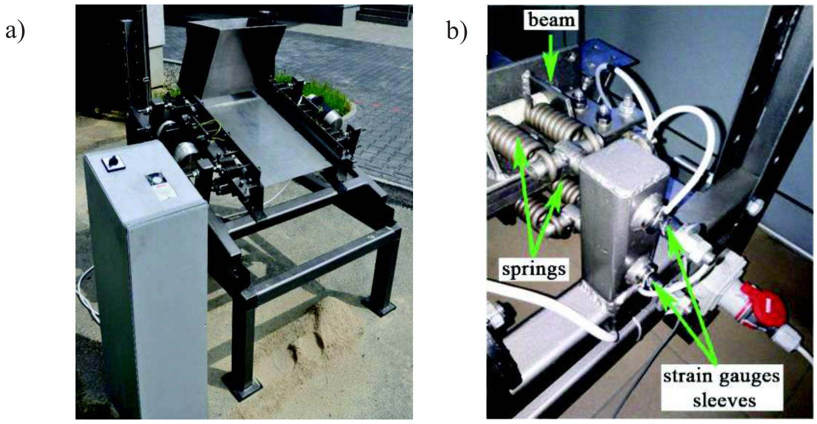

Figure 1. Laboratory parametric resonance screen: a) general view;
b) suspension assembly

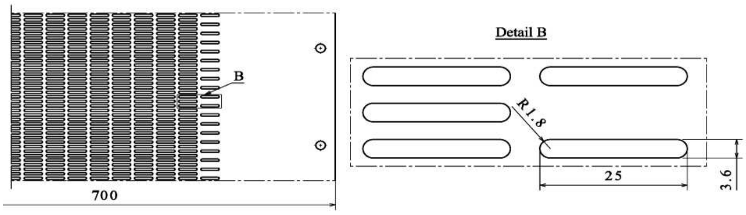

Figure 2. Sieve geometry and cut-outs enlargement

3. Experimental methods

The first step of experimental investigation was carried out for value of sieve preload equal to 1000 N. In this case three levels of excitation force were applied: 30%, 40% and 50% of nominal force. For each value of excitation force the excitation frequency was adjusted until the parametric resonance occurrence.

The second part of the investigation was performed for sieve preload values: 1600 N, 2400 N and 3000 N. Here only 40 % level of excitation force was applied. Data from accelerometers were collected as an acceleration in a function of time. Output signal was processed during the measurement by using Chebyshev filter. Further signal processing was performed in MATLAB software. Fast Fourier Transform was used to find the resonant frequency of the system. Maximum sieve displacement was obtained by double numerical integration of input signal.

4. Results and discussion

The value of sieve vibration amplitude increased with the excitation force level (Fig. 3). For each considered cases this dependence is nonlinear. For the first two values of the excitation frequency (49.24 Hz and 50.21 Hz) there is no significant increase of vibration amplitude. In this case an increase in excitation force of 10 % results in amplitude increase of 33 %. For the two last cases (52.16 Hz and 57.02 Hz) this increase is much greater and respectively is equal to 250% and 325%. Further increasing of excitation force level (from 40% to 50%) has a small effect on the amplitude value. For each considered cases the amplitude increase is less than 20 %.

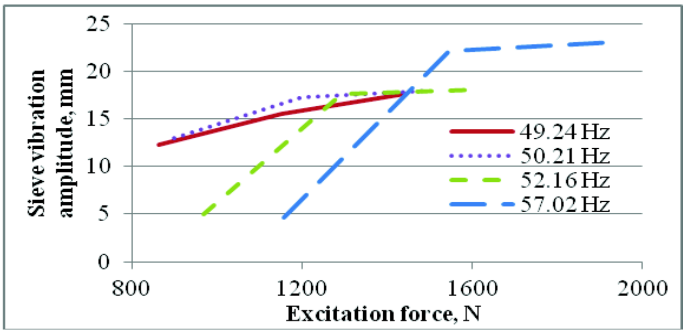

Figure 3. Effect of excitation force on sieve vibration amplitude for different excitation frequencies

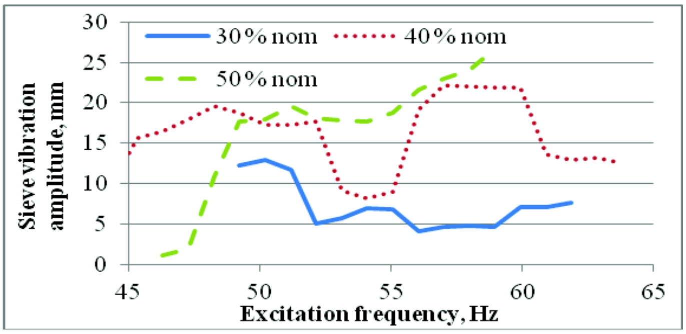

Figure 4. Effect of excitation frequency on sieve vibration amplitude for different excitation forces

The amplitude level increase is caused not only by growing excitation force but also by changes of the excitation frequency (Fig. 4). For the excitation force adjustment on 30% level, parametric resonance is detected for excitation frequencies in a range from 49 Hz to 62 Hz. Here the second mode of natural vibrations was observed [2]. The amplitude reaches the maximum value equal to 13 mm. Further increase of the excitation frequency results in a decrease of the amplitude till 5 mm. The curves of the excitation force levels equal to 40% and 50% are similar. Two local maximum can be distinguished. The first can be observed for the excitation frequency close to 50 Hz. For both excitation force levels the local maximum of amplitude is equal to 19.5 mm. The second one appeared for the frequency near to 59 Hz. Here the increasing of excitation force resulted in 20% increase of the sieve vibration amplitude. For force levels 40% and 50% the first mode of parametric vibrations was observed.

The sieve preload value has no significant effect on the amplitude level (Fig. 5). For each considered tension forces the maximum value of amplitude is within the range between 22 mm and 24 mm, however it is obtained for different excitation frequencies. This is caused by increasing natural frequency of the system due to sieve preload increase [3]. The increase of sieve preload also results in fading of first local maximum of amplitude. For tension forces 2400 N and 3000 N only one local maximum can be visible (Fig. 5).

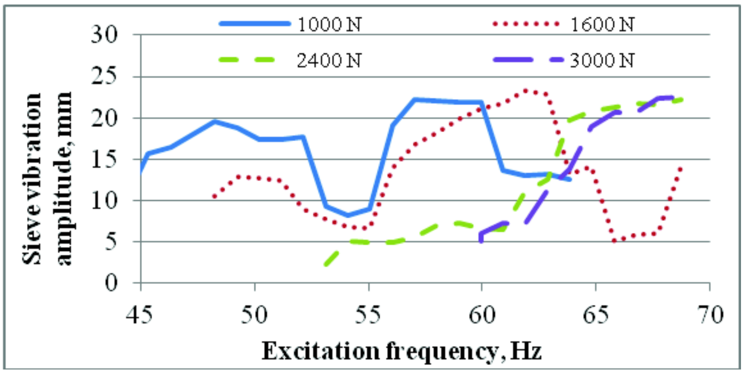

Figure 5. Effect of excitation frequency on sieve vibration amplitude for different sieve preloads

5. Conclusions

The dependence between excitation force and sieve vibration amplitude is nonlinear. Initially the increase of excitation force results in large amplitude grow, further increase has no significant effect on the amplitude value. The amplitude of vibrations excited with 30 % force level is relatively small in comparison with 40 % and 50 % force levels.

Changes of excitation frequency result in sieve vibration amplitude value. It is found that when the excitation force level is equal to 40% or more, two local maximums of amplitude appears for excitation frequencies close to 50 Hz and 59 Hz.

The value of excitation force has an effect on the sieve vibration mode shape. Two mode shapes of parametric vibrations were observed.

An increase of sieve preload results in higher natural frequency of the system, therefore to obtain maximum amplitude higher excitation frequencies must be applied. However, there is no significant effect of preload increase on the amplitude value.

Acknowledgments

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