Several ways to automatically estimate optimal technological parameters of vibrational screening devices

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Abstract

A great variety of computer analysis methods developed last years has shown their potency in a number of problems. These methods such as swarm intelligence systems, evolutionary algorithms etc could be used in any field where it is necessary to deal with large amount of data. When working with a number of problems that preclude full analytical studies, it became possible to solve extremum problems using this methods joined with numerical models. The scope of such paired application of computer models and numerical optimization techniques is constantly expanding, encompassing a variety of practical areas: from economics to engineering.

This article presents an example of such methods application in the technical field. The methods were used for making a preliminary estimation of optimal technical parameters of vibrational screening devices. Basic data were obtained using original high performance algorithm of vibrational screening modeling and experiments.

1 Introduction

When mastered by the research community, new scientific and methodological knowledge not only widens the range of approaches available for solving practical problems, but also changes the view of the objects studied [1]. In this way, development of computer simulation methods had fundamentally changed new equipment creation processes. However, the influence of such changes became widespread only quarter of a century after the laying of foundations and making up of basic principles behind the currently most common approaches. This trend is clearly evident in the development of all areas of technical knowledge, including the mining industry. The history of vibrational screening application for separating granular materials extends back over three centuries and covers numerous practical areas of human activity: from ore dressing to such sophisticated industries as pharmacology. And yet, unified engineering approaches for calculating respective equipment did not appear until the seventies of the previous century. At that time, a unified approach could not be developed as it was conceptually impossible to consider material at the level of individual particles due to their large numbers. The behavior of granular medium under vibration depends upon specific features of interaction between its particles, as well as between the particles and machinery structural parts, force fields and the environment. In this regard, high significance is attached to dry friction forces and impacts. That is, at the particle level, the system is essentially discontinuous, and small parameter modifications may lead to radical changes in behavior of the material under examination. For this reason, classical approaches considered granular materials as continuous media, were based on task-specific phenomenology, and, therefore, had very limited applicability.

2 Background in mining industry

Universal molecular dynamics and discrete element methods (DEM) that appeared in the seventies of the twentieth century were not widespread until the mid-nineties. This was due to the fact that, at that time, the scientific community had not yet sufficiently mastered computational approaches to solving practical problems, as well as to the unavailability of appropriate computing resources. By now, these two obstacles have been overcome almost completely, although the high resource intensity of methods applied for analyzing granular media at the particle level and, as a result, the high time requirements of respective simulation processes should be emphasized. In a general sense, it should be noted that development of computer simulation methods not only changed the approach to calculations of parts and machinery, but also cleared the way for radically new design and construction techniques. In particular, when working with a number of models that preclude full analytical studies, it became possible to solve extremum problems using, for example, such methods as stochastic optimization. The scope of such paired application of computer models and numerical optimization techniques is constantly expanding, encompassing a variety of practical areas: from economics to engineering [2]. Numerical optimization techniques imply relatively frequent computations of objective function values depending on the resulting parameters of the model used and, therefore, naturally require high simulation rates. This, of course, limits applicability of the above-mentioned universal granular media examination methods due to their high resource intensity. With a view to solve several problems, not excluding this one, a simplified method was developed for quick numerical simulation of vibrational screening [3].

3 The simplified model of vibrational screening process and its application for optimal design of screening devices

The proposed vibration screening simulation method is based upon generalization of classical approaches, as described in [4]. Granular material is represented in the form of a cellular continuous medium hosting the processes of segregation, mixing, sieving and vibrational displacement. A separate model is used for each process which makes the general calculation scheme highly flexible and easily adaptable to new conditions. For example, the original computational scheme [3] using ideas from [5] allowed improving simulation of the granular medium particles passage through sieve apertures; moreover, a separate program was drawn up for vibrational displacement studies [6]. The diagram for material representation on the screen surface is shown in Fig. 1.

This model has very low resource intensity and, despite its simplicity, is sufficiently accurate. Its applicability has been tested through a series of experiments. Comparative field experiment and model application results are shown in the following table (Fig. 2).

A program for automatic estimation of optimal vibrational screen parameters based on joint use of simulation approaches and particle swarm optimization [7] was presented in [8]. This program requires considerably less time, as compared even to a single detailed DEM-based simulation. At the same time, with allowable value ranges specified, it enables conducting a series of simulations and making up of a preliminary, but quite accurate assessment of such optimal screen parameters as linear dimensions, aperture diameters, useful screen area, its inclination angle and vibration parameters (i.e. the parameters determining vibrational displacement velocities), as well as screen feed and other parameters. An example of program application results is shown in Fig. 3.

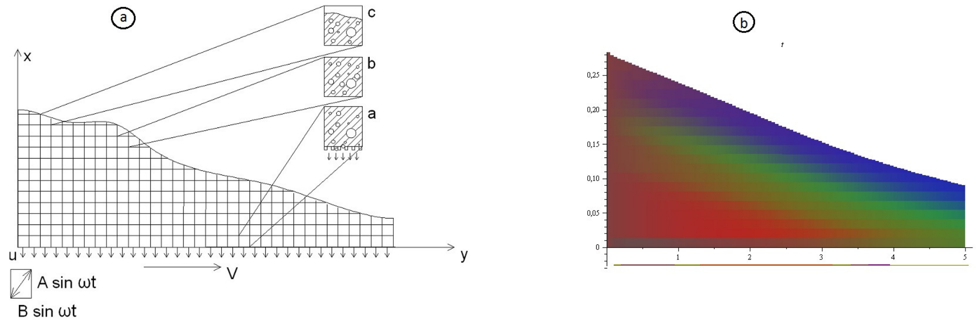

Figure 1: Material layer lateral section on the screen: a) the scheme of the section as it is processed by the program, b) simulation visualisation

	granulation mm	%	production level m. tons/h	openings mm	extraction in-situ	comp
1	-0,071+0	1,5283	1,7250	0,3150	0,8889	0,9479
	-0,18+0,071	11,9831			0,8657	0,9352
	-0,315+0,18	8,5949			0,6129	0,6788
	-0,63+0,315	17,0231			0,0000	0,0000
	+0,63	62,3989			0,0000	0,0000
2	-0,071+0	2,5017	0,4637	0,3150	0,9730	0,9606
	-0,18+0,071	12,6385			0,9898	0,9581
	-0,315+0,18	10,7355			0,8475	0,9109
	-0,63+0,315	11,9395			0,0000	0,0000
	+0,63	64,6865			0,0000	0,0000
3	-0,071+0	1,2957	0,5604	0,3150	1,0000	0,9622
	-0,18+0,071	11,7853			0,9886	0,9592
	-0,315+0,18	9,0126			0,7500	0,8984
	-0,63+0,315	16,4013			0,0000	0,0000
	+0,63	62,8007			0,0000	0,0000
4	-0,071+0	2,5819	1,0336	0,3150	0,9412	0,9574
	-0,18+0,071	12,6417			0,9663	0,9511
	-0,315+0,18	11,9143			0,7857	0,8083
	-0,63+0,315	13,0111			0,0000	0,0000
	+0,63	62,4329			0,0000	0,0000

Figure 2: Experimental validation of the model

4 Prospects of the development of the approach

The prospects of these approaches to designing vibration equipment are covered in [9]. However, it is worth adding that the software system described is constantly improving. Besides the extensive upgrading opportunities of the basic screening model itself, as mentioned above, the program may easily use other numerical optimization approaches. For

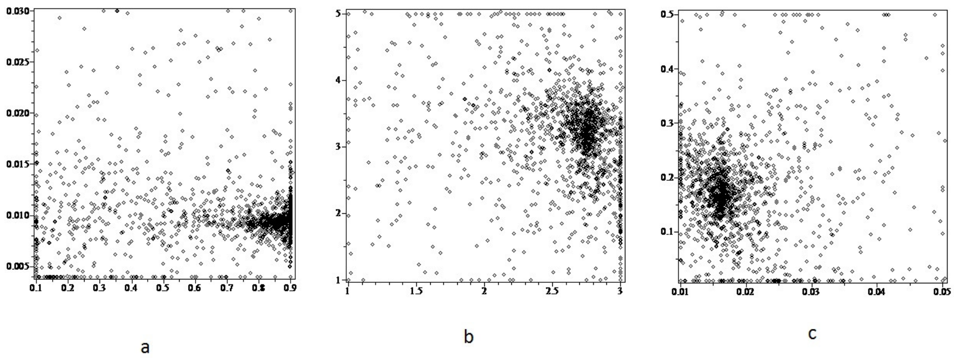

Figure 3: PSO and the vibrational screening model joined application results: crowded areas contain optimal parameters values a) useful screen area and screen openings diameter, b) length and width of the sieve, c) vibrational displacement rate and initial thickness of the material layer

example, a version of the program was implemented, based on the differential evolution method. The process of selecting optimal parameters may also be accelerated through reductions in the number of simulations carried out by storing intermediate results obtained in previous versions of the program. It may also be positively affected by reducing the initial search area through the use of the available statistics and data mining methods. Consequently, the software described allows conventionally dividing the optimal vibrating screen design process into three phases. The first phase implies shaping of a search area using alleged material characteristics and acceptable ranges of process parameters, as set by the designer, using statistics data. The second phase uses numerical optimization and the simplified screening model for preliminary estimations of equipment optimal parameters. And the third phase includes direct equipment development by the designer, using field experiments and more accurate methods, such as, for example, DEM. This structure ensures early elimination of numerous incorrect technical solutions under minimum time requirements and, all other things being equal, enables paying more attention to equipment fine-tuning and improvement.

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