UDC 502/504

O. I. Gerasymov[1]
V. V. Kuryatnikov[1]
A. Y. Spivak[1]
L. M. Sidletska[1]
A. M. Kilian[1]

DRY GRANULAR MIXTURES FOR OPTIMIZATION OF RADIACTIVE SCREENING TECHNOLOGIES

[1] Odessa State Environmental University

Анотація

Спираючись на апарат теорії Кірквуда-Баффа та данні аналізу експериментальних даних з вивчення макроскопічних параметрів бі-дисперсної суміші створений теоретичний алгоритм опису та параметризації їх фізико-механічних характеристик в термінах зв'язків її надлишкових макроскопічних та парціальних властивостей.

Запропоновано розвинутий підхід до практичного використання з метою параметризації властивостей двох-компонентних гранульованих матеріалів та оптимізації технологічних процесів в яких вони використовуються (зокрема, в конструкціях гранульованих захисних екранів). Отримані критерії максимального ущільнення та оцінки швидкості компактизації та показана можливість маніпулювання макроскопічними властивостями таких систем.

Ключові слова: захисні гранульовані екрани, гранульована двокомпонентна суміш, теорія Кірквуда-Баффа, упаковка, ущільнення, модель Карнахана-Старлінга.

Abstract

Based on the apparatus of Kirkwood Buff theory and data from the analysis of experimental data on the study of macroscopic parameters of bi-dispersed mixture a theoretical algorithm for describing and parameterization of their physical and mechanical properties in terms of their excess macroscopic and partial properties has been proposed. Developed approach we use in practice to parameterize the properties of two-component granular materials in order to optimize the technological processes in which they are used (in particular, in the construction of granular protective screens). We obtain the conditions and criteria's of maximal packing and estimation of the velocity of compactisation and show the possibility of manipulation by macroscopic properties of dry binary granular mixtures.

Keywords: protective granular screens, granular bi-component mixture, Kirkwood-Buff theory, packaging, compaction, Carnahan-Starling model.

Introduction

One of the traditionally relevant problems of the theoretical basis of production and technology is the description, parameterization and prediction of the properties of the mixture depending on the parameters of the components that form the mixture [1]. The same problem also applies to current research in statistical physics. Recently, the methods of statistical physics began to be applied to the description and modeling of certain properties of micro-mechanical systems – granular materials (GM) [2-5], which are used in many technological fields. One of the most significant problems that hinder the effective use of GM, for example in the construction industry, is the difficulty of ensuring their maximum compaction to increase the efficiency of their practical application. In this way, the study of the properties of binary granular systems, which is to study the dynamics of their compaction and the impact on this process of the ratio of component sizes and partial parameters should be a significant innovative step in the development of appropriate technologies in production. To this end, we propose to use the apparatus of Kirkwood-Buff theory in combination with model equations of state and relevant phenomenological information [6-7].

Results

In typical problems of environmental protection technologies, we deal with multicomponent, poly-disperse, multi-parameter systems that perform an insulating, protective function. The understanding of the

principles due to which the basic parameters of such systems are formed is based on basic models that allow parameterizing the measurement data in terms of quantities that characterize the individual pure components (reference data). The construction of such models is a very difficult task and, first, requires phenomenological information from several alternative sources. And secondly, the definition of the partial parameters themselves, or rather their relationship to the mixture, as well as the definition of its ideal (mixed) states is quite problematic and only partially theoretically argumented procedure.

Based on the apparatus of Kirkwood-Buff theory, we construct model equations of state and data from the analysis of relevant experiments to study the macroscopic parameters of bi-dispersed micro-mechanical mixture to build a theoretical algorithm for describing and parameterizing their physical and mechanical characteristics in terms of its macroscopic and partial properties depending from the bulk (or molar) fraction of one of the components.

We operate by models of granular bi-component mixtures, methods of theoretical statistical physics, in particular Kirkwood-Buff theory, model equations of state for mixtures of solid balls of the Carnahan-Starling type and some phenomenological information on the dynamics of compaction of simple granular mixtures.

Using Kirkwood-Buff theory, model relations for mixtures of solid balls, using phenomenological data on the nature of compaction of granular materials, we develop an algorithm to describe the macroscopic properties of binary granular systems in particular compaction, which operates on partial parameters of its components, such as molar fractions.

To analyze the experimental data (from work [8]) on the study of the dynamics of binary granular systems, the apparatus of the Kirkwood-Buff theory was used in combination with model equations of state for mixtures of solid balls and the corresponding phenomenological information. The obtained data confirm the influence of multi-dispersion on the dynamics of compaction (namely the absolute value and speed of packaging), i.e., the possibility of the mixture under the influence of external influences is predicted to change the local packaging structure and its parameters.

Conclusion

Based on the analysis of experimental data to study the dynamics of binary granular systems, which consist in measuring their compaction and the impact on this process of the ratio of component sizes and partial parameters, conclusions are made about the possibility of increasing the degree and speed of packaging.

For the purpose of theoretical description and substantiation of empirical data, it is proposed to use the apparatus of Kirkwood-Buff theory in combination with simple models such as models of Carnahan-Starling solid spheres, as well as relevant phenomenological information. The obtained data can be used to use the established effect of multi-dispersion on innovative approaches to optimize the dynamics compaction of discrete micro-mechanical materials, i.e. the ability of the granular mixture to change the local structure, degree and rate of packaging and some other parameters. In practical sense it is important for instance for the construction of irradiative screens based on use the granular mixtures.

REFERENCES

1. Gerasymov, O. I., Khudyntsev, M. M., Andrianova, I. S., and Spivak, A. Ya. (2016). Granular materials in utilization technologies of radiation-harmful substations. In: Proceedings of the National Forum: *"Problems, perspectives and strategy of waste utilization in Ukraine"* (22-23 November), Kyiv, pp. 40-42 (in Ukrainian).

2. Gerasymov, O. I. (2015). *Physics of granular materials*. Odesa: *TES*. 264p. (in Ukrainian).

3. Gerasymov, O. I., and Somov, M. M. (2015). Statistical description of excess properties of many-particle binary systems. *Ukrainian Journal of Physics*, Vol. 60, No. 4, pp. 324-327. Doi: https://doi.org/10.15407/ujpe60.04.0324

4. Gerasymov, O. I., Zagorodny, A. G., and Somov, M. M. (2013). Toward the analysis of the structure of granular materials. *Ukrainian Journal of Physics*, Vol. 58, No. 1, pp. 32-39. Doi: https://doi.org/10.15407/ujpe58.01.0032

5. Gerasymov, O. I., Vandewalle, N., Spivak, A. Ya., Khudyntsev, N. N., Lumay, G., Dorbolo, S., and Klymenkov, O. A. (2008). Stationary states in a 1D system of inelastic particles. *Ukrainian Journal of Physics*, Vol. 53, No. 11, pp. 1128-1135.

6. Gerasymov, O., Spivak, A., Andrianova, I., Sidletska, L., Kuryatnikov, V., and Kilian, A. (2021).

Micro-mechanical (granular) mixtures for environmental safety technologies. *E3S Web of Conferences*, Vol. 234, pp. 00075/1-6. Doi: https://doi.org/10.1051/e3sconf/202123400075

7. Gerasymov, O. I., Spivak, A. Y., Andrianova, I. S., Sidletska, L. M., Kuryatnikov, V. V., and Kilian, A. M. (2021). Tightening (compaction) of bi-component micromechanical (granular) system. *Science and Innovation*, Vol. 17, No. 4, pp. 79-88. Doi: https://doi.org/10.15407/scine17.04.079

8. Pillitteri, S., Lumay, G., Opsomer, E., and Vandewalle, N. (2019). From jamming to fast compaction dynamics in granular binary mixtures. *Scientific Reports*, Vol. 9, No. 1, pp. 7281/1-7. Doi: https://doi.org/10.1038/s41598-019-43519-6

Герасимов Олег Іванович — док. фіз.-мат. наук, професор, завідувач кафедри загальної та теоретичної фізики, Одеський державний екологічний університет, Одеса, e-mail: gerasymovoleg@gmail.com

Курятников Владислав Володимирович — канд. фіз.-мат. наук, доцент кафедри загальної та теоретичної фізики, Одеський державний екологічний університет, Одеса, e-mail: kuryatnikov1@ukr.net

Співак Андрій Ярославович — канд. фіз.-мат. наук, старший викладач кафедри загальної та теоретичної фізики, Одеський державний екологічний університет, Одеса, e-mail: spivaka@ukr.net

Сідлецька Людмила Михайлівна — завідуюча лабораторією фізики та фізичного експерименту кафедри загальної та теоретичної фізики, Одеський державний екологічний університет, Одеса, e-mail: milapolonskaa@ukr.net

Кільян Андрій Миколайович — асистент кафедри загальної та теоретичної фізики, Одеський державний екологічний університет, Одеса, e-mail: keramic@ukr.net

Gerasymov Oleg I. — Dr. Sc. (Phys & Math), Professor, Head of the Department of General and Theoretical Physics, Odessa State Environmental University, Odesa, email : gerasymovoleg@gmail.com

Kuryatnikov Vladyslav V. — Cand. Sc. (Phys & Math), Assistant Professor of the Department of General and Theoretical Physics, Odessa State Environmental University, Odesa, email : kuryatnikov1@ukr.net

Spivak Andrii Y. — Cand. Sc. (Phys & Math), Senior Lecturer of the Department of General and Theoretical Physics, Odessa State Environmental University, Odesa, email : spivaka@ukr.net

Sidletska Liudmyla M. — Head of the Laboratory of Physics and Physical Experiments of the Department of General and Theoretical Physics, Odessa State Environmental University, Odesa, email : milapolonskaa@ukr.net

Kilian Andrii M. — Assistant of the Department of General and Theoretical Physics, Odessa State Environmental University, Odesa, email : keramic@ukr.net