REVIEW

on the PhD thesis of Berdenova Bakytnur Amanbayevna "Adsorption characterization of composite activated carbon for application in adsorption cooling systems" submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D060300 – Mechanics

The relevance of the research topic and its relationship with general scientific and national programs.

The topic and the content of the thesis are of high scientific interest.The process of adsorption of gases is used in various applicationslike gas storage, cooling systems, heat pumps, gas capture and sequestration, and currently finding new more applications.The growing interest for adsorption process makes the development of new materials with improved characteristics relevant study.An accurate assessment of the adsorption characteristics of newly synthesized materials plays a major role in forecasting their performance as they used in different systems.

In the given work author studied how the adsorption process is used in cooling systems. I would like to emphasize the technology for producing cold discussed in the dissertation work is new on a national scale. The development of the given field would have a positive socio-economic effectvia rational use of energy and its safe operation.

Scientific results and their validity.

New consolidated composite activated carbon was synthesized with a composition ratio of 50 wt% parent AC Maxsorb III, 40 wt% graphene, 10wt% HEC binder. Porous properties and thermal conductivity of synthesized composite are investigated. In addition, adsorption characteristics of CO_2 onto composites are observed for adsorption temperature of 20 to 70°C up to 5 MPathermogravimetrically using magnetic suspension adsorption measurement apparatus. The present work also discusses comprehensive study for evaluating accurate absolute adsorption uptake. Obtained absolute adsorption data were fitted to modified D-A and Tóth isotherm models to find the isotherm parameters and heat of adsorption. Material illustrates promising thermal and adsorption characteristics for application in adsorption cooling systems.

The effective Knudsen diffusion coefficient for the working pair of carbon dioxide/activated carbon was found using the pore size distribution data and the characteristics of the diffused gas.

Present research proposes a mathematical model of non-isothermal reactive flow for the process of adsorption onto consolidated material. The model considers porosity change available for mobile gas and change in Knudsen diffusivity coefficient with adsorption uptake. These effects becomes important when deal with consolidated AC, as in case of consolidated AC the shell of the material saturates first and becomes less permeable for bulk gas. Therefore to find critical thickness for the tablets for application in different adsorption based systems these effects should be taken into account. The system of PDEs was solved in Python using explicit second order finite difference schemes. The behavior of curves tested using 1D axial dispersed plug flow geometry. Simulation results of the developed mathematical model show good agreement with the experimental data than that for existing model where the porosity and permeability are not the functions of adsorption uptake. Therefore, the developed mathematical model predicts the adsorption dynamics with better accuracy for the given configuration.

The degree of validity and reliability of each scientific results, proofs and conclusions of the applicant formulated in the thesis.

The validity and reliability of the scientific conclusions obtained in the thesis are confirmed by their consistent theoretical and mathematical justification, as well as obtained simulation results compared with experimental data. The solution method and the resulting dependency curves are relevant.

The results of the research were discussed and reported at conferences, and published in scientific journals: 3 publications in journals recommended by the Committee on the Control of Education and Science of the RK and 1 publication in international peer-reviewed journal indexed in Scopus DB.

The degree of novelty of each scientific result, proof of the applicant formulated in the PhD thesis.

- New consolidated composite adsorbent was synthesized and the adsorption characteristics of the material studied comprehensively. The material has a direct purpose and is designed to improve and compact the adsorption refrigeration reactors.
- Excessive adsorption isotherms obtained using thermogravimetric analysis were processed using two different methods for evaluating absolute uptake. In the first method the specific volume of gas in the adsorbed state is assumed to be equal to the specific pore volume. In the other method the volume of adsorbed gas tends to zero under low pressure and/or high temperature conditions. The average was taken as the best closest fit. Obtained absolute adsorption data used in constructing general isotherm models;
- New mathematical model considering the adsorption caused porosity and Knudsen diffusivity changes was developed. The temperature dependent adsorption rate change due to the energy release during adsorption process is also implemented in the model. The effective Knudsen diffusion coefficient for the working pair of CO_2/AC evaluated from Pore Size Distribution data. The validation of the developed model was performed via comparison with the results obtained experimentally on the magnetic suspension balance unit and numerical result shows good agreement with the experimental data.
- **Practical and theoretical significance of the scientific results.**

The results of the presented dissertation can be used for a detailed description of the dynamics of gas adsorptiononto consolidated activated carbon. The developed mathematical model predicts the adsorption dynamics with better accuracy. The results of the study also can be used in other adsorption related systems.

The work is of great practical importance, since the enhancement of adsorption characteristics of the working pair in ACS has a positive impact on its performance. The development of this direction has great potential, since adsorption refrigerators can operate off-grid. Later the results obtained will be used in development of the fully solar driven ACS prototype. Such technology could be used in production of from small thermostats till huge storehouses with regulated temperature.

Comments, suggestions for the PhD thesis.

- The reverse process to adsorption, the process of desorption is not studied in the work. The applicant explains this with the lack of experimental data for comparison and analysis, but for completeness, it would be interesting to show some results on desorption process too.The recommendation doesn't affect the main theoretical and practical results of the dissertation.
- The implementation of numerical schemes for system of equations is not discussed in detail.

Compliance with the content of the PhD thesis in the framework of the requirements of the Rules for the award of scientific degrees.

The PhD thesis by Berdenova B. entitled "Adsorption characterization of composite activated carbon for application in Adsorption Cooling Systems" meets all the requirements by the Committee on the Control of Education and Science of the RK for the degree of Doctor of Philosophy (PhD) on specialty "6D060300-Mechanics".

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I certify the signature of Beketayeva A.O.:

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