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Evaluation report on the PhD thesis

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Flow Dynamics and Distribution of Liquid in a System of Rotating Packed Bed

Thermal separation techniques such as distillation, desorption or absorption are unit operations of industrial processes and established methods for the purification of fluid streams and, in particular, for gas treatment. These separation processes cannot be replaced in the future, even though they usually have a very high energy demand, and this energy demand is often covered by conventional energy sources and therefore have a high CO_2 footprint during operation. Even small energy savings in the operation of these, usually also very large apparatuses, therefore, have an enormous impact on the environment and are associated with large cost savings. On the other hand, the separation of CO_2 from gas streams, among other things, is currently a very relevant task that needs to be solved efficiently.

One possible approach to reducing this energy demand is known as process intensification, which involves introducing additional driving forces into a system as a possible concept. So - known HiGEE apparatuses therefore represent a possible solution in the context of process intensification, in which large centrifugal forces act on the fluid phases to be processed. In this context, so-called ‘Rotating Packed Beds (RPB’s)’, which can be used for distillation and absorption processes and enable fluid separations in a very small space in a very short time, are currently

attracting increasing interest in research and development. These apparatuses are not yet fully understood and there is a lack of design methods, among other things. In particular, there are still many unresolved issues regarding fluid dynamics in the apparatus that are currently being discussed. There is also still a great potential in the optimisation of the rotating packings, which requires knowledge of the fluid dynamics resp. hydrodynamics and their interaction with the mass transfer.

The very complex topic described above is the subject of the cumulative PhD thesis submitted by Mr Ing. Ondřej Hájek, which deals with the development of a new experimental measurement setup and the coupling of the results obtained with investigations on mass transfer, the description by means of CFD of RPBs. Furthermore, on the basis of the experimental results obtained, new models for the fluid dynamics, especially for the cavity zone, are developed, which are novel and highly interesting. The work is of both scientific and industrial interest and will contribute to the further dissemination and deeper understanding of the mechanisms in RPB's.

The submitted cumulative PhD thesis consists of 5 published papers, preceded by a text section that categorises the papers, introduces the topic and clearly states the hypotheses and research questions of the scientific work.

The introductory text section is clearly written, very systematically structured and linguistically well resp. adequately presented.
After a brief introduction, the basic principles and the design of RPB's are briefly and clearly described. The main focus of the investigations is on the fluid dynamics, more precisely hydrodynamics in RPBs, whose basic mechanisms are clearly discussed in chapter 3 against the background of the current literature. Mr Hájek makes his scientific contributions to this aspect, which forms the core of his own work. A brief description of the gaps in scientific knowledge in Chapter 4 leads on to Chapter 5, in which the objectives and hypotheses of the scientific work are formulated. The aim is to achieve a deeper understanding of the liquid distribution, the liquid holdup, the droplet movement and the morphology of the liquid phase in RPB's, especially in the cavity zone, and to describe these. Mr Hájek achieves these complex objectives in an impressive manner. Chapter 5 provides a compact description of the structure of the PhD thesis presented. Chapter 6 gives an informative overview of the content and results of the five published articles, before Chapter 7 summarises and provides an outlook for future research.

In the following 5 published articles, the scientific contribution of Mr Ing. Ondřej Hájek is mainly of an experimental nature and can be seen in the obtaining of fluiddynamic, hydrodynamic results. The 5th article also contains interesting modelling.

Paper I
This article published in a reputed scientific journal, where Mr Ing. Ondřej Hájek is the first author, deals with the experimental analysis of liquid jet dispersion after the impact on a curved surface, which is an important fundamental investigation before the actual RPB can be considered.

Paper II
In this poster communication the improvement of packings for RPB is discussed and Mr Hájek is co-author of the paper, which is published together with colleagues from the University of Lodz. The packing improvement is mainly based on the pressure drop and optical results obtained by Mr Hájek.

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Paper III
Mr Hájek is also a co-author of this conference paper and the contents of the paper are numerical simulations (CFD) of liquid decomposition on pin packing, for which Mr Hájek developed a novel experimental setup and carried out the corresponding measurements. The results are new and the CFD validation was successful.

Paper IV
This journal paper is again a joint publication with colleagues from the University of Lodz and Mr Hájek is a co-author. Here, the mass transfer during CO_2 absorption with RPB is analysed experimentally and theoretically, using a chemical absorbent with a novel composition. A main focus of the article is the investigation of the reaction kinetics, whereby Mr Hájek has certainly contributed to the understanding of fluid dynamics here.

Paper V
Again, this journal paper is a joint contribution with colleagues from the University of Lodz, but Mr Hájek is the first author. The article seems to be at the core of the work of Mr Ondřej Hájek. Extensive experimental studies on droplet movement in the cavity zone are presented and models and correlations are developed for various aspects, which reflect the experimental results well.

In addition to the published articles submitted as part of the PhD thesis, Mr Hájek was also involved in a number of other scientific articles and conference contributions as co-author and in some cases as first author. He has thus participated intensively in the scientific discussion, which can be considered very good in the context of a dissertation. With the development of the unique fluid dynamic test rig and the performance of experimental investigations at a high scientific level, Mr Ing. Ondřej Hájek has made important contributions to the field of RPBs, which will certainly be used by other scientists in the future.

I hereby recommend with particular emphasis and expressly the acceptance of the dissertation submitted by Ing. Ondřej Hájek with the title:

Flow Dynamics and Distribution of Liquid in a System of Rotating Packed Bed

and that the dissertation procedure be continued.

Jens-Uwe Repke

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Prof. Dr.-Ing. Jens-Uwe Repke Berlin, the 6th of January 2025

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