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Report on the PhD thesis of Pawel Kondratiuk

«Dynamics of reaction fronts in porous media»

Pawel Kondratiuk present in this document the results of his research made during his PhD. The research concern the dynamics of reaction fronts in porous media with numerous applications in chemical geophysics. The work is a nice combination of theoretical, modelling and numerical approaches. The thesis is written in a good english and is very pleasant to read. It contains nine chapters and has overall about 120 pages.

The manuscript starts with a short introduction that explains the motivation of this work and the research context in geophysics.

The second chapter describes in details the general physical model of reactive front: as the fluid penetrates the porous media, a chemical reaction transform the porosity of the media and thus its fluid dynamics. The model is very well presented, introducing the different time scales of the dynamics.

Chapter 3 explains why and how the planar front of the reaction is unstable, forming eventually fingers that are famous in geophysics. The planar front solution is first computed within the thin front approximation and the linear stability analysis is performed. I have one remark here, on the simplification made by the authors on the harmonic property of the pressure field. It would be useful to write at least initially that instead of $\Delta p=0$, the correct equation is $\nabla(K\nabla p)=0$ which simplifies into $\Delta p=0$ in each domain but with a jump condition of the derivative on the front.

In the fourth very short chapter, a simple nonlinear model is deduced to explain the nonlinear evolution of the fingers leading to the coalescence of the front into few large fingers. It is followed by chapter 5, very short also, were numerical simulations of the equations are performed that exhibit the coalescence dynamics leading to few growing fingers. Here a more detailed analysis could have been done by Pawel Kondratiuk: indeed, the evolution of the Fourier spectrum of the front could give interesting information on the coarsening process that could be investigated using self-similar arguments for instance.

Chapter 6 and chapter 7 are the masterpieces of the thesis. In chapter 6, Pawel Kondratiuk investigates the steady state of the fully nonlinear patterns formed by the instability. This is a

very difficult problem to solve fully analytically since nonlinear terms are dominant and Mr Kondratiuk proposes in this thesis a local analysis for the two edges of the fingers pattern, the tip and the root. In both case, he develops an elegant conformal mapping technics that allows to obtain the local form of each structure, both in 2 and 3 spatial dimensions.

In chapter 7, the same general approach is repeated for more difficult and more general systems, the dissolution-precipitation fronts where thus the dissolution of the initial media upstream is followed by the formation of a new material downstream. The same techniques of linear stability analysis is reproduced and give similar results but a new instability mechanism is identified due to the non-monotoneous variation of the permeability within the front.

Chapter 8 presents 2D numerical simulation of this dynamics, showing the formation of complex structures that are positively compared with natural patterns.

A general conclusion of the work is proposed in chapter 9.

To conclude, the work presented by Pawel Kondratiuk in this manuscript is of very high quality and offers a very interesting and complete investigation on the modelling and analysis of the formation of natural patterns due to dissolution in geophysics. Numerous scientific achievements, both in theory, modelling and numerics have been obtained. Therefore, I am enthousiast to support the defense of the thesis of Pawel Kondratiuk.

Palaiseau, tuesday June 20th 2017

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Letter to support the highest distinction for the PhD thesis of Pawel Kondratiuk

«Dynamics of reaction fronts in porous media»

It is my pleasure to write this letter in addition to my report to support the obtention of the highest distinction for the thesis of Pawel Kondratiuk. I would like to emphasize that this work presents an outstanding achievement in the modelling and the dynamics of the reaction front in porous media with important potential application in geophysics. I have particularly appreciated the complete description of the patterns formed from the linear instability to the nonlinear complex structure and the combination of scientific approaches, from theory, modelling to full numerical simulations.

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