



HAL
open science

Transient buoyant convection of a highly thermodependant viscous fluid in a cylindrical drum

Charles Brissot, Arnaud Poulesquen, Rudy Valette

► **To cite this version:**

Charles Brissot, Arnaud Poulesquen, Rudy Valette. Transient buoyant convection of a highly thermodependant viscous fluid in a cylindrical drum. 10th International Conference on Heat Transfer and Fluid Flow (HTFF 2023), Aug 2023, Londres, United Kingdom. cea-04665176

HAL Id: cea-04665176

<https://cea.hal.science/cea-04665176>

Submitted on 31 Jul 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Transient buoyant convection of a highly thermodependant viscous fluid in a cylindrical drum

Charles Brissot¹, Rudy Valette², Arnaud Poulesquen¹

¹CEA, DES, ISEC, DPME, Univ Montpellier
Marcoule, France

²Cemef Mines ParisTech

1 rue Claude Daunesse, 06904 Sophia Antipolis, France

charles.brissot@cea.fr; rudy.valette@minesparis.psl.eu Arnaud.poulesquen@cea.fr

Extended Abstract

The study of the thermal behaviour of highly thermodependant fluids is primordial to study several topics. The most prolific field is the earth mantle study [1-3]. However, rock is not the only material that undergoes large viscosity variations with temperature. Bitumen is also a candidate to such variations. The study of this material is important as it is used in several fields implying transient variations of temperature, such as building. Another minor field is the management of radioactive bituminous waste products (BWP) contained in drums, and more specifically their behaviour while undergoing a thermal stress. This configuration is transient, and the behaviour of the fluid during each time step is important to predict the behaviour of these waste packages to a thermal stress.

Usually, convective systems are studied in permanent state [4-5]. The main known conclusions are that there is a separation between a viscous cold domain and a fluid hot domain, with two distinct convective or diffusive regimes. Heat transfers are imposed by the diffusive part, but the convective one reduces the length scale of the first one. All of this is driven by the viscosity ratio. Regarding transient systems, there are fewer studies available only in 2D [6-8]. Moreover, to the author's knowledge, there is a lack of study for cylindrical shapes. The present study aims at fulfilling this gap.

The configuration of a constant temperature stress on the vertical boundary is then considered. To estimate the key features of the system, a simplified view of the problem is proposed. Since the large thermodependancy (more than 6 decades in viscosity ratio between the hot and cold parts and an activation energy of around 150 kJ/mole) leads to regions of distinct behaviour, an ideal system composed of two phases of constant viscosities is studied. This allows us to draw a first general understanding of the system behaviour, assumed to be representative of the real system. Numerical simulations for various parameters on a 3D Finite Element solver with the Boussinesq approximation are then carried out to confirm the analytical results.

The main parameters influencing the characteristic times and intensities of the heat fluxes are the density difference, the viscosity ratio, the diffusivity and the length scales of the drum. Four phases are enhanced: a diffusive thermal choc, a vertical boundary layer convection, a global convection lead by the collapse of the cold inner core, and finally the heating of the remaining cold area by diffusion. The flow is globally driven by a competition between this collapsing inner cold core and the movement of the surrounding hot fluid. This primarily changes the speed of heating of the upper parts of the drum, while the bottom is mainly heated by diffusion during the end of the process. Consequently, the radius and the diffusivity mostly set the order of magnitude of the time of homogeneity.

Additional simulations with non-newtonian rheological laws (such as Hershel-Bulkley model) were also tested. The addition of a yield stress reduces the convection and thus the intensity of the second and third phases.

References

- [1] U. R. Christensen, "Heat transport by variable viscosity convection and implications for the Earth's thermal evolution" *Phy. Earth. Plan. Int.*, vol. 35, pp. 264-282, 1984.
- [2] P. J. Tackley, "Effects of strongly variable viscosity on three-dimensional compressible convection in planetary mantles," *J. Geo. Res.*, vol. 101, no. B2, pp. 3311-3332, 1996.

- [3] P. J. Tackley, "Modelling compressible mantle convection with large viscosity contrasts in a three-dimensional spherical shell using the yin-yang grid," *Phys. Earth Plan. Int.*, vol. 171, pp. 7-18, 2008.
- [4] K. E. Torrance and D. L. Turcotte, "Thermal convection with large viscosity variations," *J. Fluid Mech.*, vol. 47, part 1, pp. 113-125, 1971.
- [5] J. R. Booker, "Thermal convection with strongly temperature-dependent viscosity," *J. Fluid. Mech.*, vol. 76, part 4, pp. 741-754, 1976.
- [6] A. Davaille and C. Jaupart, "Transient high-Rayleigh-number thermal convection with large viscosity variations," *J. Fluid Mech.*, vol. 253, pp. 141-166, 1993.
- [7] J. M. Hyun, "Transient Buoyant Convection of a Contained Fluid Driven by the Changes in the Boundary Temperatures," *J. App. Mech.*, vol. 52, pp. 193-198, 1985.
- [8] V. S. Solomatov and A. C. Barr, "Onset of convection in fluids with strongly temperature-dependent, power-law viscosity," *Phys. Earth Plan. Int.*, vol. 155, pp. 140-145, 2006.