



FINAL REPORT

Properties of two phase flow of water and steam in geothermal reservoirs

Project ID: 09-01-011

Coordinator: Guðrún Sævarsdóttir

Start date: 01.08.2009

Duration: 4 years

Partners: Reykjavik University, University of Iceland and Iceland Geosurvey.

1 Project summary

The project „Properties of two phase flow of water and steam in geothermal reservoirs“ is partially financed by GEORG, the rest of the funding comes from The Energy Research Fund of Landsvirkjun, University of Iceland Equipment fund and the Energy Fund of the National Energy Authority (Orkusjóður). The application for the grant to GEORG was submitted in June 2009 and accepted later that year.

The objective of the project is to perform measurements of two phase flow of water and steam which resembles the fluid flow in porous geothermal reservoirs. The goal is to gain a better understanding and knowledge of which theoretical and empirical relations are applicable for simulation of two phase geothermal reservoirs.

The project started in 2009 when one Ph.D. student was hired to perform the following tasks as her Ph.D. project.

The first part was to perform a detailed literature research on geothermal reservoirs in general with emphasis on the flow of two phase fluid in porous materials. This included a summary of previous work in the field, and the available relations used in geothermal simulations were outlined. This resulted in two conference papers and one journal papers where the concept of relative permeabilities of water and steam in geothermal reservoirs was reviewed and a possible flaw of the state of the art relations was introduced.

The second part was to design, construct, install and operate a measurement device which could operate in geothermal environment. This device was installed in the Reykjanes power plant where fluid from the geothermal separators was used for laboratory tests. This resulted in measurements of two phase flow of water and steam through a porous filling of the measurement device, which consisted mainly of a 4m long steel pipe with diameter of 10 inches. The fluid was flashed through the porous filling and pressure was measured at several locations on the device. The relative permeabilities of the two phases were calculated from the measured parameters. The measurements were gathered for a range of inlet pressure and flow directions inclined from horizontal. The results were presented in one conference paper and a journal paper is now under preparation.

The third part was to compare the results of the calculated relative permeabilities to field data. Information on well flow from different geothermal fields in Iceland was collected and the relative permeabilities of the two phases calculated according to the Shinohara method. The results are presented in a journal paper which is now under preparation.

The original time schedule in the grant application stated that the project end date would be 1.7.2012. This date was shifted to 1.5.2013 due to a 10 months maternity leave of the Ph.D. student. Due to complications in the installation of the measurement device the project is delayed for several months and the estimated project end is at the end of year 2013, when the journal papers have been completed and a thesis which collects the main results has been written.

The research work and results are described in the published papers and paper drafts listed in section 4.

2 Project Management

Guðrún Sævarsdóttir is PI and the principal supervisor of the PhD student but the project was managed in close collaboration with the rest of the Doctoral committee, Prof. Halldór Pálsson at the University of Iceland, Prof. Emeritus Jónas Elíasson and Dr. Guðni Axelsson at ISOR.

3 Student involvement

One Ph.D. student, María Sigríður Guðjónsdóttir, was involved in the project which is her Ph.D. project. All the main tasks of the project were performed by the student under supervision of the students Ph.D. committee.

4 Publications and disseminations

One paper has been submitted to a journal:

Maria Gudjonsdottir, Jonas Eliasson, Halldor Palsson, Gudni Axelsson, Gudrun Saevarsdottir. "Gravity effect on relative permeabilities of water and steam in geothermal reservoirs". Submitted to *Advances in Water Resources*, 2013.

Two journal papers are under preparation and are planned to be submitted by the end of year 2013:

Maria Gudjonsdottir, Jonas Eliasson, Halldor Palsson, Gudni Axelsson, Gudrun Saevarsdottir. "Calculation of relative permeabilities from laboratory measurements". Manuscript under preparation and will be submitted to *Transport in Porous Media*.

Maria Gudjonsdottir, Jonas Eliasson, Halldor Palsson, Gudni Axelsson, Gudrun Saevarsdottir. "Calculations of relative permeabilities from field data and comparison to laboratory measurements". Manuscript under preparation and will be submitted to *Geothermics*.

Following conference papers have been published and the Ph.D. student has given presentations at the conferences on the papers content:

Maria Gudjonsdottir, Jonas Eliasson, Halldor Palsson et al. (2013). „Measurements of relative permeabilities of water and steam“. In 38th Workshop on Geothermal Reservoir Engineering.

Maria Gudjonsdottir, Jonas Eliasson, Gudni Axelsson et al. (2012). „Effect of flow configuration on the relative permeabilities of water and steam in two phase flow in geothermal reservoirs“. In 37th Workshop on Geothermal Reservoir Engineering.

Maria Gudjonsdottir, Jonas Eliasson, William Harvey et al. (2010). „Assessing relative permeabilities of two phase flows of water and steam in geothermal reservoirs: State of the art relations. In 34th Geothermal Resource Council Annual Meeting.

The project has also been presented at the following workshops/conferences:

European Geothermal PhD day 2011, Reykjavik Iceland. Oral presentation and a poster. Received 2nd price at the poster award.

European Geothermal PhD day 2012, Pisa Italy. Oral presentation and a poster. Received 2nd price at the poster award.

Geothermal reservoir research in Iceland. Work shop held in Reykjavik Iceland 2010.

5 Cost statement

The funding from GeoRG and LV went mostly into covering the PhD candidates fellowship. The experimental costs were covered by equipment grants as well as RU and HÍ.

Cost item		Requested funding		Other financing		Total
2009/2010	Salaries					3.960
	Operational expenses					4.420
	Travel expenses					0
	Total 2009/2010:	1.000	12%	7.380	88%	8.380
2010/2011	Salaries					4.170
	Operational expenses					3.330
	Travel expenses					300
	Total 2010/2011:	2.300	29%	5.500	71%	7.800
2011/2012	Salaries					7.140
	Operational expenses					6.660
	Travel expenses					300
	Total 2011/2012:	1.300	10%	12.800	90%	14.100
2012/2013	Salaries					6.660
	Operational expenses					6.660
	Travel expenses					300
	Total 2011/2012:	1.300	0%	12.320	0%	13.620
Grand Total		4.600	13%	25.680	85%	43.900