Modeling of the Mutnovsky Geothermal Field (Dachny) in Application to Optimal Exploitation Load Design

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Keywords

Mutnovsky, TOUGH2V2.0, coupled wellbore flow, exploitation load

ABSTRACT

The Mutnovsky geothermal field modeling study previously performed using TOUGH2 (Kiryukhin, 2004) was verified based on TOUGH2V2.0 with coupled wellbore flow option. Modeling results basically agree with those previously obtained: total steam production of the wells from the central part of Dachny site (E4, 016, 26, 029W, E5) will decline from 63 kg/s to 33 kg/s during the 10 year exploitation period due to overload of the north part of the Main production zone. Additional exploitation load on the central part of the Dachny site has no significant effect on steam production. Modeling of additional exploitation load in the south-eastern part of the Dachny site to maintain 50 MWe power plant is on-going.

Introduction

Here is a brief explanation of the current TOUGH2-based numerical model of the Main production zone of the Dachny site, Mutnovsky geothermal field (Figure 1, for details see Kiryukhin, 2004). The geothermal reservoir is represented as a combination of two layer-type reservoirs: For simplicity we will use A-reservoir and B-reservoir (Figure 2, overleaf) for the two layers. A-reservoir corresponds to the "single fault type" Main production zone. B-reservoir includes three elements corresponding to diorite intrusion contact permeability zones. In total 24 existing wells, 39 additional interior elements and 12 boundary (inactive) elements (B-elements) are specified in the model. Figure 2 also demonstrates the grid and the permeability distributions assigned to the A-reservoir and B-reservoir of the model. This model still being applied in connection to 50MWe Mutnovsky power plant steam supply. Here, specific feature of the coupled wellbore flow in this model was verified based on TOUGH2V2.0 (K.Pruess, 1999) option.

Modeling of Well-Reservoir Interaction

A special subroutine DEBIT was used for well-reservoir interaction representation in the TOUGH2-based model (Kiryukhin, 1992, 2004). Mass flowrate is determined from the following equation: $Q = PI * (P_r - P_b(WHP, Q, h, d))$ where Q mass flowrate of the well; PI production index of the well; P_r reservoir pressure, $P_b(WHP, Q, h, d)$ bottom hole pressure that is a function of Q, fluid enthalpy h, well head pressure WHP and well construction features d (well diameter vs depth).Bottom

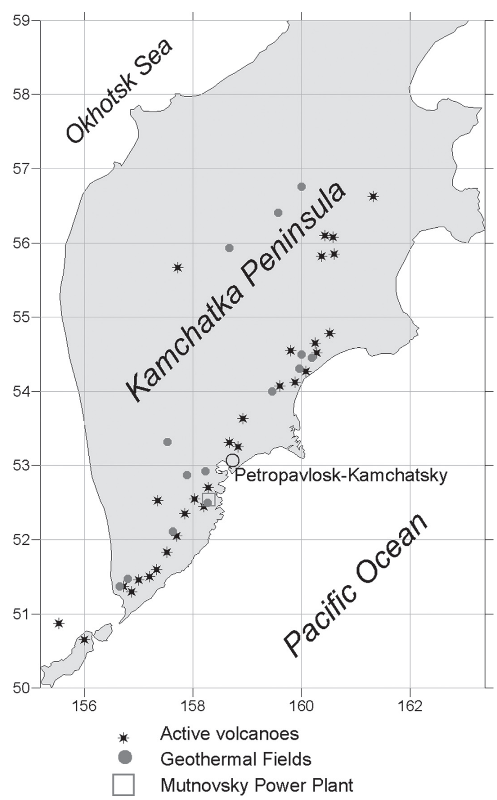
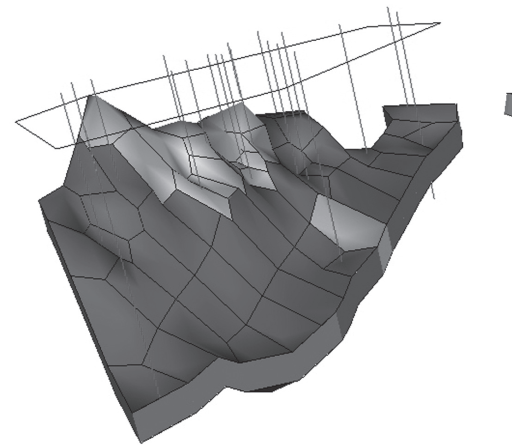


Figure 1. Kamchatka (Russia) map, showing location of active volcanoes, geothermal fields and Mutnovsky power plant.



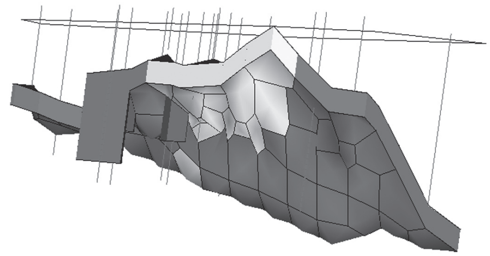


Figure 2. Geometry of the 3-D numerical model of the Main production zone of the Dachny site Mutnovsky geothermal field. Left – view from above south-east, Right – view from below south-west. Colors correspond to different permeability domains. For details see (Kiryukhin, 2004)

hole pressure P_b(WHP, Q, h, d) is calculated in the form of electronic tables based on HOLA code. At that time the total productivity indexes (PI) of five production wells were estimated based on wells rates (Q) and wells head pressures (WHP) (accordingly to initial exploitation data), flowing enthalpies h, reservoir P_r and bottomhole P_b pressures derived from the model (Table 1).

Now, the TOUGH2V2.0-based coupled wellbore flow option used. For this purpose the total production indexes were split:

$$PI = (k_{rs}\rho_s / \mu_s + k_{rw}\rho_w / \mu_w)\ PI_0$$

where $k_{r\beta}$ relative phase permeability, μ_β viscosity Pa*s, ρ_β density, kg/m^3, PI_0 productivity indexes (m^3) (liquid (β=w) or steam (β=s)). Productivity indexes PI_0 of five production wells were estimated according to wells rates (Q) and wellhead pressure (WHP) (corresponding to initial exploitation data), flowing enthalpies h, reservoir P_r and bottomhole P_b pressures, and relative permeabilities (k_{rs}, k_{rw}) derived from the model (Table 1). Grant type relative permeabilities used (K.Pruess, 1991).

Table 1. Exploitation wells O16, 26, E4, O29W and E5 (Figure 3) parameters used for productivity index estimation.

Well	Q kg/s	WHP bar	h kJ/kg	P_b Bar	P_r Bar	PI kg/s bar	k_{rs}	k_{rw}	PI_0 m^3
O16	17	7.5	2400	13.9	21.6	2.2	0.9640	0.0360	2.52 10^{-11}
26	18	7.5	2800	13.7	25.5	1.5	0.9999	0.0001	1.97 10^{-11}
4E	26.7	9	1338	24.9	58.2	0.8	0.3077	0.6923	1.37 10^{-12}
029W	72.5	9	1216	50.4	58.4	9.1	0.0330	0.9670	1.20 10^{-11}
5E	39	7	1072	27	33.5	6.0	0.1296	0.8704	9.22 10^{-12}

Exploitation Modeling of Dachny Site Exploitation in the Mutnovsky Geothermal Field up to Year 2012

Production wells are assigned wellhead pressure conditions corresponding to the data from Table 1. Well 027 is specified as a reinjection well with mass rate 84 kg/s and enthalpy 700 kJ/kg. Two scenarios of exploitation up to 2012 year are studied: (1) five wells 016, 26, 029W, E4 and E5 producing, (2) the withdrawal rates are doubled in the elements containing these five production wells compared to the first scenario.

Figure 4 shows scenario #1 total steam production drop (at 7 bars) of the wells 016, 26, 029W, E4 and E5 from 63.1 to 32.6 kg/s during the 10 year exploitation period, and 13.0 bars pressure drop in reservoir (A3 element).

Figure 5 shows scenario #2 total steam production drop (at 7 bars) of the wells from 126.2 to 42.0 kg/s during the 10 year exploitation period, and 19.5 bars pressure drop in reservoir (A3 element).

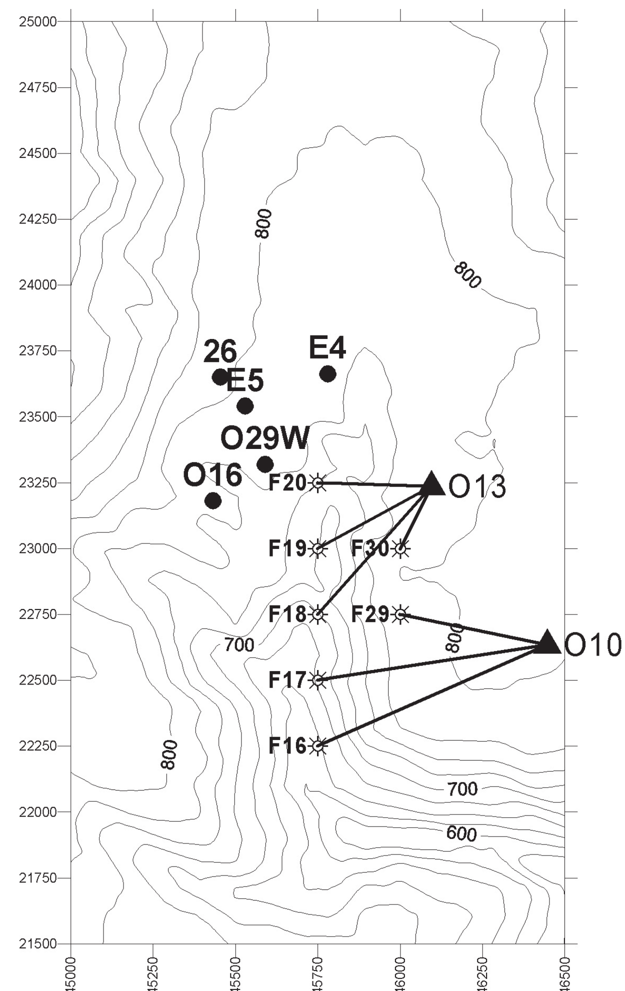


Figure 3. Well locations corresponding to modeling scenario: exploitation wells (26, O16, O29W, 4E, 5E) – filled circles. Well locations corresponding to modeling scenario on-going: new drilling targets projections for additional exploitation wells (F16, F17, F18, F19, F20, F29 and F30) – open stars, sites for directional drilling rigs (wells O13, O10 sites) - triangles. Shaded areas shows topo surface elevations (from +500 to + 1000 m.a.s.l.)

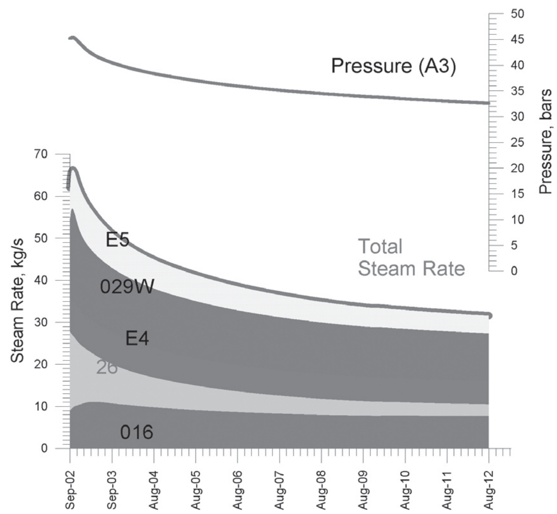


Figure 4. Scenario #1: modeling of the steam production (wells 016, 26, E4, 029W, E5) and reservoir pressure (A3 model element) response in the Dachny site of the Mutnovsky geothermal field up to 2012 year.

Conclusions

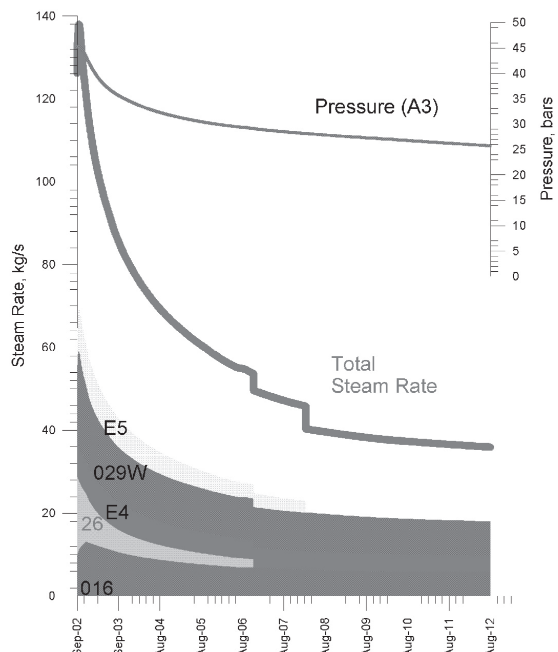


Figure 5. Scenario #2: modeling of the steam production (doubling load of the wells 016, 26, E4, 029W, E5) and reservoir pressure (A3 model element) response in the Dachny site of the Mutnovsky geothermal field up to 2012 year.

1. The TOUGH2 Mutnovsky geothermal field modeling study previously carried out (Kiryukhin, 2004) was verified based on TOUGH2V2.0 with coupled wellbore flow option. Steam production from the existing production wells of the Dachny site in the Mutnovsky geothermal field (016, 26, E4, 029W, E5) is limited to 60-70 kg/s with possibility of decline down to 33 kg/s during the first 10 years of the exploitation. Significant exploitation load in central part of the Dachny site will not yield adequate steam production increase.
2. The Mutnovsky 50MWe power plant needs a stable 100 kg/s supply of 7 bar steam for a 20–30 year exploitation period. Additional study of the steam productivity increase from south-east portion of the Main production zone of the Dachny site (model elements F16, F17, F18, F19, F20, F29 and F30) is ongoing (Figure 3).

Acknowledgements

The author expresses gratitude to AO "Geoterm" staff: General Director V.E. Luzin, Chief Manager V.M. Morgun, hydrogeologists I.I. Chernev and L.K. Moskalev for helpful discussion and data support; Kamchatka EMSD GS RAS scientist D.V. Droznin for computer graphics support. This work has been supported by AO "Geoterm" contract №30 of 16.04.2003, Russian Basic Sciences Foundation grant 03-05-65373, and Russia Ministry of Education Grant 02.01.023.

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