PROGRESSIVE TECHNOLOGY EXTRACTION OF GEOTHERMAL ENERGY (GEOTHERMAL CIRCULATION SYSTEMS)

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ABSTRACT

The paper presents the results of investigation of hydrodynamic processes in the systems, optimization of technological parameters and heat-carrier circulation stability conditions. The solution we obtained for distribution of pressure, flowrate and leakage of fluid in the doublet circulation system.

It was solved the problem of the transient heat-mass transfer in the complex fissured-porous media with constant and periodical foundary conditions. The paper presents investigation results of filtration problems in the most general formulation, with allowance for the spatial nature and complex structure of the rock material (its inhomogeneity and anisotropy).

The solution of the problem on determination and estimation of the heat-carrier leakages in the underground horizon is important significance for operation of geothermal circulation systems (GCS). Heat carrier leakages influence upon stable operation of the GCS and geological environment. We consider the leakages related to the elasticity – capacity of the working horizon. The leakages depend on the distance between the wells, the time and hydrodynamic and technological conditions of the GCS operation. When leakages tend to zero, the GCS reaches steady state and equilibrium discharge operating regime. The leakage are estimated for different technological schemes: a) for the system where formation pressure is kept stafle; b) for foundation technology; c) for pumping technology.

The result were extended to GCS with optional numbers of injection and production wells.

KEY WORDS: geothermal circulation system, heat-transport medium, leakage, flowrate.

INTRODUCTION

The use of renewable sources of energy results in the saving of organic fuel and improvements of environmental impacts. The earth heat is one of the basic renewable energy source. Progressive technology extraction of geothermal energy is connected with development of GCS.

The positive social factor for exploitation of geothermal energy, specially progressive technology used is a reduction of the negative environmental impact. In the 21st century the ecological purity of geothermal plans and other non-traditional plants may be the main factor which will determine their large scale usage.

By their operation manner, geothermal technologies are divided into the following types: fountain, pumping. By their injecting manner, they may be without pumping (discharge on surface), injectional, circulation.

Waste thermal water may be discharged on the surface: to the reservoirs: rivers, lakes, seas; to the lowered parts of the relief in the desert regions; to the land-reclamation systems.

It leads to the fouling of the land and surface water.

The environmentally safest technologies are technologies injectional and circulation, when waste thermal water is pumped into the some underground horizons, or into working horizons. The geothermal circulation technologies are the most progressive and environmentally pure. Apart from the environmental protection, in this case the formation pressure is kept in the thermal water deposit.

MATHEMATICAL MODEL AND SOLUTION

To implement geothermal circulation technologies we must consider and estimate analytical models (GCS), the investigate the filtration problems in the most general formulation under injectivity of pumping wells.

It was solved the problem of the transient heat-mass transfer in the complex medium with constant and periodical boundary conditions. The paper presents investigation results of problems of filtration in the most general formulation, with allowance for the spatial nurture and complex structure of the rock material (i.e.,its inhomogeneity and anisotropy) [1]. The paper analyzes transient filtration of fluids through an inhomogeneusly anisotropic fissured and porous layer. Percolation through a jointed and porous layer is described by the equations

$$\chi \nabla(k_{ij}\ \nabla P_1) + \frac{P_2 - P_1}{\tau} = 0; \qquad \frac{\partial P_2}{\partial t} + \frac{P_2 - P_1}{\tau} = 0, \qquad (1)$$

where P_1 and P_2 are the pressure in the fissures and in the non-fissured rock (porous blocs); χ is the piezoconductivity coefficient; $\tau = \mu\beta/\alpha$; β - is the elastic capacity coefficient of the joints and α- parameter representing the rate of exchange between the two media. μ – vicosity of liquid. Eliminating one of the pressures from *Eq*. (1), we obtain, instead of a set of eguations, a single third-order equation

$$\frac{\partial P}{\partial t} = \chi \nabla(k_{ij}\ \nabla P) + \eta \frac{\nabla(k_{ij}\ \nabla P)}{\partial t} \qquad (2)$$

which should be satisfied by each of functions P_1 and P_2 . At η=0 ($\eta=\chi\tau$) we obtain the piezoconductivity equation. We consider the operation of a non-ideal well of radius r_0 with constant flowrate Q, drilled in an inhomogeneously anisotropic fissured and porous rock stratum that is initially under a stratal pressure P_s. The stratum has a finite thickness h, its base and roof are impermeable; the length l of the well is $l<h$. It is assumed that the permeability k_{ij} exhibits a power-law variation in the horizontal direction and is constant in the vertical direction. The problem refined is solved by a Laplace transformation with respect to the time-dependent variables and the Fourier transformation with respect to spatial variables. To find the inverse transform we use the Fourier-Mellin formula. We obtain for the dimensionless pressure in the fissure-bounded blocks the expression as the series of integrals of linear combination by the Bessel functions the I and II kind by the fractional index. The pressure distribution in layer is a function of fissured state value, variable permeability, degree of the well imperfection. At $l=h$ we can obtain from general solution the pressure distribution in the fissured and porous bed in the case of an ideal well, whereas at we obtain expressions for the pressure distribution in a homogeneously anisotropic porous bed. Figure 1 compares the dimensionless pressure distribution curves for different values of the fissuring parameter ξ for points r = 1(m) and r =2(m). The solid curves are for ξ=0, the dashed – for ξ=1000 and thedash-dotted – for ξ=10000 [2,3].

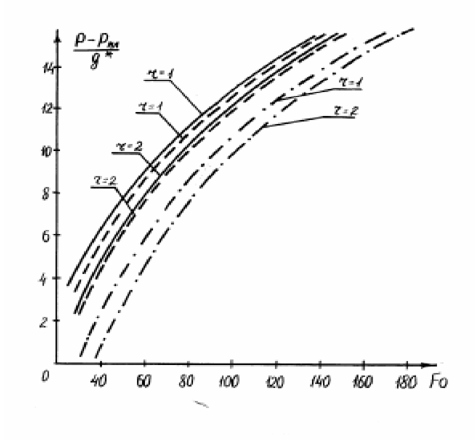

Fig. 1

To determine the distribution of pressure, flowrate of operation well, the leakage of heat-transport medium in water-yieding strata it was solved the task of two-dimensional non-stationary filtration in double wells system for porous medium.

The operation ideal well of radius r_0 with constant pressure P_s and injected well with flowrate **Q** (pointwise source). The flow of heat-transfer is assumed to be instability two-demensional, time-depending, loving Darcy's law.

This results was extended to GCS with optional numbers wells (injected and operational). In this case the operational wells have the central finite radius r_0; the injected wells are the pointwise sources [2].

The solution of the problem on determination and estimation of the heat-carrier leakages in the underground horizon is of important significance for operation of GCS.

Heat carrier leakages influence upon stable operation of the geothermal circulation systems and geological environment. The calculation of the heat carrier leak through the water bearing horizon's bottom and roof is presented in the formula (3).

$$f(F_0, R) = \frac{Q_p - Q_o}{Q_p}, \qquad (3)$$

where $\beta = 4kh\frac{P_{op} - P_{pl}}{\mu Q}$, R – the distance between the wells.

$\beta =$ comprehensive quality, take account of permeability, formation of the water-bearing horizon, facing and stratum pressure, flowrate of the injected wells, dynamics viscosity, and stratum temperature.

We consider the leakages related to the elasticity capacity of the working horizon.

At elastic filtration condition when constant pressure P_3 is sustained in the bottom of the exploitation well, the GCS flow rate will be changed in time and it will be related to the leakages of the heat carrier pumped into the formation. The leakages depend on the distance between the wells, the time and hydrodynamic and technological conditions of the GCS operation.

Figure 2 shows distribution curves of the leakage with respect to F_0 for different distance between wells, 1-300, 2-600, 3-900 (m). The solid curves are for $\beta = -0.3$; the dashed – for β=0; and dash-dotted – for β=1,

When leakages tend to zero, the GCS reaches steady state and equilibrium discharge operating regime [2].

The leakages are estimated for different technological schemes:

a) for the system where formation pressure is kept stable $P_{op}=P_{pl}, \beta=0;$
b) for fountain technology $P_{op}>P_{pl}, \beta>0;$
c) for pumping technology $P_{op}<P_{pl}, \beta<0.$

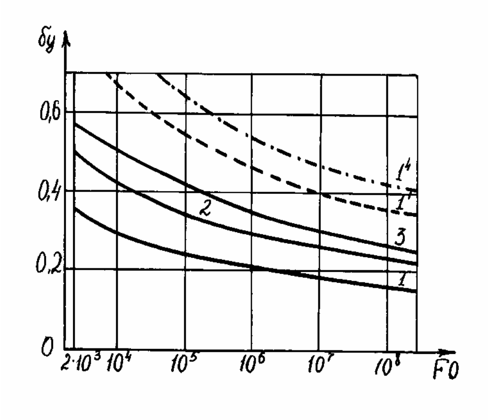

Fig. 2

CONCLUSIONS

The obtained results for doubles wells system were extended on GCS with optional numbers well (injected and operational).
After calculation and analysis of this problems it is concluded that the leakage of that systems don't connected with number injected wells, but general flowrate of the injected wells influence on the quality of the leakages.
From the general models with anisotropic inhomogeneously fissured-porous media we obtain solution for ideals wells in homogeneously porous and fissured media.

NOMENCLATURE AND INITIAL DATA FOR GCS CALCULATION

1.	Well discharge of thermal water	Q	m^3/day	1500 2400
2.	Well depth	H	m	2250
3.	The range of inflow of water	$H_1 – H_2$	m	2250-2150
4.	Effective thickness	H	m	100
5.	Diameter of production well	D	m	0,14
6.	Radius of production well	R_s	m	0,07
7.	Temperature of thermal water at the discharge hole mouth	T	C^o	90^o
8.	Porosity	M		0,1
9.	Static pressure	P_{st}	MPa	1,24
10.	Stratum pressure	P_{pl}	MPa	0,5
11.	Temperature of injected heat-carrier	t	C^o	30^o
12.	Density	ρ	kg/m^3	$\rho(30^o)=995{,}7$ $\rho(90^o)=965{,}3$
13.	Dynamic viscosity	μ	Pa*s	$\mu(30^o)=801{,}5*10^{-6}$ $\mu(90^o)=314{,}5*10^{-6}$ $\mu_a= 558{,}2*10^{-6}$
14.	Kinematic viscosity	ν		$\nu(30^o)=0{,}805*10^{-6}$ $\nu(90^o)=0{,}326*10^{-6}$

15.	Permeability	k	m^2	10^{-13}
16.	Distance between wells	l	m	300, 500, 1000

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