Characterization of the Ogachi HDR Reservoir by Tracer Test

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ABSTRACT

In order to characterize the Ogachi reservoir, five tracer tests have been carried out in 1993, 1994, 1995 and 1997, at the Ogachi HDR site in Akita Prefecture, Japan. Two response curves were obtained from the tracer testing because there are two reservoirs (upper and the lower) at Ogachi. A numerical simulation based on a conceptual model with two fractured flow paths between the injection and production well was developed to separate the two response curves from each other.

Using the response curves obtained by monitoring and calculation, the characteristics of the Ogachi reservoir was estimated. The results are summarized as follows;

1) Both the calculated and observed curves indicate that the Ogachi reservoir has multiple flow paths.

2) Modal volumes of the upper reservoir are estimated to be 8.4 m^3 in 1994's 1st test, 11.7 m^3 in 1994's 2nd test and 6.6 m^3 in 1995. Modal volumes of the lower reservoir are estimated to be 289 m^3, 236m^3 and 117 m^3 from the same test. During the circulation tests, the modal volume of the lower reservoir decreased, particularly in 1995 test. Before 1995 circulation test, a large volume water injection to the injection and production wells was carried out, in order to improve the permeability of the reservoir. This decreasing of the lower reservoir may have been caused mainly by the improvement.

3) Value of width at 1/2 height that is assumed to represent dispersion of the reservoir, decreases between 1994 and 1995, but the value increases in 1997. This increase may have been caused by plugging of the fracture with sand or by mineral precipitation in the fracture as it cooled in response to injection of a large volume of cool water.

Introduction

The Central Research Institute of Electric Power Industry (CRIEPI) has been conducting circulation tests at the Ogachi HDR site in Akita prefecture, Japan, since 1993. At the Ogachi site, there are two reservoirs of different depths. The upper one is found at a depth of 700 m and the lower one at a depth of 1000 m. Circulation tests were conducted through both reservoirs in 1993, 1994, 1995 and 1997. The tracer tests were carried out during these circulation tests to evaluate the volume of the reservoir.

Theory

Tracer can be used to estimate travel time of fluid and channeling in the reservoir. Danckwerts (1953) generalized a concept of Residence Time Distribution (RTD) to evaluate a fluid flow in a vessel such as a reactor. Each fraction of the fluid that flows through a different flow path has its own characteristic residence time, and the RTD can be represented as the distribution of the time that each fraction flows from entrance to exit (Figure 1). The following statistical quantities are often used in the analysis of the RTD curve (Robinson *et al.*, 1984);

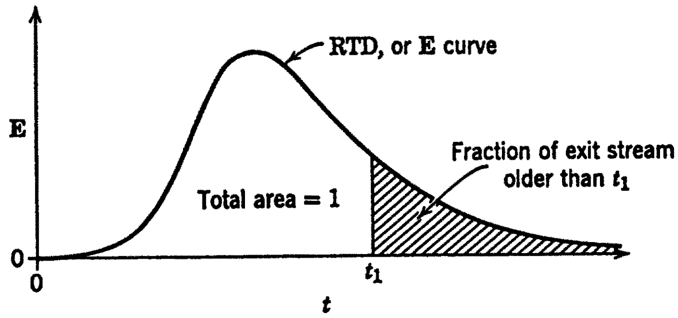

Figure 1 Concept of Residence Time Distribution

[Modal volume: Vm]

The volume corresponding to the maximum probability of the RTD curve. In flow through fractured HDR geothermal reservoirs, Vm most likely represents the volume of the low-impedance fracture connections which follow a direct route from inlet to outlet.

both curves were not always well matched. It is possible that there are two flow paths in the upper reservoir (a faster path and a slower path), one more flow path in the lower reservoir with a larger dispersion value than that of flow path we adopted in this analysis.

Table 2. List of the reservoir characteristics estimated by tracer test.

Item	Year	Test Name	Upper Reservoir	Lower Reservoir	Upper and Lower Reservoir
Breakthrough Time: Tb(min)	1994	1st test	94	517	-
		2nd test	100	816	-
	1995		170	124	-
	1997		-	-	-
Modal Volume: Vm(m^3)	1994	1st test	8.4	289	-
		2nd test	11.7	236	-
	1995		6.6	117	(135)
	1997		-	-	(138)
Integral Mean Volume: <V>(m^3)	1994	1st test	-	-	618
		2nd test	-	-	545
	1995		-	-	459
	1997		-	-	340
Width at 1/2 Height: $W_{1/2}$(m^3)	1994	1st test	18	407	-
		2nd test	32	288	-
	1995		35	177	(183)
	1997		-	-	(324)

The observed and calculated response curves provide a basis for characterizing the reservoir. The results are summarized as follows (see Table 2):

(1) Breakthrough time

The values of breakthrough time of the upper reservoir can be regarded as 94 min. in 1994's 1st test, 100 min. in 1994's 2nd test and 170 min. in 1995, and those of lower reservoir also can be regarded as 517, 816, 124 min., respectively. The values of the lower reservoir are generally larger than those of the upper one, and the value of the lower reservoir decreases remarkably in 1995.

(2) Modal volume

The values of the modal volume of the upper reservoir can be regarded as 8.4 m^3 in 1994's 1st test, 11.7 m^3 in 1994's 2nd test and 6.6 m^3 in 1995, and those of lower reservoir also can be regarded as 289, 236, 117 m^3, respectively. The values of the lower reservoir are about 30 times bigger than that of the upper reservoir. In the upper reservoir, there is no systematic change with time, but the value of the lower reservoir decreases step by step, and in 1995 decreases suddenly.

Assuming that modal volume deduced from the observed curve indicates the modal volume of both reservoirs, the modal volume of the Ogachi reservoir can be regarded as 135 m^3 in 1995 and 138 m^3 in 1997. There is no volumetric change between these two years.

(3) Integral mean volume

This value is estimated using only observed curve. The values of the Ogachi reservoir are 618 m^3 in 1994's 1st test, 545 m^3 in 1994's 2nd test, 459 m^3 in 1995 and 340 m^3 in 1997.

(4) Width at 1/2 height

The values of the upper reservoir can be regarded as 18 m^3 in 1994's 1st test, 32 m^3 in 1994's 2nd test and 35 m^3 in 1995, and those of lower reservoir also can be regarded as 407, 288, 177 m^3, respectively. Those values of the lower reservoir have a tendency to decrease with time.

Conclusion

After separating observed response curve into each curve corresponding to the each reservoir by using numerical analysis, the reservoir characteristics were estimated from the observed and calculated curves.

(1) A numerical model of two fractured flow paths between the injection and production wells provided a good match between observed and calculated curves, from the viewpoint of distribution of mode and breakthrough. But the shapes of the tail and standing up of both curves were not always well matched. There may be two flow paths, faster and slower, in the upper reservoir, and there might be one more flow path in the lower reservoir which dispersion value is larger than that of flow path we adopted in this analysis

(2) The modal volume of the upper reservoir can be regarded as 6 to 12 m^3, and the values of the lower reservoir can be regarded as 289 m^3 in 1994's 1st test, 236 m^3 in 1994's 2nd test and 117 m^3 in 1995. During the circulation tests, the modal volume of the lower reservoir decreased, particularly in 1995 test. Before 1995 circulation test, a large volume water injection to the injection and production wells was carried out, in order to improve the permeability of the reservoir. This decreasing of the lower reservoir may have been caused mainly by the improvement. The modal volume of the Ogachi reservoir can be regarded as 135 m^3 in 1995 and 138 m^3 in 1997. There is no volumetric change between these two years.

(3) The value of the width of the return curve at 1/2 height, assumed to represent dispersion of the reservoir, decreases between 1994 and 1995, but the value increases between 1995 and1997. This increase may have been caused by plugging of the fracture with sand or by mineral precipitation in the fracture as it cooled in response to injection of a large volume of cool water.

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