Research on Flow Boundary of Different Kinds of Heavy Oil with Different Fluidities

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Abstract:

For that viscosity of heavy oil decreases with the increase of temperature, influence of different temperature on flow ability of different types of heavy oil which flow through porous media with different permeability was studied, and flow boundary of different types of heavy oil under different fluidity has been analyzed quantitatively. The experimental results show that the threshold pressure gradients of heavy oil from Henan Oil Field under different permeabilities, different temperature and different porous media are neglectable. Threshold pressure gradient increases with the viscosity of heavy oil, heavy oil starts to flow when the fluidity of crude oil is less than 0.14 mD/mPa·s.

Key words: heavy oil; fluidity; threshold pressure gradient; flow boundary; physical simulation experiment

1. Introduction

Heavy oil is a complex mixture naturally existing in the porous media, which has a high viscosity and a high relative density. Low flow ability makes it obvious different for heavy oil to flow in porous media compared with conventional crude oil, which was often characterized as non-Newtonian fluid according to a lot of scholars [1-6].

Thermal recovery of heavy oil reservoirs is commonly used by many countries, and steam can reduce the viscosity of heated heavy oil in the process of thermal recovery. This paper studies influence of different temperature on flow ability of different types of heavy oil which flow through porous media with different permeability, to study the impact of steam on flow ability of heavy oil, and flow boundary of different types of heavy oil under different fluidity has been analyzed quantitatively, in order to improve the recovery of heavy oil reservoirs.

2 Physical properties of heavy oil and sand pack

Sand pack and heavy oil used in experiment are shown in Table 1. Mixed crude oil is composed of 33% mass fraction of heavy oil of Henan Oil Field and 67% mass fraction of heavy oil of Liaohe Oil Field. Physical properties of sand core used in experiment are shown in Table 2.

Table1 The basic physical properties of sand pack

Number	Length of sand pack （mm）	Outer radius of sand pack （mm）	permeability （mD）	Heavy oil	Oil viscosity (40℃) （mPa·s）
1	300	38	5 977	Oil from Henan Oil Field	4 075

2	300	38	958	Oil from Henan Oil Field	4 075
3	300	38	357	Oil from Henan Oil Field	4 075
4	300	38	744	Oil from Henan Oil Field	3 275
5	300	38	1 357	Mixed Crude Oil	>62 000
6	300	38	1 560	Oil from Liaohe Oil Field	>62 000

Table 2 The basic physical properties of sand core

Number	Length of sand pack （mm）	Outer radius of sand pack （mm）	permeability （mD）	Heavy oil	Oil viscosity (30℃)（mPa·s）
1	45.12	25	141	Oil from Henan Oil Field	4 075

3 Experiment results and discussions

3.1 Flow experiment of the same heavy oil under different permeability

From Fig.1 to Fig.4, we can find that the relationship between pressure difference and flow rate shows a straight line going through the origin. The threshold pressure gradients of heavy oil from Henan Oil Field under different permeabilities (sand pack with permeabilities of 5.977D, 0.958D and 0.357D respectively), different temperature (30℃ and 40℃) and different porous media (sand pack filled with grass bead and sand core) are neglectable.

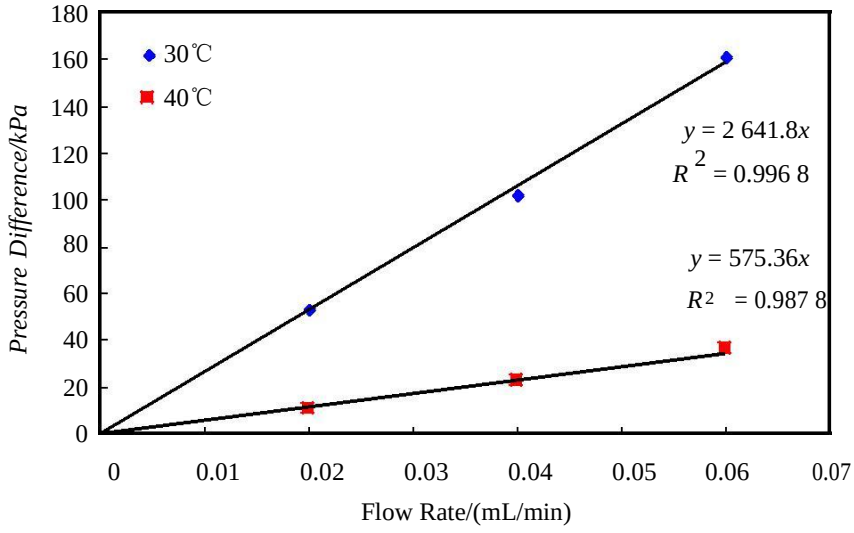

Fig. 1 Flow experiment of heavy oil from Henan Oil Field in No.1 sand pack (*K*=5.977 D)

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Fig. 2 Flow experiment of heavy oil from Henan Oil Field in No.2 sand pack (*K*=0.958 D)

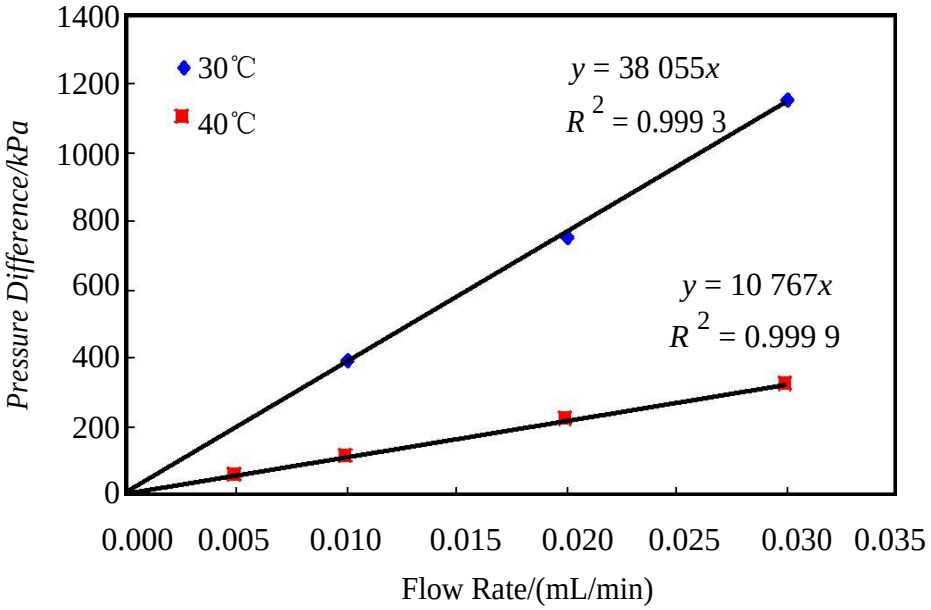

Fig. 3 Flow experiment of heavy oil from Henan Oil Field in No.3 sand pack (*K*=0.357 D)

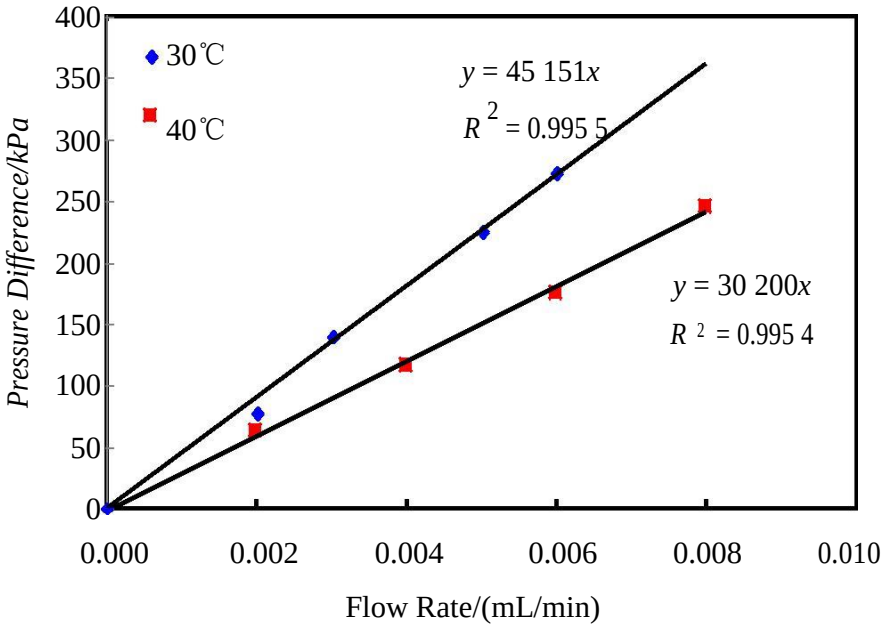

Fig. 4 Flow experiment of heavy oil from Henan Oil Field in sand core (*K*=0.141 D)

The line slope gradually rises with the decrease of permeability of sand pack from Fig. 1 to Fig. 4. Pore structure also can affect flow ability of heavy oil apart from the viscosity of heavy oil. The pressure difference needed for heavy oil to flow in low permeability formation is bigger than flow in high permeability formation, so it is appropriate to use fluidity to contrast the flow ability of different kinds of crude oil flowing through porous media with different permeabilities.

3.2 Flow experiment of different kinds of heavy oil

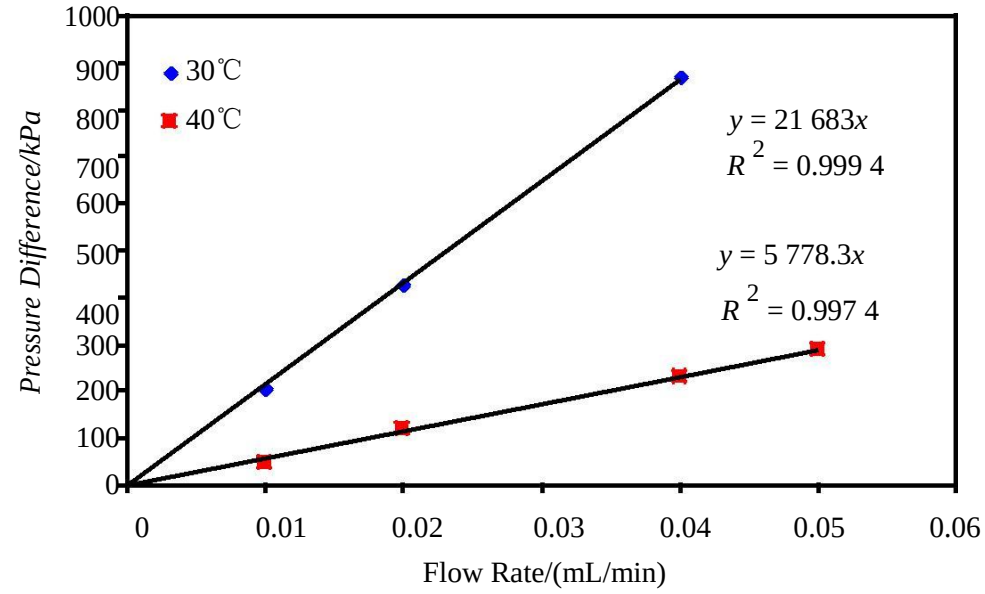

Fig. 5 Flow experiment of heavy oil from Henan Oil Field in No.4 sand pack (K=0.744 D)

Fig. 5 illustrates the experiment result of heavy oil from Henan Oil Field flow through No.4 sand pack. The threshold pressure gradient of heavy oil from Henan Oil Field flowing through sand pack with permeability of 0.744 D can be neglectable for that the relationships between pressure difference and flow rate under different temperature both show straight lines going through the origin.

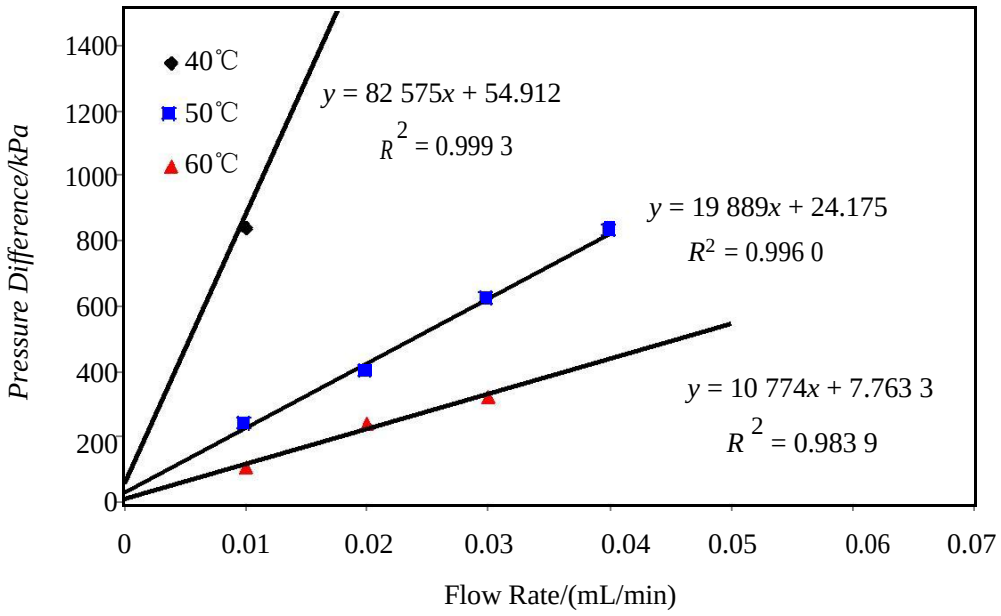

Fig. 6 Flow experiment of mixed crude oil in No.5 sand pack (K=1.357 D)

Fig. 6 shows the experiment result of mixed crude oil flow through No.5 sand pack. The threshold pressure gradient of mixed crude oil flowing through sand pack with permeability of 1.357 D cannot be neglectable when experiment temperature is lower than 60℃. And the mixed crude oil turned to be Newtonian fluid when temperature exceeds 60℃.

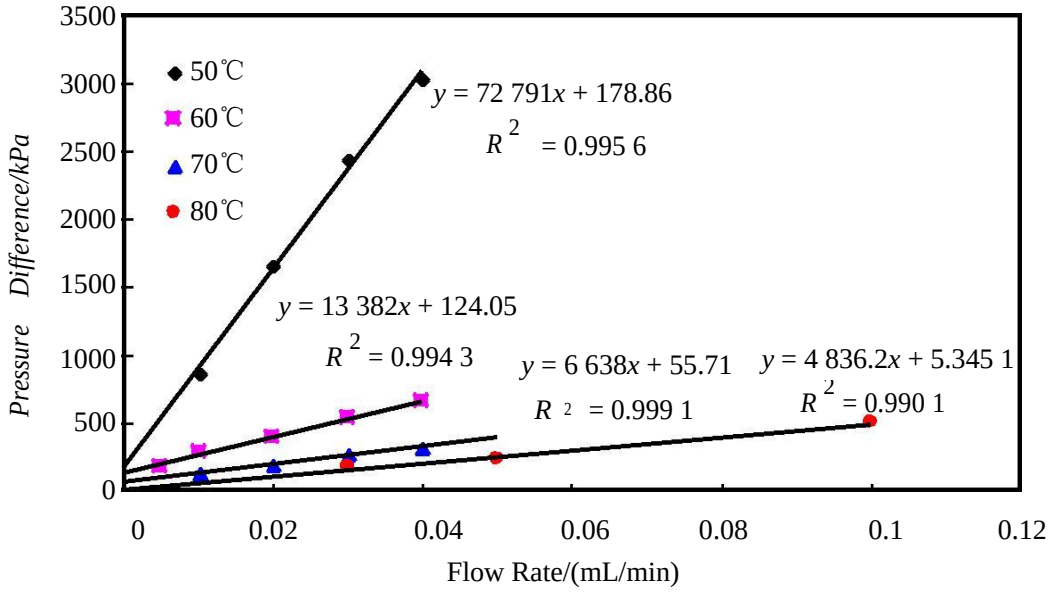

Fig. 7 Flow experiment of heavy oil from Liaohe Oil Field in No.6 sand pack (K=1.560 D)

Fig. 7 presents the experiment result of heavy oil from Liaohe Oil Field flow through No.6 sand pack. The threshold pressure gradient of mixed crude oil flowing through sand pack with permeability of 1. 560 D cannot be neglectable when experiment temperature is lower than 80℃. And heavy oil from Liaohe Oil Field turned to be Newtonian fluid when temperature exceeds 80℃.

3.3 Flow boundary of different kinds of heavy oil with different fluidities

The threshold pressure gradients of heavy oil mainly relate with the viscosity of crude oil and the permeability of formation. The bigger the viscosity of heavy oil is, the lower the permeability of formation, the fluidity of heavy oil gets smaller in formation and the threshold pressure gradient becomes bigger. According to Table 3, threshold pressure gradients occurs when the fluidity of crude oil is less than 0.14 mD/mPa·s.

Table 3 Threshold pressure gradient of heavy oil with different fluidities

Temperature (℃)	Viscosity (mPa·s)	Permeability (mD)	Threshold pressure gradient (MPa/m)	fluidity （mD/mPa·s）
50	388.5	5 977.0	0	15.385
50	388.5	958.3	0	2.467
50	601.6	677.0	0	1.125
50	388.5	357.0	0	0.919
50	1 478.0	664.0	0	0.449
50	388.5	141.0	0	0.360
50	7 750.0	1 088.0	0.081	0.140
50	16 060.0	870.0	0.596	0.054

4 Conclusions

(1) Flow experiments of heavy oil from Henan Oil Field flowing through porous media with different permeability are studied, The threshold pressure gradients of heavy oil from Henan Oil Field under different permeabilities, different temperature and different porous media are neglectable.

(2) Flow experiment of heavy oil from Henan Oil Field, mixed crude oil and heavy oil from Liaohe Oil Field are analyzed, threshold pressure gradient increases with the viscosity of heavy oil.

(3) The fluidities of different kinds of heavy oil flowing in porous media with different permeabilities are calculated, heavy oil starts to flow when the fluidity of crude oil is less than 0.14 mD/mPa·s.

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