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Growth Velocity and Branch Length of Fingering Pattern Using Two Viscous Oils

Wasim Ahmed Hydery[1], Gulam Rabbani[2], A.R Khan[2] ,Yusuf H Shaikh[3]*

ABSTRACT: We study the fingering pattern development, which arise because of the instability at the interface of two gear oils of different viscosities in Hele-Shaw cell. Fingering is a very instant process, is last for few seconds only, it is recorded using digital camera and movie frames extracted and selected for certain interval of time .We focus here on the development of fingering pattern for different pressure of the two gear oils HP90 and Veedol140.To compare their branch length and growth velocity at different interval of time. It is interesting to note that there is appreciable change in the fingering length and fingering growth velocity of the pattern with two oils at the approximately same pressure. In this paper details are presented and results discussed.
KEYWORDS: Viscous Fingering, Hele Shaw Cell, Branch Length, Growth Velocity.

1. INTRODUCTION

Viscous fingering is the process of formation of patterns in a unstable interface between two fluids in a porous medium. The non-equilibrium growth is characterized by the Fractal patterns[1], such as the dendritic shape of snowflakes[2] viscous fingering[3], the shape of bacteria colonies growing in stressed environments[4], dielectric breakdown[5] and the electro-deposition[6] etc. All these growth processes lead to structures that are complex in shape and the parameters governing shape are large in number.

When an invading viscous fluid is forced into a defending viscous fluid under pressure, the interface between the two becomes unstable which leads to the formation of a finger-like pattern known as “viscous fingers”[7] which may repeatedly branch and sometimes form a fractal pattern. Under appropriate approximation the Laplace equation can express the interface, as in diffusion- limited process

$$\nabla^2 U(x,t) = 0 \qquad (1)$$

with suitable boundary conditions.

Viscous fingering is first observed by petroleum engineers when an aqueous solution displaces more viscous oil in underground reservoirs. During secondary oil recovery[8] the viscous fingering phenomenon is important in problems such as combustion in two dimensions[9] , dendritic solidification, electrochemical deposition[10] and fluid flow in porous media[11,12] Extensive research efforts have been undertaken by workers in the field to understand the various physical factors governing viscous fingering.

1 Maharashtra College of Arts, Commerce and Science Mumbai-08
2Maulana Azad College Dr.Rafiq Zakaria Campus, Dr. Rafiq Zakaria marg, Rauza Bagh, Aurangabad.
3 Shivaji Arts,Commerce and Science College, Kannad.
*Corresponding Author & Guide: Yusuf H Shaikh
Shaikh:shaikhyh@gmail.com

2. EXPERIMENTSL SETUP:

Hele Shaw cell is used in growth of Viscous fingering pattern construction discuss[13]. In this Hele Shaw cell the two different types of viscous (thick) oil as ‘defending’ viscosity fluid and an air as ‘invading’ viscosity fluid.

Defending viscous oil or fluid displaces the invading viscous fluid at different pressure.As this process is fast we have used video recording instead of “still” photography with help of illuminated diffuse light in the background of the cell by digital camera. Then the frames are separated for the finer details of the development at different interval of time for different pressure.

3. TIME COURSE OF DEVELOPMENT:

The course of development of fingering patterns was studied using video recording with a digital camera at the framing rate of 30 frames per second. The images shown are extracted from a movie recorded during the development of fingering pattern and the time point for each frame is obtained from the framing rate of the video. For the purpose of study of the growth process with time the length of different branches was calculated for each step corresponding to the respective time. This was implemented using the two-color bitmap image and recording the x and y coordinates of each growing tip and finding out the distance from centre using the distance formula. The distance so obtained is in terms of pixels, knowing the DPI or pixels per inch, this distance can be converted in cm or any desired unit.

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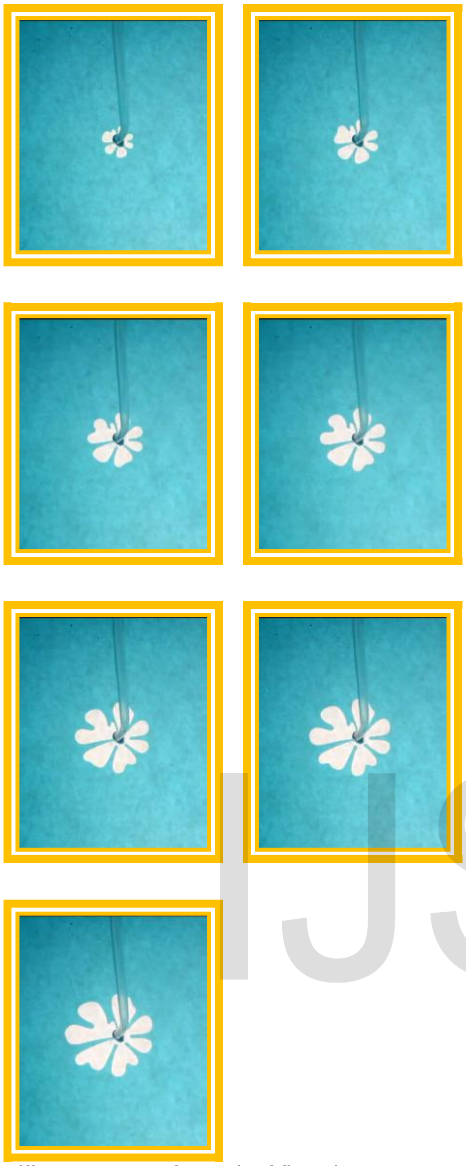

Figure 1: Different stages of growth of fingering pattern using HP90 oil under low pressure conditions, last image is at a time interval of 5.6 s.

TABLE 1: MINIMUM AND MAXIMUM LENGTH OF THE BRANCH OF THE TWO OILS AT LOW & HIGH PRESSURE

Defending Fluid	Fig. No.	Low Pressure Branch Length (mm)		High Pressure Branch Length (mm)	
		Min	Max	Min	Max
HP90	3a &3b	17	30	67	79
VEEDOL140	3c & 3d	21	37	53	62

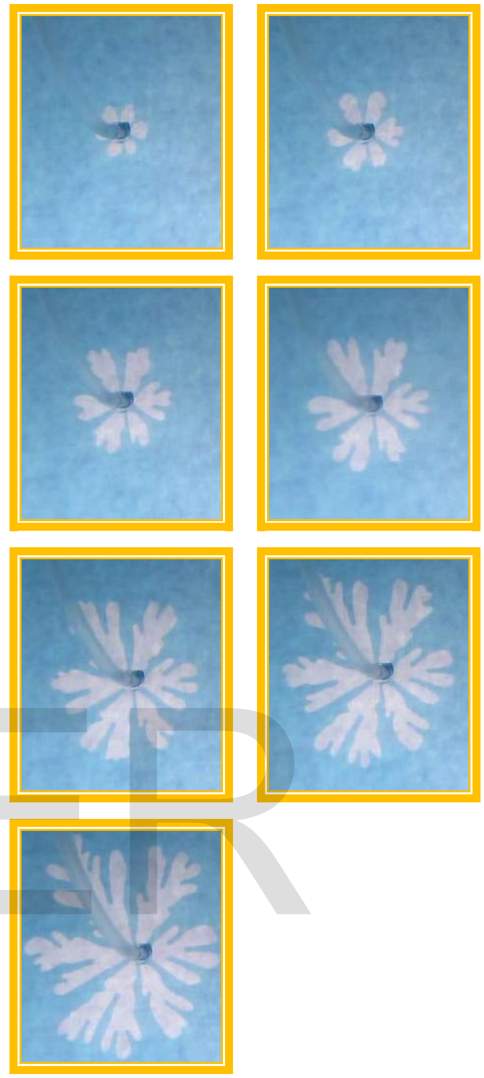

Figure 2: Different stages of growth of fingering pattern using Veedol140 oil under low pressure conditions, last image is at a time of4

As the viscosities of both oils are different, their branch length and number of branches are also different at the approximately same pressures as shown in Fig. 1, Fig. 2 and Table-1

From the Fig.3 (a-d), it is observed that the growth is fast initially and from the second stage it becomes slower and increases steadily for almost all the branches. As is expected all the branches do not develop at the same rate, some of them tend to be slow and others are relatively fast as the process is governed by random phenomena. It is also observed that from the plot of time against length that in case of HP90 oil different branches grows close to each other compare to Veedol140 oil at both low and high pressures.

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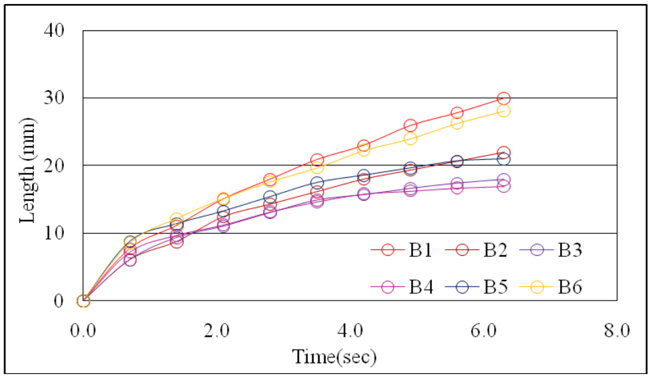

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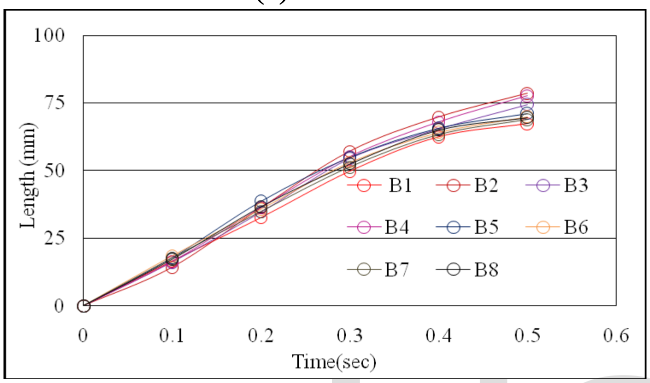

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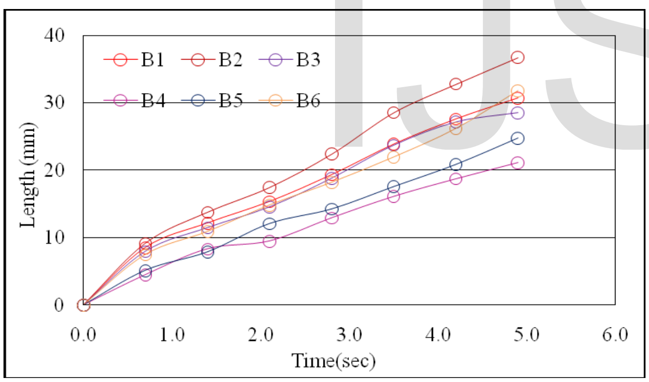

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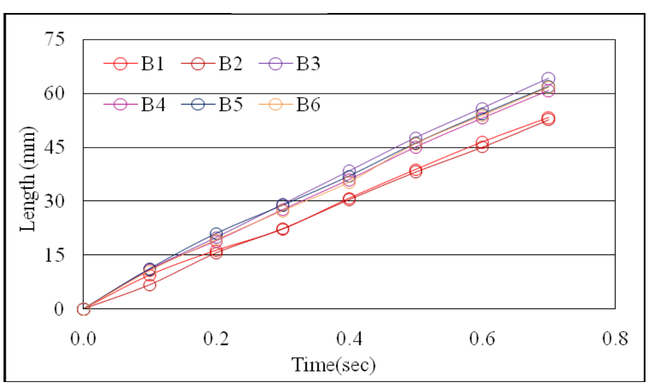

(d)

Fig 3: Plot of time against Length of a) HP90 oil at Low pressure b) HP90 oil at High pressure c) Veedol140 at Low pressure and d) Veedol 140 at High pressure.

Figure 4: Different stages of growth of fingering pattern using HP90 oil under High pressure conditions, last image is at a time of 0.5s

TABLE 2: MINIMUM AND MAXIMUM AND STEADY GROWTH VELOCITY OF THE BRANCH OF TWO DIFFERENT TYPES OF OILS AT LOW & HIGH PRESSURE

Defending Fluid	Fig. No.	Low Pressure Growth Velocity (mm/s)			High Pressure Growth Velocity (mm/s)		
		Min	Max	Steady Value	Min	Max	Steady Value
HP90	5a& 5b	8.7	12.5	2.98-4.97	142.5	184.6	134.5-157.7
VEEDOL 140	5c& 5d	6.44	13.1	4.32-7.49	67.46	112.2	75.3-90.0

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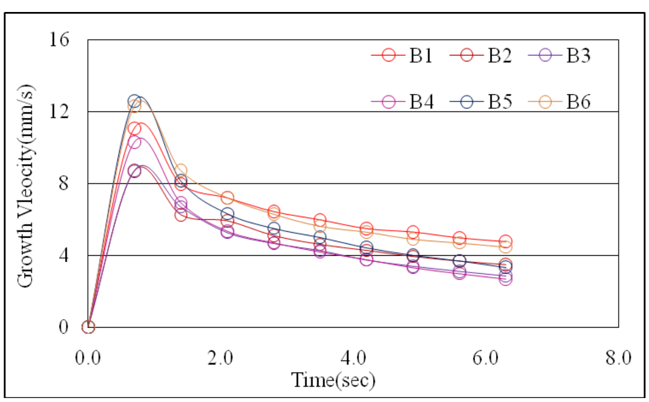
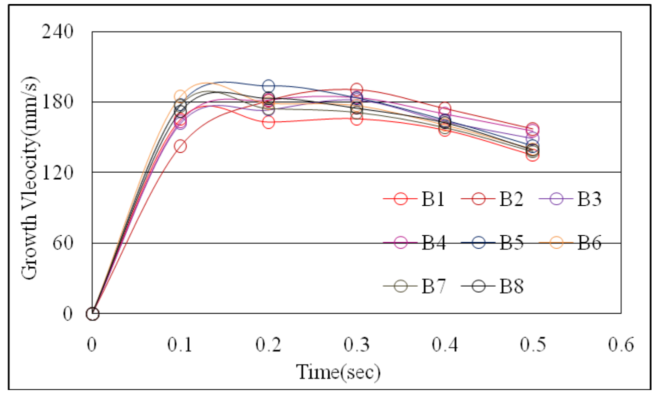
Figure 5: Different stages of growth of fingering pattern using Veedol140 oil under High pressure conditions, last image is at a time of 0.8



(a)



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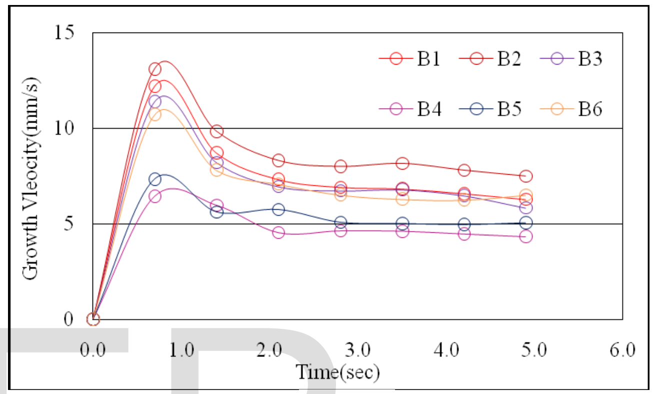

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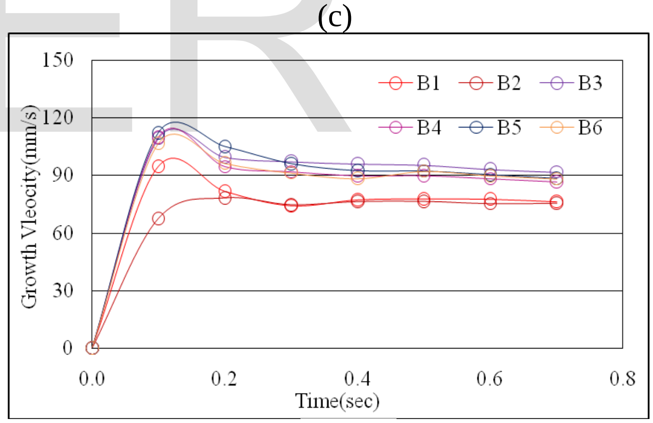

(d)

Figure 6: Plot of time against Growth velocity of a) HP90 oil at Low pressure b) HP90 oil at High pressure c) Veedol140 at Low pressure and d) Veedol 40 at High pressure.

Fig 6(a-d) shows plot of time against growth velocity for the viscous fingering pattern obtain using HP90 oil and Veedol140 oils under low and high pressures, it shows that all the branches grow at the faster rate initially and the growth velocity falls down gradually with time. It is also observed that in case of low pressure there is sharp fall in velocity and then remain approximately constant while in high pressure it decreases slightly and then remain almost constant. The maximum, minimum and steady growth velocity is Shown in the Table-2.

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4. CONCLUSION

Viscous fingering studied using two different types of viscous oil as defending viscous fluid and air as invading viscous fluid at two different pressures in Hele Shaw cell. The branch length of two different types of oil, approximately at the same pressure i.e. low or high pressure, the branch lengths are changes appreciably. It is also observed that as the pressure increases the HP90 oil has finer fingering pattern and more branches than Veedol140 viscous oil.

In growth velocity of branches, it is observed that growth velocity is different for the different oil at the same pressure and initially it increases very rapidly than fall down exponentially and later on it becomes almost constant at low the pressures but at high pressure than the after rapid increase in growth velocity , it remains almost steady. It is also observed that the branches velocity is closer at high pressure than low pressure for both the oils. It is also observed that the growth velocity is more at higher pressure for HP90 viscous oil than Veedol140 viscous oil while for low pressure there is some uncertainty in the result of growth velocity.

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