정상상태에서 기울어진 판 위를 흐르는 유체의 속도구배 관찰

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Steady-state velocity profile developed in the thin film flowing down an inclined plane

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Introduction

We can often see the fluid like water flowing down an inclined channel in our circumstances. This flow pattern has been employed in many processes of chemical engineering, and thus many scientists have paid attention to its behavior.

To verify the characteristics of this flow, the velocity profiles in the laminar flow down an inclined plate are investigated experimentally by using a silicone oil as an incompressible Newtonian fluid [1] and [2]. In addition, we have also derived explicit characteristic equations describing film flow by comparing with the experimental results. We assume that the velocity profile is a parabolic and our experimental velocities are had the similar values to the theoretical ones which are gotten by using the equation

$$v_z = \frac{\rho g \delta^2 \cos\beta}{2\mu}\left[1 - \left(\frac{h}{\delta}\right)^2\right], \qquad \textbf{(1)}$$

where v_z is the velocity distribution, δ is the falling-film thickness, β is the angle between inclined plane and direction of gravity, h is the part of depth, μ, g, ρ are the acceleration of gravity, the viscosity and the density, respectively.

Procedures

Since channeling is occurred when water flows on an inclined plate slowly, so to avoid this we use silicone oil (kinematic viscosity=1000cS, Shinetsu Silicone Cooperation, KF-96-1). We have installed a cylindrical tank reservoir with a diameter of 14cm and a height 51cm to supply the silicone oil to keep up the constant flow rate. The plate is also fixed in its

Figure 1 The experiment equipment.

inclination to the horizontal as 1.5°, as seen in Fig.1. After it overflows on the acryl plate (Sumitomo Chemical Affiliated Company, the width 5cm, the length 30cm, the height 2.5cm and the thickness 0.5cm) for making steady-state, we have made the film at a constant thickness. After that, we inject an ink through a needle mounted in the film to trace after the streamline of the flow. Then we observe the ink line with a microscope to measure the distance the fluid runs on. Changing the velocity of fluid by controlling a valve, we repeat this experiment 10 times. And we take pictures of ink lines as time elapses in an even intend (Fig.2). Dividing thickness of the fluid into five, we measure

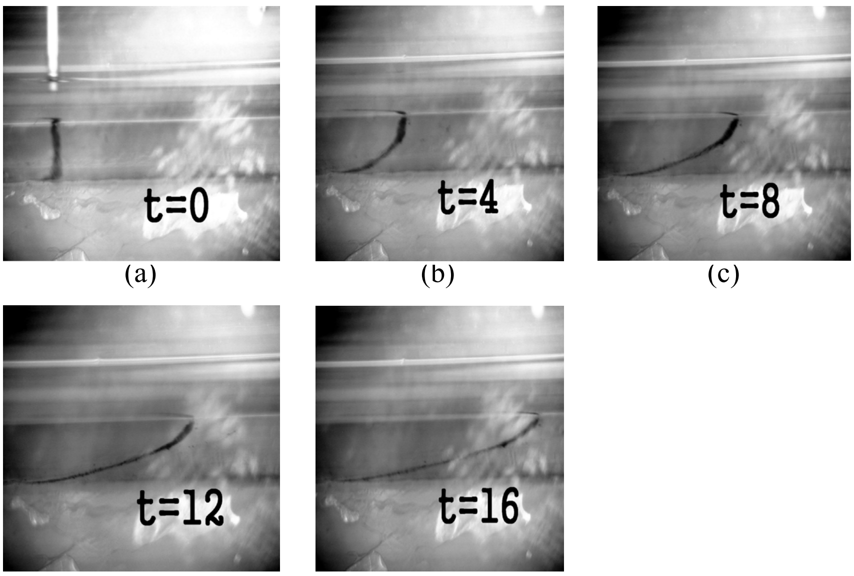
the distance from the starting point to calculate the fluid velocities to the depth as

$$v = \frac{s}{t},$$

where v is the experimental velocity, s is the moving distance and t is the moving time. And then, we compare these data with the theoretical results from Eq.(1) after setting up quadratic equations with experimental data by using Matlab [3].

Results

The ink line becomes a parabolic form with passage of time.



(a) (b) (c) (d) (e)

Figure 2 The transition of the injected ink spots with times (sec), (a: t=0, b: t=4, c: t=8, d: t=12, e: t=16).

Conclusions

We have prepared two kinds of film thickness such as 3.0mm and 1.5mm. In 3.0mm case, the velocity profile v to the film depth h is obtained as

$$v = -0.16h^2 + 0.09h + 1.17 \tag{2}$$

and it is plotted in Fig.3.

In 1.5mm case, the velocity equation is as follows

$$v = -0.12h^2 + 0.06h + 0.20 \tag{3}$$

and it is depicted as in Fig.4. Therefore, we can conclude that the velocity distribution profile has a parabolic form.

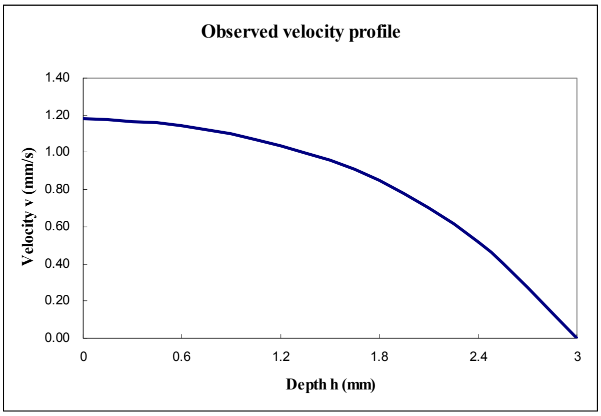


Figure 3 An example of 3.0mm case results.

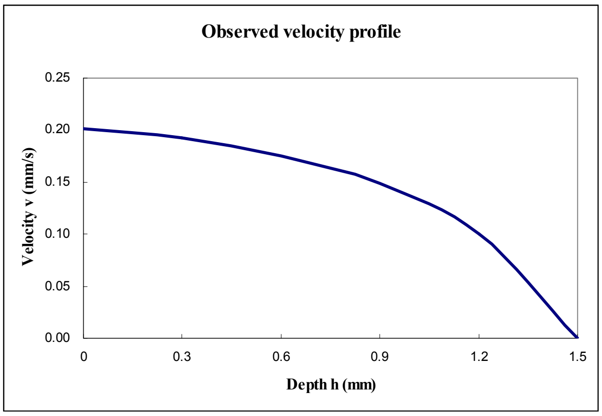


Figure 4 An example of 1.5mm case results.

Table 1 and 2 represent that the experimental data are similar to the theoretical ones and there is the no-slip boundary condition with $v = 0$ at the bottom.

Table 1. Comparison between theoretical and experimental data in the 3mm thickness (h is measured from the top).

3mm thickness case			
v(mm/s) / h(mm)	Theoretical values	Experimental values	standard deviation
0.0	1.15	1.08	0.20
0.6	1.11	1.04	0.20
1.2	0.97	0.97	0.19
1.8	0.74	0.81	0.17
2.4	0.42	0.52	0.12
3.0	0.00	0.00	0.00

Table 2. Comparison between theoretical and experimental data in 1.5mm thickness (h is measured from the top).

1.5mm thickness case			
v(mm/s) / h(mm)	Theoretical values	Experimental values	standard deviation
0.0	0.29	0.24	0.04
0.3	0.28	0.23	0.04
0.6	0.24	0.21	0.02
0.9	0.18	0.19	0.01
1.2	0.10	0.14	0.03
1.5	0.00	0.00	0.00

References

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3. The MATH WORKS Inc., *MATLAB*, 3 Apple Hill Drive, USA(2000).