MEASUREMENT OF LIQUID COEFFICIENT OF VISCOSITY USING LIQUID SURFACE WAVE

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Abstract: Surface waves are generated at the micron scale using disturbances of appropriate size. When the laser beam irradiates the liquid surface waves with different amplitudes, the optical effects of diffraction and reflection are observed respectively. On this basis, two methods, laser diffraction method and laser slope method, are proposed to measure the viscosity coefficient of liquid. This experiment takes water as an example. For the laser diffraction method, the relationship between the liquid viscosity coefficient and the liquid surface wave attenuation coefficient and wave number is theoretically derived. The experimental setup is given, and high visible diffraction patterns are observed on the screen. The attenuation curve of liquid surface wave is obtained by the relationship between diffraction fringes and surface wave. By studying the diffraction phenomenon of laser oblique incident surface wave, the viscosity coefficient of water is measured. For the laser slope method, the liquid viscosity coefficient is measured by studying the reflection of liquid surface wave with larger amplitude. Compared with capillary method and ball drop method, these two methods are real-time and non-contact for measuring low viscosity coefficient of liquid.

Key words: liquid Coefficient of Viscosity；liquid Surface Wave；light diffraction；reflection of light；attenuation coefficient

INTRODUCTION

Liquid viscosity coefficient is an important parameter to characterize the anti deformation ability of liquid. It has important applications in the fields of production, life, engineering and medicine. When the fluid flows under external force, there is shear stress between the fluid layers. The traditional measurement methods of viscosity coefficient include ball drop method and capillary method. However, because they are all contact measurement, the instrument is difficult to clean and restore. Therefore, the design idea of this experiment is to use a disturbance of appropriate size to make the liquid move, and then excite the surface wave of the liquid. As the surface wave propagates forward, the amplitude of the surface wave becomes weaker and weaker due to viscous resistance. The attenuation of liquid surface wave is studied by optical method, and the viscosity coefficient is obtained. On this basis, we propose two methods to measure the viscosity coefficient η Key parameters in expressions α and K: laser diffraction method and laser slope method. The relationship between the liquid viscosity coefficient and the optical effect on the liquid surface wave is systematically studied, and the measurement method and results are given. These two methods have the characteristics of real-time and non-contact.

METHOD

2.1 Laser Diffraction Method

For liquid with small viscosity coefficient, when surface wave propagates, the change of surface wave frequency caused by hysteresis is small. For amplitude, as the distance increases, the amplitude of surface wave is:

$$A = A_0 e^{-\frac{2k^2\eta}{\rho v}x} \cos\left(\omega t - Kx\right), \quad where \alpha = \frac{2K^2\eta}{\rho \cdot v}$$

Note:A is amplitude, η is Coefficient of Viscosity, α is the attenuation coefficient.

According to the dispersion relation of surface wave, the expression of liquid viscosity coefficient is derived.

$$\eta = \frac{\alpha\rho}{2K^2} \cdot \frac{g + \frac{3\sigma K^2}{\rho}}{2 \cdot (gK + \frac{\sigma K^3}{\rho})^{\frac{1}{2}}}$$

The intensity distribution of diffraction fringe is obtained by Fourier optics is

$$I(x') = \sum_{n=-\infty}^{n=\infty} J_n^2(4\pi A\cos\theta/\lambda)\delta(\frac{x'}{\lambda z} - \frac{n}{\Lambda\cos\theta})$$

For a given incident Angle θ and laser wavelength λ, the intensity is A function of the surface wave amplitude A. The surface wave amplitude A can be calculated by the light intensity ratio of any first-order diffraction fringe to zero-order diffraction spot .Since Delta function,the interval between adjacent diffraction fringes is $d = z\lambda / \Lambda\cos\theta$.

Finally, the key parameters will be calculated α And K, the viscosity coefficient can be obtained.

The experiment set up is shown in JPG.1 Under the control of computer, the vibration source device generates vibration of specific frequency such as 140hz, which makes the water surface stir up stable concentric surface waves. The water tank and laser are placed on the shockproof platform . The tank is lined with black paper. Turn on the laser, obliquely incident the laser beam(He -- Ne laser, A= 632.8 nm) onto the liquid surface , and the incident point is a certain distance from the center of the vibration source. The incident angle is 1.436rad. Measure the distance between the incident light point and the observation screen to be 8.215m. Adjust the frequency and size of the vibration until a clear diffraction pattern appears on the screen. The intensity of each diffraction point is measured with a light intensity meter controlled by a single chip microcomputer. Change the position of the vibration source for many times, and repeat the above steps.

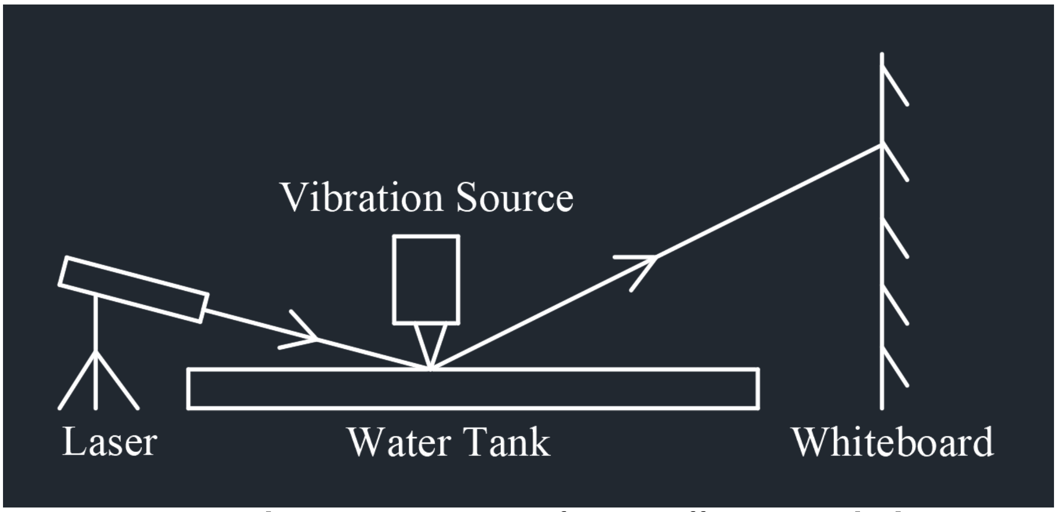

Fig. 1. The experiment set up of Laser Diffraction Method

2.2 Laser Slope Method

The amplitude expression for the surface wave specified displacement:

$$A = A_0 e^{-\frac{2K^2\eta}{\rho v}x} sin(Kx)$$

Taking the derivative with respect to A, we can get the slope at specified point :

$$A' = A_0(x_{Specify})\ Kcos\ (Kx_{Specify})$$

When the surface wave amplitude is maximum at the incident point (maximum slope),slope is A_0K,which corresponds to the highest point of spot movement on the observation screen. In summary, the amplitude of the specified position was calculated, and the attenuation coefficient α was obtained by the attenuation relationship between amplitude and displacement. Finally, the attenuation coefficient and wave vector are substituted into the formula of η to calculate the liquid viscosity coefficient.

The experiment set up is shown in JPG.2.The dripping device is controlled by a peristaltic pump, which arouses a series of concentric circles of micro-amplitude water surface waves. Turn on the laser and irradiate laser beam on the liquid surface, so that the reflected light spot is projected on the distant optical screen. Observe the phenomenon of light spot moving up and down with surface wave propagation. A long exposure camera is used to capture the moving track of the light spot, and the highest position of the light spot and the distance D between the incident point and the light screen are recorded to calculate the slope of the reflected light, so as to further obtain the viscosity coefficient.

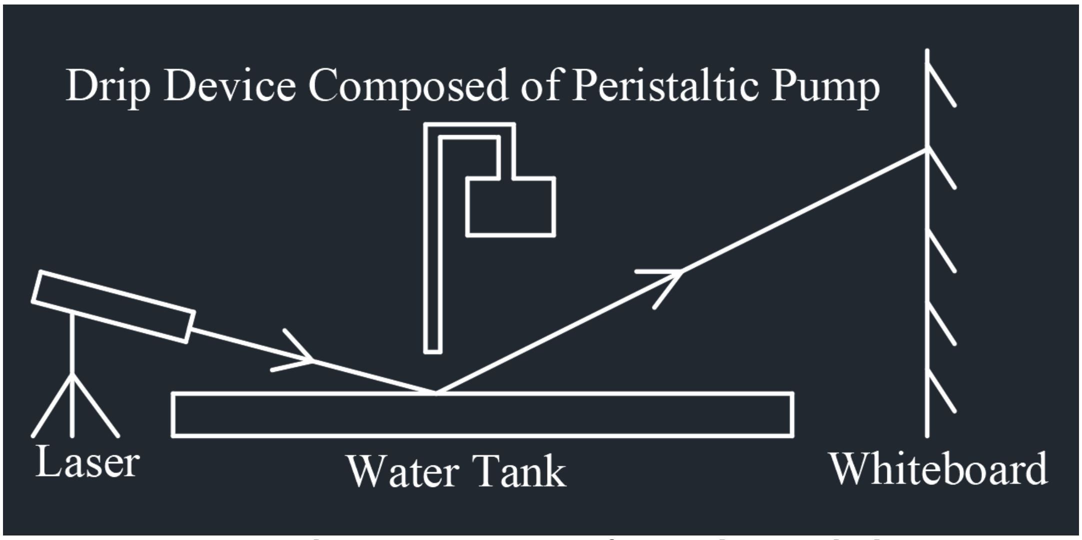

Fig. 2. The experiment set up of Laser Slope Method

RESULTS

3.1 Laser Diffraction Method

The spot intensity and fringe spacing of diffraction images obtained by laser diffraction method are shown in Table 1.

Table 1

Light Intensity Units:lx / the distance D Units: mm	I_{-2}	I_{-1}	I_0	I_{+1}	I_{+2}	The distance between the stripes Units:cm
25.0	315	750	407	735	30	2.00
30.0	81	620	968	640	99	2.00
35.0		364	1251	371		2.00
40.0		124	1547	151		2.00
45.0		78	1879	57		2.00

Table1.The spot intensity and fringe spacing of diffraction image obtained by Laser Diffraction Method.

In this experiment, the distance between incident spot and observation screen is 8.2150m.The coefficient of viscosity is 0.432×10^(-3)N*s/m^2.

3.2 Laser Slope Method

The The horizontal distance between the vibration source and the light screen and the vertical distance between the highest point of the reflected light spot and the incident point obtained by laser diffraction method are shown in Table 2. In this experiment, the distance between incident spot and observation screen is 8.2150m.The coefficient of viscosity is 1.414×10^(-3) N*s/m^2.

Table2.The spot intensity and fringe spacing of diffraction image obtained by Laser Diffraction Method.

Table 2

Spot Spacing of Vibration Source	the Peak	Slope
70mm	130.60cm	0.0153
75mm	127.66cm	0.0135
80mm	124.66cm	0.0117
85mm	123.00cm	0.0107
90mm	122.00cm	0.0101

CONCLUSION

The experiment combines optics and utilizes laser collimation to measure the viscosity coefficient of liquid in the attenuation phenomenon of liquid surface wave. At the same time, the measurement of some parameters provides two different measurement schemes. The idea is novel, the principle is clear and reliable, the measurement method is simple and convenient, the measurement results are relatively accurate, the experimental cost is relatively low, and the experimental results can be obtained in real time and without contact.

References

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