SIMULATION OF TERMINAL VELOCITY AND VISCOSITY OF FLUID USING ANALYSIS VIDEO WITH *TRACKER* AND MODELLUS

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Abstract. The motion of marbles in viscous fluid have been analysed with using Tracker and Modellus software. The result of video analysis in tracker was using to determine the terminal velocity of marbles in viscous fluid. Viscosity effect in the marbles motion on fluid can be formulated with using the relation with terminal velocity. This research aim to determine the terminal velocity of marbles in viscous fluid and to simulated of this motion with using Modellus Software. The result find that the greater the viscosity the lower the terminal velocity. The presision of position track of marbles in the different viscous fluid in each time fitted in video analysis in Modellus simulation to validate the tracker results.
Keyword : Terminal Velocity , Software Tracker Software, Modellus and Viscosity

I. INTRODUCTION

Bubbles, drops, globules of a liquid in another liquid was a very substantial thing in many natural physical processes and in a host of industrial activities [1]. One of the importance in learning of the characteristic of motion in viscous fluid is how to visualize the motion processes so it can make the student interest, understanding, and expertise in physics and learning. While an understanding of behavior of marbles motion in viscous fluid is obviously valuable in real-world applications, there have been very few studies that explore the basics of drop motion, such as their response to the buoyant force. The properties of fluids or plasma in which small particles or corpuscles are suspended and carried about by the motion of fluid. The presence of particles will influence the properties of the suspension in bulk and in particular its viscosity will be increased. Many quation must to answer in drops of liquids less dense than water, among others: are they moving upward due to buoyancy continue to accelerate upward or will there be a difference between the observed and the theoretical values for the terminal velocity of the drops, and if so, can this be explained mathematically. In order to do this work, the experiment will modificate with using tracker and modulus software. *Tracker* is using for analysis of video to give some information about the position of marbles in time, and the modulus application help to simulate and modeling which it was representation with animation, table, data or graph. [2]

II. THEORETICAL BACKGROUND

An object submerged in a fluid displaces a volume of fluid equal to the volume of the object itself, with the buoyant force acting upon that object if it is less dense than the surrounding fluid [2]. The buoyant force is equal in magnitude to the weight of the displaced fluid, but opposite in direction; i.e., upwards. Thus, expressing mass as the product of density and volume, the buoyant force (F_b) can be expressed by the formula [4]:

$$F_b = -V\vec{g}\rho_f \qquad (1)$$

in which ρ_f is the density of the surrounding fluid and V is the volume of both the displaced fluid and the immersed object, in this case a drop of liquid less dense than water ($\vec{g}$ = acceleration due to gravity). When small spherical bodies move through a viscous medium, the bodies drag the layers of the medium that are in contact with them. This dragging results in relative motion between different layers, which are away from the body. Therefore, a viscous drag comes into play, opposing the motion of the body. It is found that this backward force or viscous drag, increases with increase in velocity of the body. When an object fall through a fluid a viscous drag acts on it. According to Stoke's law, the resistive force depends on the coefficient of viscosity η of the medium, the terminal velocity (v_T) of the body and radius (r) of the spherical body.

$$F_d = 6\pi r v_T \eta \text{ ....} \quad (2)$$

This formulation will applying if the velocity of small spherical bodies is very small so there is no turbulence, in stability position the equation become

$$6\pi\eta r v_T + \frac{4}{3}\pi r^3 \rho_f g = \frac{4}{3}\pi r^3 \rho_b g \text{ ....} \quad (3)$$

$$v_T = \frac{2}{9}\frac{r^2 g}{\eta}(\rho_b - \rho_f) \text{ ....} \quad (4)$$

In which ρ_b is the mass density of marble, ρ_f is the mass density of fluid and η is viscosity. The equation of motion in viscous fluids which have the friction coefisien *v* reprsentated by

$$m\frac{d^2 y}{dt^2} = mg - bv \text{ ....} \quad (5)$$

If $u = v - \left(\frac{mg}{b}\right)$ and $du = dv$, so

$$\int \frac{du}{u} = \ln u = \ln\left(v - \left(\frac{mg}{b}\right)\right) = -\frac{b}{m}t + C \text{ ....} \quad (6)$$

$$v = \frac{mg}{b} + \left(v_0 - \frac{mg}{b}\right)e^{-\left(\frac{b}{m}\right)t} \text{ ....} \quad (7)$$

$$v(t) = v_0 e^{-\left(\frac{b}{m}\right)t} + \frac{mg}{b}\left(1 - e^{-\left(\frac{b}{m}\right)t}\right);\ v(t) = \frac{mg}{b}\left(1 - e^{-\left(\frac{b}{m}\right)t}\right) \text{ ....} \quad (8)$$

$$\frac{dy}{dt} = v_0 e^{-\left(\frac{b}{m}\right)t} + \frac{mg}{b}\left(1 - e^{-\left(\frac{b}{m}\right)t}\right);\ y(t) = \left(\frac{mg}{b}\right)t - \left(\frac{m}{b}\right)^2 g\left(1 - e^{-\left(\frac{b}{m}\right)t}\right) \text{ ....} \quad (9)$$

In which $v_T = \frac{mg}{b}$ dan $t_R = m/b$ and $y(t) = h_t$, $b = 6\pi r \eta$ the relation of terminal velocity and that of position in each time showed in

$$h_t = v_T t - v_T t_R (1 - e^{\frac{-t}{t_R}}) \text{ ....} \quad (10)$$

t_R is time of relaxation $t_R = \frac{m}{6\pi r \eta}$

III. METHOD

All experiments were performed at room temperature 29 ^{0}C. A 1 cm3 syringe was used to inject palm oil with mass density 873,167 kg/m^3, standard (vehicle) gasoline (841,333kg/m^3) and aquades with the density 961,833 kg/m^3 into a straight-sided centimeter ruled glass tube filled high 31,9 cm and diameter 0,0493 m in fig.1.

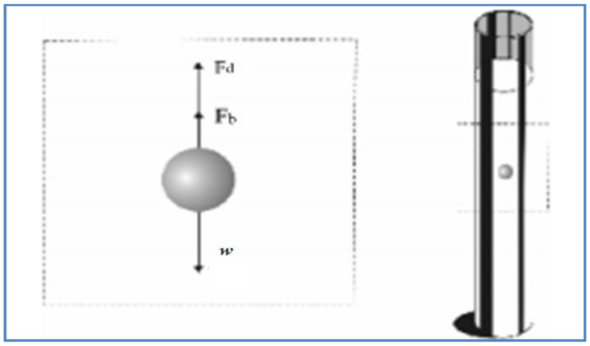

Figure 1. Preparation of samples

Marbles with radius 0,008015 released slowly and a digital video camera (Fuji film Sony S300) operating at 30 frames per second was used to capture the marble motion as it rose in the water column. The experiment was repeated three times for each liquid. The video data was imported into the freeware program Tracker® (Open Source Physics), and the kinematics of each liquid (velocity, acceleration) were determined. Simple mathematics were used to evaluate the position and time relation of the marble point at which terminal velocity was reached for each liquid which visualize in fig.2

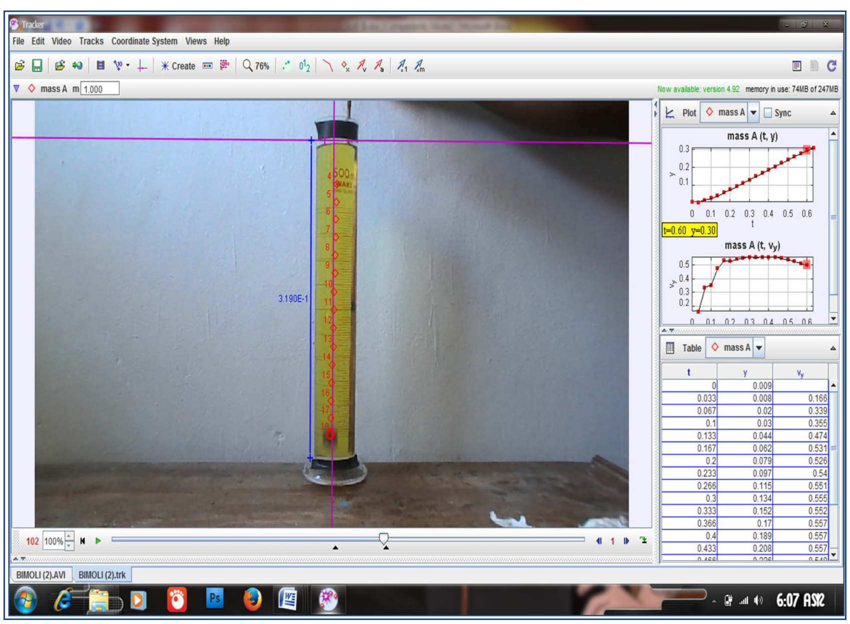

Figure2. Analysis of tracker

To simulate the computational modeling of the marbles in the liquid was using the freeware program *Modellus* (Open Source) [6] with insert Mathematical Model of the equations of motion in eq.6 and then the simulation design can be perform from tracker analysis resulted

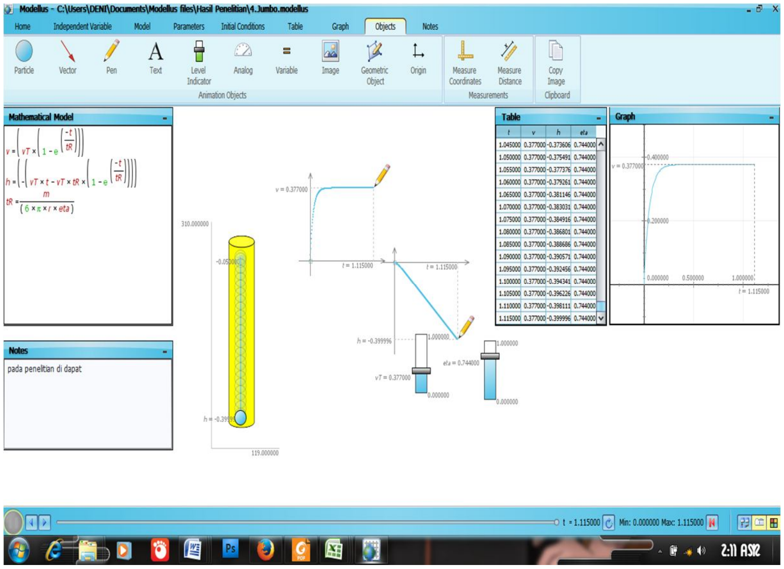

Fig.3 Simulation of marbles motion in gasoline

IV. RESULT

The marbles tracking results performed in velocity and time koordinat on three times treatment and then they analysed with spreadsheet excel respctivelly displayed in fig.4, fig.5 and fig.6 following

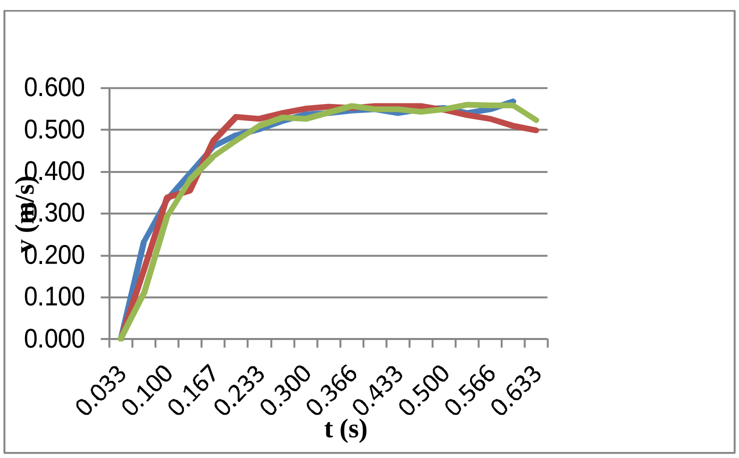

Figure 4. The velocity display of marble in palm oil

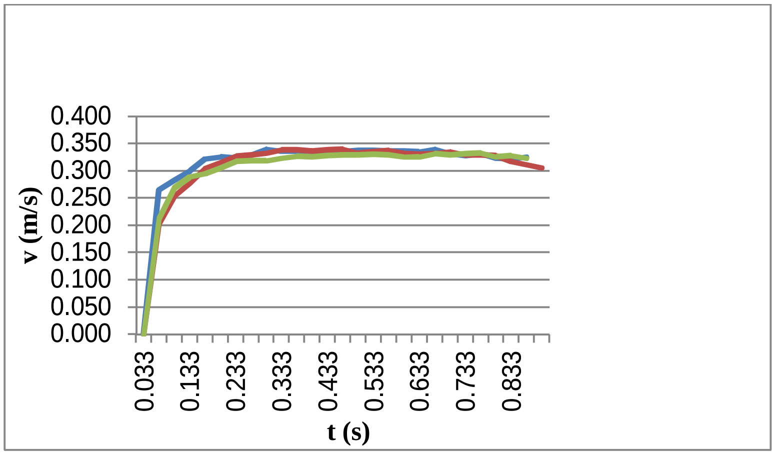

Figure 5. The velocity display of marble in gasoline

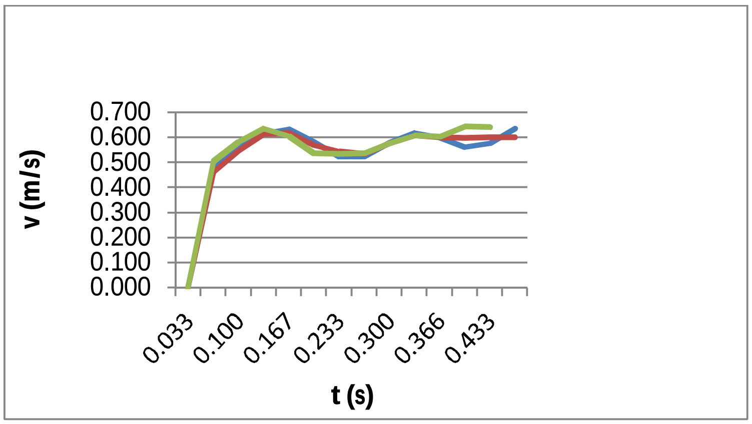

Figure 6. The velocity display of marble in aquades

Analysis the graph of mabble motion and with simple statistik using to determine the average of terminal velocity for each fluid resulted the value of terminal velocity and relative uncertainty (RU) showed in table following

Table 1. The terminal velocity value from video analysis calculation

Fluid	$\bar{v}_T \ (m/s)$	$\Delta v_T \ (m/s)$	RU(%)	$(\bar{v}_T \pm \Delta v_T)(m/s)$
Palm oil	0,551	$2{,}271 \times 10^{-3}$	0,412	0,551 $\pm$ 0,002271
Gasoline	0,333	$2{,}250 \times 10^{-3}$	0,676	0,333 $\pm$ 0,002250
Aquades	0,625	12,03	1,925	0,625 $\pm$ 0,012033

The viscosity of each fluid can be determine with using their terminal velocities using equation $\eta_i = \frac{2}{9}\frac{r^2 g(\rho_b - \rho_f)}{v_{Ti}}$. Calculation using simple statistic for each measurenment give the value of viscosity of each fluid following

Table 2. The viscosit value from video analysis calculation

Fluid	$\overline{\eta}$ ($Pa.s$)	$\Delta\eta$ ($Pa.s$)	RU (%)	$(\overline{\eta} \pm \Delta\eta)$ ($Pa.s$)
Palm Oil	0,499	$0{,}796\times10^{-3}$	0,159	0,499 $\pm$ 0,000796
Gasoline oil	0,831	$5{,}122\times10^{-3}$	0,616	0,831 $\pm$ 0,005122
Aquades	0,416	$7{,}929\times10^{-3}$	1,905	0,416 $\pm$ 0,007929

V. DISCUSION

The experiments also showed that in the case of falling marbles in each liquid the velocity of flow show noot smoth on the graph which means that the flow must have beel little turbulent. Using this estimated the reynolds number even with a small gab become out hihger than 1. On the measurement of viscosity and terminal velocity the mathematic calculation of Reynold numbers ($\mathrm{Re} = \frac{\rho_f v_T r}{\eta}$) result 7,07 for palm oil, 2,714 for gasoline and 11,65 for aquades which all of that values greater than 1. These results imply that there might be a better interpretation of the accepted formula used for predicting the terminal velocity of marbles, if that is a fluid that experiences compression during movement. This, The value of viscocity that we have found from analysis video using tracker lower than from the value from the standar value $0{,}8324\times10^{-3}$ $Pa.s$ where measurement in 29^0C [5]. As a result, the calculated value with the new term accurately predicted the observed, doing so better than the accepted term for all three liquids, and might be used to improve the accepted theory.

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VI. CONCLUSION

Considering the importance to visualize drops in many natural processes, the tracking of marbles can be evaluated with using video analysis. The terminal velocity and viscosity of palm oil, gasoline and aquades calculated with using the statistic error. To simulate this motion which useful as a tool for student to learning of physics present with using moddelus application. For the accuracy on this work our revised term for determining projected area of a fluid compressible marbles to reduce impact of turbulence, or a modification of the drag coefficient for flattening the marbles should be of interest to many scientists and engineers who study drop behaviour.

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