Graph Applications to Fluid Mechanics

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Abstract Fluid mechanics is an important subject which has been given equal weight age in Mechanical, civil, Chemical Engineering curriculum. It deals with the flow of fluids. This paper designed to explain the fundamentals of fluid mechanics in the areas of properties of fluids. And its applications to graphs A general graph approach for computational fluid dynamics is presented. Density, velocity and entropy per unit volume are used as independent variables for a single-phase, single-component flow. As a result of a combination of graph concepts with elements of Fluid mechanics, a new approach was developed principles and concepts of Fluid mechanics presented in simple and clear terms. The paper has an easy to read style and is going to benefit the readers. Important findings are a fluid is a substance which can i)attain the shape of the container as it has no definite shape.
ii) Fluid is a substance which can't acquire any static equilibrium under the action of any sheer force of even a small magnitude

Index Terms— Introduction, properties of fluids, objectives, Graphical representations

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1. INTRODUCTION

It is the science in which we study the behavior of fluids which are either in rest or in motion. Fluid is a substance which can flow. Technically the flow of any substance means a continuous relative motion between different particles of the substance The analysis of the behavior of fluids is based on the fundamental laws of mechanics which relate continuity of mass and energy with force and momentum together with the familiar solid mechanics properties. The study of fluids under static conditions is called Fluid statistics. Matter exists in two states; the solid and the fluid, the fluid state being commonly divided into the liquid and gaseous states. Solids differ from liquids and liquids from gases in the spacing and latitude of motion of their molecules, these variables being large in a gas, smaller in a liquid, and extremely small in a solid. Thus it follows that intermolecular Cohesive forces are large in a solid, smaller in a liquid, and extremely small in a gas

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2. IMPORTANCE

Drawing a graph is a natural part of doing Fluid Mechanics, with applications in all areas to the presentation of advanced theoretical or experimental research results. Modern computer packages are very good, but are of limited use unless the user is fully aware of their strengths and weaknesses. The student in has to decide whether the results of an analysis are physically meaningful. This requires a thorough understanding of the experiment being performed and a full appreciation of the reasons for plotting a graph at all.

Why plot graphs?. A clear picture reveals several things of data alone and provides answers to the following questions:

i. *How does a change in one variable lead to a change in the other?*

iiDo we have sufficient data?

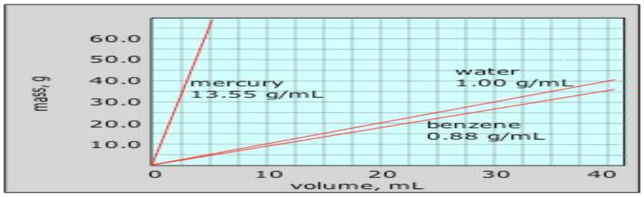
iii .Is there a region of interest that suggests further analysis?

Defining density

The density of an object is one of its most important and easily-measured physical properties. Densities are widely used to identify pure substances and to characterize and estimate the composition of many kinds of mixtures .

. These plots show how the masses of three liquids vary with their volumes. Notice that the plots all have the same origin of (0,0): if the mass is zero, so is the volume; the plots are all straight lines, which signify direct proportionality The only difference between these plots is their slopes. Denoting mass and volume by m and V respectively, we can write the equation of each line as $m = \rho V$, where the slope ρ (rho) is the proportionality constant that relates mass to volume. This quantity ρ is known as the ***density***, which is usually defined as the mass per unit volume:

$\varrho = m/V$.



Specific volume

It is sometimes more convenient to express the volume occupied by a unit mass of a substance. This is just the inverse of the density and is known as the ***specific volume***. ***Specific gravity*** is the ratio of the mass of a material to that of an equal volume of water. Because the density of water is about 1.00 g mL^{-1}, the specific gravity is numerically very close to that of the density, but being a ratio, it is dimensionless

Scope It is essentially a study of statics, kinematics and dynamics of fluid. It has important applications in diverse branches of mechanical, civil, Chemical Engineering .A Sound knowledge of fluid mechanics is essential the design of dams and irrigation structures fluid mechanics at present finds applications in new fields like bio-medical engineering, magneto –hydro dynamics. Being basic science it helps to develop an insight to common problems dealing with movement of air and water around us.

3..OBJECTIVES

Define the nature of a fluid.

- Show where fluid mechanics concepts are common with those of solid mechanics and indicate some fundamental areas of difference.
- Introduce viscosity and show what are Newtonian and non-Newtonian fluids
- Define the appropriate physical properties and show how these allow differentiation between solids and fluids as well as between liquids and gases

2. There are two aspects of fluid mechanics which make it different to solid mechanics:

- The nature of a fluid is much different to that of a solid
- In fluids we usually deal with *continuous* streams of fluid without a beginning or end. In solids we only consider individual elements.

Properties of Fluids

The term fluid includes both liquid and gases. The main difference between a liquid and a gas is that the volume of a liquid remains definite because it takes the shape of the surface on or in which it comes into contact, whereas a gas occupies the complete space available in the container in which it is kept. In hydraulics in civil engineering, the fluid for consideration is liquid, so, we will examine some terms and properties of the liquids.

Viscosity: Viscosity is the property of fluid which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. The viscous force is due to the intermolecular forces acting in the fluid. The flow or rate of deformation of fluids under shear stress is different for different fluids due to the difference in viscosity. Fluids with high viscosity deform slowly.

Compressibility: When pressure is applied on a fluid, its volume decreases. This property of a fluid is called compressibility.

Elasticity: When the force generating the pressure on the fluid, is released it returns to its original volume. This property of a fluid is called elasticity of the fluid.

Vapor Pressure: Molecules of a liquid escape from its surface to fill the space above the liquid surface and the container until such time when the pressure due to these molecules above the liquid surface reaches the vapor pressure of the liquid. This is how the vapor pressure of a liquid is defined.

Surface Tension: The molecules on the surface of a liquid, that is, the interface between the liquid and the air are bound together by a week force called surface tension. This force makes the liquid form a layer and is caused due to the cohesive force between the molecules of the liquid.

Capillarity: The molecules of a liquid have two types of forces acting on them. One is, cohesive force, the force among the molecules of the liquid only, and the other one is adhesive force, the force acting between the molecules of the liquid and some other substance. When the adhesion between the liquid and the container wall is more than the cohesion among the liquid molecules, the liquid sticks to the container walls and this results in capillary

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rise. The opposite of this behavior happens when the cohesion is more than the adhesion - the capillary level dips

Viscosity in Liquids

There is some molecular interchange between adjacent layers in liquids but as the molecules are so much closer than in gasses the cohesive forces hold the molecules in place much more rigidly. This cohesion plays an important roll in the viscosity of liquids. Increasing the temperature of a fluid reduces the cohesive forces and increases the molecular interchange. Reducing cohesive forces reduces shear stress, while increasing molecular interchange increases shear stress. Because of this complex interrelation the effect of temperature on viscosity has something of the form: $\mu_T = \mu_0(1 + AT + BT)$ where μ_T is the viscosity at temperature TC, and μ_0 is the viscosity at temperature 0C. A and B are constants for a particular fluid. **Absolute Viscosity**

Absolute viscosity is the characteristic of a fluid which causes it to resist flow. The higher the numerical value of absolute viscosity assigned to a fluid, the greater the resistance that fluid offers to flow.The viscosity of a fluid causes a loss in pressure as it flows, so that an increase in viscosity requires an increased amount of energy to pump fluid at the same rate. When it is necessary to cause fluids to flow through small openings, such as in low capacity flow meters, too high a viscosity can cause so much pressure loss that it becomes impossible to establish the desired flow rate. Expressed another way, flow from a constant pressure source will decrease as the viscosity of the flowing fluid increases. The viscosity of a liquid is highly temperature dependent. An increase in temperature will cause a decrease in viscosity. For this reason, it is possible for a temperature change to affect the performance of a flowmeter considerably.

Absolute Viscosity

The ratio between shear forces and the velocity gradient in a fluid (as defined in the previous section) is absolute viscosity, and is identified with the symbol μ

$$\nu = \frac{\mu}{\rho}$$

Pressure The absolute viscosity of a fluid is strongly influenced by temperature. As temperature increases, the viscosity of a liquid decreases and the viscosity of a gas increases. It is customary to express these relationships as a plot of viscosity vs. temperature, and such plots can be found in many references for common engineering fluids. Many oils have a straight line characteristic if the viscosity temperature relationship is plotted as on an ASTM chart

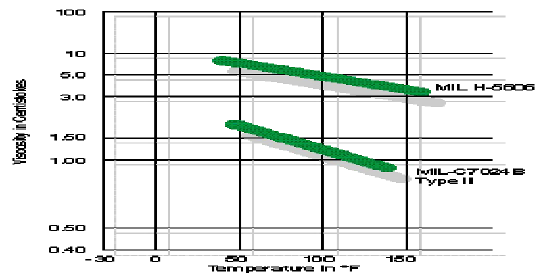

Figure 2

The influence of pressure on absolute viscosity is usually neglected, and this approximation is reasonable for low pressures. However, for pressures over about 1000 PSI, the absolute viscosity of a fluid may be a strong function of pressure. Generally, an increase in pressure will increase the viscosity of a liquid.

Kinematic viscosity is the ratio of absolute viscosity and density. Therefore, if density changes with temperature or pressure, the kinematic viscosity will also change. For gas applications, kinematic viscosity is a strong function of pressure.

When a viscous fluid flows over a solid surface, a force is exerted on the surface in a tangential direction. In effect, the moving fluid is attempting to drag the solid surface along with it. The magnitude of this force is dependent upon the viscosity and velocity of the fluid.

Experimentally measured drag forces are generally plotted in terms of CD vs. Re on a log-log chart. CD is the drag coefficient and Re is the Reynolds Number.

The drag coefficient is defined by:

$$C_D = \frac{F}{1/2\ V^2 A} \quad \text{where}$$

F = Drag force
V = Fluid velocity
A = Wetted surface area

A plot of CD vs. Re usually looks something like Figure 6. The drag coefficient decreases rapidly with the Reynolds Number in laminar flow, rises abruptly in the transition region, then levels off and eventually decreases slowly inTurblent region

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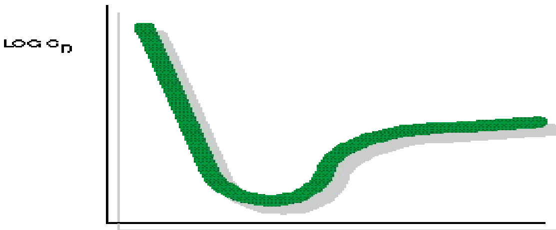
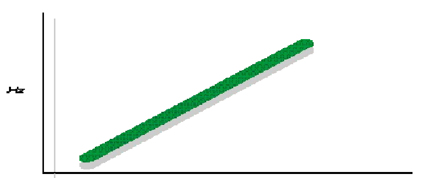


LOG Re
Figure 6

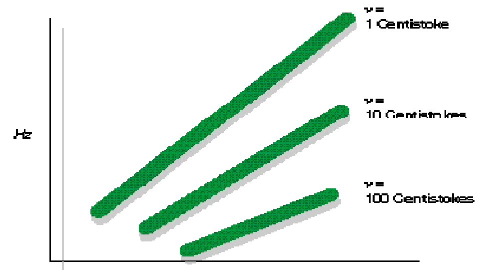
Because of the viscous retarding forces on the rotor, it does not spin as fast as it would in an in viscid fluid..The viscous drag also contributes to the pressure drop across the turbine meter.

For operation in high viscosity fluids, the curve in will have less slope and a positive zero offset along the horizontal axis.. Since a different curve will result for every viscosity, this is not a usable form for the calibration data except for single and constant viscosity operation.

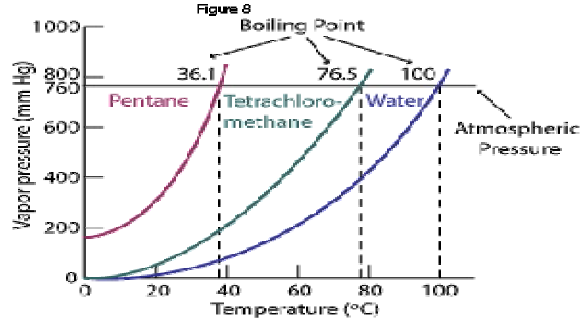


GPM
Figure 7

1. Determine output frequency Hz
2. Measure kinematic viscosity v or measure temperature and use temperature to determine v
3. Calculate Hz/v
4. Read up from known Hz/v to curve
5. Read over from curve to find K factor
6. Calculate GPM: GPM = Hz x 60/K



GPM
Figure 8



A more usable form for the calibration data is called a universal viscosity curve. This is a semi log plot of the sensitivity of the meter as a function of the ratio of the output frequency to the kinematic viscosity. the Universal Viscosity Curve is essentially a plot of meter sensitivity vs. Reynolds Number. As such, it reflects the combined effects of velocity, density and absolute viscosity acting on the meter. The latter two are combined into a single parameter by using kinematic viscosity (v).

The Universal Viscosity Curve is formed by plotting K vs. HZ/v for every calibration data point. Typically, thirty points are used; ten each for three different fluids. The thirty points are plotted on a common graph to form a smooth curve. Once this is done, the K factor may be determined for any flow rate in fluid of any viscosity as long as the ratio HZ/v is within the range of values covered by the graph.

To determine the flow rate from measured output frequencies and viscosities simply follow the steps shown in Figure

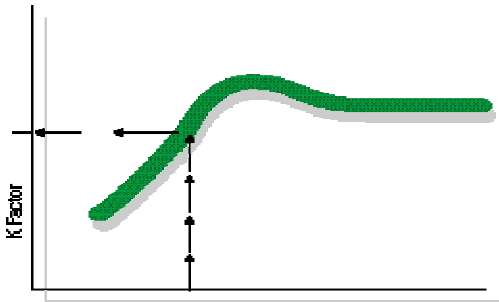
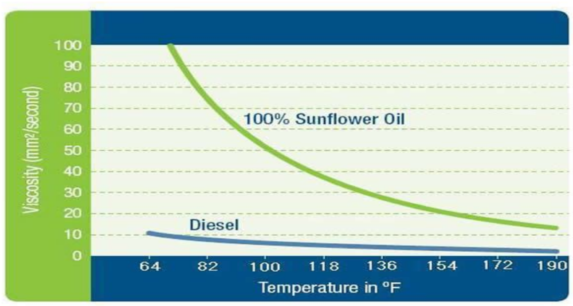
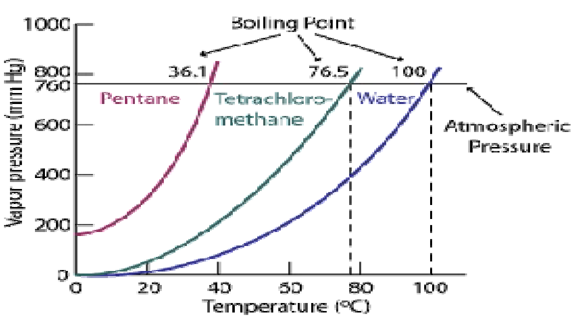
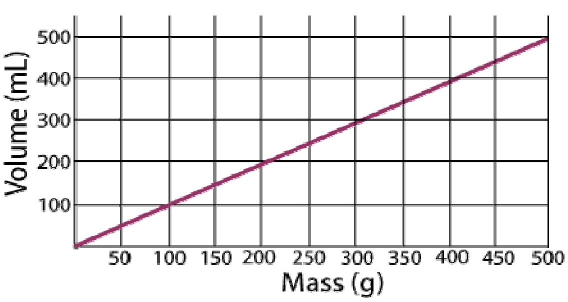


Figure 10

4.GRAPHICAL REPRESENTATIONS







5.CONCLUSION

Thus Fluid has important applications in diverse branches of mechanical, civil, Chemical Engineering . A Sound knowledge of fluid mechanics is essential in the design of dams and irrigation structures a civil engineer can construct dams and pipelines across countries for transportation of oil, petrol, gases, etc. in these cases we should know the behavior r of fluids so that structures could be designed in such possible manner for ease of flow of fluids. fluid mechanics serves this purpose. Applications of fluid mechanics include a variety of machines, ranging from the water-wheel to the airplane

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