Micro Irrigation Engineering
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Lecture-02
Fundamentals of Fluid Mechanics and its Application in Micro Irrigation

Hello participants, I invite you to lecture 2 micro irrigation engineering subject. This lecture is on the fundamentals of fluid mechanics and its application in micro irrigation engineering. In this particular lecture, we are just exposing you to the different terminologies which are dealing with fluids, mainly water. We will be using basic equations in micro irrigation engineering, so the fluid mechanic concepts are being dealt with.

This is a very brief lecture on the fluid mechanic's aspect which will be discussed. You have been given in your other subject, a fluid mechanic subject where you might have been taught in detail about the fluid mechanics part. But here it is briefly we are talking so which will be directly relevant to micro-irrigation.

In this particular lecture, we are dealing with the properties and types of fluid. Pressure and its measurement, kinematics of dynamics of fluid flow, this will be discussed.

Now when we talk of fluid mechanics, fluid is a substance that deforms continuously under the action of shear stress regardless of its magnitude and this can be a gas or a liquid. When we talk of fluid mechanics, it is the branch of science which deals with the behavior of fluid at rest as well as in motion. So, fluid can be in the position which is at the rest position or it can be in the motion.

We can classify fluid mechanics into 3 components. So, one classification when we say fluid statics means fluid is at rest. Water is stored in the tank, which means the liquid is in rest position, so that is a fluid static. And we are finding out what is the head of water, how much is the pressure at this water depending on the depth of water, whether it is below the soil?

When we are talking groundwater there also we are talking about the amount of water available in the well or the depth of water which is at the rest position in a reservoir, in a tank, it is fluid statics.

When we talk of fluid kinematics, so fluid is in motion without considering the force. And fluid dynamics means fluid in motion when we consider the effect of forces. So, the effect of forces with the flow when we are talking means this is basically fluid dynamics when we say flow through the pipe and flow through a deformable boundary. A pipe has a fixed boundary, but when it is a deformable boundary, so there are forces also working, and then the water is also taken means flow is also taking place.

Now, there are different fluid properties we come across. There are different terminologies we come across when we are talking about fluid. So, one is density, and density is given by mass per unit volume and the density of water is considered as 1000 and it is expressed as kilogram per cubic meter. A specific weight when we talk, the weight of fluid per unit volume of fluid. The specific weight of water is 9810 and the unit is expressed in force, so this is Newton per cubic meter.

Specific gravity is the ratio of the weight density of the fluid to the weight density of a standard fluid, that is your water. The specific gravity of the water is 1. Viscosity, there are two types of viscosity one is the dynamic viscosity, another one is the kinematic viscosity. So, viscosity is a measure of the resistance of fluid flow as a result of intermolecular cohesion. For water, the dynamic viscosity is 1.14×10^{-3} N-s/m^2.

Kinematic viscosity is the ratio of the dynamic viscosity to the density of the fluid. And its value for water is 1.14×10^{-6} m^2/s. Surface tension is used basically when we are dealing with the soil water tension when we are talking about, how much water is held by the soil particles because of the forces of surface tension.

So, a tensile force acting on the surface of a liquid that is in contact with the gas or other liquid is expressed in Newton per meter. Capillarity is another phenomenon in which water moves through the capillary forces through the capillary motion. So, there is say water table that is a saturated zone, and water moves from the saturated zone to the root zone of the plant. So, water movement takes place through the capillary motion.

So, rise and fall of the liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid, generally it is defined but it is applicable when there is a saturated soil and from the saturated soil water moved from the saturated media to the unsaturated media that is the capillarity action it takes place.

Types of fluid, these fluids can be given by ideal fluid it can be real fluid, Newtonian fluid, non-Newtonian fluid, or ideal plastics. So, this fluid when we say ideal fluid, ideal fluid it is incompressible having no viscosity, practically such fluid does not exist. Ideal fluid is the case which you see here and means it is just you can see this is the rate of demarcation that is you are seeing here is ideal, this particular part it is known as the ideal fluid.

The real fluid having some viscosity and all fluids are considered as real fluid. Newtonian fluid, when we say means it is a real fluid in which the shear stress is directly proportional to the shear stress. So, in this particular part when you are drawing there is a straight line you see a straight line that passes to the 45-degree line between the rate of the formation is nothing but your stress.

So, this is a shear strain and this is shear stress. So, when we have plotted and then 45-degree line when the slope is equal to 1 this is your Newtonian fluid. Non-Newtonian flow when it does not follow this particular graph. An ideal plastic is in which the shear stress is proportional to the rate of shear strain and shear stress is more than the yield value. So, this is the case with your ideal plastic.

Pressure, we are using this particular terminology when the fluid or water flow takes place. We are measuring how much pressure in the pipeline or how much is the pressure at the drip system is to be operated. What is the pressure at which the sprinkler systems should be operated? So, pressure is an important point and this is why I am discussing it in this particular lecture.

So, pressure is defined as the amount of force exerted by the fluid on any boundary it is in contact with. So, pressure is given by force per unit area. It is given by Newton per square meter. And then the pressure is measured or it is expressed in different ways gauge pressure, sometimes we say absolute pressure, sometimes we say negative pressure that is a vacuum, and sometimes we use differential pressure.

So, there are different terminologies that are used and when we say gauge pressure it means the reference to atmospheric pressure. So, water level measurement or in pipe hydraulics, we use gauge pressure. Absolute pressure, when we talk of the reference is a vacuum and it is used in measuring the barometric pressure, and for many metrological operations, we do use absolute pressure.

Vacuum, when we say means the pressure is below atmospheric pressure and there are pumps which are used to measure the vacuum pumps. Or there are say when we are talking about the soil water tension or soil water concept when we are dealing tensiometer is used. So, the tensiometer is using the concept of the vacuum or when we are using the Venturi system. So, Venturi system, if the pressure reduces means it becomes negative pressure then only the Venturi will suck the water.

So, in the fertigation system, we use a vacuum type of condition so a vacuum is used. And differential pressure measuring the difference between 2 pressure port readings and is used for the measurement of the pressure across the filter. Filter means your drip irrigation filter I am telling you that is used for monitoring the pressure at different points in the pipeline, so that is a differential pressure which is used.

Now when the water is moving in a pipeline or it is in a pipeline, how much pressure of water is available? This is just simply a piezometric tube that gives what is the pressure available. So, h refers to the pressure in the piezometric tube or the pipeline when we are taking the U-tube manometer. So, the U-tube manometer gives that how much is pressure available in the pipeline.

So, in the manometer, if there are suppose this is the water and then another one is your mercury or alcohol is used. So, there we are using a U-tube manometer and find out how much is the water pressure is available. So, this delta h means the pressure available the difference here between these 2 points this pressure is your manometric pressure between the two points.

There is a differential manometer, it is also used. You can see here fluid is flowing and then this is used. So, you are taking the measurement at this left limb of what is the water level available. And at the other right limb, you are getting the difference between these levels are used for this one. There are different other pressure measuring gauges available.

This is your bourdon gauge pressure and then you are using another pressure gauge. So, this is the front view and this is the rear view of your pressure gauge. So, these kinds of pressure gauges are being used to monitor the pressure, liquid pressure, or gas pressure.

Kinematics of the fluid flow, fluid kinematics deals with the motion of fluids without considering the forces and movements which create the motion. So, methods of describing fluid flow motion, one is the Lagrangian description, that tracks the position and velocity of individual particles that are used in the case of Lagrangian description. Eulerian description, a flow domain or control volume is defined by fluid flows in and out, means how much is the fluid it is entering in the control volume and how much is the fluid which is going out of the control volume.

So, this difference particularly when we are talking of the conservation of mass at that particular point we are using the Eulerian description, most commonly used in the fluid flow.

The types of fluid flow we discussing here is the steady-state flow means the velocity component is independent of time so that it becomes your steady-state flow. Unsteady state flow having a function of time. Means dv/dt means the first derivative of the velocity with respect to time is not equal to 0. When we call it a uniform flow, it means the velocity does not change with space.

This means when we are taking 2 sections, particularly of open channel flow. In open channel flow, we considered uniform flow. So, Manning's equation is the example of uniform flow formula, where we consider the velocity which is independent of the space as well as other properties, the discharge, the pressure with respect to time between 2 sections it remains the same.

And the non-uniform flow when the dv/dl is not equal to 0. Laminar flow has defined the state of flow where the laminar means the ratio of the inertial flow to the viscous pore. Viscous flow that gives threshold Reynolds number is less than 2000, it is considered as up to 2200. It is considered ideal laminar flow. And then the value it is given that when the Reynolds number goes more than 4000 is turbulent flow and in between these two, there is a transitional flow.

Compressible or incompressible flow is another category of the flow and these are being dealt with. The flow can be one dimensional, two dimensional, three dimensional depending upon the particular material and at through which the flow takes place. Accordingly, these properties, these types of flows they are defined. Rotational flow, irrotational flow, so where from the flow is taking place.

The continuity equation is following the principle of conservation of mass and you are seeing here two sections say we are considering a pipe flow. So, one section where the diameter of the pipeline is here the section 1 is like this, and then when you see the diameter of the pipeline is this one. So, the velocity component, as well as the area, is different, so we can say at section 1, the density, area, and velocity that can be given at section 1 as:

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

So, 2 refers to section 2, this particular equation is applicable for compressible and incompressible fluids. Fluid dynamics deals with the motion of fluid considering the forces causing the flow. So, these could be forces in fluid flow and so what are the forces one is the gravity force means when we are talking about the Froude number. So, the gravity force is important when we are talking about the pressure force means the fluid at the rest height, at what cost it is working.

So, this is the pressure gauge which I was telling you at what pressure the water is flowing into the pipeline. So, pressure force can consider force due to viscosity. That is means when we are talking about how much is the viscosity of the fluid. So, particularly this is more when we are dealing with the viscous material, where viscosity is important, so Navier-Stokes theorem or when we are adding fertilizer with the water and then fertigation takes place.

So, forces due to viscosity are considered when we talk about the turbulent force means your inertial force is more than the viscous force then turbulence takes place. And then compressibility there could be a different situation when the compressibility takes place. But here in our case, we are taking the incompressible flow. So, the equation of the motion that deals with means when we are using Reynolds equation of the motion, force is due to compressibility is neglected.

When we talk of the Navier-Stokes theorem force is due to turbulence is neglected but other forces are prominent. And when we talk about Euler's equation, the flow we assume ideal and zero viscous force take place.

Bernoulli's equation, is one of the forms of the energy equation and it is assumed that the flow is inviscid or frictionless, flow is steady and flow is incompressible. The flow is considered along the same streamline. And when you are considering Bernoulli's principle, you are taking section

1, this is the pipe flow you are taking that is a one. This is the inlet section of the pipe and this is the throat section of the pipeline.

Mainly you can see this is the case of a Venturi meter, the Venturi meter looks like the same. So, here in section 1, the area, this is your area vector, this is the velocity vector, and this is the pressure part. So, at the point 1, and 1 it is given by A_1, $V_{1,}$ and P_1 and at point 2 that is your throat section. So, when the area reduces from A_1 to A_2 means in diameter of the pipeline it reduces this.

That has caused the increase in the velocity and that change the pressure component and this pressure means it has reduced because of the increase in the velocity. So, this is what is explained by Bernoulli's equation, that the velocity $V^2/2g$ plus this is your elevation head z and this is your pressure head that is equal to constant. When we are taking 2 sections so, we can write

$$\frac{(V_1)^2}{2g} + Z_1 + \frac{P_1}{\rho_1 g} = \frac{(V_2)^2}{2g} + Z_2 + \frac{P_2}{\rho_2 g}$$

So, and if we assume this is in the same plane means this is at the same level.

So, $V_1^2 - V_2^2 = (P_2 - P_1)$

So, this will come in this form that is how the pressure difference takes place.

The continuity equation is defined by the partial differential form of this equation that is the velocity in the X direction, partial means velocity in the X direction

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

So, in the differential form, this continuity equation is given by this one, which is in the x, y, and z-direction. We in the algebraic form this continuity equation it is given by

$A_1 V_1 = A_2 V_2$

Or just now, in the previous case, we have given

$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$.

When we are considering the density component is different, the area component is different and the velocity component is different. But both the side it becomes equal that is the continuity equation. Navier-stokes theorem is defined by these equations where you can see the force means this particular let me just discuss this part the rate of change of momentum that is with respect to time is dealt by

$$\frac{\partial(\rho u)}{\partial t} + \nabla.(\rho u U) = -\frac{\partial p}{\partial x} + \mu\nabla^2 u + \rho f_x$$

$$\frac{\partial(\rho v)}{\partial t} + \nabla.(\rho v U) = -\frac{\partial p}{\partial y} + \mu\nabla^2 v + \rho f_y$$

$$\frac{\partial(\rho w)}{\partial t} + \nabla.(\rho w U) = -\frac{\partial p}{\partial z} + \mu\nabla^2 w + \rho f_z$$

That is your one means your direction that is your rho u capital U. So, this is the velocity component. In your i, j, and k or i, j, and w that is in three-dimensional form this velocity is given. And then that can be given by the change in the pressure head in x-direction plus the viscosity multiplied by these mean derivative second derivative of the velocity component, that is del square u plus the body force.

This particular component is the body force the rho into fx, similarly, in the y-direction, it has been given So, Navier-stokes theorem is describing the flow when the density of the liquid and the flow is incompressible that can be considered.

Now there are different units that are used in fluid problems and particularly, so one can use these units and convert them into the other. So, normally SI unit is used and but if the problem we are given in another system then this can be converted to other systems. So, length is given from 1 meter to 1 kilometer like this and then it can be equivalent to different unit feet, centimeter, millimeter, and miles.

Similarly the volume units it is expressed in a liter, meter cube, feet cube, and which is equivalent to gallons or liter. So, this is already available, area it is expressed in an acre or hectare, so they are equivalent and thee are available. Pressure, we are expressing in kg per square centimeter which is equivalent to 10.3 meters of the water column. So, this is a value that is used when we are operating the sprinkler system.

This is the value that means your kg per square centimeter when we are using it in sprinkler system, drip irrigation system, micro-irrigation system we are using. When we are talking about the pressure in the atmosphere normally this is used in the soil water concept when we are using the water held by the soil particle that in the negative pressure. So, that is expressed in the soil in the atmosphere are these are the other unit which you are using.

Also, you find out the discharge, so different units of discharge either in meter cube per second or in liter per second, these are used.

So, for this particular topic you refer to these books for getting more details, I have just discussed in a short about this particular concept it can be used in micro irrigation subject.

So, we discussed in this particular lecture, what are the different types of fluids. We discussed how to measure the pressure measurement, differential pressure as well as absolute pressure. We also discuss different types of fluid flow kinematics of kinematics or dynamics of fluid flow. We also discussed the Continuity equation, Bernoulli's equation, Navier-stokes equations. Now in the coming lecture, we will be discussing about soil water concept.

Thank you very much.