Original Article: Effect of Polymers on Transient Reynolds Number Change in Pipe Flow and Reduction of their Coefficient of Friction

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ABSTRACT

There are many ways to reduce the coefficient of friction as a result of pressure drop in internal flows and thrust force in external flows. For example, film suction, injection of gas bubbles in the boundary layer, use of magnetic fluid, etc., which are mostly intermediate fluids. Polymers are among the materials that can be used as intermediate fluids. Due to their ring structure and chain structure, polymer particles stretch and elongate when they are inside the stream. This stretching first absorbs energy from the fluid and does not allow this energy to be used to produce vortices. Second, stretching the polymer chain like a wall prevents the growth of vortices. The higher the molecular mass of the polymer, the greater the drop loss and the lower the critical concentration due to the heavier the polymer. As the concentration of polymer in water increases, the drop curve in terms of discharge towards the horizontal axis of Shifa and gets closer to it. In other words, the friction drops decreases. Percentage drop for 100gr per cubic meter of water is 4.54%, 200gr per cubic meter is 12.78%, 300gr per cubic meter is 27%, 400gr per cubic meter is 30.7% and 500gr per cubic meter is 39.4%, the maximum amount of reduction is.

Introduction

The increasing industrial development of the world and the need to transport materials such as water, oil and similar fluids from one point to distant places, cause a high cost to transport these materials by users [1-5]. To this end, and in order to reduce these costs, human beings thought of finding a way to reduce the pressure drop of these fluids to spend the minimum necessary cost for this transfer. One way to reduce this drop and minimize pressure boosting stations is to add polymeric materials to the fluid, especially water, which is our focus in this project [6-8].

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This issue was first addressed by TOMS in 1949. He published an article stating that the coefficient of friction in the turbulent flow inside the pipe can be significantly reduced by adding a small amount of water-soluble polymer. And since the pressure drop has a linear relationship with the coefficient of friction, the pressure drop also decreases [9-11].

We will try to explain this in detail in the following sections of this inscription. We first review the boundary layer theory, which consists of two sections of fluid motion on a flat surface and inside a tube, and discuss in detail the reduction of drag in either of these two modes [12-15]. Then we will explain the transition region (the region of slow current to turbulence) and in this passage we will introduce Newtonian and non-Newtonian fluids and the theories presented in this field [16].

A brief article on the properties of tragacanth as a polymer used in our experiments will be followed, and at the end we will analyze the test apparatus, draw the curves, how to perform the experiment and conclude [17].

Speed boundary layer

To introduce the boundary layer, consider the flow on the flat plate in the figure below. The velocity of the fluid particles in contact with the surface is zero. These particles slow down the motion of the particles in the adjacent fluid layer $y = \delta$ and these particles in turn affect the motion of the next particles and this phenomenon continues until this point is ignored [18-20]. Slow motion of particles is related to shear stresses, t, which act on a plane parallel to the velocity of the fluid. As the distance y from the surface increases, the x component of the fluid velocity u increases to a value in free flow u_∞ , and the caption is used to indicate free flow conditions outside the boundary layer [21-23]. The quantity δ is the thickness of the boundary layer and its value is equal $u = 099u_\infty$ to y.

The boundary layer velocity profile refers to how u with y change in the boundary layer. Accordingly, the fluid flow is determined by two distinct regions [24-27]. The first region is the region in which there is a thin layer of fluid (boundary layer) and the gradient is the velocity of shear stresses and the second region is the area outside the boundary layer which ignores the velocity gradient and shear stresses.

As the distance from the initial edge increases, the effects of viscosity penetrate more and more into the free flow and the boundary layer grows. In other words, it increases with x. Because the above boundary layer is related to fluid velocity, it is usually called velocity boundary layer. Whenever fluid flows on a surface, this layer is formed [28-31]. In fluid mechanics, the importance of this layer for an engineer stems from its relationship to the shear stress on the surface, t_s and hence the frictional effects of the surface. In external flows, the boundary layer is the basis for determining the coefficient of local friction, which this dimensionless parameter in turn is used to determine the drag force and surface friction.

$$C_f = \frac{t_s}{p\frac{U_\infty^2}{2}}$$

The shear stress of the surface can be calculated using information about the velocity gradient at the surface. We have:

$$t_s = \mu \frac{\partial u}{\partial y}\Big|_{y=0}$$

Parallel flow on a flat plate: Parallel flow on a flat plate as in the figure below, in addition to simplicity, occurs in countless engineering applications [32-35]. In addition, the flat plate is often a reasonable approximation for flow on a curved surface with a large radius of curvature, such as aerophytes or turbine blades.

Smooth flow and similarity solution: Assuming constant, incompressible and smooth flow with constant fluid properties, small friction losses and considering that $\frac{dp}{dx} = 0$ the boundary layer equations are as follows.

$$\frac{\partial u}{\partial x}+\frac{\partial V}{\partial y}=0 \quad (1\text{-}1)$$

$$u\frac{\partial u}{\partial x}+V\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial^2 y}=V \quad (2\text{-}1)$$

Solving these equations becomes easier due to the fact that for fixed properties, the conditions in the velocity (hydro mechanical) boundary layer are independent of temperature [36-39]. So we start solving the hydro mechanical problem with the equations written above. By solving the hydro mechanical problem, the solution of problems (1) and (2), which are related to u and V, can be obtained. Blasius method is used for hydrodynamic solution. The velocity components are defined in terms of the functions of the flow function, which is itself a function of x and y.

$$U=\frac{\partial \psi}{\partial Y}, V=\frac{\partial \psi}{\partial x}$$

Because the above definition holds in equation (1), there is no need to solve the problem. The dependent variables f and η independent are defined as follows [40].

$$f(\eta)=\frac{\psi}{u_\infty\sqrt{\frac{VX}{u_\infty}}} \quad (3\text{-}1)$$

$$\eta=y\sqrt{\frac{u_\infty}{VX}} \quad (4\text{-}1)$$

As we will see, the use of these variables converts the partial differential equation (2) to a normal differential equation, which thus simplifies the problem [41-45]. The solution of Blasius is similar and η is called a similarity variable. This naming is due to the fact that despite the growth of the boundary layer over the distance from the initial edge, the velocity profile remains geometrically similar $\frac{u}{u_\infty}$. The functional form of this similarity is as follows.

$$\frac{u}{u_\infty}=\phi\left(\frac{y}{\delta}\right) \quad (1\text{-}5)$$

Which δ is the thickness of the boundary layer, assuming that this thickness changes under the relation $\sqrt{\frac{VX}{u_\infty}}$, we will have

$$\frac{u}{u_\infty}=\phi(\eta) \quad (6\text{-}1)$$

Therefore, the velocity profile is determined exclusively by the similarity variable η that depends on y and x. Using equation (4-1) and the values u and v in terms of $\psi(x,y)$:

$$(7\text{-}1)\ u=\frac{\partial\psi}{\partial y}=\frac{\partial\psi}{\partial\eta}\times\frac{\partial\eta}{\partial y}=u_\infty\sqrt{\frac{vx}{u_\infty}}\frac{df}{d\eta}=u_\infty\sqrt{\frac{u_\infty}{VX}}=u\frac{df}{d\eta}$$

Similarly, by deriving the components of velocity, it can be shown that:

$$(8\text{-}1)\ V=-\frac{\partial\psi}{\partial Y}=-(u_\infty\sqrt{\frac{VX}{u_\infty}}\frac{df}{dx}+\frac{u_\infty}{2}f\sqrt{\frac{V}{u_\infty X}})=\frac{1}{2}\sqrt{\frac{Vu_\infty}{x}}(\eta\frac{df}{d\eta}-f$$

$$(9\text{-}1)\ \frac{\partial}{\partial x}=-\frac{u_\infty}{2x}\eta\frac{d^2 f}{d^2\eta}$$

(10-1) $$\frac{\partial u}{\partial x} = -u_\infty \sqrt{\frac{u_\infty}{vx}\frac{d^2 f}{d\eta^2}}$$

(11-1) $$\frac{\partial^2 u}{\partial y^2} = \frac{u_\infty^2}{VX}\frac{d^2 f^3}{d\eta^3}$$

By separating these expressions in relation (1), the following expression is obtained

(12-1) $$2\frac{d^3 f}{d\eta^3} + f\frac{d^3 f}{d\eta^2} + f\frac{d^2 f}{d\eta^2} = 0$$

$$u(x,\infty) = u_\infty$$

and $0 = u(x,0) = V(x,0)$

Or consider in terms of similarity variables. We know that when the fluid comes in contact with the surface, the effects of viscosity appear and the boundary layer grows with increasing x [46].

This expansion leads to a narrowing of the non-viscous region of the fluid and eventually the boundary layer in the axis of the pipe come together. The distance from the point of contact of the boundary layers to the inlet is called the "hydrodynamic inlet length" denoted by $x_{fd,h}$.

There is $x \succ x_{fd,h}$ for the boundary layer and the effects of viscosity across the cross section. And the flow is called fully development. When discussing internal flows, it is important to know the input length (input area), which depends on whether the flow is slow or turbulent [47-49]. The Reynolds number for the flow inside the pipe is obtained as follows:

(15-1) $$R_D = \frac{\rho u_m D}{\mu}$$

Which u_m is the average velocity of the fluid across the pipe section. The critical Reynolds number in which the current is confused is:

Therefore, the hydrodynamic boundary layer problem leads to the solution of a typical nonlinear differential equation of order 3. Relevant border conditions are:

$R_{e_{D,C}} = 2300$ and if $R_{e_D} \succ 4000$ the flow is completely confused. It is for smooth flow $R_{e_D} \succ 2300$.

Average speed

Because the velocity of the fluid changes at the cross section and there is no free flow, it is necessary to work at medium velocities in internal flows u_m. When ρ this velocity A_e is multiplied by the specific gravity of the fluid and the cross section of the pipe, the flow rate in the pipe is obtained. So:

(16-1) $$m^\circ = \rho u_m A_c$$

In constant current, they are incompressible in a tube with a uniform surface m° and u_m constants independent of x. Combining the two relations, it follows that:

$$R_{e_D} = \frac{4m^\circ}{\pi D\mu}$$

Because leaky discharge can be written as an integral of the mass flow intensity (ρu) on the cross section.

$$m^{\circ} = \int_{AC} \rho u(r,x) dA_c$$

For uncontrolled flow, we have density in the pipe:

$$u_m = \frac{2}{r_0^2} \int_0^{r_0} u(r,x) r dr \quad (17\text{-}1)$$

Using the above results and knowing the velocity profile u (r) at a particular point u_m can be determined at any point on the x-axis.

Speed profile in the fully developed area

The velocity profile shape can be obtained for a smooth flow of an incompressible fluid with constant properties in the fully developed area of the pipe. The two important hydrodynamic conditions are that the radial component of velocity v and the gradient of the axial component of velocity $\frac{\partial u}{\partial x}$ are zero everywhere.

$V = 0, \frac{\partial u}{\partial x} = 0$ therefore, the axial component of velocity depends only on r. $u(x,r) = u(r)$

The radial dependence of the axial velocity can be obtained by solving the momentum equation in the x direction. The shape of the momentum equation is determined by the fact that for hydrodynamic conditions the net current intensity of the momentum is zero for any point in the fully developed region. Thus, the momentum survival equation becomes a simple balance between shear and compressive forces in the flow. For a circular differential element, we have the following figure:

$$-t_r(2\pi r dx) + \{t_r(2\pi r dx) + \frac{d}{dr}[t_r(2\pi r dx]dr\}$$
$$+ \rho(2\pi r dr) - \{\rho(2\pi r dr) + \frac{d}{dx}[P(2\pi r dr]dx\} = 0 \quad (18\text{-}1)$$

Which after simplification is converted to the following form $\frac{d}{dr}(rt_2) = r\frac{dp}{dx}$ by placing the equation $t_r = \mu \frac{du}{dr}$ relation (18-1) as follows:

$$\frac{\mu}{r}\frac{d}{dr}(r\frac{du}{dr}) = \frac{dp}{dx} \quad (19\text{-}1)$$

Because the Murray gradient is a pressure independent of r with two integrals from equation (19-1) obtained:

$$r\frac{du}{dr} = \frac{1}{\mu}(\frac{dp}{dx})\frac{r^2}{2} + c_1 \quad (20\text{-}1)$$

$$\Rightarrow u(r) = \frac{1}{\mu}(\frac{dp}{dx})\frac{r^2}{4} + c_1 1nr + c_2 \quad (21\text{-}1)$$

Integration constants are obtained by applying the following conditions: $\frac{\partial u}{\partial r}\Big|_{r=0} = 0 \quad u(r_0) = 0$ which express the evil of non-slip on the surface of the pipe and the axial symmetry around the center line, respectively. By determining the mentioned constants, the velocity distribution is obtained.

$$u(r) = \frac{-1}{4\mu}\left[\frac{dp}{dx}\right] r_0^2 \left[1 - (\frac{r}{r_0})^2\right] \quad (22\text{-}1)$$

Therefore, the velocity profile is parabolic in the fully developed area. Note that the pressure gradient is always negative so u (r) is always positive.

Using the above results, the average flow velocity can be obtained by combining equation (22-1) and u_m the value obtained from the equation $\frac{1}{\rho A_C}\int pu(r,x)dA_c = u_m$, the following equation is obtained.

$$u_m = -\frac{r_0^2 dp}{8\mu dx} \quad (23\text{-}1)$$

By placing this expression in equation (22-2), the velocity profile is equal to:

$$\frac{u(r)}{u_m} = 2\left[1-(\frac{r}{r_0})^2\right] \quad (24\text{-}1)$$

Because u_m mass flow is calculated using equation (23-1), the pressure gradient can be obtained.

Friction coefficient pressure gradient in fully developed flow

Because the power of a fan or pump is determined by the pressure drop in the internal flow, an engineer is often faced with these parameters. To determine the pressure drop, it is appropriate to work with the friction coefficient of Modi (Darcy), which is a dimensionless parameter as follows:

$$f = \frac{-\frac{dp}{dx}d}{\rho u_m^2/2} \quad (25\text{-}1)$$

By placing equations (15-1) and (23-1), the coefficient of friction for a fully developed smooth flow is obtained according to the following equation.

$$f = \frac{64}{R_{e_D}} \quad (26\text{-}1)$$

For a well-developed turbulent flow, the analyzes are much more complex and ultimately lead to the use of experimental results. In addition to the Reynolds number dependence, the coefficient of friction is a function of the surface conditions of the pipe. The coefficient of friction for smooth surfaces has the lowest value and increases with increasing surface roughness. Relationships that are a reasonable approximation for smooth surfaces include:

$$0 \prec R_{e_D} \prec 2\times10^4 \quad , f = 0.316R^{-1/4}{}_{e_D} \quad (27\text{-}1)$$

$$R_{e_D} \succ 2\times10^4 \quad , f = 0.184R_{e_d}^{-1/5} \quad (28\text{-}1)$$

Note that $\frac{dp}{dx}, f$ they are fixed in the fully developed area. From equation (25-1) the pressure drop $\Delta P = P_1 - P_2$ of a fully developed flow from point x_1 to x_2 can be written as follows:

$$\Delta P = -\int_{p_1}^{p_2} dp = f\frac{\rho u_m^2}{2D}\int_{x_1}^{x_2} dx \quad (29\text{-}1)$$

$$\Rightarrow \Delta P = f\frac{\rho u_m^2}{2D}(x_2 - x_1) = f\frac{\rho u_m^2 L}{2D}$$

Where L is the length (distance) of two points (1) and (2).

Methods of reducing shell post

Fluid molecules adhere to objects due to their viscosity when passing through them, thus causing friction between the fluid and the body. This friction depends on the type of surface, its amount, fluid characteristics and flow. Here, to clarify the human issue, a little about the boundary layer and the effect of surface type and flow on the amount of stress will be: In a boundary layer, the following areas are clear:

1- The area of calm flow that starts from the beginning of the surface and gradually its thickness increases. There is shear stress in this area $t_w = \mu\frac{du}{dy}\Big|_{y=0}$.

2- Transition area is the area where disturbances and vortices begin.

3- Confused area in which the shear stress varies depending on the type of surface and its roughness.

A. If the surface is smooth (if the thickness under the laminar sublayer is large enough to cover the roughness, the surface will still be smooth).

Shear stress is that $t_w = (\mu + \mu T)\frac{du}{dy}$ the molecular viscosity is fluid and independent of the flow pattern, while μ_T the turbulent viscosity is apparent and strongly depends on the state of turbulence in the flow. At a distance close to the wall μ_T, the effect decreases μ and the effect appears, and this is due to the existence of a layered sub cortex.

While outside this sub-cortical layer, the effect will be small μ and the effect will appear μ_T. In addition to the problem of computational flow μ_T, which has not yet been solved theoretically, the velocity gradient problem $\frac{du}{dy}$ is also problematic in the above formula, and there is still no theoretical equation that can cover the entire thickness of the boundary cortex in turbulent flow.

In figure (2-2), the velocity gradient of two layers and turbulent flow in a smooth surface in the boundary cortex is compared: the friction coefficient of turbulent flow is greater than the laminar flow and, secondly, the velocity distribution is not uniform. This layer is divided into 3 regions.

I: The area under the Laminar Sub Layer where the flow can be assumed to be layered and the velocity distribution is usually assumed to be linear.

It should be noted that the thickness of this layer is very small compared to the thickness of the turbulent boundary layer and it is not yet possible to determine the exact coordinates of the flow with the available measuring instruments. The thickness of the sub cortex $S_1 = a\frac{u}{u^*}$ is a constant coefficient a and $u^* = \sqrt{\frac{t_w}{\rho}}$, as a result $t_w = \frac{a\rho u^2}{\partial L^2}$, it can be seen that if the thickness of the subcortical can be increased, the shear stress will decrease.

II - Buffer Layer is an area where the flow is neither sub-layered nor completely turbulent.

Physically, it can be said that this is the area where eddies begin to form.

III- The completely turbulent region (Turbulent Core) where the effect of molecular viscosity is not very noticeable and the fluid flow is so rotational and the eddies are so intertwined that the turbulent relations in that region are completely dominant. In this part, to reduce the shear stress, either the eddy must be damped or its start and formation must be delayed. B. If the surface is rough or in other words the roughness is protruding from under the stratum corneum, the shell friction depends entirely on their height and placement. In this way, any roughness causes more turbulence and increases energy loss. On the other hand, eddy roughness is created and thus with the interaction of eddy turbulence in the flow is greatly increased. The shear stress at these levels is expressed by a purely empirical relation. For example, for a perfectly rough plate with turbulent flow C_f, $(C_f = \frac{t_w}{1/2\rho V^2})$ the coefficient of shell friction is L, the length of the plate from the beginning, $C_f = (1.89 + 1.62\log\frac{L}{e})^{-2.5}$ and e is the height of the roughness.

From all the problems mentioned above, it can be seen that the shear stress on the wall, in other words, the shell friction in the turbulent flow is much greater than the layered flow and always insist on reducing it and thus reducing the energy consumption to overcome it. Shell friction plays an important role in some issues. The table below shows the percentage of shell friction relative to the total strength.

The following are the methods for reducing crustal lag: We have seen that in layered flow the shear stress on the wall is smooth $t_w = \mu \frac{du}{dy}\Big|_{y=0}$ and $\frac{du}{dy}$ on the other hand the laminar flow is much less compared to the turbulent flow. So if we keep the boundary layer in a way, we have achieved the goal. The following methods can be used to keep the boundary layer in a layer:

Roughness reduction: To layer the boundary layer should be done in such a way that the edges cannot be produced. Surface roughness is one of the parameters that plays an important role in eddy production and flow turbulence. The presence of roughness causes a severe drop in energy because, firstly, each roughness acts as a barrier to the flow and secondly, it is produced between two eddy roughness's. The production of these eddies in three directions and their effect on each other will cause a pressure drop. So if we remove the roughness and make the surface smooth and polished, it will reduce the shell friction.

Delay in the onset of disturbance in objects

There is a transition zone between the stratified boundary cortex and the turbulent region. This practice has been extensively researched in airfoils, especially in Transonic airfoils. For example, research at NASA (ACEE: Air Craft Energy Efficiency) was conducted in the 1970s and 1980s. In this regard, they have succeeded in making airfoils with a border layer up to 60% on the upper edge and up to 50% layer on the lower edge, for the angle swept by the airfoil 26 degrees and Mach number 0.81-0.85 and Reynolds number Chord. The reduction rate of airfoil drag coefficient was 55% compared to the same airfoil with 26 angle and completely turbulent flow.

Blowing

As mentioned before, blowing can delay the onset of disturbance. The physical cause of this will be discussed in the section on secondary fluid.

The blowing action can either give more momentum to the fluid and delay the separation, or it can dampen the turbulence and keep the boundary layer layered, thus delaying the transition point. NASA has re-used the airfoil of the previous topic and used blowing in it. The name of these airfoils (ATC: Anti Separtation Tailord Control) has been specified.

Cooling

If we cool the air, its viscosity decreases, so if we can keep the flow of the boundary cortex in a layer and reduce it on the other hand, the drag coefficient will be drastically reduced. This method is used in cryogenic combustible aircraft. In the hornbeam cortex, cooling can also be used to increase stability and delay the onset of perturbation.

Restriction of the boundary layer: If the boundary layer cannot be kept as a layer, it is necessary to change the structure of the turbulent boundary layer, which reduces it and $\frac{du}{dy}$ consequently the shell friction is also reduced. To change the shape of the wall or to create a groove on the surface, as mentioned before, what increases the friction of the shell in a turbulent flow is the creation of eddies and their effect on each other.

If the perturbation is delayed in some way, or the eddies can be dampened or prevented from growing, or at least some of them can be dormant, one can expect the shell friction to decrease. Experiments in this regard have been performed by Walsh on grooved surfaces. He has tested various surfaces with different longitudinal and transverse grooves. The grooves are V-shaped with circular, circular, wavy and irregular with dimensions of 0.025-0.05/cm and distance 0.025-0.315 cm. The results of the experiment showed that longitudinal V-shaped grooves with dimensions of 0.025 cm height and distance between two grooves 0.05 cm had a drag reduction of about 7% at a speed of 11/s, which decreased with increasing drag rate and decreased to one percent in the speed reaches 40m/s.

It seems that crustal friction is reduced by creating a v-shaped groove and damping large eddy. In other forms of grooves, an increase in drag is usually shown. Walsh has suggested that if the natural roughness of the surfaces can be regulated regularly, it will be effective in reducing drag.

Adding a secondary fluid: The structure of the turbulent boundary cortex can be changed by entering a fluid different from the main fluid in the boundary cortex. This fluid can be in the form of a film on the body below the main fluid or solid particles or gas in the boundary cortex of the main fluid. Because of the importance of this type of drag reduction for us, we will bring it in a separate chapter.

Reduce shell friction by adding secondary fluid

It seems that a natural phenomenon that has attracted the attention of researchers in this regard is that the muddy river moves faster than the river with clear water. A study of the effects of sludge in river water with very small dimensions (particles less than 60 microns and usually between 1-20 microns) has shown that what speeds up water is the reduction of river friction due to the presence of mud particles and damping. The disturbances are by them.

In this regard, it was observed that if fine particles enter the boundary layer, the crustal friction will decrease under certain conditions. Many studies and experiments in this field have been done during the last 20 years. The results show that with this method, about 50-90% of drag will be reduced.

Theory of how eddy came to be and its properties

By definition, a fluid is a body that deforms under stress. When the fluid passes through a wall, the presence of a very small roughness on the surface changes the shape of the fluid and the resulting stress is transferred to the upper layer.

This causes a wave of two-layer boundary (a) from now on it can be said that it produces three eddy processes.

A. Lift process: A tab of fluid rises slowly (b).

B. Eddie birth process: When the tongue reaches its critical distance from the wall, velocity is created downstream of Eddie (c, d).

C- Break up process: In this part, the vortices are destroyed and a large amount of turbulence and chaos is created in the fluid. The effect of this chaos in three dimensions increases the size and size of the eddy and on the other hand some of them shrink and fade (e). As a result, in a turbulent flow we will have the process of eddy birth and its enlargement (Generation) eddy. (dissipation) larger edibles have more energy and, conversely, smaller edibles have less energy. Large eddies are more unstable and therefore easier to break, while smaller eddies, although less energetic, are very stable and difficult to break.

Creating a secondary fluid on the body

There are many different ways to create a secondary fluid on an object.

Creating a film: A film of a different fluid with the main properties can be placed on the body. This fluid naturally has a lower viscosity than the main fluid and the velocity gradient will be the secondary fluid velocity gradient to calculate the stress on the body. Here we will have two boundary layers, one is the boundary layer of the secondary fluid on the body and the other is the boundary layer of the main fluid with the secondary fluid. How the two layers will interact and what the shear stress on the surface will be is theoretically solved for the laminar flow. But this method has not been tested. In practice, to create a film on the body can be done in the following ways:

A- Use of magnetic fluid

By placing a magnetic fluid on the wall and creating an electric field, the fluid is kept on the body.

B- Using mesh pages

If the surface is made of mesh and secondary fluid is injected through these holes, a layer of secondary fluid can be created under the main fluid.

C- Using Film Boiling: If the temperature of the body walls increases so that the fluid on the wall can evaporate quickly, a layer of vapor will form under the main fluid and the wall surface.

D- Sublimation: If the body wall is one of the items that can be sublimated (such as dry ice), the body wall will be covered with a film of steam.

E- Active Surface: The wall material can be such that a layer of it is removed by chemical or physical reaction due to the passage of fluid over it and covers the film around the wall.

Insertion of particles into the boundary layer: It can inject solid, liquid, or gas bubbles into the boundary layer.

A- Air bubbles can be introduced into the boundary layer using lattice surfaces.

B- Polymer materials can be used because of their properties. Numerous experiments have been performed on the reduction of drag by polymer. These materials are heavy molecules that are stretched by flow and move with flow.

C- Injection of gas bubbles can be done by electrolysis of water and production of hydrogen bubbles in the boundary layer.

The dimensions of these particles must be very small, and it has been reported that sizes of about 2-50 mm can reduce crustal friction, otherwise it will increase drag.

Conclusion

How the secondary fluid film on the surface or the presence of particles in the boundary layer reduces the shear stress is an issue that has not been completely resolved during twenty years of research in this field. At first, simple theories were given, but the more accurate the measuring devices became and the more work was done on this research, the closer the theories became to reality. Here are some of these theories:

A: Whenever a film of secondary fluid with lower viscosity is created on the body, t_w it reduces the viscosity during laminar flow according to the relation $t_w = \mu \frac{du}{dy}\Big|_{y=0}$.

This action can create a positive viscosity gradient near the surface, which also affects the velocity profile and contributes to the stability of the boundary layer. In addition, due to the increase in v in the Reynolds secondary flow, x at each distance from the edge decreases and the transition location is delayed and the boundary cortex area becomes longer layered. The presence of particles in the boundary layer increases the thickness of the boundary layer, because the particles are concentrated in the boundary layer in the Buffer Zone. On the one hand, according to new research, it is the beginning of turbulence and turbulence production in this region, and the concentration of particle concentrations in this region creates and dampens turbulence, and part of this region becomes sub-layered and can have rough effects in friction.

Or the thickness under the layer crust has increased, which according to the relation $t_w = \frac{upu^2}{\delta L^2}$, the more, δ_1 the lower the shear stress. On the other hand, due to their properties, polymer particles stretch and stretch when they are inside the stream. This stretching first absorbs energy from the fluid and does not allow this energy to be spent on producing eddy vortex and enlarging it.

Second, the stretching of a polymer chain is like a wall that prevents the eddy from growing. Bubble particles due to their elastic properties absorb the energy of small particles and prevent them from enlarging, on the other hand because these particles can create a viscosity gradient at the height of the boundary layer and transfer turbulence to the substrates. Prevents and possibly reduces shear stress on the wall. Particles do not follow the motion of small particles due to their inertia. On the other hand, the relative motion between fluid and particles causes a decrease in energy, damping small particles.

More than 30 years ago, an article by Toms (1949) it was reported that the results showed that the coefficient of friction in turbulent flows from within the initial lines could be significantly reduced by adding a small amount of high molecular weight polymers that are soluble in the fluid inside the tube. The information obtained for polymers that cause an effective reduction in the coefficient of friction became the starting point for conducting various research works for the practical use of the drag reduction property. This phenomenon ultimately leads to a reduction in the cost of transporting materials through pipelines and an increase in transport capacity in emergencies.

Increasing the capacity of materials to pass through closed and open canals and reducing drag in warships and using these materials to increase the production of petroleum products are among the other applications of this phenomenon. Specifically, among the effective applications of polymers in relation to the transfer of water and crude oil, the following cases can be stated. He named water for industrial use and fire engines.

In relation to ships, both tug and warship (1965), Emerson performed experiments with Guragum, polyethylene oxide, and in this regard, a good match was obtained between the experimental model and the actual model of a large-scale ship with 220 Wppm polymer, so that approximately 40% A decrease in the amount of drag property has been observed.

Dove injected a solution of Polyox WSR-301 polymer solution from the nose and other parts of a submarine at 16.4 feet and observed a drag drop of about 30%. A large-scale experiment was performed on a relatively large 140-foot (HMS Highburton) ship, and Canham reportedly reduced the drag by about 12.5 percent due to the non-uniform injection of 10 Wppm of Polyethylene Oxide. As a result, the power required by the home engine to reach a speed of 9 knots has been reduced by 17%. Knowing that the above practical aspect in warships is in the category of secret information and is not freely available to the public.

The second application of water-soluble polymers is the use of this phenomenon in the transfer of water from water pipes in fire engines and pipes related to the water supply network and its use in emergencies. In the case of fire engines, an increase of 200 Wppm in polyethylene oxide in water has caused a path of 700 feet with a 40% decrease in pressure drop and a 50% increase in volume flow. In case of huge fires in a city, it seems necessary to transfer a lot of water in a short period of time in the network of urban water lines. In this situation, this phenomenon can be a solution. The above plan has been accepted as an emergency plan for New York City. In addition to the above, the use of polymer material causes the water leaving the pipe of the fire engine to be cohesive, so that it prevents the dispersion of water and the jet of water is constantly targeted at the desired point.

Green Fabula have shown that this phenomenon can be effectively applied in relation to fire departments. Another case of drag reduction is the use of polymer to increase the transmission capacity of oil pipelines (1967). Ram, has shown that the addition of poly isobutylene to crude oil and kerosene significantly reduces the coefficient of friction.

In this regard, for the transfer of diesel in a military pipeline with a diameter of 6.4 inches and a length of 6.5 miles, even due to mechanical damage by centrifugal pumps, a drag reduction of 37.5% with 30% of the pump energy has been obtained. Good results have been obtained in transferring crude oil from a 12-inch-diameter, 32-mile pipe. Apart from the above, in relation to the transfer capacity and reduction of drag, the above phenomenon has been used to identify the molecular structure and study polymerization and de-polymerization. In view of the above, the question may arise that other than the above in relation to the transfer phenomena in fluid mechanics, do other aspects of the transfer phenomena such as heat transfer and mass transfer undergo changes in this regard or not?

According to existing research, because the major changes are near the wall, the phenomena that are in the upper boundary relation will be subject to change. Among them, the phenomenon of heat transfer and mass transfer can be mentioned. In general, there is a significant reduction in heat and mass transfer coefficients in fluids containing polymers, so that the combination of reducing the coefficient of friction with reducing the heat transfer coefficient leads to special applications such as the transfer of crude oil from cold regions. With regard to heat transfer and mass transfer due to the fact that we were discussing this topic, the explanation in this case and its scientific and practical aspects are omitted. So far, full industrial use of this phenomenon has not been possible due to the unknown mechanism of this phenomenon.

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