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A Study on Pressure Loss for Incompressible Fluid Flow Through a Tube in the Presence of Magnetic Field

Dr. Mahesh Chandra
Assistant Professor, Department of Mathematics, FS University, Shikohabad, (U.P.), INDIA.

Corresponding Author: maheshchandra2047@gmail.com

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ABSTRACT

The Present Paper deals with the pressure loss due to presence of magnetic field in a fluid flow through a tube. Magnetic field equations are derived with the help of standard equations of flow. The pressure loss is obtained by the projecting the linear grid lines in fully development regions to the upstream and down stream limits. It was the observed that pressure drop is proportional to the square of Magnetic field angle. Also the pressure drop is proportional to the flow rate. Transverse magnetic field change the axial velocity profile from parabolic to relatively flat shape.

Keywords- Pressure loss, Magnetic field Project, Axial Velocity.

I. INTRODUCTION

Dimensional code for modeling major ion equilibrium and kinetic non equilibrium chemistry in variably saturated porous media. Bruce et al (1996) developed physical model to study the transport of solute utilized by micro organism forming bio-film coating on soil gains in porous medium. Zhou and Pereira (1997) simulated machine air flame in porous media by using multi step reaction mechanism. They found that N.O and C.O emission is reduced within porous media combustion. Eeluck and Shutton (1998) an structured porous pipe made up of recycled automobile tyres was tested to study its efficacy for use as a micro irrigation later. A two dimensional simulation was carried out by Malico and Pereira (1999) having a single step reaction to analysis pollutant formation in porous medium. Zhangxin et al (1999) developed a model for three phase multi components fluid flow in porous medium. Bouhouch et al (1999) did mathematical modeling of isothermal low Reynolds numbers transient compressible flow through porous media.

Berner et al (2000) did work on laminar and turbulent permeability tensor conductivity and emissivity of the porous medium as a function of temperature for alumina fiber and sic lamellae structure. Karner and Perktold (2000) studied the effects of porous media during brain injury and increased blood pressure. Larafie and Vafai (2001) anlysed mathematically the non-Darcian effects on temperature variations in porous media. Kendall et al (2001) studied phase change in porous media. Alzami and Vafai (2001) studied the fluid flow and heat transfer will like to go in detailed study which have previously done in this Anderson and Malone (1974) studied on osmotic flow in pemembrane. O, Brain and Ehrlich (1985) Studied simple pulsatile f l human arteries. Although this work is not directly related to concern field but gives an idea to control the flow.

Mishra Chakravarty (1986) investigated the flow of blood considering theof stenosis and find out the effects of orthotropic elastic connetissues on the motion of walls. The scope of porous mediu considered as a device which is capable to control the fluid f Stefan (1986) studied Stoke flow through porous medium in term.

The method of volume averaging. Stefan and Cuthiel (1990) studies effects of a actual core -scale heterogeneity on the steady state transient fluid flow in aquifers and reservoirs and found that effect values of hydralaulic parameters are dependent on both the introduction structure of the heterogeneous porous medium on the flow proc Bachu and Cuthiel (1990) studied the effects of actual core-sheterogeneity on the study state and transient fluid flow in aquifers reservoirs and found that effective values of parameters are depen on both the intrinsic structure of the heterogeneous porous medium discretely fractured porous media for the importance of matrix diffusion of colloids as well as filtrations and remobilization of colloidal particles in both the fractured and porous matrix. Sharma et al (2001) studied MHD Flow in stenosed artery. They have used finite difference method to obtain the results. T. C. et al (2002) investigated the effects of conductivity of living tissues with directional blood flow during thermal therapy.

Hsis et al (2003) obtained numerical solution for transient two dimensional convection from a heated horizontal cylinder embedded in an enclosed porous medium. Laurant et al (2004) analysed the displacement of viscous fluid by a miscible more viscous one in heterogeneous porous media, they have applied to their study of the dispersion of a passive tracer in a stochastic heterogeneous porous medium. Sanyal et al (2007) developed a mathematical model of pulsatile blood flow through an inclined circular tube with periodic body acceleration. Reddaish et al (2008) made an investigation of heat transfer in enclosures containing porous media considering mixed conventional flows.

Arthur et al (2008) studied the particle image velocimetry of the flow of water layers of model parallel communicating porous media when the layers have the same porosity and when the properties of layers differs. Nakayama and Kuwahara (2008) studied a closed set of macro scoping governing equation for velocity and temperature fields in intra and extra vascular phases using the terry of porous media.

Willitiam et al (2008) determined if a pore scale model could accurately capture the physical and chemical process that control transverse mixing and reactor in the micro fluidic pore structure and found that sub continuum effects play an important role in the over all extent of mixing and reaction in ground water and hence may need to be considered when evaluating reactive transport. Esmaeilzadeh et al (2008) developed a one dimensional numerical model for natural as production from the dissociation of methane hydrate in hydrate capped gas reservoir under the pressurization and thermal solution using porous medium.

James et al (2008) studied the particle image velocimetry of the flow of water through the layers of model parallel communicating porous media, when the layers have the same porosity and when the properties of layers differ. Rathod and Tanveer (2009) Studied the pulsatile flow of couple stress fluid flow through porous medium. Pedro et al (2010) developed a mathematical model based on mass balance equation and dispersion transport. Laurent et al (2010) derived a two equation macro-scopic model for bio reactive transport at the Dracy scale from the pose-scale description using volume description method. Nicolson and Petropoulous (2010) developed the mathematical model for study state flow of dilute gases with and without additional surface flow in a series capillary model using porous media.

Mishra and Verma (2010) Studied the effects of stenosis on non-Newtonian flows of blood in blood vessels Mansourish and Shoki (2011) showed that a strong correlation between the growth dynamics of precipitated salt at the surface and the evaporation rate such that the maximum rate of surface coverage by salt coincide with the end of evaporation initially. This potentially offers a new method to under structively study the evaporation process from salive porous Convection flow in a two dimensional fluid saturated porous medium enclosures with localized heating from below symmetrically cooling from the sides and the top and rest of the bottom walls are insulated.

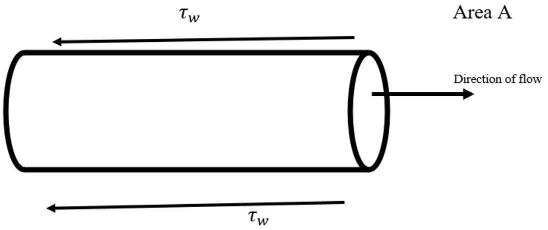
Growa (2012) made an experimental study of effective permeability of two phase flow of air and water-glycyrol solution under steady state conditions in a two dimensional model of porous medium. Santanu and Allex (2012) made numerical simulations and and a mean field calculation that immiscible two phase flow in porous medium. Zheng and Boming (2012) investigated gas permeability through matrix porous media embedded with randomly distributed fractal- like tree network. Veshalaxmi et al (2012) analysed the three dimensional Coutte- flow and heat transfer of a dusty fluid between two infinite horizontal parallel porous plates through a porous medium. behavior and back.

Dabirl J, O at el (2013) did work on measuring ostrocard, swimming group flow. Katija k (2014) studied quantitatively measuring in situ flows using a self contained under water velocimetry. Ruizla (2015) studied vertex enhanced propulsion. Collin at ei (2016) did work on stealth predation the bases of ecological success. Whittlesey at el (2017) did work on schooling as a bases for vertical axis wind turbine farm design.

Breithburg at el (2018) studied ecosystem engineers in the pelagicrealm. J.c at el (2019) did work on Phenotypic plasticity in Juvenile Jellipish medusae facilitates effective fluid interaction. J.o at el (2020) worked on a Langrangian approach to identifiy vortex pinch of chaos 20. Rosinfield at el (2021) studied circulation generation and vortex ring formation by statics conic nozzles. Kratika & Dabril (2022) studied a viscosity enhanced mechanism for biogenic ocean mixing.

II. MATHEMATICAL MODELING AND GOVERNING EQUATIONS

Consider a cylindrical element of incompressible fluid flowing in the pipe as shown.



The pressure at the upstream end, is *p*, and at the downstream end, the pressure has fallen by p to (p-△ p).

The driving force due to pressure (F=Pressure×Area) can then be written

$$pA-(p-\Delta p)A= \quad p\Delta A=\Delta p\frac{\pi d^2}{4}$$

The retarding force is that due to the shear stress by these walls

= shear stress × area over which it ects.
= τ_w × area of pipe walls
= τ_w πdL

As the flow is in equilibrium.

force =retarding force

$$\Delta P\,\frac{\pi d^2}{4} = \tau_w\ \pi dL$$

$$p = \frac{\tau_w 4L}{d} \qquad \ldots\ldots 1$$

Giving an expression for pressure lose in a pipe in terms of pipe diameter and the shear stress at the well on the pipe.

The shear stress will vary with velocity of flow and hence with Re. May experiments have been done with various fluids measuring the pressure loss at various Reynolds numbers. These results plotted to show a graph of the relationship between pressure loss and Re look similar to the figure below

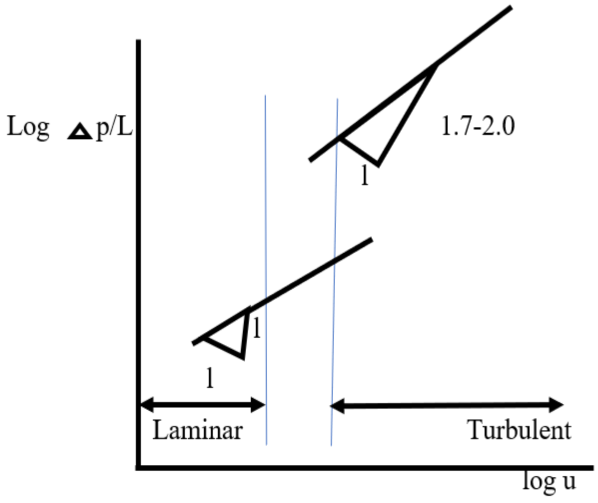


Figure 2: Relationship between velocity and pressure loss in pipes

This graph shows that the relationship between pressure loss and Re can expressed as

laminar $\triangle$ p∝ u
turbulent $\triangle$ p∝ u^a

Where 1.7<a<2.0

As these are empirical relationships. They help in determining the pressure loss but not in finding the magnitude of the shear stress at the well τ_w on a particular fluid. If we know τ_w we could then use it to give a general equation to predict the pressure loss.

1- Pressure loss during laminar flow in a tabe

In general the shear stress $\tau_w$is almost impossible to measure. But for laminar flow it is possible to calculate the theoretical value for given velocity, fluid and pipe dimension. The pressure loss in a pipe with laminar flow is given by the Hagen-Poiseuille equation:

$$P = \frac{32\mu Lu}{d^2}$$

Or in terms of head

$$h_f = \frac{32\mu Lu}{pgd^2} \qquad \ldots\ldots\ldots 2$$

When the equation for elevation pressure drop is Pe=Pg z When pe is the evaluation Pressure drop p is the fluid density, g is the gravitational force acceleration Z is the elevation. h_f is know as the head loss- due to friction

2- Pressure Loss During Turbulent Flow in a Tube

Consider the element of fluid, shown in figure 3 blow, flowing in a channel, it has length L and with wetted perimeter P. The flow is steady and uniform so that uniform so that acceleration is zero and the flow area at sections l and 2 is equal to A.

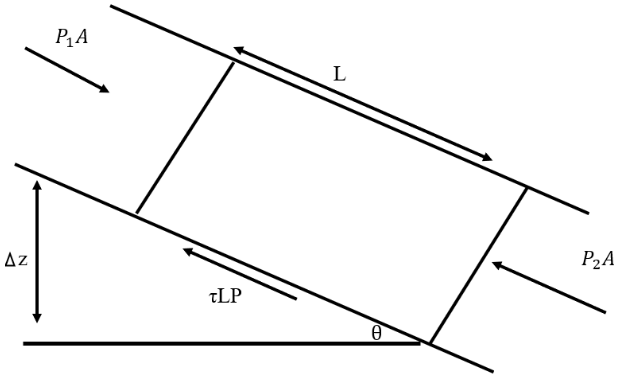


Figure 3: Element of fluid in a channel flowing with uniform flow

$$P_1A - P_2 - A\tau_w LP + W\sin\theta = 0$$

Writing the weight term as *pgAL* and sinθ = -△ z/L gives

$$A(P_1 - P_2) - \tau_w LP - PgA\Delta Z = 0$$

This can be rearranged to give

$$\frac{[(P_1 - P_2) - Pg\Delta z]}{L} - \tau_o \frac{P}{A} = 0$$

Where the first term represents the piezometric head loss of the length L

$$\tau_o = \text{m}\,\frac{dp}{dx}$$

……….3

Where m = A/P is know as the hydraulic mean depth
Writing piezometric head loss as p = pgh_f then shear stress per unit length is expressed as

$$\tau_o = \text{m}\,\frac{dp}{dx} = \text{m}\,\frac{Pgh_f}{L}$$

So we now have a relationship of shear stress at the wall to the rate of change in piezometric pressure. To make use of this equation an empirical factor must be introduced. This is usually in the form of the form of a friction factor *f* and written
Where u is the mean flow velocity.
Hence

$$\frac{dp}{dx} = f\,\frac{Pu^2}{2m} = \frac{Pgh_f}{L}$$

So for a general bounded flow, head loss due to friction can be written

$$h_f = \frac{flu^2}{2m} \qquad \text{……..4}$$

More Specifically, for a circular pipe, m = A/P = πd^2/4πd = d/4 giving

This equation is equivalent to the Hagen-Poiseuille equation for laminar flow with the exception of the empirical friction factor *f* introduced.

It is sometimes useful to write the Darcy equation in terms of discharge Q, (Using Q = AU)

$$\text{u} = \frac{4Q}{\pi d^2}$$

$$h_f = \frac{64flQ^2}{2g\pi^2 d^2} = \frac{flQ^2}{3.03d^2}$$

……….5

Or with a 1% error

$$h_f = \frac{flQ^2}{3d^2}$$

……….6

The value of *f* must must be chosen with care or else the head loss will not be correct. Assessment of the physics governing the value of friction in a fluid has led to the following relationships

1. $h_f \propto$ L
2. $h_f \propto v^2$
3. $h_f \propto$ l/d
4. h_f depends on surface roughness of tabe
5. h_f depends on fluid density and viscosity
6. h_f is independent of pressure

Consequently *f* cannot be constant if it is to give correct head loss values from the Darcy equation. An expression that give *f* based on fluid properties and the flow conditions is required.

III. THE VALUE OF *F* FOR LAMINAR FLOW

The equation derived for head loss in turbulent flow is equivalent to that derived for laminar flow-the only difference being the empirical *f* . Equation the two equations for head loss allows us to derive an expression of *f* that allows the equation to be applied to laminar flow.

Equation the Hagen-Poiseuille and Darcy-Weisbach equation gives:

$$\frac{32\mu Lu}{Pgd^2} = \frac{4fLu^2}{2gd}$$

$$f = \frac{16\mu}{Pvd}$$

$$f = \frac{16}{Re}$$

……….7

Equation for f

Blasius in 1913 was the first to give an accurate empirical expression for *f* for turbulent flow in smooth pipes that is:

$$f = \frac{0.079}{Re^{0.25}}$$

……….8

This expression is fairly accurate head losses +/- 5% of actual value of Re up to 100000.

Nikuradse made a contribution to the theory of pipe flow by differentiating between rough and smooth pipes. A rough pipe is one where the mean height of roughness is greater than the thikness of the laminar sub-layer. Nikuradse artificially roughness is grater than the thickness of the laminar sub-layer. Nikuradse artificially roughened pipe by coating them with sand. He defined a *relative roughness* value K_s/d and produced graphs of *f* against Re for range of relative roughness 1/30 to 1/1014.

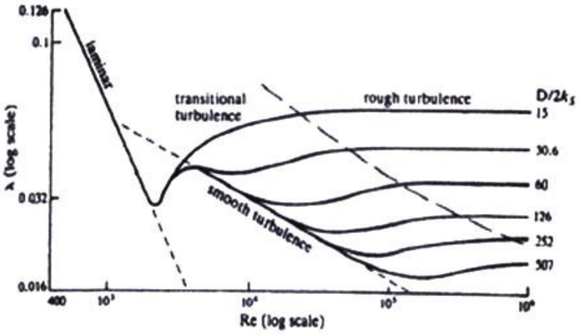


Figure 4: Regions on plot of Nikurades's data

A Number of distinct region can be identified on the diagram.

The region which can be identified are:

1. Laminar flow (f = 16/1Re)
2. Transition from laminar to turbulent
3. An unstable region between Re = 2000 and 4000. Pipe flow normally lies outside this region
4. Smooth turbulent ($f = \frac{0.079}{Re^{0.25}}$)
5. The limiting line of turbulent flow. All values of relative roughness tend toward this as Re decreases.
6. Transitional turbulent
7. The region which f various with both Re and relative roughness. Most pipes lie in this region.
8. Rough turbulent. f remains constant for a give relative roughness. It is independent of Re.

Making the assumption that the pressure at the annular area $A_2 - A_1$ is equal to the pressure in the smaller pipe P_1. If the apply the momentum equation between positions

$$P_1A_2 - P_2A_2 = \text{pQ}(u_2 - u_1)$$

Now use the continuity equation to remove Q (i. e. substitute Q = A_2u_2)

$$P_1A_2 - P_2A_2 = \text{p}A_2u_2(u_2 - u_1)$$

Rearranging and dividing by g gives

$$\frac{P_2 - P_1}{pg} = \frac{u_2}{g}\,(u_2 - u_1)$$

……….9

Now apply the Bernoulli equation

$$\frac{P_1}{Pg} + \frac{u_1{}^2}{2g} = \frac{P_2}{pg} + \frac{u_2{}^2}{2g} + h_L$$

And rearranging gives

$$h_L = \frac{u_1{}^2 - u_2{}^2}{2g} - \frac{P_2 - P_1}{Pg}$$

……….10

Combing Equation 9 and gives

$$h_L = \frac{u_1{}^2 - u_2{}^2}{2g} - \frac{u_2}{g}(u_1 - u_2)$$

$$h_L = \frac{(u_1 - u_2)^2}{2g}$$

……….11

Substituting again for the continuity equation to get an expression involving the two areas, (i.e. $u_2 = u_1 \quad A_1/A_2$) gives

$$h_L = (1 - \frac{A_1}{A_2})\frac{u_1{}^2}{2g}$$

……….12

Comparing this with equation (14) gives K_L

$$K_L = (1 - \frac{A_1}{A_2})^2$$

……….13

When a pipe expands in to a large tank $A_1 < A_2$ i.e. $A_1/A_2 = 0$ so $K_L = 1$. That is the head loss is equal to the velocity head just before the expansion into the tank.

IV. LOSSES AT SUDDEN CONTRACTION BY MAGNETIC FIELD

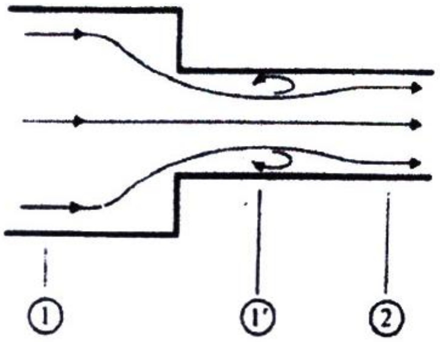


Figure 7: sudden contraction

In a sudden contraction flow contract from point 1 to point l', forming a vena contraction. From experiment it has been shown that this contraction is commonly about 40% (i.e. A_1 = 0.6 A_2), It is possible to assume that energy losses from 1 to l,' are negligible (no separation occurs in contracting flow) but the major losses occur between l,' and 2 as the flow expands again. In this case equation 20 can be used from point l' to 2 to give (by continuity $u_l = A_2\, u_2 / A_1 = A_2\, u_2 / 0.6A_2 = u_2/0.6$)

$$h_L = (1 - \frac{0.6\,A_2}{A_2})^2\,\frac{(u_2/0.6)^2}{2g}$$

$$h_L = 0.44\,\frac{u_2{}^2}{2g}$$

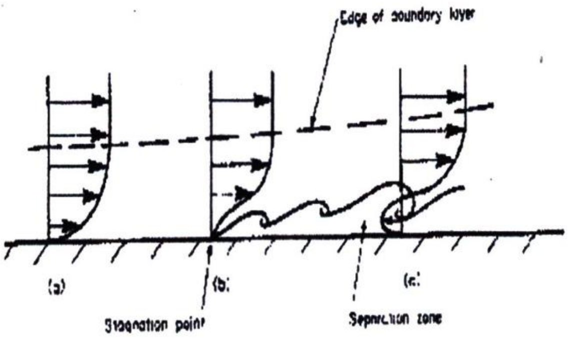
At a sudden contraction K_L = 0.44

As the different in pipe diameters gets large (A_1 / A_2) than this value of K_L will tend toward 0.5 which equal to the value for entry loss from a reservoir into a tube.

V. OTHER LOCAL LOSSES BY MAGNETIC FIELD

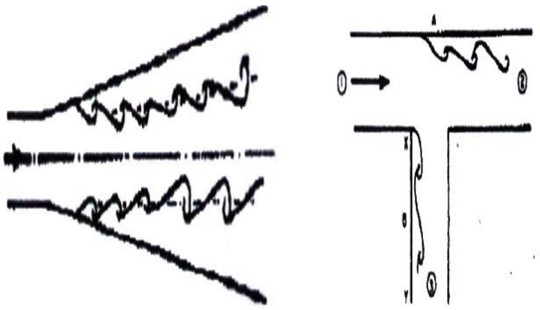
Large losses in energy in energy usually occur only where flow expands. The mechanism at work in these situations is that as velocity decreases so pressure must increase.

When the pressure increases in the direction of fluid outside the boundary layer has enough momentum to overcome this pressure that is trying to push it backward. The fluid within the boundary layer has so little momentum that it will very quick be brought to rest and possibly reversed in direction. If this reversal occurs it lifts the boundary layer away from the surface as shown in figure 8. This phenomenon is know as boundary layer separation.



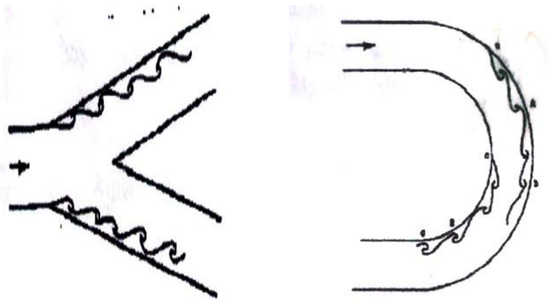
At the edge of the separated boundary layer, Where the velocities direction a line of vortices occur This happens fluid to either side is moving in the opposite direction. This boundary layer separation and increase in the turbulence because of the vortices results in vary large energy losses in the flow. These separating/ divergent flows are inherently unstable and far more energy is lost than in parallel or convergent flow.

Some common situation where where significant head losses occur in pipe are shown in figure 9



A divergent duct or diffuser

Tee- junction



Y- Junction

Bends

Figure 8: Local losses in pipe flow

Bernoulli's equation is the statement of conversation of energy along a streamline, by this principle the total *energy* in the system does not change. Thus the total head does not change. So the Bernoulli equation can be written.

$$\frac{P}{pg}+\frac{u^2}{2g}+z=H=\text{constant}$$

Of

Pressure + kinetic + potential = Total

energy per + energy per + energy per = energy per
unit weight unit weight unit weight unit weight

As all of these elements of the equation have units of length, they are often referred to as the following.

Pressure head $= \frac{P}{Pg}$
Velocity head $= \frac{u^2}{2g}$
Potential head $= z$
Total $= H$

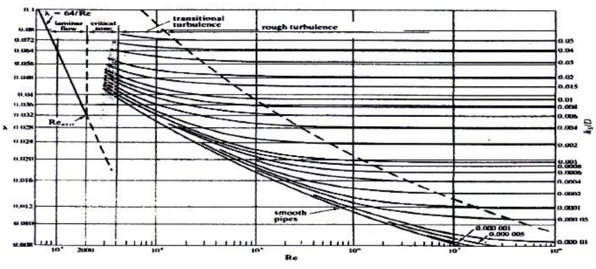
In this from Bernoulli's equation has some restrictions in its applicability, they are

- Flow is stready:
- Density is constant (i. e. fluid is incompressible):
- Friction losses are negligible.
- The equation relates the states at two points along a single streamline.

Applying the equation between two points an including entry, expression exit and friction losses, we have

$$\frac{P_1}{Pg}+\frac{{u_1}^2}{2g}+z_1=\frac{P_1}{Pg}+\frac{{u_2}^2}{2g}+z_2+h_{Lentry}+h_{Lexpanation}+h_{Lexit}+h_f$$

The above equation can easily solved by finite element method



He is also developed an equation based on the Colebrook white on that made it simpler to calculate *f*

$$f=0.001375\left[1+\left(\frac{200k_s}{d}+\frac{10^6}{Re}\right)^{1/3}\right]$$

this equation of moody gives f correct to +/- 5% for $4\times 10^3 < Re < 1\times 10^7$ and for k_s/d < 0.01.

$$\frac{1}{\sqrt{f}} = -4\, log_{10} \left[\frac{K_s}{3.71d} + \frac{5.1286}{Re^{0.89}}\right]$$

Or

$$f = 1/[-4log_{10} \left(\frac{K_s}{3.71d} + \frac{5.286}{Re^{0.89}}\right)]^2$$

VI. RESULT AND DISCUSSION

Effect of the magnetic on the MHD Pressure drop in the flow in square duct at b=1, m-10m , um -.1m/s thin steel heart man walls with the = 5 mm walls are non conducting magnetic field have magnetic pressure is contained in the boundary conditions the gradient of the field causes a force due pressure gradient and this is pressure change the shape the effect of uniform and non uniform magnetic field on a tuble as specification problem flow through a tube motion of a magnetic field plug is in investigated.

The force due to electromotive is poopolional to the square of magnetic fluid density. The tendency of pressure loss with force due to electromotive according to the system geometry. As the system duct height increases the force due to electromotive decreases.

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