PROCEEDINGS, Thirty-Third Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 28-30, 2008
SGP-TR-185

MOODYCHART: AN ACTIVEX COMPONENT TO CALCULATE FRICTIONAL FACTOR FOR FLUID FLOW IN PIPELINES

Mahendra P. Verma

Geotermia, Instituto de Investigaciones Electricas
Av. Reforma 113, Col. Palmira
Cuernavaca, Morelos, 62490, Mexico
e-mail: mahendra@iie.org.mx

ABSTRACT

An ActiveX component, *MoodyChart* is written in Visual Basic 6.0 to calculate frictional factor for fluid flow in a pipeline using one of the three implicit and four explicit forms of Colebrook equation. The *MoodyChart* can be integrated in any computer language, which support object link embedding (OLE) in the windows environment. A function, *FrictionalFactor* (EqNo, Re, RelR), where EqNo, Re and RelR are equation number, Reynold number and relative roughness, respectively, is written in Visual Basic for Application (VBA) to use the *MoodyChart* in a workbook of MS-Excel. A comparative study among the calculated values of frictional factor indicates that the explicit equations of Serghide, and Zigrang and Sylvester provide reasonably consistent values of frictional factor for whole range of Re and RelR.

INTRODUCTION

The Darcy-Weisbach equation is used to calculate pressure drop and energy loss resulting from fluid motion in pipes and other closed conduits. Brown (2002) presented a precise historical development of this equation. The frictional factor is estimated through Moody chart for the above calculations (Moody, 1944). The Moody chart is a graphical representation of Colebrook equation (Colebrook, 1939, Colebrook and White 1937, Lester 2002). During a computer simulation of fluid flow the direct application of Colebrook equation has advantages over the graphical approach of Moody chart.

Lester (2002) reviewed the different forms of Colebrook equation available in the literature. Table 1 presents the most commonly used three implicit and four explicit forms of Colebrook equations. The original Colebrook equation is in the implicit form. An implicit equation is solved through iteration; therefore, the computer execution time is relatively larger for an implicit form than that for an explicit form. To make the calculations easier many researchers developed explicit expression for the Colebrook equation (Swamee and Jain 1976, Zigrang and Sylvester 1985, Serghides 1984, Tsal 1989). During a numerical simulation of fluid flow in a pipeline or pipe-network, the calculation of frictional factor is performed several times. Thus an explicit form is preferred, if it provides the reasonable accurate and consistent values of frictional factor.

In this article an activeX component, *MoodyChart* in MS-Visual Basic 6.0 is developed to calculate the frictional factor using the implicit and explicit forms of Colebrook equation. The *MoodyChart* can be integrated in any computer language, which support object link embedding (OLE) in the Windows environment. A function, *FrictionalFactor* (EqNo, Re, RelR), where EqNo, Re and RelR are equation number, Reynold number and relative roughness, respectively, is written in Visual Basic for Application (VBA) to illustrate the use of *MoodyChart* in a workbook of MS-Excel.

MoodyChart: ActiveX COMPONENT

Reynold (1883) demonstrated experimentally the existence of two types of flow, laminar and turbulent, which are governed by the relative magnitude of the inertial and viscous forces (i.e. Reynold number (Re)). For practical purposes, it is considered the laminar flow for $Re<2000$, turbulent flow for $Re>4000$ and transition region in the range $2000<Re<4000$. The laminar flow equation is well established. There are many forms of the Colebrook equation for turbulent flow. There is no study to estimate the frictional factor for the transition region. Therefore, a linear interpolation of frictional factor for the values of laminar flow at $Re=2000$ and turbulent flow at $Re=4000$ for the respective Colebrook equation is used here.

The program *MoodyChart* is created as an ActiveX component in the library "MyActiveXLib.dll" and a class module is written in Visual Basic 6.0.

Table 1: Description of different forms of Colebrook equation, programmed in the *MoodyChart* ActiveX component (Lester, 2002)

Laminar Flow (Re>=2000)	Transition (2000<Re<4000)	Turbulent flow (Re>=4000)
$f = \dfrac{64}{\text{Re}}$	Liner interpolation of frictional factor for the values of laminar flow at Re=2000 and turbulent flow at Re=4000 for the respective equation.	**Implicit form**
		1. $\dfrac{1}{\sqrt{f}} = -2\log_{10}\left(\dfrac{\text{RelR}}{3.7} + \dfrac{2.51}{\text{Re}\sqrt{f}}\right)$
		2. $\dfrac{1}{\sqrt{f}} = 1.74 - 2\log_{10}\left(2\text{RelR} + \dfrac{18.7}{\text{Re}\sqrt{f}}\right)$
		3. $\dfrac{1}{\sqrt{f}} = 1.14 + 2\log_{10}\left(\dfrac{1}{\text{RelR}}\right) - 2\log_{10}\left(1 + \dfrac{9.3}{\text{Re}\ \text{RelR}\sqrt{f}}\right)$
		Explicit form
		4. Serghide equation $$f = \left[A - \left\{(B-A)^2 \big/ (C - 2B + A)\right\}\right]^{-2}$$ where $A = -2\log_{10}\left(\dfrac{\text{RelR}}{3.7} + \dfrac{12}{\text{Re}}\right)$, $B = -2\log_{10}\left(\dfrac{\text{RelR}}{3.7} + \dfrac{2.51A}{\text{Re}}\right)$, $C = -2\log_{10}\left(\dfrac{\text{RelR}}{3.7} + \dfrac{2.51B}{\text{Re}}\right)$
		5. Zigrang and Sylvester equation $$f = \left[-2\log_{10}\left\{\dfrac{\text{RelR}}{3.77} - \dfrac{5.02}{\text{Re}} \times \log_{10}\left\{\dfrac{\text{RelR}}{3.77} - \dfrac{5.02}{\text{Re}}\log_{10}\left(\dfrac{\text{RelR}}{3.77} + \dfrac{13}{\text{Re}}\right)\right\}\right\}\right]^{-2}$$
		6. Swamee and Jain equation $$f = \left[\dfrac{0.25}{\left\{\log_{10}\left(\dfrac{\text{RelR}}{3.7} + \dfrac{5.74}{\text{Re}^{0.9}}\right)\right\}^2}\right]$$
		7. Altshul-Tsal equation $$f' = 0.11 \times \left(\text{RelR} + \dfrac{68}{\text{Re}}\right)^{0.25}$$ if $f' < 0.018$ then $f = 0.85f' + 0.0028$; otherwise $f = f'$

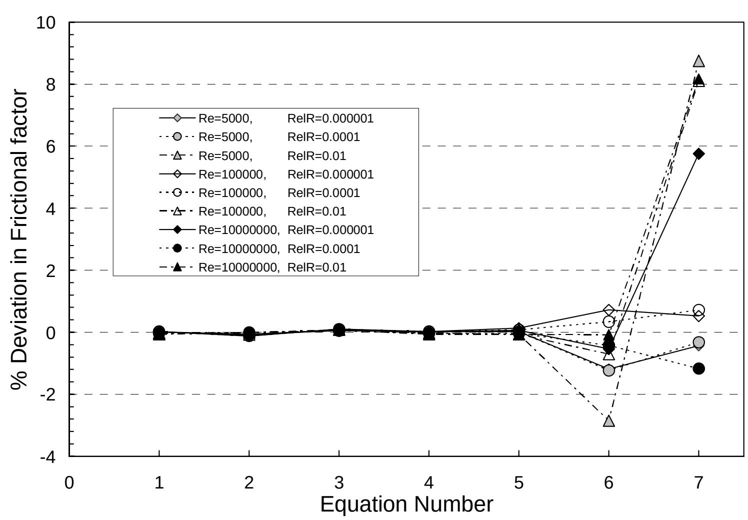

Figure 1: Comparison of the values of fractional factor calculated using the seven forms of Colebrook equation. The numbering of equation is same as given in Table 1.

An activeX component is a server application that exposes its functionality through an interface consisting of properties, methods and events (Petroutsos 1998). Programmers may access the module within their projects in any language that supports Object Link Embedding (OLE) in the Windows environment. This approach also avoids name conflicting among various variables as the object variables are identified together with an object name.

The "MyActiveXLib.dll" must be registered with the REGSVR32 utility in the Windows environment. First copy the file "MyActiveXLib.dll" in a folder (directory) and locate the REGSVR32 file your computer. It is mostly in the folder C:\WINDOWS\SYSTEM32. To register the DLL, open a command prompt window (a DOS window), switch to the folder where the DLL resides, and issue the following commend:

```
C:\WINDOWS\SYSTEM32\REGSVR32 MyActiveXLib.dll
```

There are several options one can use with the REGSVR32 utility. The /u option will uninstall a previously registered DLL. To uninstall the file "MyActiveXLib.dll", use the command:

```
C:\WINDOWS\SYSTEM32\REGSVR32 /u
        MyActiveXLib.dll
```

Once a DLL is registered, it may be accessed in a computer program in any language that supports Object Link Embedding (OLE) in the Windows environment.

The *MoodyChart* has three write properties: *EquationNumber*, *ReynoldNumber* and *RelRoughness*, which server as input parameters (i.e., user can change their values). Similarly, it has one read only property: *FrictionalFactor* to get the calculated value of fractional factor for a given set of input data.

Using *MoodyChart* in MS-Excel

A function, *FrictionalFactor* is written here in VBA to use MoodyChart is a Workbook in MS-Excel. The storing of a MS-Excel macro in different locations is presented earlier (Verma 2003). Here we will write the function, *FrictionalFactor* in a currently opened Workbook.

1. Choose Tools|Macro|Visual Basic Editor from the menu bar of your MS-Excel.
2. In the menu bar of the Visual Basic editor select Tool|References. In the reference window press the browse button to locate the file MyPrograms.dll in the folder it was copied earlier. The reference will show up as ''MyActiveXLib''. Check OK to close this window. The library MyActiveXLib contains the activeX component, *MoodyChart*.

Type the following lines is a module in the Visual Basic editor

```
Dim MdyChart As New MoodyChart
Function FrictionalFactor(EqNo As _
       Integer, Re As Double, RelR As _
       Double) As Double
       MdyChart.EquationNumber = EqNo
       MdyChart.ReynoldNumber = Re
       MdyChart.RelRoughness = RelR
       FrictionalFactor = _
       MdyChart.FrictionFactor
End Function
```

Now the function *FrictionalFactor* can be used on a Worksheet in the Workbook.

Figure 1 shows a comparative study of the three implicit (1-3) and four explicit (4-7) forms of Colebrook equation. First the values of frictional factor for Re= 5000, 10^5 and 10^7 and RelR=10^{-2}, 10^{-4} and 10^{-6} are calculated on a worksheet in workbook of MS-Excel. All the implicit forms provide similar values of frictional factor; therefore, the average values of frictional factor from implicit equations for each set of Re and RelR are used to calculate the percentage deviation in the values of frictional factor from the explicit forms.

It can be observed in Figure 1 that the explicit equations 4 and 5 provide the values of frictional factor within ±0.2% deviation from the values of implicit forms. The deviation in the values of frictional factor for the Swamee and Jain equation is between -3 to 1%. Similarly, the deviation for Altshul-Tsal equation is between -1 to 9%. Thus the equations of Serghide equation and Zigrang and Sylvester equation are good for the calculation of frictional factor during the fluid flow in pipelines and pipeline networks.

CONCLUSIONS

The ActiveX component, *MoodyChart* works well to calculate the frictional factor for fluid flow in pipelines and pipeline networks using all the implicit and explicit forms of Colebrook equations. The explicit equations of Serghide, and Zigrang and Sylvester are quite accurate for the numerical simulation of fluid flow in pipelines. The function, *FrictionalFactor* is an efficient approach to calculate frictional factor in a MS-Excel worksheet.

We are working to include these ActiveX components in a program to simulate the steam flow in a geothermal pipeline network. The ActiveX component library MyActiveXLib is available for scientific use with free of charge from the author. Presently, the library contains the following ActiveX components:

SteamTables95:	Thermodynamic properties of water as a function of T and P using the IAPWS-95 formulation
QrtzGeotherm:	Geothermal reservoir temperature and vapor fraction calculation from quartz geothermometry
MoodyChart:	The present ActiveX
OrificeMeter:	Calculation of Steam flow in a geothermal pipeline with a differential head orifice flow meter

REFERENCES

Brown, G. O., (2002), "The history of the Darcy-Weisbach equation for pipe flow resistance," In Environmental and water resources history, Proceedings and invited papers for ASCE 150th Anniversary (1852-2002), Fredrich, A., and Rogers, J., (eds.), ASCE, Reston, VA, 34-43.

Colebrook, C.F., (1939), "Turbulent flow in pipes with particular reference to the transition region between the smooth and rough pipe laws," *Proceedings Institution Civil Engineers*, **12,** 393-422.

Colebrook, C.F., and White, C. M., (1937), "Experiments with fluid-friction in roughened pipes," *Proceedings Royal Society, London*, **161**, 367-381.

Lester, T., (2002), "Solving the Colebrook equation for friction factors," http://www.cheresources.com

Moody, L. F., (1944), "Fraction factors for pipe flow," *ASSME Transactions*, **66**, 671-684.

Petroutsos, E., (1998), "Mastering Visual Basic 6", BPB Publications, New Delhi, India, 1285p.

Reynolds, O., (1883) "An experimental investigation of the circumstances which determine whether the motion of water shall be direct or sinuous and of the law of resistance in parallel channel", *Philosophical Transactions of the Royal Society*, **174**, 935-982.

Serghides, T. K., (1984), Estimate friction factor accurately. *Chemical Engineering*, **91**, 63-64.

Swamee, P. K., and Jain, A. K., (1976), "Explicit equations for pipe-flow problems," *Journal of Hydraulics*, Division, ASCE, **102**, 657-664.

Tsal, R. J., (1989), "Altshul-Tsal friction factor equation", *Heating, Piping and Air Conditioning*. (august).

Verma, M. P., (2003), "Steam Tables for pure water as an ActiveX component in Visual Basic 6.0", *Computer & Geosciences*, **29**, 1155-1163.

Zigrang, D. J., and Sylvester, N. D. (1985), "A Review of Explicit Friction Factor Equations", *Transactions of ASME, Journal of Energy Resources Technology*, **107**, 280-283.