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A Computer Program for Pipe Friction Factor Calculation

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ABSTRACT

The iterative nature of the Colebrook pipe friction factor equation can be overcome by using the Visual Basic for Applications (VBA) solver options provided in Microsoft Excel ™. A Friction Factor Calculator that spans the entire fluid flow regime is presented together with the program guide to develop one. The results are validated by comparison to results from Moody Friction factor Chart. A solution method for the explicit turbulent equation of Swamee-Jain through the use of Microsoft Excel Functions is also presented.

Keywords: *friction factor, fluid friction factor, Colebrook friction factor, Colebrook-White friction factor, Swamee-Jain friction factor, fluid mechanics programs, Microsoft Excel engineering programs*

1. REQUIRED EQUATIONS

For Laminar Flow, (*Re≤2100*): friction factor, *f*, is obtained from:

$$f = \frac{64}{R_e} \qquad (1)$$

For Turbulent Flow, (*Re>2100*): friction factor, *f*, is obtained by the Colebrook [1] equation (2). The Colebrook equation (sometimes referred to as the Colebrook-White equation) is the basis of the ever so familiar Moody Plots [2], available in most Fluid Mechanics texts.

$$\frac{1}{f^{\frac{1}{2}}} = -2Log\left\{\frac{\left(\varepsilon/D\right)}{3.7} + \frac{2.51}{\left(\sqrt{f}\right)R_e}\right\} \qquad (2)$$

2. EXAMPLES

The examples shown in figures (1) and (2) are the Microsoft Excel interface screens

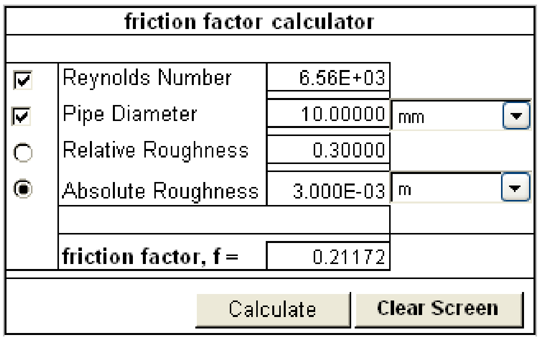

Figure 1. Friction Factor Calculator: Given, Re = 6560; D =10 mm; ε = 0.003 m

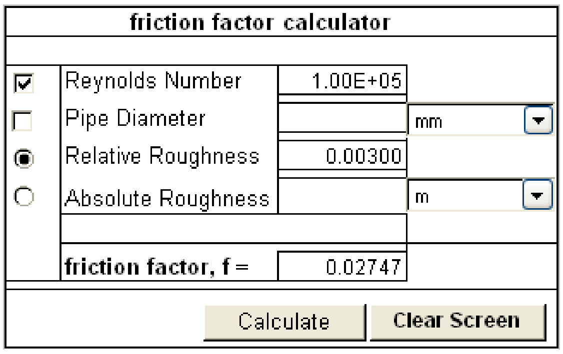

Figure 2. Friction Factor Calculator: Given, Re =100000; (ε/D) = 0.003

3. ALTERNATE METHOD OF SOLUTION: USING MICROSOFT EXCEL ™ FUNCTION CATEGORY

A Microsoft Excel ™ Functions option available through the click-down options, Insert-Function category can be used to develop a function database of mouse click, friction factor calculator. The Swamee-Jain [3] friction factor equation has been developed into such a function. The results are comparable from same inputs of Reynolds Number and Pipe Relative Roughness. The method relies on the mathematical relation, *function* (Reynolds Number, Roughness), i.e. $f\ [R_e, (\varepsilon/D)]$.

3.1 The Swamee-Jain Equation

The Swamee-Jain [3] relationship, equation (3) applies for turbulent flow within an extended Reynolds number range:

Range of application: $10^{-6} \le (\varepsilon/D) \le 2 \times 10^{-2}$

$3 \times 10^{3} \le R_e \le 3 \times 10^{8}$

$$f = 0.25\left[Log\left\{\frac{\left(\varepsilon/D\right)}{3.7} + \frac{5.74}{R_e^{0.9}}\right\}\right]^{-2} \quad (3)$$

Swamee-Jain	
FriCalcSwameeJain(Reys,Rough)	
solverSolve	**solution**
	1.00E+05
	0.003
	0.027705

Figure 3. Microsoft Excel Function result for the Swamee-Jain [3] Equations

4. METHOD OF SOLUTION AND SCREEN FORMATTING

Microsoft Excel VBA icons as button types are pasted directly on the worksheets to obtain the output interface Microsoft Excel screens shown in Fig. (1) and Fig. (2). The Fig.(4) shows icon button type identifiers (or icon i.d.) which is needed for the program formulae icon values of the check box, option and combo buttons. The outputs obtainable for different piping parameter inputs are displayed using the VBA Worksheet subroutine macros shown in the program routines in the Appendix.

buttontype	i.d	solverSolve	solution
chkReynolds	TRUE	sngRecipfric	2.173294
chkDiameter	TRUE	Relative Roughness2	0.30000
optRoughness	1	sngFricfunction	3.81E-06
optAbsolute	1	sngFriction=**f**	0.21172
cboDiameter	2		
cboAbsolute	2		

Figure 4. Non-Display link showing button i.d. and Microsoft Excel Cells with Built in Formula

5. WRITING THE COLEBROOK, AND SWAMEE-JAIN FUNCTIONS PROGRAMS

5.1 Solution to the Colebrook Equation

Two interpolation search solution methods – the Newton method and the Conjugate Gradient method are provided to handle non-linear type problems in Microsoft Excel ™. The steps involved in finding a solution are as follows:

Rewrite the equation (2) in the solution form required in the Microsoft Excel cells as given by equation (4)

$$\frac{1}{f^{\frac{1}{2}}} + 2Log\left\{\frac{\left(\varepsilon/D\right)}{3.7} + \frac{2.51}{\left(\sqrt{f}\right)R_e}\right\} = 0 \quad (4)$$

Using the Solver Add-in option dialog box under the Tools menu, together with settings for the degree of precision desired and the level of convergence (i.e. the decimal floating points), set the calculation constraints as follows:

Set Target Cell:

Equal To:

Subject to: Guess value:

The Goal Seek option is also useful in changing certain cells to meet with set constraints, with care being exercised to avoid circular reference – repeated recalculation of particular cell values as input and output.

5.2 Function Solution for the Swamee-Jain Equation

The VBA Module Function code procedure, for the Swamee-Jain Equation (3) is of the form:

```
Function FriCalcSwameeJain (Reynolds, Rough)
    K=(Rough/3.7)
    M=5.74*((1/Reynolds)^0.9)
    N=(K+M)'returns the Swamee-Jain value in the
        bracket'
    FriCalcSwameeJain=(0.25*(Log(N))^(-2))
End Function
```

The program indicates that a FUNCTION procedure has a return value. This is obtained by referencing the function dependent cell. In this case the functions are dependent on Reynolds Number and Relative Roughness.

Note that the Swamee-Jain equation has been suggested by Miller [4], to be used as an initial estimate for solution to the Colebrook-White equation, observing that a single iteration will produce a result within 1% of the Colebrook-White formula. Fox [5] gives an explicit relation developed by Moody for the turbulent region, given by the equation (5):

$$f = 0.001375\left\{1 + \left[20000\left(\frac{\varepsilon}{D}\right) + \frac{10^6}{R_e}\right]^{1/3}\right\} \quad (5)$$

Fox [5] observes that the equation (5) agrees to within 5% of the Colebrook-White formula, and suggests using the equation (5) as an initial value in the iterative solution of the Colebrook-White formula to avoid the inaccuracies that might arise if used alone. The Miller [4] suggestion is applied in the solution method presented in this paper.

6. VALIDATION: COMPARISON OF THE PROGRAM OUTPUT WITH RESULTS FROM MOODY CHART

The program was tested for validity with different input values in comparison with the industry accepted Moody Plots. An example of such a validity check is shown with the following values:

Given: Reynolds Number = 546000; and Relative Roughness, (ε/D) = 0.00045

Solution from Moody Diagram Reads: friction factor, *f* = 0.0175

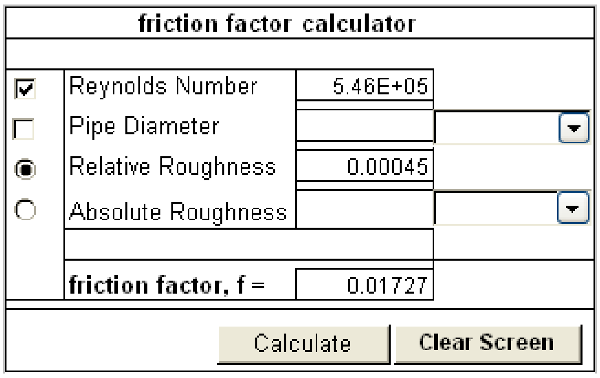

Figure 5. Friction Factor Calculator: Given, Re=546000; (ε/D) = 0.00045

Swamee-Jain	
FriCalc3(Reys,Rough)	
solverSolve	**solution**
	5.46E+05
	0.00045
	0.01737

Fig. (6) Microsoft Excel Functions for the Swamee-Jain [4] Equation

7. CLOSING

It will be observed that the friction factor values obtained in Fig. (2) and Fig. (3), for the given values of Reynolds Number, R_e = 100000, and Relative Roughness (ε/D) =0.003 are comparable. Also, the comparison with the Moody Plot show good agreement with the Example of fig. (5) and (6). Comparisons were also made to several worked examples in the Fluids Mechanics Text [6] to further confirm validity. All results were satisfactory.

NOMENCLATURE

D	Pipe diameter, mm
f	Friction Factor
Re	Reynolds Number
ε	Absolute Roughness, m

REFERENCES

[1] C. F. Colebrook, "Turbulent flow in Pipes with Particular Reference to the Transition between Smooth and Rough Pipe Laws", *Journal of Institution of Civil Engineers, London*, 11, 1939, pp. 133-156

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[3] P. K. Swamee, A. K. Jain, "Explicit Equations for Pipe Flow Problems" *Journal of Hydraulic Division, Proc. ASCE*, pp. 657-664., May, 1976

[4] R. W. Miller, Flow Measurement Engineering Handbook, McGraw-Hill,1985,

[5] J. A. Fox, "The Surge Analysis of Pumped Pipe Networks ", *Proceedings of Imech.E*, Paper. No. C158/76, pp.145-151, 1976

[6] J.B. Evett, *2500 Solved Problems in Fluid Mechanics and Hydraulics*, McGraw-Hill, 1989

[7] AlignaGraphics Co., Friction Factor Program, *User Manual*, 1998

APPENDIX

Microsoft Excel Visual Basic for Applications (VBA) Friction Factor Program for Screens: figure 1, 2, and 5

```
Option Explicit
'Declare variables
Dim Reynolds As Variant, Roughness As Single,
vntRetVal As Variant
Dim sngFricfunction As Single, sngRecipfric As Single,
sngFriction As Single
Const conBtns = vbOKOnly + vbExclamation +
vbDefaultButton1 + vbApplicationModal
Const conMsg As String = "the reynolds number must not
exceed 1e+08."
' Perform calculations friction factors
Sub FriCalc1()
'Assign values to variables
Reynolds = ActiveSheet.Range("E4")
Roughness = ActiveSheet.Range("E8")
sngRecipfric = ActiveSheet.Range("K4")
   If ActiveSheet.Range("I4").Value = True And
ActiveSheet.Range("I8").Value = 2 Then
      If ActiveSheet.Range("E4") <= 2100 Then
                  sngFriction = (64 / Reynolds)
      ElseIf 2100 < ActiveSheet.Range("E4") And
ActiveSheet.Range("E4") < 100000000# Then
                  sngFriction = ActiveSheet.Range("K10")
```

```
            Range("K4").Select
            ActiveCell.FormulaR1C1 = "1"
            Range("K8").GoalSeek Goal:=0,
ChangingCell:=Range("K4")
            sngFricfunction =
ActiveSheet.Range("K8")


    End If
  End If
  If ActiveSheet.Range("I4").Value = True And
ActiveSheet.Range("I6").Value = True And
ActiveSheet.Range("I8").Value = 1 Then
    If ActiveSheet.Range("E4") <= 2100 Then
            sngFriction = (64 / Reynolds)
    ElseIf 2100 < ActiveSheet.Range("E4") And
ActiveSheet.Range("E4") < 100000000# Then
            ActiveSheet.Range("E8") =
ActiveSheet.Range("K6")
            sngFriction = ActiveSheet.Range("K10")
            Range("K4").Select
            ActiveCell.FormulaR1C1 = "1"
            Range("K8").GoalSeek Goal:=0,
ChangingCell:=Range("K4")
            sngFricfunction =
ActiveSheet.Range("K8")
    End If
  End If
  ActiveSheet.Range("E13") =
ActiveSheet.Range("K10")
    Select Case Reynolds
    Case Is <= 100000000#
      Reynolds = ActiveSheet.Range("E4")
    Case Else
      vntRetVal = MsgBox(conMsg, conBtns, "FriCalc-
Reynolds Error")
    End Select
      sngFriction = ActiveSheet.Range("K10")
End Sub
'
' Clear Macro
' Clear screen for new input
'
' Keyboard Shortcut: Ctrl+l
'
Sub Clear()
ActiveSheet.Range("E4").ClearContents
ActiveSheet.Range("E6").ClearContents
ActiveSheet.Range("E8").ClearContents
ActiveSheet.Range("E10").ClearContents
ActiveSheet.Range("E13").ClearContents
End Sub
```