Proximity Effect Functions

The functions below were used to generate Figs. 12.35, 12.36, and 12.38. The functions are written in Microsoft Visual Basic, and were called by an Excel spreadsheet. The functions can be easily modified for other programming languages.

Functions Gone and Gtwo implement Eq. (12.73). Function FR(phi, M) is identical to Eq. (12.84). Figure 12.32 is a plot of FR for various values of M and φ. Figure 12.33 is a plot of FR(phi, M)/phi.

Function Pj(Phi1, M, j, D) is a normalized version of Eq. (12.89), the power loss in harmonic *j*. Function FH(phi1, M, D) coincides with Eq. (12.90) and (12.91). The series is summed numerically.

The copper loss in a winding is evaluated as follows. First, the dc and fundamental components of the current waveform are evaluated using Eq. (12.86). Then the functions FH and FR are evaluated. Finally, the results are plugged into Eq. (12.92).

```
Option Explicit

Function cosh(x)
     cosh = 0.5 * (Exp(x) + Exp(-x))
End Function

Function sinh(x)
     sinh = 0.5 * (Exp(x) - Exp(-x))
End Function

Function Gone(phi)
     Gone = (sinh(2 * phi) + Sin(2 * phi)) / (cosh(2 * phi) -
          Cos(2 * phi))
End Function

Function Gtwo(phi)
     Gtwo = (sinh(phi) * Cos(phi) + cosh(phi) * Sin(phi)) /
          (cosh(2 * phi) - Cos(2 * phi))
End Function

Function FR(phi, M)
     FR = phi * (Gone(phi) + 2 / 3 * (M * M - 1) * (Gone(phi) - 2
          * Gtwo(phi)))
End Function

Function pi()
     pi = 3.14159265
End Function

Function Pj(phi1, M, j, D)
     Dim sj, Ga
     sj = Sqr(j)
     Ga = Gone(phi1 * sj)
     Pj = (1 / (j * sj)) * (Sin(j * pi() * D)) ^ 2 * (Ga + 2 / 3 *
          (M * M - 1) * (Ga - 2 * Gtwo(phi1 * sj)))
End Function
```

```
Function FH(phi1, M, D)
     Dim P1, Ptot, Pke, Pko, Peps, j, Pk
     P1 = Pj(phi1, M, 1, D)
     Pko = P1
     Pke = Pj(phi1, M, 2, D)
     Pk = Pko + Pke
     Ptot = P1
     Peps = P1 * 0.0002
     j = 3
     Do
          Pko = Pj(phi1, M, j, D)
          j = j + 1
          Pke = Pj(phi1, M, j, D)
          Pk = Pke + Pko
          Ptot = Ptot + Pk
          j = j + 1
     Loop Until Pk < Peps
     FH = Ptot / P1
End Function
```