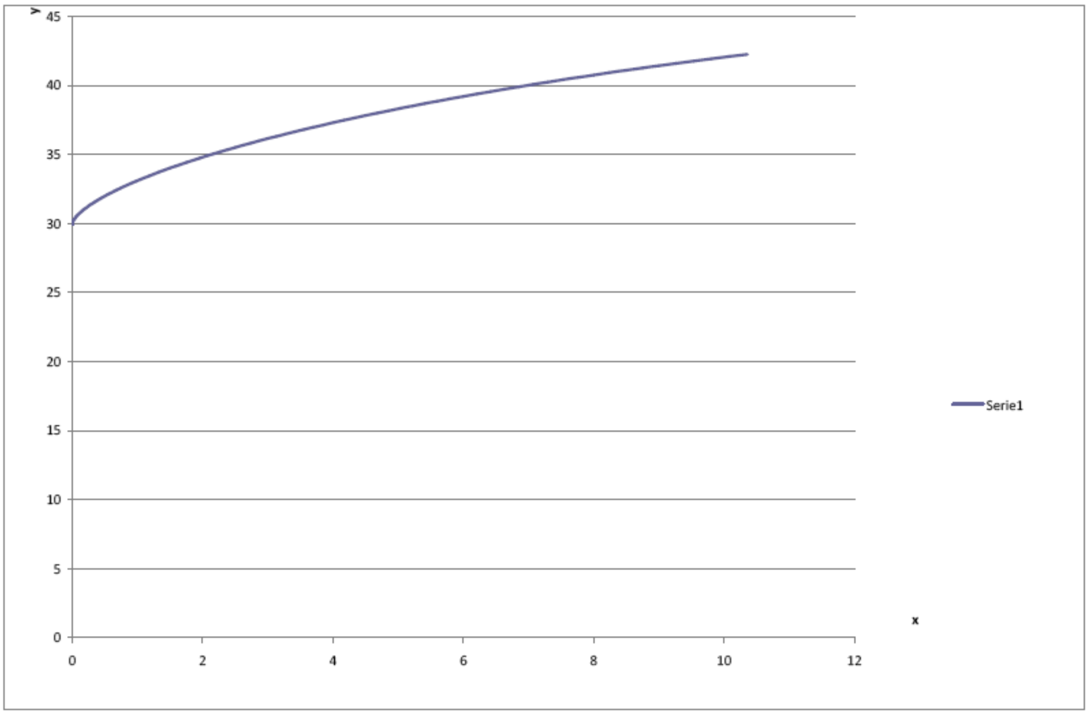
# ANEXO I: PROGRAMACIÓN PARA OBTENER LA TRAYECTORIA DEL DENTADO

```
Sub epicicloide()
Columns("D:K").Select
   Selection.ClearContents
   Range("I1").Select
Aini = Cells(13, 2): Afin = Cells(14, 2): Inc = Cells(7, 2)
r1 = Cells(1, 2): r2 = Cells(2, 2): Pi = 4 * Atn(1)
f = 0
For c = Aini To Afin Step 0.01
x = (r1 + r2) * Sin(c) - r2 * Sin(c * (r2 + r1) / r2)
y = (r1 + r2) * Cos(c) - r2 * Cos(c * (r2 + r1) / r2)
r = Sqr(x ^ 2 + y ^ 2)
zz = (125 - r) * Inc
'MsgBox (Str(zz) + Str(r) + Str(c))
f = f + 1
Cells(f, 4) = x: Cells(f, 5) = y: Cells(f, 6) = 0: Cells(f, 7) = r
Next c

'evolvente
Afin = Cells(17, 2): rb = Cells(16, 2): f = 0
For c = 0 To Afin Step 0.01
x = rb * Cos(c) + c * rb * Sin(c)
y = rb * Sin(c) - c * rb * Cos(c)
f = f + 1
Cells(f, 8) = x: Cells(f, 9) = y: Cells(f, 10) = 0
Next c
End Sub
```

Una vez introducidas las ecuaciones en el programa, mediante diferentes valores de ángulo (c), se obtienen los diferentes valores x, y de los puntos de la trayectoria epicicloide, como puede verse a continuación. Se muestran algunos de los primeros valores de la compilación del programa:

| | | | | | | |
|---|---|---|---|---|---|---|
| r1= | 30 | | 0 | 30 | 0 | 30 |
| r2= | 500 | | 1,0918E-05 | 30,00159 | 0 | 30,00159 |
| rini= | 30 | | 8,734E-05 | 30,0063593 | 0 | 30,0063593 |
| rfin= | 100 | | 0,00029476 | 30,0143066 | 0 | 30,0143066 |
| módulo= | 5 | | 0,00069863 | 30,0254292 | 0 | 30,0254292 |
| Dientes= | 35 | | 0,00136439 | 30,0397236 | 0 | 30,0397237 |
| Inclinaciòn= | 0,24 | | 0,00235739 | 30,0571853 | 0 | 30,0571854 |
| | | | 0,00374293 | 30,0778087 | 0 | 30,077809 |
| | | | 0,00558622 | 30,1015873 | 0 | 30,1015878 |
| | | | 0,00795238 | 30,1285134 | 0 | 30,1285144 |
| | | | 0,01090641 | 30,1585784 | 0 | 30,1585804 |
| | | | 0,0145132 | 30,1917728 | 0 | 30,1917763 |
| αini= | 0 | 0 | 0,01883747 | 30,228086 | 0 | 30,2280919 |
| αfin= | 3,092928428 | 177,211745 | 0,02394383 | 30,2675064 | 0 | 30,2675159 |
| rp= | 87,5 | | 0,02989669 | 30,3100214 | 0 | 30,3100361 |
| rb= | 82,22310432 | | 0,03676029 | 30,3556173 | 0 | 30,3556396 |
| φfin= | 0,363970234 | | 0,04459869 | 30,4042797 | 0 | 30,4043124 |
| | | | 0,05347571 | 30,4559929 | 0 | 30,4560398 |
| | | | 0,06345499 | 30,5107403 | 0 | 30,5108063 |
| | | | 0,07459991 | 30,5685044 | 0 | 30,5685954 |
| | | | 0,0869736 | 30,6292667 | 0 | 30,6293902 |
| | | | 0,10063893 | 30,6930076 | 0 | 30,6931726 |
| | | | 0,11565851 | 30,7597066 | 0 | 30,7599241 |
| | | | 0,13209465 | 30,8293424 | 0 | 30,8296253 |
| | | | 0,15000936 | 30,9018923 | 0 | 30,9022564 |
| | | | 0,16946433 | 30,9773331 | 0 | 30,9777966 |
| | | | 0,19052092 | 31,0556403 | 0 | 31,0562247 |
| | | | 0,21324016 | 31,1367887 | 0 | 31,1375188 |
| | | | 0,23768271 | 31,2207519 | 0 | 31,2216566 |
| | | | 0,26390888 | 31,3075027 | 0 | 31,308615 |
| | | | 0,29197857 | 31,3970131 | 0 | 31,3983707 |
| | | | 0,32195132 | 31,4892538 | 0 | 31,4908996 |
| | | | 0,35388624 | 31,5841948 | 0 | 31,5861773 |
| | | | 0,38784202 | 31,6818053 | 0 | 31,6841791 |
| | | | 0,42387693 | 31,7820532 | 0 | 31,7848797 |
| | | | 0,46204878 | 31,8849058 | 0 | 31,8882534 |
| | | | 0,50241493 | 31,9903294 | 0 | 31,9942744 |
| | | | 0,54503226 | 32,0982893 | 0 | 32,1029163 |
| | | | 0,58995719 | 32,2087501 | 0 | 32,2141527 |
| | | | 0,63724561 | 32,3216753 | 0 | 32,3279566 |
| | | | 0,68695292 | 32,4370277 | 0 | 32,4443011 |
| | | | 0,73913401 | 32,5547691 | 0 | 32,5631588 |
| | | | 0,79384321 | 32,6748605 | 0 | 32,6845024 |
| | | | 0,85113433 | 32,7972619 | 0 | 32,8083041 |
| | | | 0,9110606 | 32,9219325 | 0 | 32,9345362 |
| | | | 0,9736747 | 33,0488309 | 0 | 33,0631708 |
| | | | 1,03902872 | 33,1779144 | 0 | 33,19418 |
| | | | 1,10717416 | 33,3091399 | 0 | 33,3275357 |
| | | | 1,17816192 | 33,4424632 | 0 | 33,4632098 |
| | | | 1,25204227 | 33,5778393 | 0 | 33,6011741 |




Esta gráfica muestra los valores que van tomando x e y, como puede observarse obtenemos la trayectoria epicicloide deseada para el dentado del engranaje hipoide.

# ANEXO II: TABLAS PARA OBTENER LOS PARÁMETROS DE DISEÑO DE LOS ENGRANAJES HIPOIDES:

Table 1 Formulas for Computing Blank and Tooth Dimensions

| Item | Item no. | Member | Formula |
|---|---|---|---|
| Pitch diameter | 1 | Pinion<br>Gear | $d = \frac{n}{P_d}$<br>$D = \frac{N}{P_d}$ |
| Pitch angle | 2 | Pinion<br>Gear | $\gamma = \tan^{-1} \frac{\sin \Sigma}{N/n + \cos \Sigma}$<br>$\Gamma = \Sigma - \gamma$ |
| Outer cone distance | 3 | Both | $A_o = \frac{0.50D}{\sin \Gamma}$ |
| Mean cone distance | 4 | Both | $A_m = A_o - 0.5F$ |
| Depth factor $k_1$ | 5 | Both | Table 2 |
| Mean working depth | 6 | Both | $h = \frac{k_1 A_m}{P_d A_o} \cos \psi$ |
| Clearance factor $k_2$ | 7 | Both | Table 3 |
| Clearance | 8 | Both | $c = k_2 h$ |
| Mean whole depth | 9 | Both | $h_m = h + c$ |
| Equivalent 90° ratio | 10 | Both | $m_{90} = \sqrt{\frac{N \cos \gamma}{n \cos \Gamma}}$ |
| Mean addendum factor $C_1$ | 11 | Both | Table 4 |
| Mean circular pitch | 12 | Both | $P_m = \frac{\pi A_m}{P_d A_o}$ |
| Mean addendum | 13 | Pinion<br>Gear | $a_P = h - a_G$<br>$a_G = C_1 h$ |
| Mean dedendum | 14 | Pinion<br>Gear | $b_P = h_m - a_P$<br>$b_G = h_m - a_G$ |
| Sum of dedendum angles | 15 | Both | $\Sigma\delta$ (see Table 7 ) |

**TABLE 1** Formulas for Computing Blank and Tooth Dimensions (*Continued*)

| Item | Item no. | Member | Formula |
|---|---|---|---|
| Dedendum angle | 16 | Pinion<br>Gear | $\delta_P$ (see **TABLE** 7 )<br>$\delta_G$ (see **TABLE** 7 ) |
| Face angle of blank | 17 | Pinion<br>Gear | $\gamma_o = \gamma + \delta_G$<br>$\Gamma_o = \Gamma + \delta_P$ |
| Root angle of blank | 18 | Pinion<br>Gear | $\gamma_R = \gamma - \delta_P$<br>$\Gamma_R = \Gamma - \delta_G$ |
| Outer addendum | 19 | Pinion<br>Gear | $a_{oP} = a_P + 0.5F \tan \delta_G$<br>$a_{oG} = a_G + 0.5F \tan \delta_P$ |
| Outer dedendum | 20 | Pinion<br>Gear | $b_{oP} = b_P + 0.5F \tan \delta_P$<br>$b_{oG} = b_G + 0.5F \tan \delta_G$ |
| Outer working depth | 21 | Both | $h_k = a_{oP} + a_{oG}$ |
| Outer whole depth | 22 | Both | $h_t = a_{oP} + b_{oP}$ |
| Outside diameter | 23 | Pinion<br>Gear | $d_o = d + 2a_{oP} \cos \gamma$<br>$D_o = D + 2a_{oG} \cos \Gamma$ |
| Pitch apex to crown | 24 | Pinion<br>Gear | $x_o = A_o \cos \gamma - a_{oP} \sin \gamma$<br>$X_o = A_o \cos \Gamma - a_{oG} \sin \Gamma$ |
| Mean diametral pitch | 25 | Both | $P_{dm} = P_d \dfrac{A_o}{A_m}$ |
| Mean pitch diameter | 26 | Pinion<br>Gear | $d_m = \dfrac{n}{P_{dm}}$<br>$D_m = \dfrac{N}{P_{dm}}$ |
| Thickness factor $K$ | 27 | Both | **TABLE** 6 |
| Mean normal circular thickness | 28 | Pinion<br>Gear | $t_n = P_m \cos \psi - T_n$<br>$T_n = \dfrac{P_m}{2 \cos \psi} - (a_P - a_G) \tan \phi + \dfrac{K \cos \psi}{P_{dm} \tan \phi}$ |

**TABLE 1** Formulas for Computing Blank and Tooth Dimensions (*Concluded*)

| Item | Item no. | Member | Formula |
|---|---|---|---|
| Outer normal backlash allowance | 29 | Both | $B$ (Table 5. ) |
| Mean normal chordal thickness | 30 | Pinion | $t_{nc} = t_n - \frac{t_n^3}{6d_m^2} - 0.5B\frac{A_m}{A_o}\sec\phi$ |
| | | Gear | $T_{nc} = T_n - \frac{T_n}{6D_m^2} - 0.5B\left(\frac{A_m}{A_o}\right)\sec\phi$ |
| Mean chordal addendum | 31 | Pinion | $a_{cP} = a_P + \frac{t_n^2\cos\gamma}{4d_m}$ |
| | | Gear | $a_{cG} = a_G + \frac{T_n^2\cos\Gamma}{4D_m}$ |

**TABLE 2** Depth Factor

| Type of gear | No. pinion teeth | Depth factor $k_1$ |
|---|---|---|
| Straight bevel | 12 and higher | 2.000 |
| Spiral bevel | 12 and higher | 2.000 |
| | 11 | 1.995 |
| | 10 | 1.975 |
| | 9 | 1.940 |
| | 8 | 1.895 |
| | 7 | 1.835 |
| | 6 | 1.765 |
| Zerol bevel | 13 and higher | 2.000 |
| Hypoid | 11 and higher | 4.000 |
| | 10 | 3.900 |
| | 9 | 3.8 |
| | 8 | 3.7 |
| | 7 | 3.6 |
| | 6 | 3.5 |

**TABLE 3** Clearance Factors

| Type of gear | Clearance factor $k_2$ |
|---|---|
| Straight bevel | 0.140 |
| Spiral bevel | 0.125 |
| Zerol bevel | 0.110 |
| Hypoid | 0.150 |

**TABLE 4** Mean Addendum Factor

| Type of gear | No. pinion teeth | Mean addendu factor $C_1$ |
|---|---|---|
| Straight bevel | 12 and higher | $C_1$† |
| Spiral bevel | 12 and higher | $C_1$† |
| | 11 | 0.490 |
| | 10 | 0.435 |
| | 9 | 0.380 |
| | 8 | 0.325 |
| | 7 | 0.270 |
| | 6 | 0.215 |
| Zerol bevel | 13 and higher | $C_1$† |
| Hypoid | 21 and higher | $C_1$† |
| | 9 to 20 | 0.170 |
| | 8 | 0.150 |
| | 7 | 0.130 |
| | 6 | 0.110 |

†Use $C_1 = 0.270 + 0.230/(m_{90})^2$.

**TABLE 5** Minimum Normal Backlash Allowance†

| Range of diametral pitch, teeth/in | Allowance, in (for AGMA quality number range) | |
|---|---|---|
| | 4 to 9 | 10 to 13 |
| 1.00–1.25 | 0.032 | 0.024 |
| 1.25–1.50 | 0.027 | 0.020 |
| 1.50–2.00 | 0.020 | 0.015 |
| 2.00–2.50 | 0.016 | 0.012 |
| 2.50–3.00 | 0.013 | 0.010 |
| 3.00–4.00 | 0.010 | 0.008 |
| 4.00–5.00 | 0.008 | 0.006 |
| 5.00–6.00 | 0.006 | 0.005 |
| 6.00–8.00 | 0.005 | 0.004 |
| 8.00–10.00 | 0.004 | 0.003 |
| 10.00–12.00 | 0.003 | 0.002 |
| 12.00–16.00 | 0.003 | 0.002 |
| 16.00–20.00 | 0.002 | 0.001 |
| 20.00–25.00 | 0.002 | 0.001 |

†Measured at outer cone in inches.

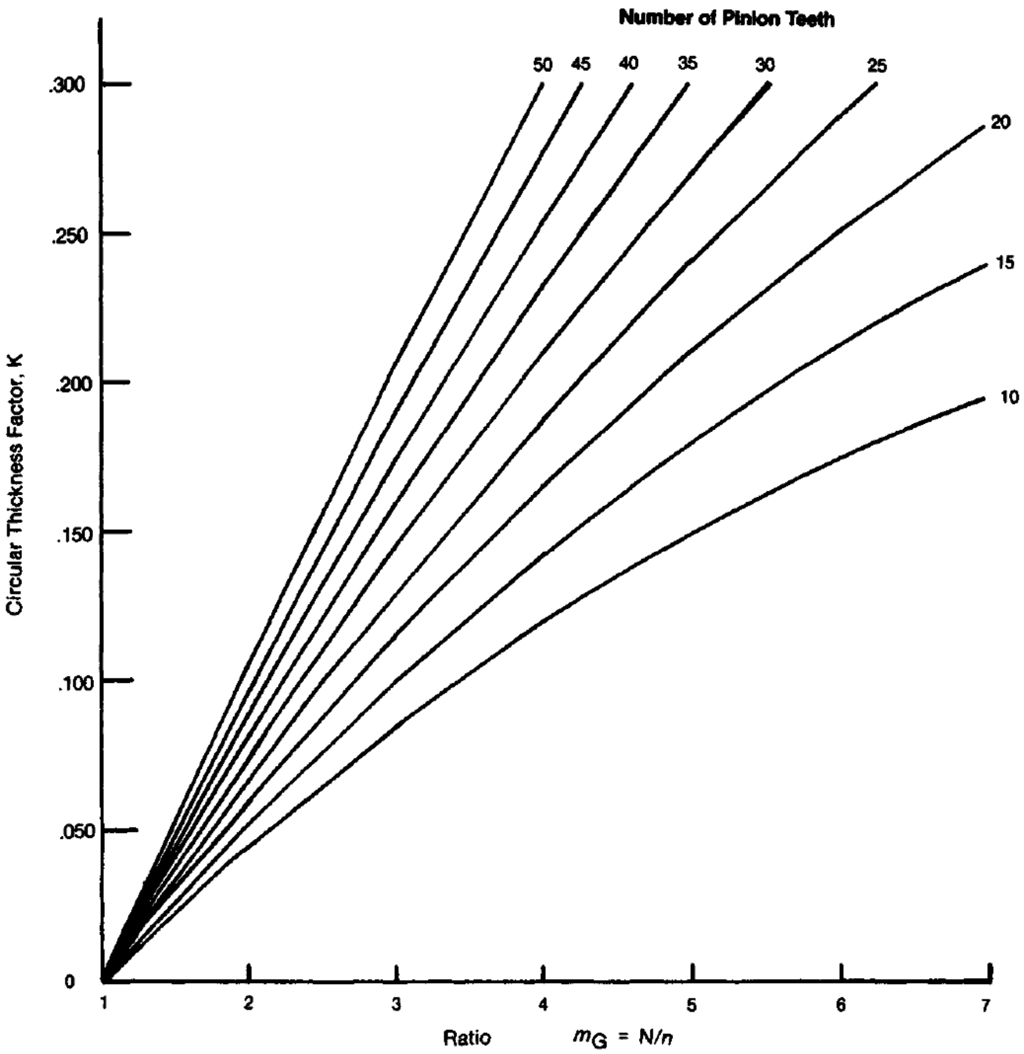



**TABLE 6** Circular thickness factor. These curves are plotted from the equation $K = -0.088 + 0.092m_G - 0.004m_G^2 + 0.0016\,(n - 30)\,(m_G - 1)$.

**TABLE 7** Formulas for Computing Dedendum Angles and Their Sum

| Type of taper | Formula |
| --- | --- |
| Standard | $\Sigma\delta = \tan^{-1}\frac{b_P}{A_m} + \tan^{-1}\frac{b_G}{A_m}$<br>$\delta_P = \tan^{-1}\frac{b_P}{A_m} \qquad \delta_G = \Sigma\delta - \delta_P$ |
| Duplex | $\Sigma\delta = \frac{90[1 - (A_m/r_c)\sin\psi]}{(P_d A_o \tan\phi \cos\psi)}$<br>$\delta_P = \frac{a_G}{h}\Sigma\delta \qquad \delta_G = \Sigma\delta - \delta_P$ |
| Tilted root line | Use $\Sigma\delta = \frac{90[1 - (A_m/r_c)\sin\psi]}{(P_d A_o \tan\phi \cos\psi)}$<br>or $= 1.3\tan^{-1}\frac{b_P}{A_m} + 1.3\tan^{-1}\frac{b_G}{A_m}$<br>whichever is smaller.<br>$\delta_P = \frac{a_G}{h} \qquad \delta_G = \Sigma\delta - \delta_P$ |
| Uniform depth | $\Sigma\delta = 0$<br>$\delta_P = \delta_G = 0$ |