Solution of the problem 10.9

Computation of the transient process while an iron core coil is switched on direct current source by method of graphical integration

ORIGIN := 1 Magnetization curve of steel 1512

$$BH1 := \begin{pmatrix} 0 & 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 & 1 & 1.1 \\ 0 & 0.13 & 0.25 & 0.35 & 0.5 & 0.65 & 0.8 & 0.95 & 1.15 & 1.5 & 2.0 & 3.0 \end{pmatrix}$$

$$BH2 := \begin{pmatrix} 1.15 & 1.2 & 1.25 & 1.3 & 1.35 & 1.4 & 1.45 & 1.5 & 1.55 & 1.6 & 1.7 & 1.76 \\ 3.7 & 4.65 & 6 & 7.2 & 9.2 & 12 & 15 & 23 & 33 & 49 & 90 & 120 \end{pmatrix}$$

$BH := augment(BH1, BH2)$ $\quad Bi := \left(BH^T\right)^{\langle 1 \rangle}$ $\quad Hi := \left(BH^T\right)^{\langle 2 \rangle}$

$J := 10 \quad R := 1 \quad l := 50 \quad w := 490 \quad S := 10^{-2}$

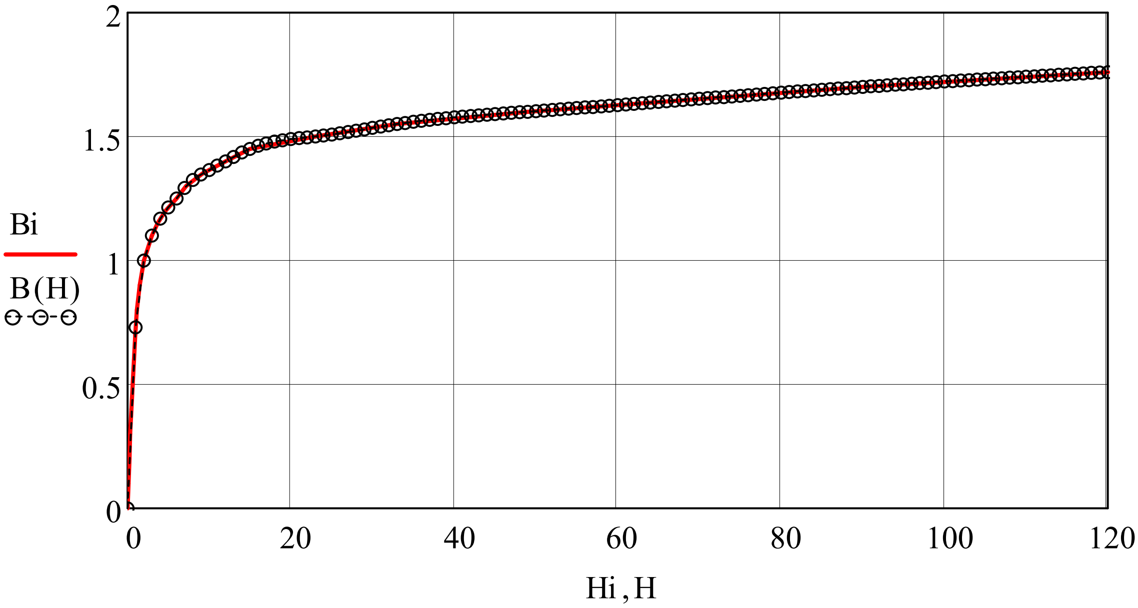
Spline-approximation of dependence B(H)

$vHB := lspline(Hi, Bi)$ $\quad fB(x) := interp(vHB, Hi, Bi, x)$ $\quad length(Bi) = 24$

$vBH := lspline(Bi, Hi)$ $\quad fH(x) := interp(vBH, Bi, Hi, x)$

$B(H) := fB(H)$ $\quad H := 0, 1 .. 120$

Verification of the approximation



Steady-state values of current, magnetic intensity and induction

Number of integration points

$Iu := J$ $\quad Hu := \dfrac{w \cdot Iu}{l}$ $\quad Bu := fB(Hu)$ $\quad m := 200$

$Iu = 10$ $\quad Hu = 98$ $\quad Bu = 1.717$ $\quad Bm := 0.995 \cdot Bu$ $\quad i := 1 .. m$

Integration step $\quad dB := \dfrac{Bm}{m}$ $\quad d\Psi := dB \cdot w \cdot S$

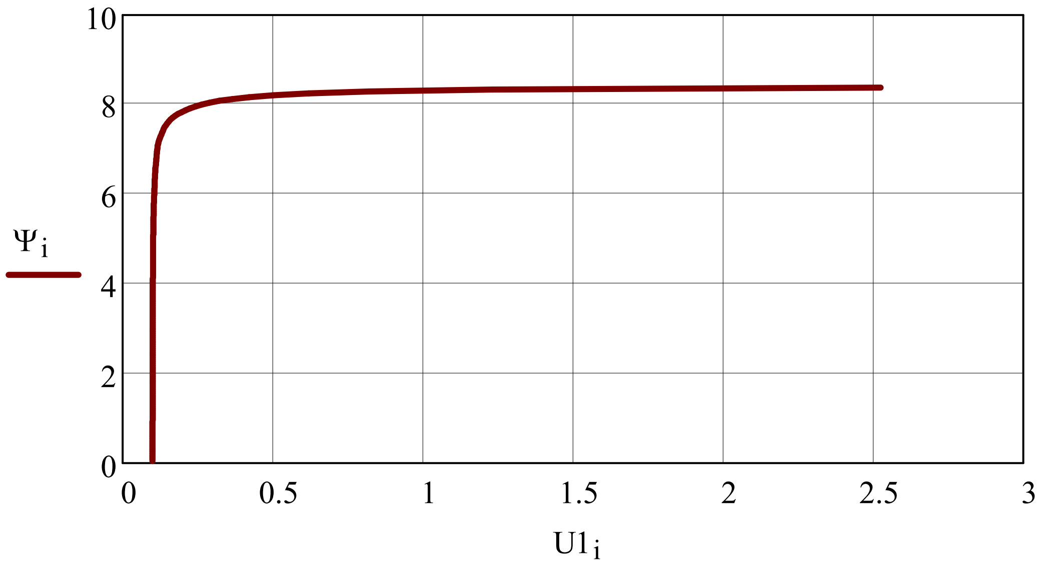
Verification

Function to integrate

$\Psi_i := i \cdot dB \cdot w \cdot S$

$I_i := \dfrac{1 \cdot fH(i \cdot dB)}{w}$

$U1_i := \dfrac{1}{(J - I_i) \cdot R}$

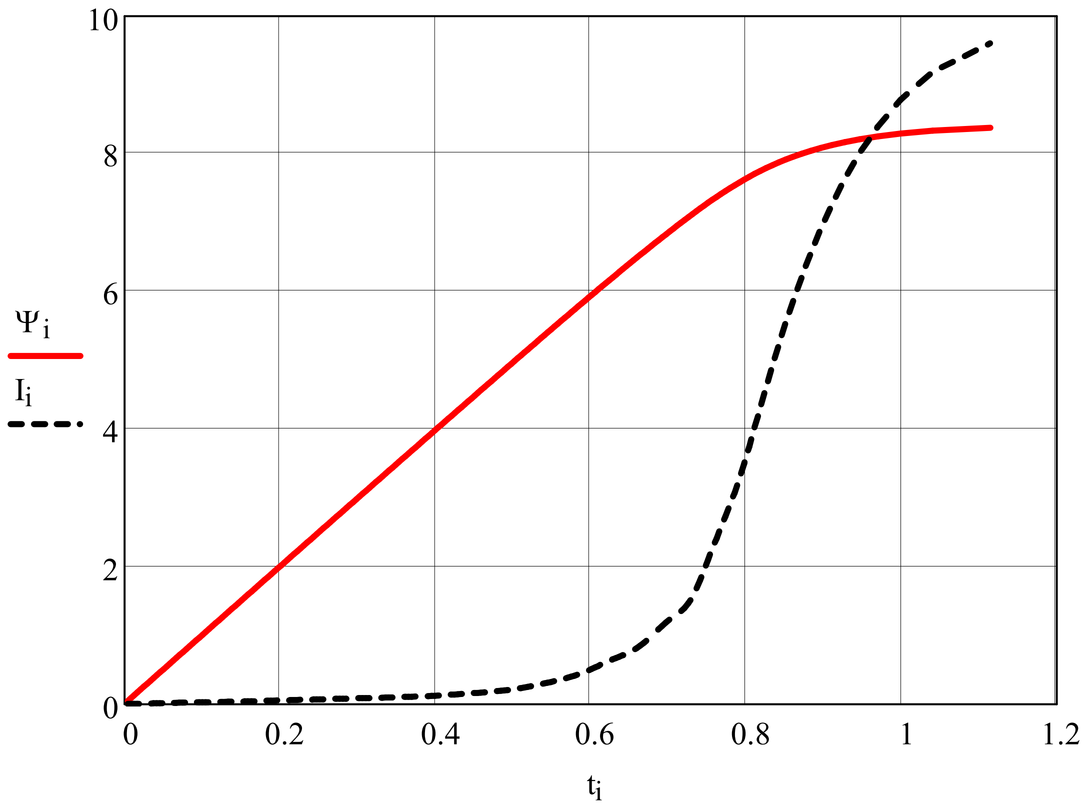


Dependences Ψ(t) and i(t) and their graphs

$k := 1 .. m$ $\quad t_k := k \cdot d\Psi$ $\quad s := cspline(t, U1)$

$g := 1, 2 .. m$

$t_i := T(i)$ $\quad T(g) := \int_0^{g \cdot d\Psi} interp(s, t, U1, x)\, dx$



Solution of the problem 10.10

Computation of the transient process while an iron core coil is switched on sinusoidal voltage

Magnetization curve

$ORIGIN := 1$

$BT1 := (0\ \ .1\ \ .2\ \ .3\ \ .4\ \ .5\ \ .6\ \ .7\ \ .8\ \ .9\ \ 1\ \ 1.1\ \ 1.15)$

$BT2 := (1.2\ \ 1.25\ \ 1.3\ \ 1.35\ \ 1.4\ \ 1.45\ \ 1.5\ \ 1.55\ \ 1.6\ \ 1.7\ \ 1.76)$

$HT1 := (0\ \ 18\ \ 25\ \ 35\ \ 50\ \ 65\ \ 80\ \ 95\ \ 115\ \ 150\ \ 200\ \ 300\ \ 370)$

$HT2 := (465\ \ 600\ \ 740\ \ 900\ \ 1200\ \ 1500\ \ 2200\ \ 3300\ \ 4900\ \ 9000\ \ 12000)$

$BT := augment(BT1, BT2)$ $\qquad HT := augment(HT1, HT2)$

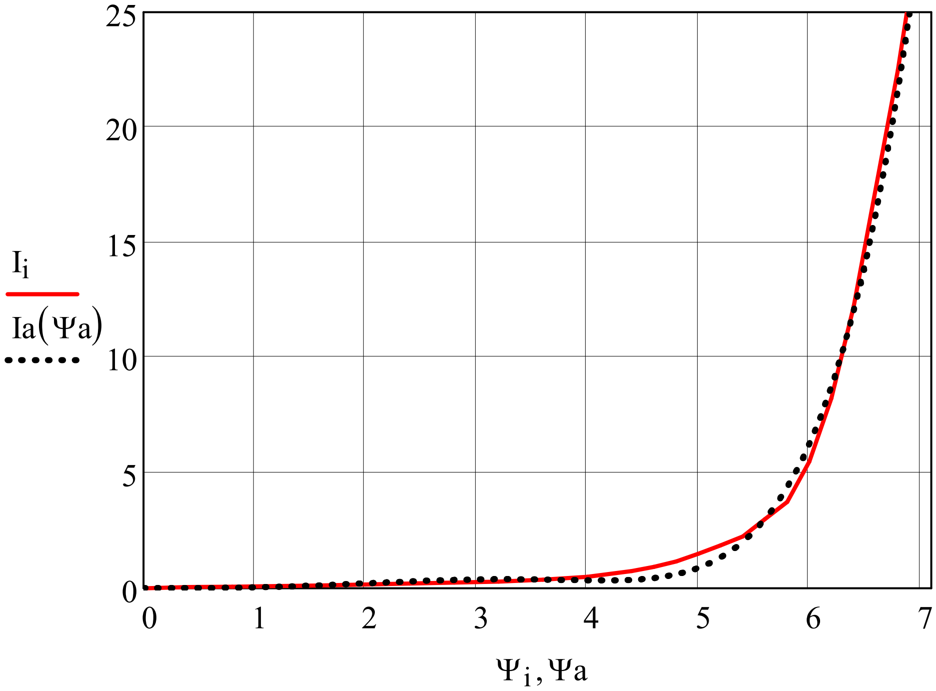
$H := HT^T \quad B := BT^T \quad U := 2000 \quad R := 2 \quad l := 0.5 \quad w := 200 \quad S := 2\cdot 10^{-2}$

$\Psi := B\cdot S\cdot w \qquad I := \frac{H\cdot l}{w}$ $\quad$ Approximation of dependence Ψ(I) $\quad m := length(B)$

$$Ik := \begin{bmatrix} \Psi_5 & (\Psi_5)^3 & (\Psi_5)^5 & (\Psi_5)^7 \\ \Psi_{10} & (\Psi_{10})^3 & (\Psi_{10})^5 & (\Psi_{10})^7 \\ \Psi_{18} & (\Psi_{18})^3 & (\Psi_{18})^5 & (\Psi_{18})^7 \\ \Psi_{24} & (\Psi_{24})^3 & (\Psi_{24})^5 & (\Psi_{24})^7 \end{bmatrix} \qquad \Psi k := \begin{pmatrix} I_5 \\ I_{10} \\ I_{18} \\ I_{24} \end{pmatrix} \qquad \Psi k = \begin{pmatrix} 0.125 \\ 0.375 \\ 3 \\ 30 \end{pmatrix}$$

$K := Ik^{-1}\cdot \Psi k$ $\qquad$ Verification

$Ia(\Psi a) := K_1\cdot\Psi a + K_2\cdot\Psi a^3 + K_3\cdot\Psi a^5 + K_4\cdot\Psi a^7 \qquad i := 0, 1 .. m \qquad \Psi_{24} = 7.04$



$p := 0$ Solution of the differential equation by Runge-Kutt method

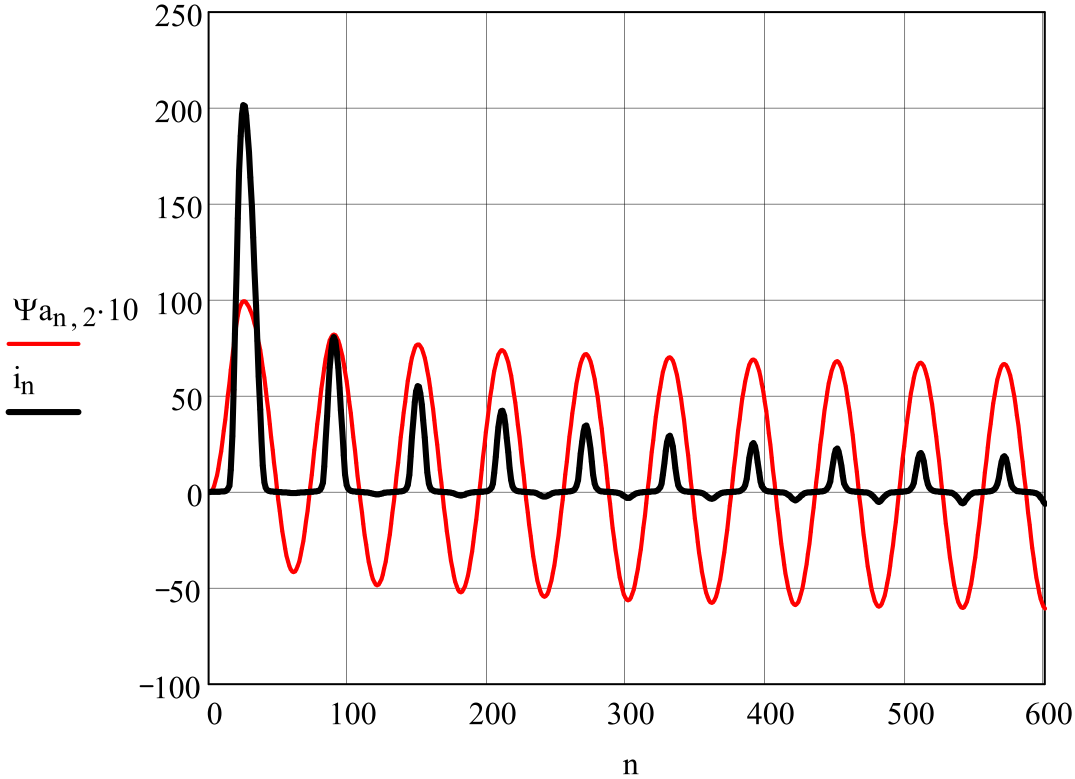
$$Ur(t,p) := U\cdot\sin(100\cdot\pi\cdot t) - R\cdot\left(K_1\cdot p + K_2\cdot p^3 + K_3\cdot p^5 + K_4\cdot p^7\right)$$

$\Psi a := \text{Rkadapt}(p, 0, 0.2, 600, Ur)$ $\quad n := 1 .. 600$

Interpolation of Ψ(I) $\quad vbh := \text{pspline}(\Psi, I)$ $\quad fh(x) := \text{interp}(vbh, \Psi, I, x)$

Current determination

$$i_n := \begin{cases} fh\left(\Psi a_{n,2}\right) & \text{if } \Psi a_{n,2} > 0 \\ -fh\left(\left|\Psi a_{n,2}\right|\right) & \text{otherwise} \end{cases}$$



Determination of the approximate values of amplitudes of the current and flux-linkage in steady-state condition

$\Psi u := \dfrac{U}{100\cdot\pi}$ $\quad \Psi u = 6.366$ $\quad Iu := fh(\Psi u)$ $\quad Iu = 11.505$

$$\frac{\max(i)}{Iu} = 17.511$$