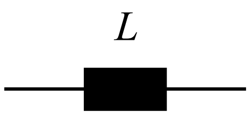
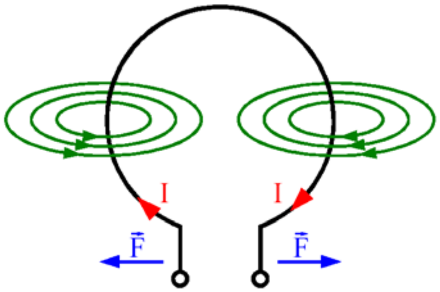
Pasivne komponente – dušilka

- poseduje snovno lastnost: induktivnost, ki je merilo … $u(t) = L\frac{di(t)}{dt}$
- sposobnost začasne akumulacije energije … $W = \frac{1}{2}LI^2$
- delitev:
  - -zračne,
  - -z jedrom

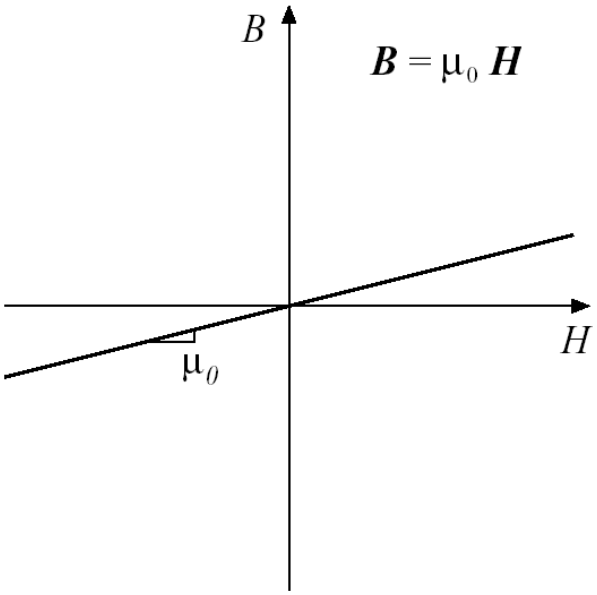
Pasivne komponente - dušilka

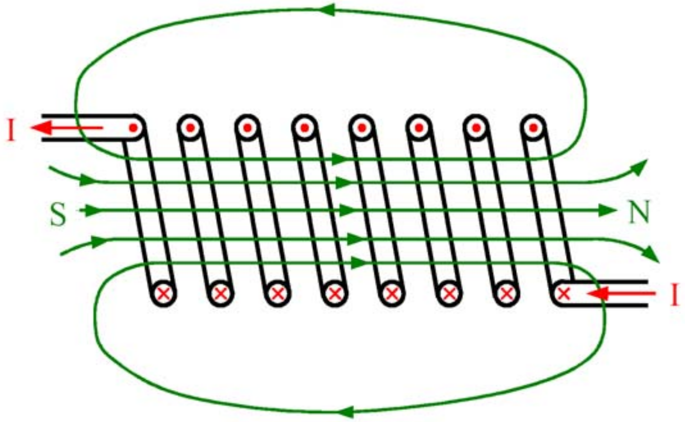
➢zračna dušilka





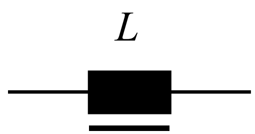
$$L = \frac{\mu_0 \cdot N^2 \cdot S}{l_S}$$



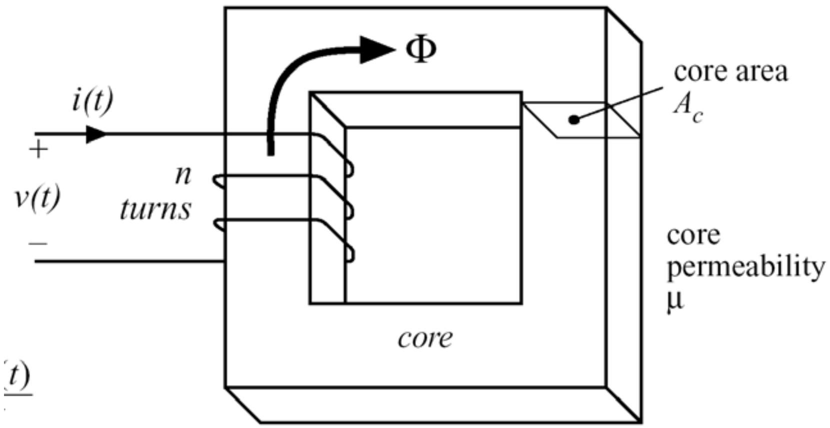


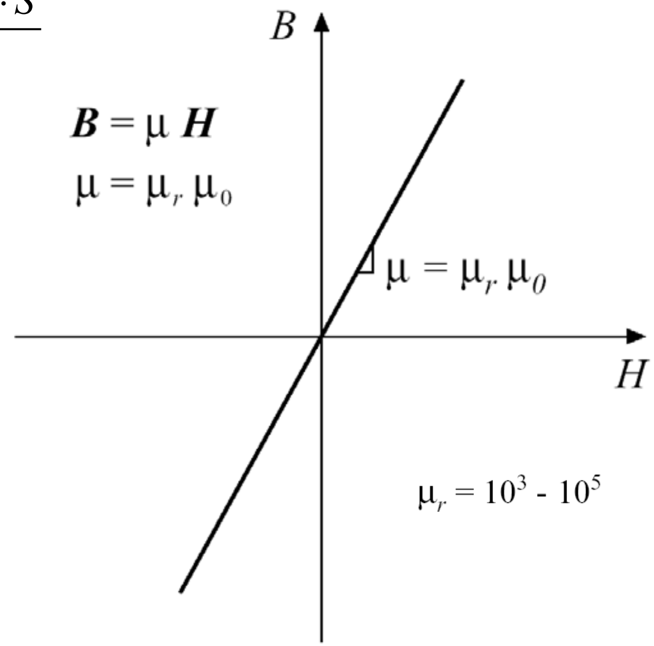
Pasivne komponente - dušilka

- dušilka z jedrom



$$L = \frac{\mu_0 \cdot \mu_r \cdot N^2 \cdot S}{l_S}$$

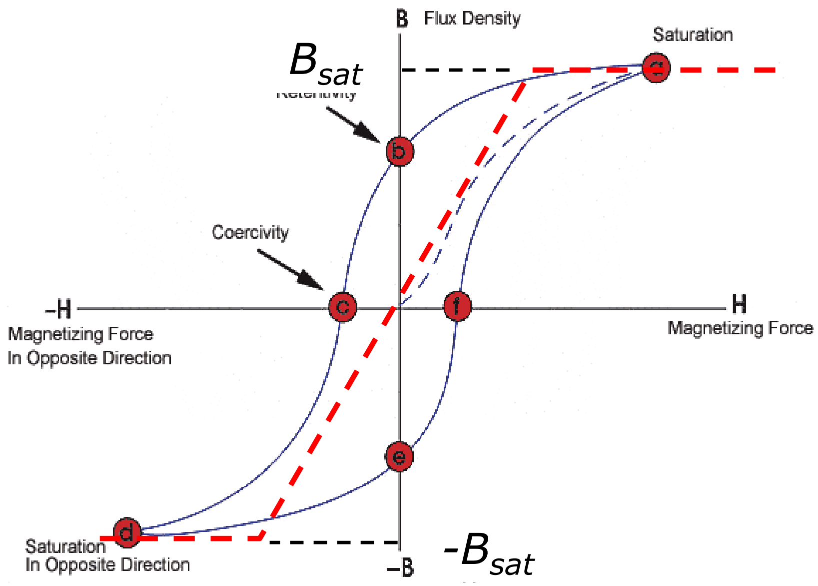




- feromagnetni materiali:Fe, Ni, Co (in njihove zlitine)
- feriti:

Pasivne komponente - dušilka

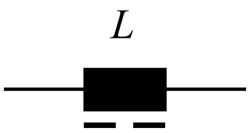
- dušilka z jedrom: BH karakteristika

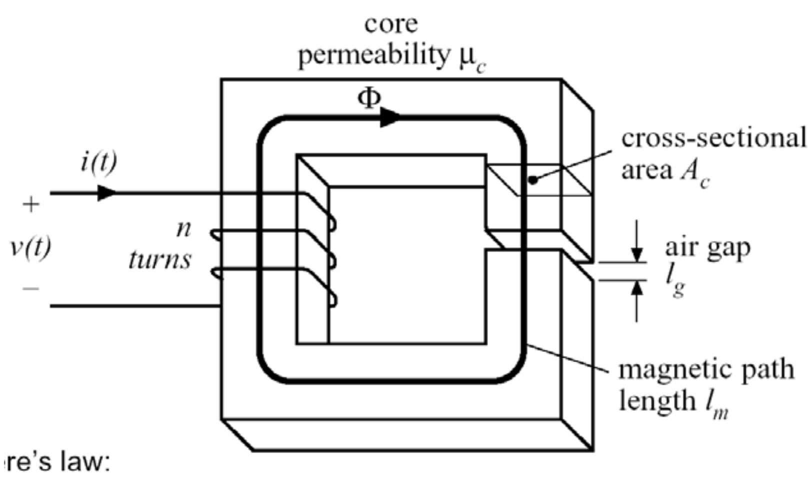


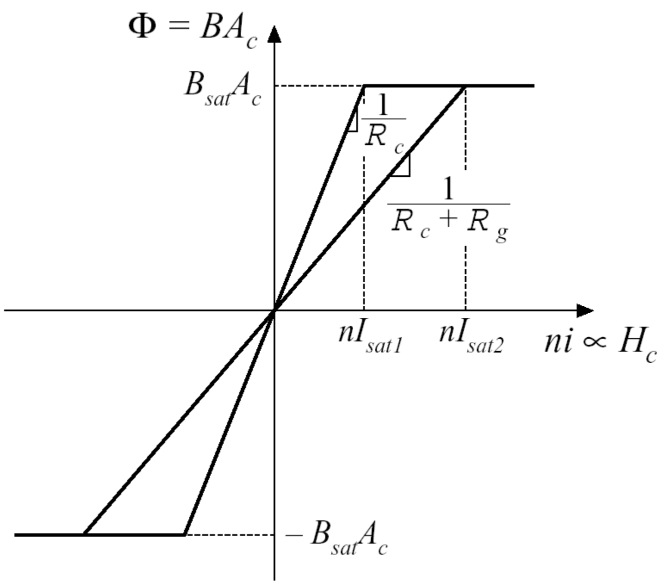
B_{sat} = 0.3-0.5T, ferrite
0.5-1T, powdered iron
1-2T, iron laminations

Pasivne komponente - dušilka

- dušilka z zračno režo



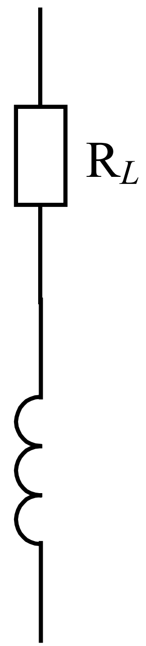




- posledice reže:
  - -zmanjšanje induktivnosti,
  - -zvečanje toka pri katerem jedro doseže nasičenje,
  - -nelinearna odvisnost permeabilnosti ima manjši vpliv na L

Izgube v dušilki

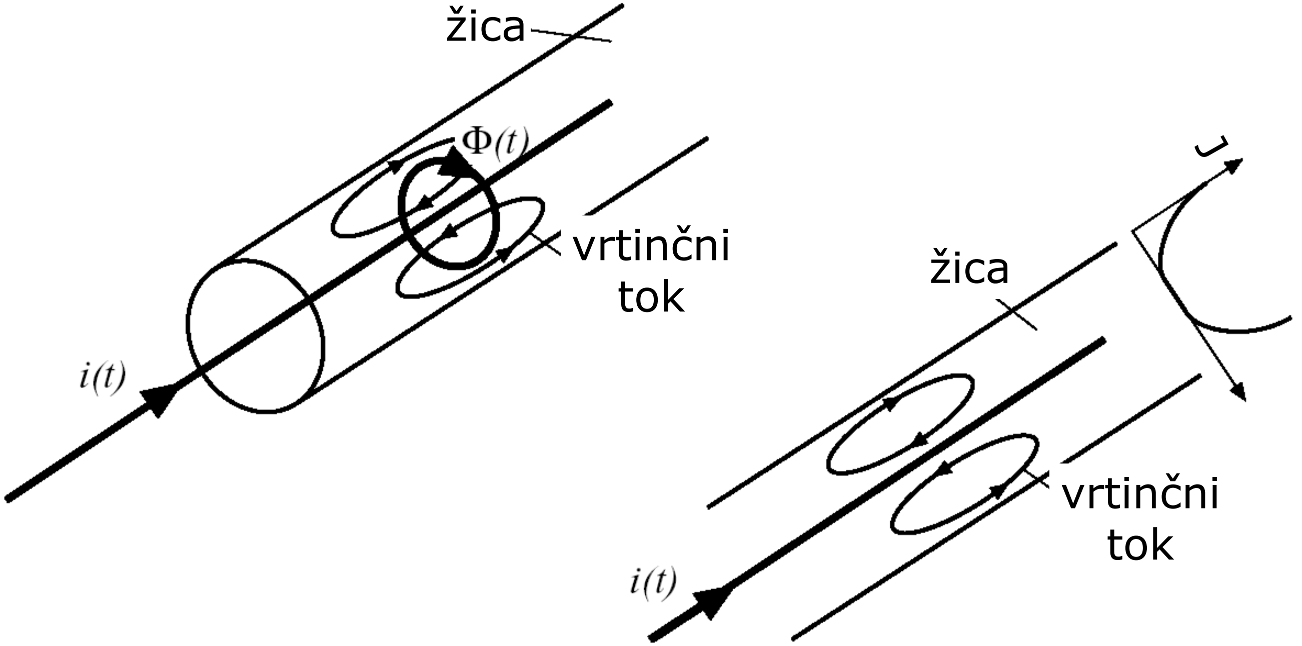
- izgube v navitju:
  - -ohmska upornost žice,
  - -skin efekt,
  - -efekt bližine (angl. proximity effect)



- izgube v jedru:
  - -histerezne,
  - -vrtinčne

Izgube v dušilki

➢izgube v navitju: kožni (skin) efekt



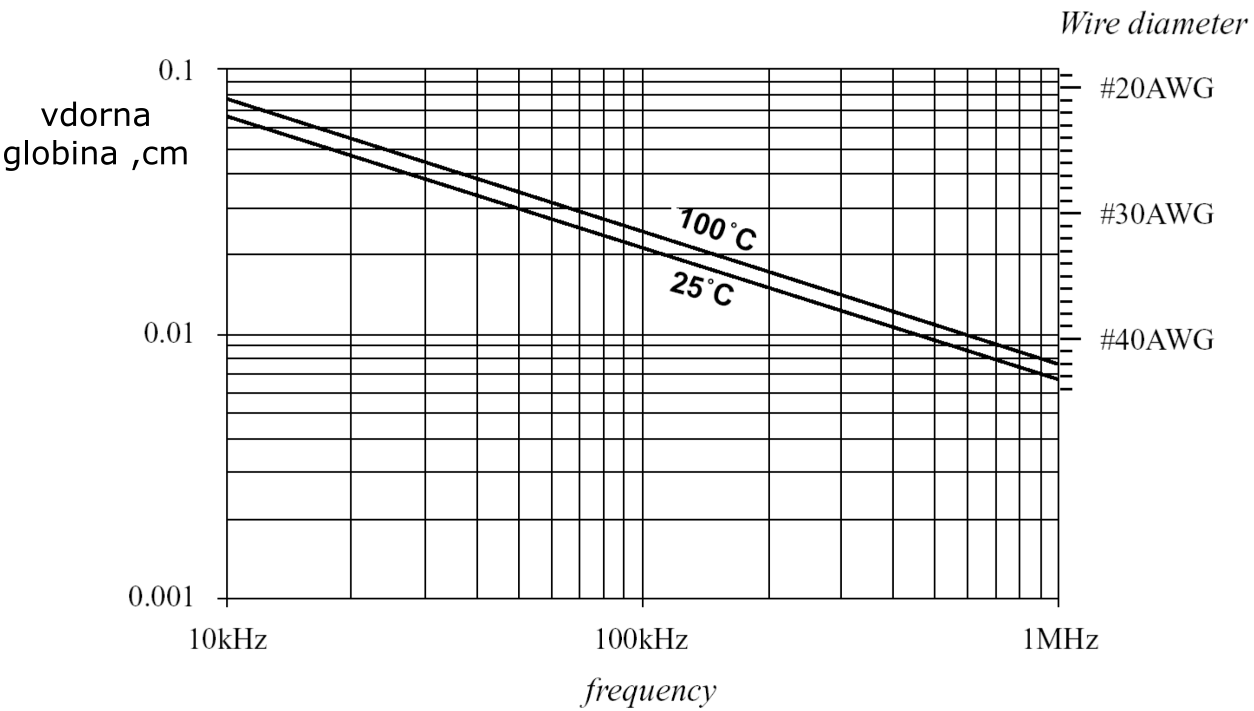
⇒ vdorna globina

Izgube v dušilki

- pri sinusni obliki toka tokovna gostota eksponencialno upada proti sredini vodnika, karakteristično dolžino vdora imenujemo **vdorna globina** δ

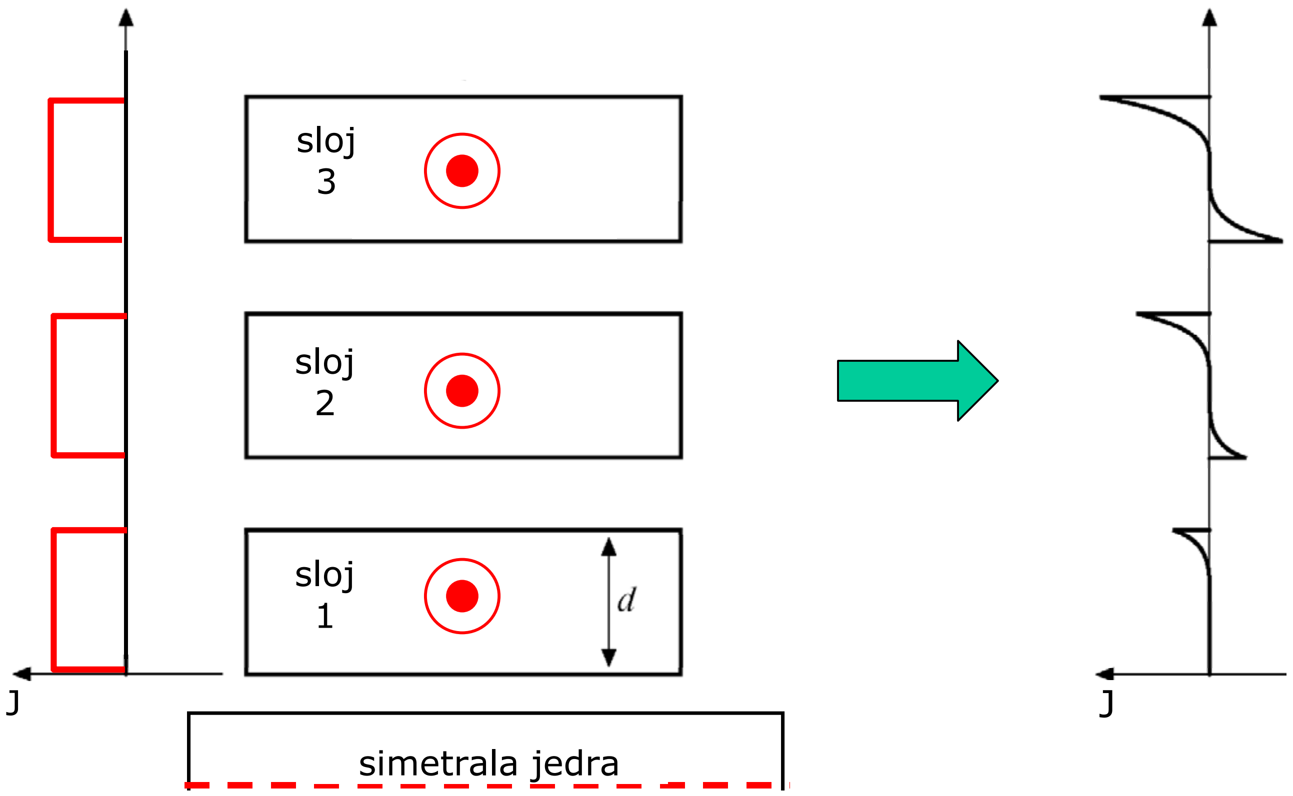
$$\delta = \sqrt{\frac{\rho}{\pi\mu \cdot f}}$$

$$R_{AC} = R_{DC} \cdot \frac{d}{\delta}$$



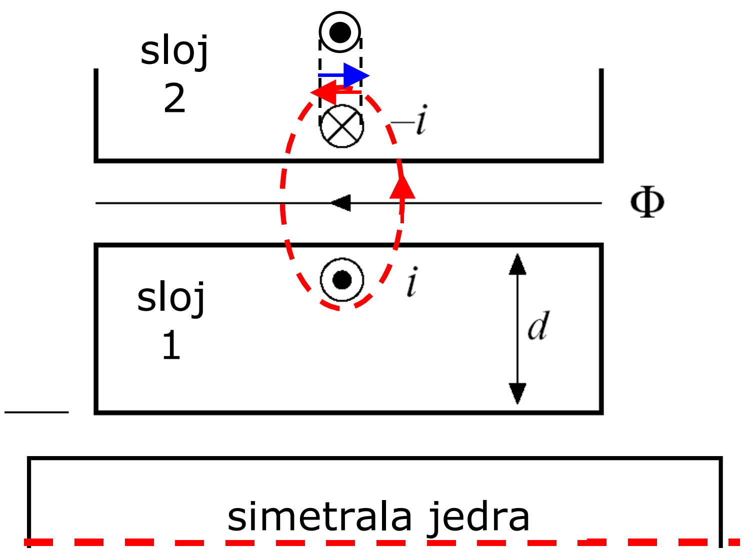
Izgube v dušilki

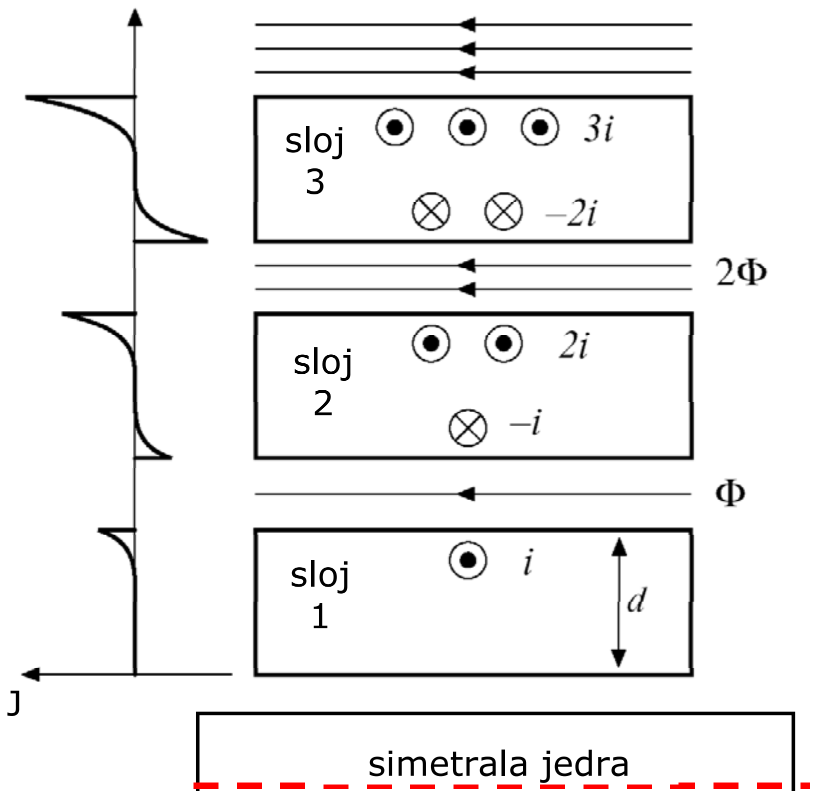
➢izgube v navitju:efekt bližine



Izgube v dušilki

- ➢izgube v navitju:efekt bližine





Izgube v dušilki

- izgube v navitju: efekt bližine

Izgube v prvem sloju znašajo

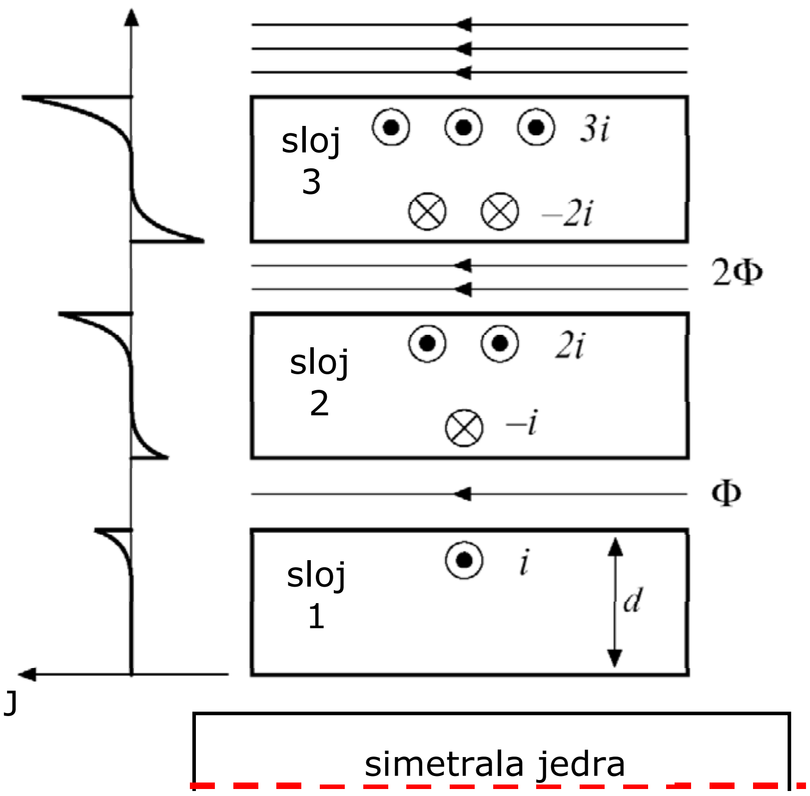
$$P_1 = I_{ef}^2 R_{DC} \cdot \frac{d}{\delta}$$

Izgube v drugem sloju znašajo

$$P_2 = I_{ef}^2 R_{DC} \cdot \frac{d}{\delta} + (2I_{ef})^2 R_{DC} \cdot \frac{d}{\delta} = 5 \cdot P_1$$

Izgube v tretjem sloju znašajo

$$P_3 = (2I_{ef})^2 R_{DC} \cdot \frac{d}{\delta} + (3I_{ef})^2 R_{DC} \cdot \frac{d}{\delta} = 13 \cdot P_1$$



Splošno: $P_m = ((m-1)^2 + m^2) P_1$

Izgube v dušilki

➢izgube v jedru:histerezne

❖Energija magnetenja/perioda

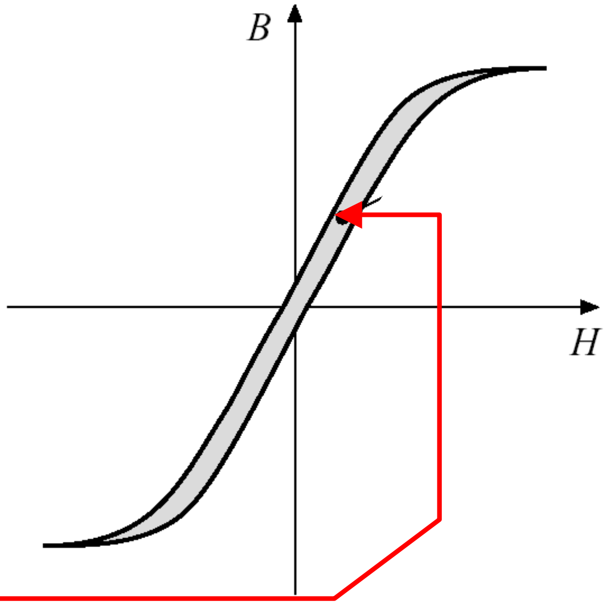
$$E = \int_0^T u(t) \cdot i(t) dt$$

po zamenjavi z:

$$u(t) = N \cdot S_J \frac{dB}{dt} \qquad H \cdot l_S = N \cdot i(t)$$

dobimo:

$$E = \int_0^T \left[N \cdot S_J \frac{dB}{dt} \right] \cdot \left[\frac{H \cdot l_S}{N} \right] dt = S_J \cdot l_S \int_0^T H dB$$



volumen jedra! površina BH zanke!

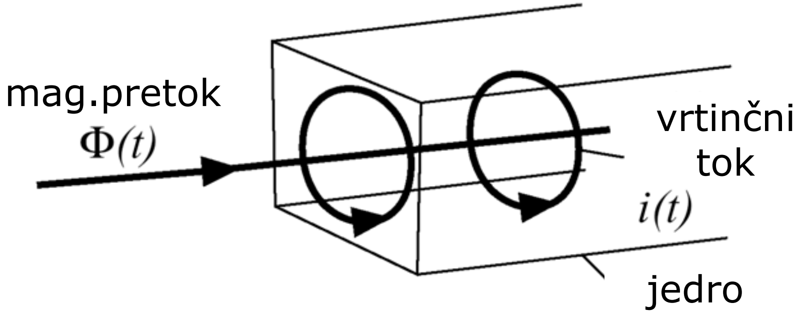
$$P_H = f \cdot E$$

Izgube v dušilki

➢izgube v jedru:vrtinčne

❖ jedro je električno prevodno ⇒ izmenični magnetni pretok inducira napetost ⇒ vrtinčni tok

❖ magnetni pretok povzročen z vrtinčnimi toki se zoperstavlja zunanjemu mag.pretoku ⇒ preprečuje enakomerno porazdelitev magnetnega pretoka preko prereza



Izgube v dušilki

➢ izgube v jedru: vrtinčne

❖ izmenični magnetni pretok inducira napetost ($U_{tem} \propto f$) $\Rightarrow$ vrtinčni tok ($I_{tem} \propto f$), če je $Z_{jedra}=R$ **!**

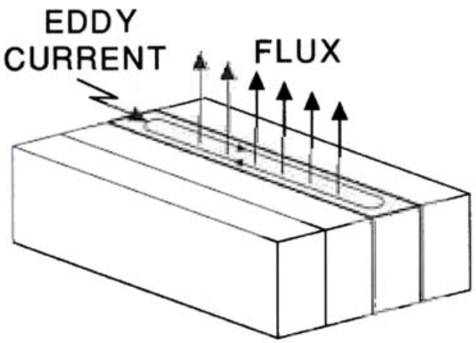
❖ izgube zaradi vrtinčnih tokov $\Rightarrow P_{vrt} \propto f^2$

Steinmetz-ova enačba: $$P_{vrt} = K_E \cdot f^2 \cdot B_{tem}{}^2$$

➢ feritni materialni imajo impedanco kapacitivnega značaja $\Rightarrow P_{vrt} \propto f^{4}$

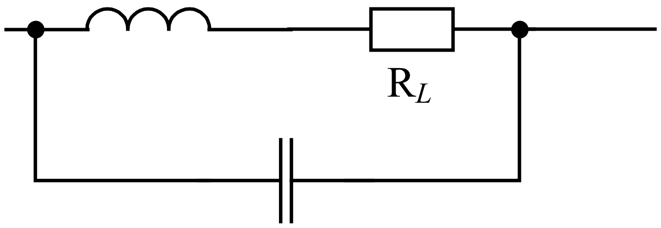
Izgube v dušilki

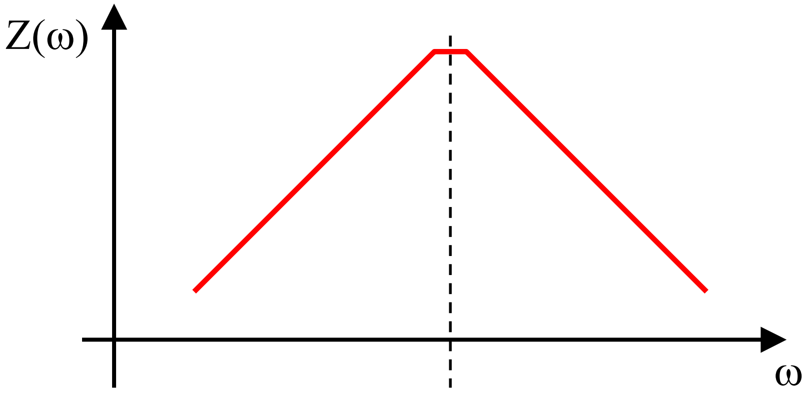
- izgube v jedru:vrtinčne $P_{vrt} = K_E \cdot f^2 \cdot B_{tem}{}^2$
- ukrepi za zmanjšanje:
  - -laminiranje,praškasta jedra,
  - -uporaba materialov z večjo spec.upornostjo



Core type	B_{sat}	Relative core loss	Applications
Laminations iron, silicon steel	1.5 - 2.0 T	high	50-60 Hz transformers, inductors
Powdered cores powdered iron, molypermalloy	0.6 - 0.8 T	medium	1 kHz transformers, 100 kHz filter inductors
Ferrite Manganese-zinc, Nickel-zinc	0.25 - 0.5 T	low	20 kHz - 1 MHz transformers, ac inductors

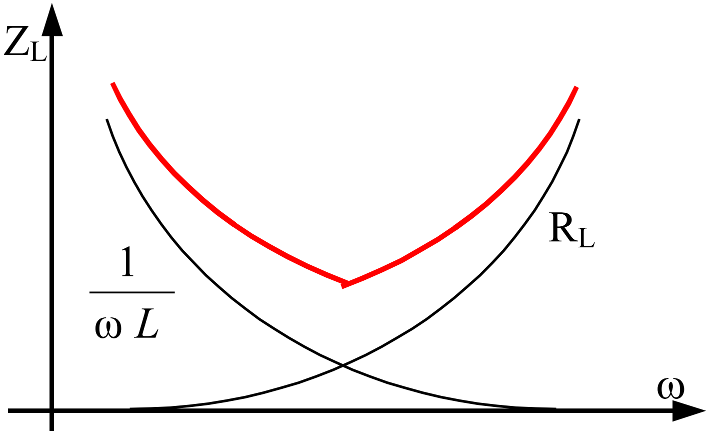
Nadomestno vezje





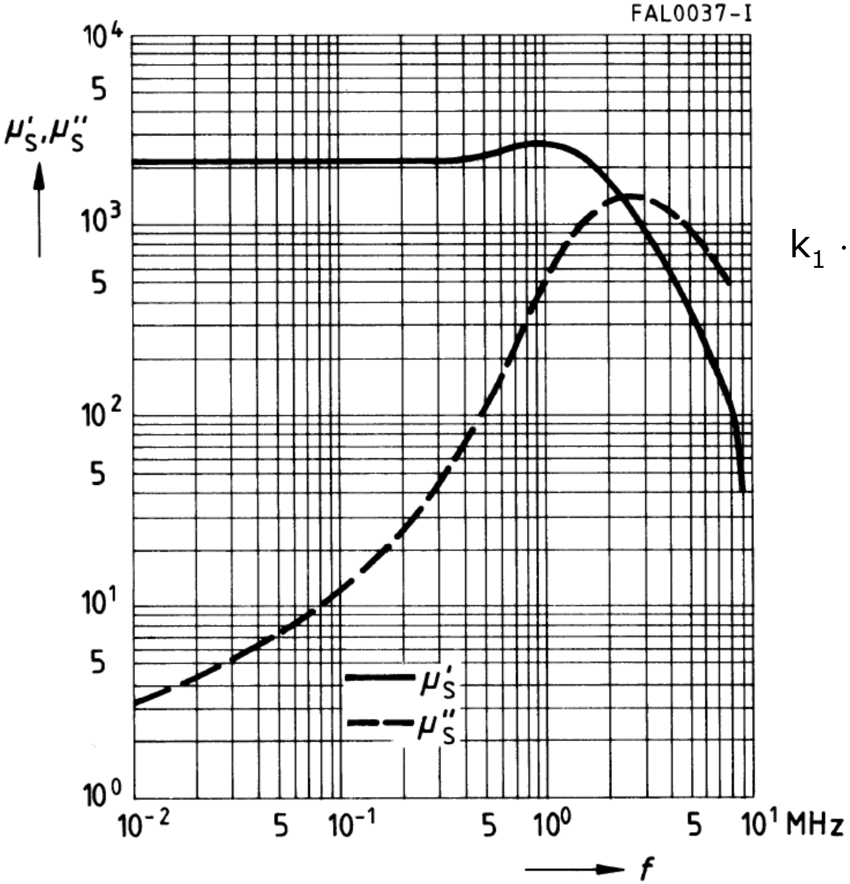
$$Q = \frac{\operatorname{Im} Z}{\operatorname{Re} Z} = \frac{\omega L}{R_L}$$

$$tg\delta = Q^{-1} = \frac{\operatorname{Re} Z}{\operatorname{Im} Z} = \frac{R_L}{\omega L} = \frac{R_L}{2\pi f L}$$



Nadomestno vezje

- kompleksna permeabilnost



$$\overline{\mu} = \mu_S' - j \cdot \mu_S''$$

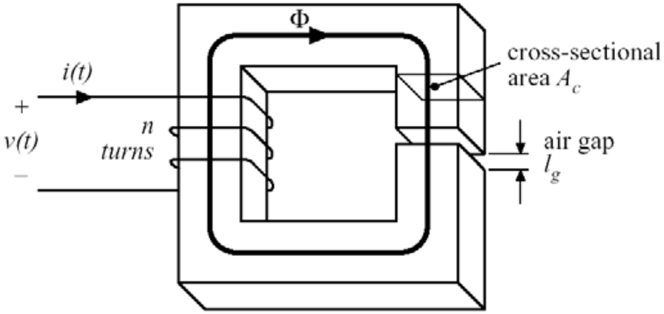
$k_1 \cdot$ induktivnost

$k_2 \cdot$ izgube

$$\overline{Z} = j\omega\overline{\mu} \cdot L_0$$

Dimenzioniranje dušilke

➢Primer 1:splošna pot



$$L = \frac{\mu \cdot N^2 \cdot A}{l_m} \qquad R_m = \frac{l_m}{\mu \cdot A} \qquad L = \frac{N^2}{R_m}$$

$$L = \frac{N^2}{R_{mZ} + R_{mF}} \qquad L = \frac{\mu_0 \cdot N^2 \cdot A}{l_{mZ} + \frac{l_{mF}}{\mu_F}}$$

$$I \cdot N = H_F \cdot l_F + H_Z \cdot l_Z \qquad I \cdot N = \frac{B \cdot l_Z}{\mu_0} + \frac{B \cdot l_F}{\mu_0 \cdot \mu_F}$$

$$L = \frac{A \cdot B^2}{\mu_0 \cdot I^2}\left(l_Z + \frac{l_F}{\mu_F}\right) \qquad \frac{I^2 \cdot L}{A \cdot B} = \frac{B \cdot l_Z}{\mu_0} + \frac{B \cdot l_F}{\mu_0 \cdot \mu_F} \qquad l_Z = \frac{\mu_0 \cdot I^2 \cdot L}{A \cdot B^2} - \frac{l_F}{\mu_F}$$