

Figura 4.1



Figura 4.3

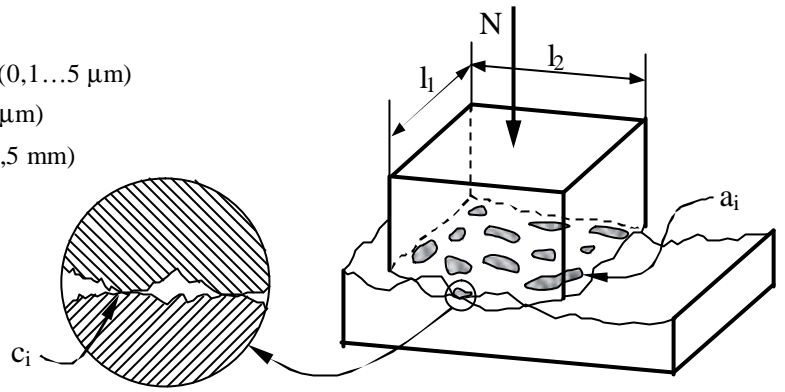


Figura 4.2

$$F_f = \mu_a \cdot N \tag{4.1}$$

$$A_r = \frac{N}{\sigma_c} \tag{4.2}$$

$$F_f = A_r \cdot \tau_r \tag{4.3}$$

$$\mu = \frac{\tau_r}{\sigma_c} \tag{4.4}$$

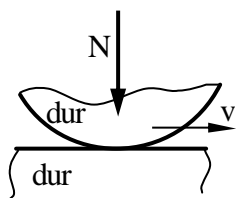


Figura 4.4.a

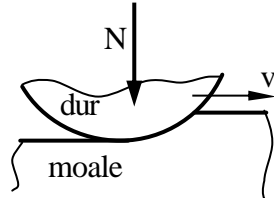


Figura 4.4.b

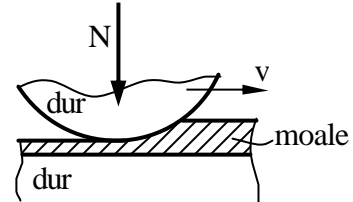


Figura 4.4.c

Tabelul 4.1

m	OL / Bz fosforos	OL / Bz sinterizat	OL / OL	OL / Fc	OL / Grafit	OL / Compozitie (aliaj moale neferos)	OL/ferodo (azbest impregnat cu rasini)
Regim uscat	0,7	0,28	0,6 ÷ 1,2	0,18 ÷ 0,6	0,08 ÷ 0,1	0,15 ÷ 0,18	0,3 ÷ 0,4
Regim limita sau mixt	0,1 ÷ 0,2	0,11 ÷ 0,25	0,1 ÷ 0,25	0,1 ÷ 0,2	-	0,08 ÷ 0,1	-

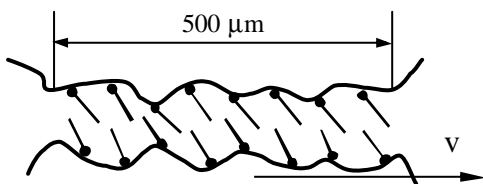


Figura 4.5

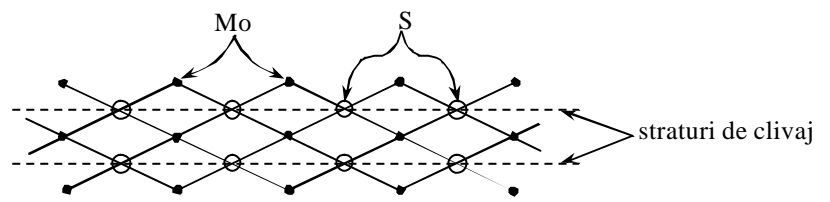


Figura 4.6

Tabelul 4.2

Cupla de frecare	Tipul stratului	Coefficientul de frecare
OL / OL, OL / Fc, OL / Bz	Molecular de ulei	0,1 ... 0,16
	Acizi grasi	0,05 ... 0,12
OL / OL	Acid stearic	0,1 ... 0,11
OL / Cu	Acid stearic	0,09

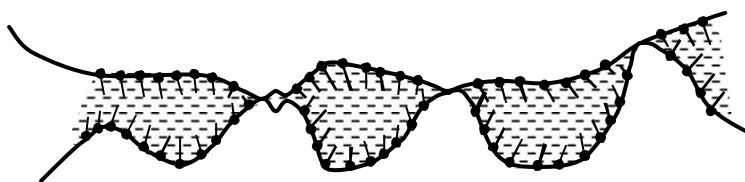


Figura 4.7

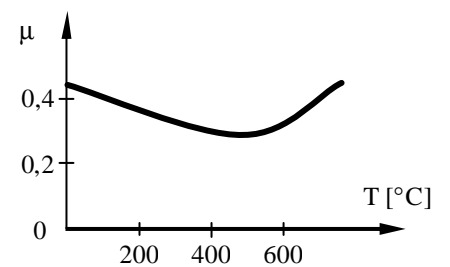


Figura 4.8

Tipul de frecare	Tipul de ungere	Coefficientul de frecare
Uscata	Fara ungere	> 0,3
Limita	Ungere la limita	0,1...0,3
Mixta	Ungere mixta	0,005...0,1
Fluida	Ungere HD sau HS	0,001...0,005

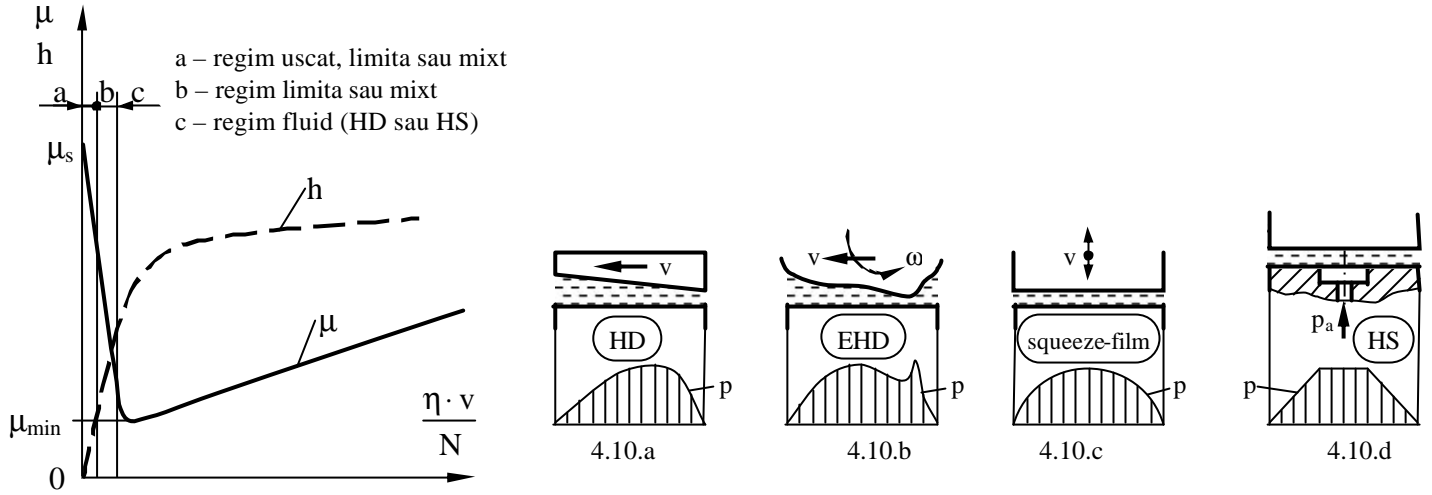


Figura 4.9

$$\tau = \eta \cdot \frac{dv}{dn} \quad (4.5)$$

$$\tau = \frac{F_f}{A} = \eta \cdot \frac{\pi \cdot d \cdot v}{\Delta r} \quad (4.6)$$

$$f = \frac{F_f}{F_n} = \frac{A \cdot \eta \cdot \frac{\pi \cdot d \cdot v}{\Delta r}}{p_m \cdot d \cdot l} = \frac{\pi \cdot d \cdot l \cdot \eta \cdot \pi \cdot d \cdot v}{\Delta r \cdot p_m \cdot d \cdot l} = \pi^2 \cdot \eta \cdot \frac{v}{p_m} \cdot \frac{d}{\Delta r} \quad (4.7)$$

$$p_m = \frac{F_n}{d \cdot l} = 10^7 \text{ N/m}^2 \text{ si } f = \pi^2 \cdot \eta \cdot \frac{v}{p_m} \cdot \frac{d}{\Delta r} = 10^{-6} \quad (4.8)$$

$$\frac{\partial}{\partial x} \left(\frac{h^3}{12 \cdot \eta} \cdot \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial z} \left(\frac{h^3}{12 \cdot \eta} \cdot \frac{\partial p}{\partial z} \right) = \frac{v}{2} \cdot \frac{\partial h}{\partial x} \quad (4.9)$$

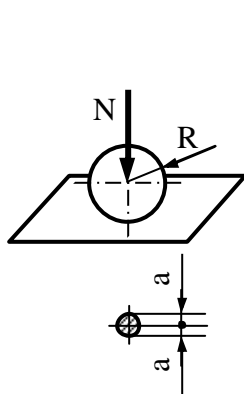


Figura 4.11.a

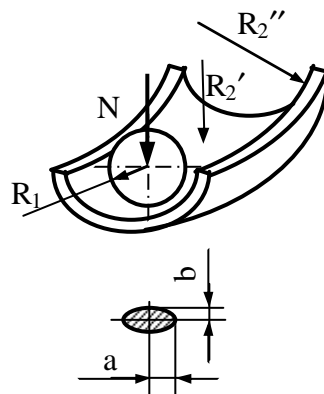


Figura 4.11.b

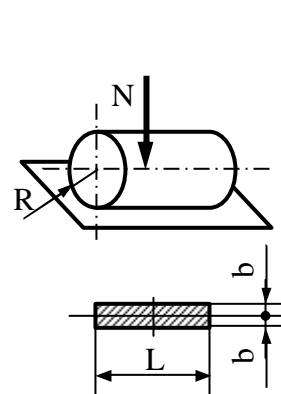


Figura 4.11.c

$$a = n_1 \cdot \left[\frac{3}{4} \cdot \pi \cdot \frac{N \cdot (K_1 + K_2)}{B + A} \right]^{1/3}, \quad b = n_2 \cdot \left[\frac{3}{4} \cdot \pi \cdot \frac{N \cdot (K_1 + K_2)}{B + A} \right]^{1/3} \quad (4.10)$$

Distributia este de forma elipsoidala cu un maxim central de marime $\sigma_{H \max} = \frac{3}{2} \cdot \frac{N}{\pi \cdot a \cdot b}$.

$$\tau_{\max} \cong 0,3 \cdot \sigma_{H \max} \quad (4.11)$$

$$\eta = \eta_0 \cdot e^{\alpha(p-p_0)} \quad (4.12)$$

$$\eta = \eta_0 \cdot \left(1 + \frac{p}{k} \right)^n \quad (4.13)$$

$$\rho = \rho_0 \cdot \left[1 + \frac{0,6 \cdot (p - p_0)}{1 + 1,7(p - p_0)} \right] \quad (4.14)$$

$$\frac{dp}{dx} = 12 \cdot \eta \cdot u \cdot \left[\frac{\rho \cdot h - (\rho \cdot h)_m}{\rho \cdot h^3} \right] \quad (4.15)$$

$$\frac{dp}{dx} = 12 \cdot \eta \cdot u \cdot \frac{h - h_m}{h^3} \quad (4.16)$$

$$\frac{dp}{dx} = 12 \cdot \eta_0 \cdot u \cdot \frac{h - h_m}{h^3} \cdot e^{\alpha \cdot p} \quad (4.17)$$

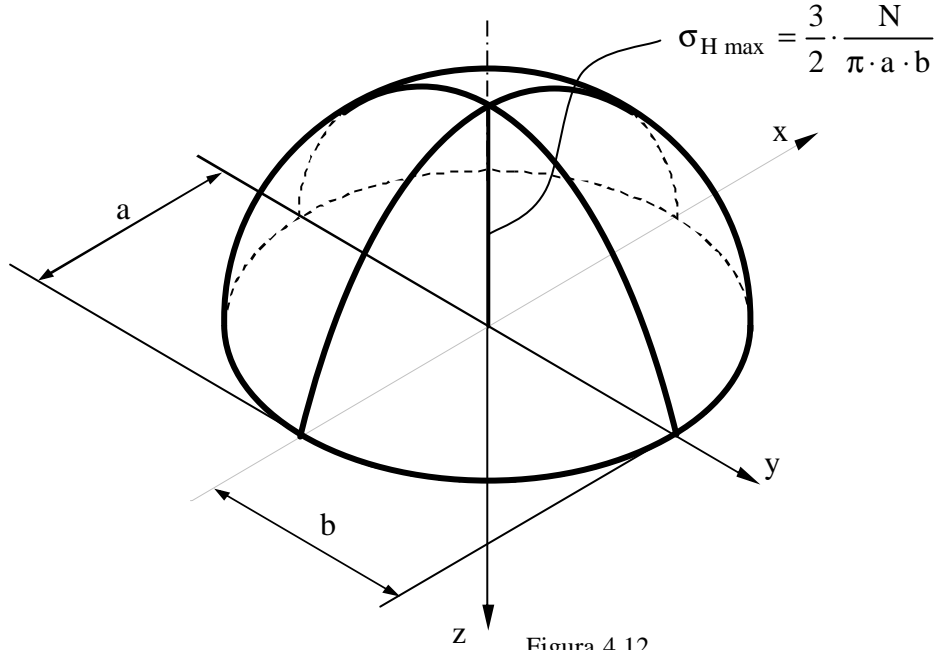


Figura 4.12

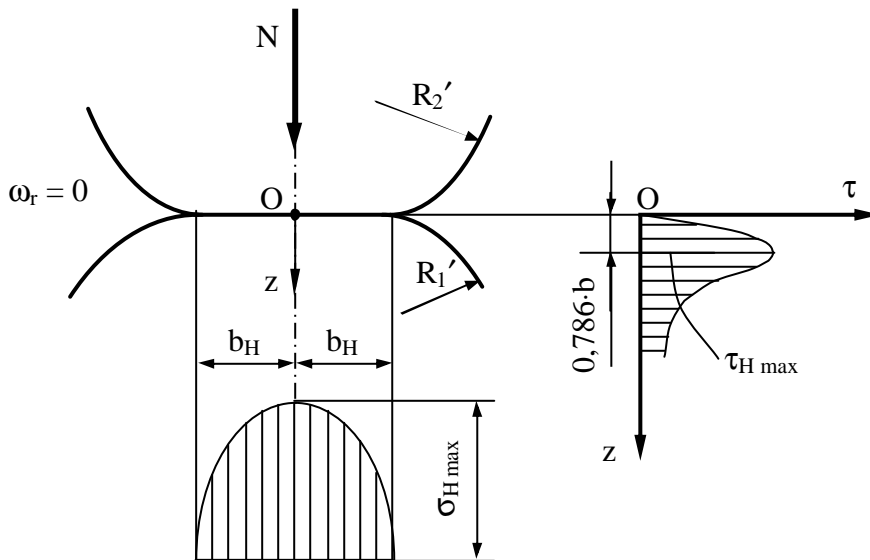


Figura 4.13

$$h = h_0 + h_1 + h_2 \quad (4.18)$$

$$h = h_0 + \frac{x^2}{2 \cdot R_1} + \frac{x^2}{2 \cdot R_2} = h_0 + \frac{x^2}{2} \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \quad (4.19)$$

$$h = h_0 + \frac{x^2}{2 \cdot R_e} \quad (4.20)$$

$$N - \int_{-z_e}^{+z_e} \int_{-x_e}^{+x_e} p(x, z) dx dz = 0 \quad (4.21)$$

$$\frac{d\Pi}{dx} = 6 \cdot \eta_0 \cdot u_0 \cdot \frac{h - h_m}{h^3}, \text{ unde } \Pi = \frac{1 - e^{-\alpha p}}{\alpha} \text{ si } u_0 = 2 \cdot u \text{ este viteza redusa de rostogolire.} \quad (4.22)$$

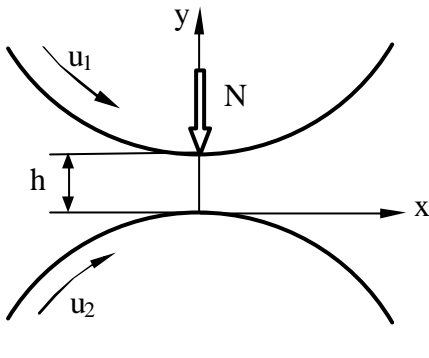


Figura 4.14

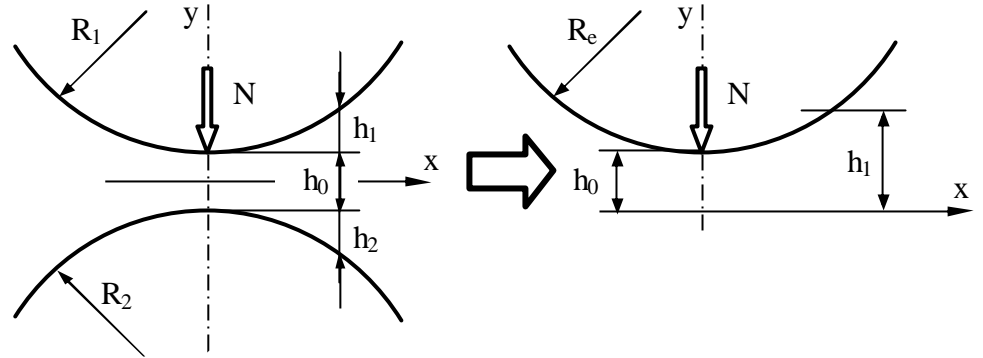


Figura 4.15

Pentru rezolvarea acestei ecuatii, Grubin a facut mai multe ipoteze:

- Într-un contact hertzian lubrifiat, geometria este data de teoria lui Hertz, cu o translatăre pe direcția Oy a celor două solide.
 - Filmul separator este continuu și nu modifică distribuția de presiuni.
 - Presiunea redusă Π atinge valoarea $1/\alpha$ și are distribuția din figura 4.16.
- Din teoria hertziana au rezultat următoarele caracteristici:

- presiunea maximă hertziană este dată de $\sigma_{H \max} = \frac{2}{\pi} \cdot \frac{N}{b_H \cdot L}$;
- semilatimea contactului este $b_H = \left(\frac{4 \cdot N \cdot R}{L \cdot E'} \right)^{1/2}$;
- raza redusă (echivalentă) este $R_e = \left(\frac{R_1 \cdot R_2}{R_1 + R_2} \right)^{-1}$;
- modulul de elasticitate redus $E' = \left[\frac{1}{\pi} \cdot \left(\frac{1 - \nu_1^2}{E_1} + \frac{1 - \nu_2^2}{E_2} \right) \right]^{-1}$.

$$H_m = 1,13 \cdot \frac{(G_0 \cdot U_0)^{0,727}}{W_0^{0,091}} \quad (4.23)$$

- $G_0 = \alpha \cdot E'$ este parametrul de material;
- $U_0 = \frac{\eta_0 \cdot u_0}{E' \cdot R_e}$ este parametrul vitezelor;
- $W_0 = \frac{F}{E' \cdot R_e \cdot L} = \frac{q}{E' \cdot R_e}$ este parametrul sarcinii;
- $H_0 = \frac{h_0}{R_e}$ (sau $H_m = \frac{h_m}{R_e}$) este parametrul grosimii filmului.

$$H_m = k \cdot G^a \cdot U^b \cdot W^c \quad (4.24)$$

$$h_T = \Phi_T \cdot h_0 \quad (4.24)$$

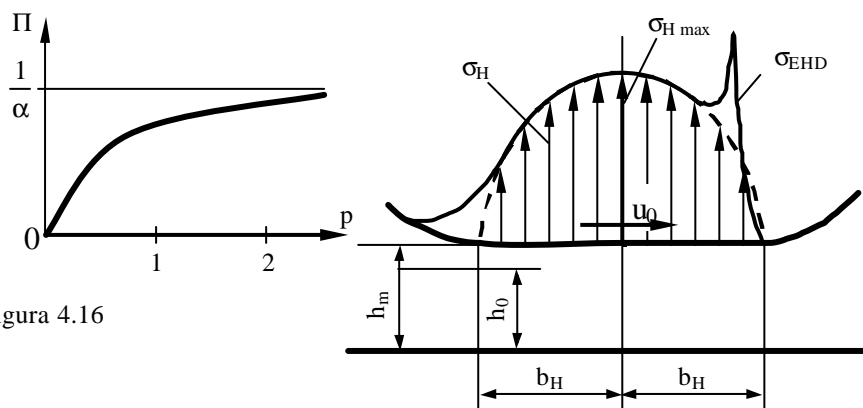


Figura 4.16

Figura 4.17

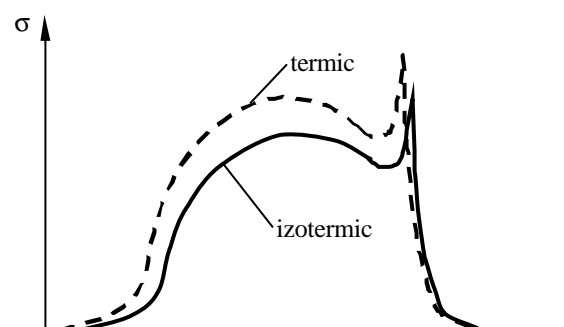


Figura 4.18

$$h_T = \Phi_T \cdot \Phi_A \cdot h_0 \quad (4.26)$$

$$\tau = \tau_0 \cdot \sinh \left(\beta \cdot \frac{\partial u}{\partial y} \right) \quad (4.27)$$

$$\eta = \eta_0 \cdot \exp \left\{ (\ln \eta_0 + 9,67) \left[\left(\frac{T+135}{T-135} \right)^{-S_0} (1 + 5,1 \cdot 10^{-9} \cdot \sigma)^Z - 1 \right] \right\} \quad (4.28)$$

$$\rho = \rho_0 \left(1 + \frac{d_1 \cdot \sigma}{1 + d_2 \cdot \sigma} \right) [1 + d_3 \cdot (T - T_0)] \quad (4.29)$$

$$\chi = \frac{h_0}{(R_{a1}^2 + R_{a2}^2)^{1/2}} \quad (4.30)$$

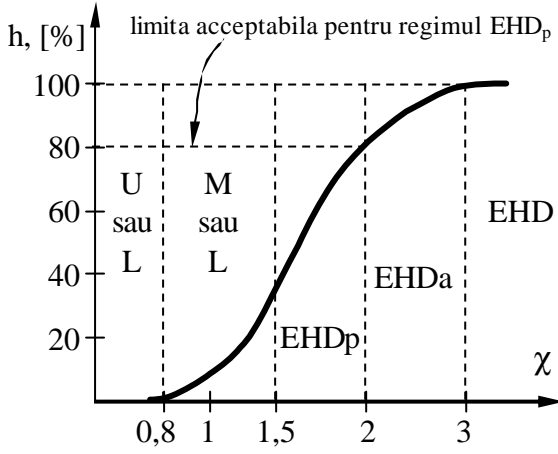


Figura 4.19

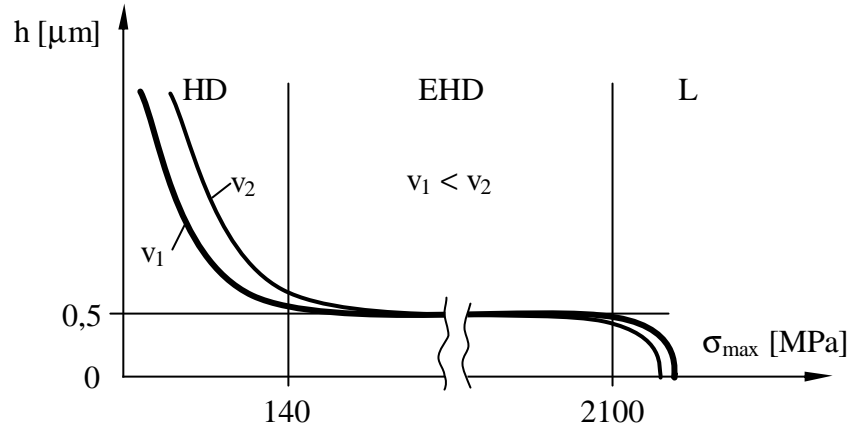


Figura 4.20

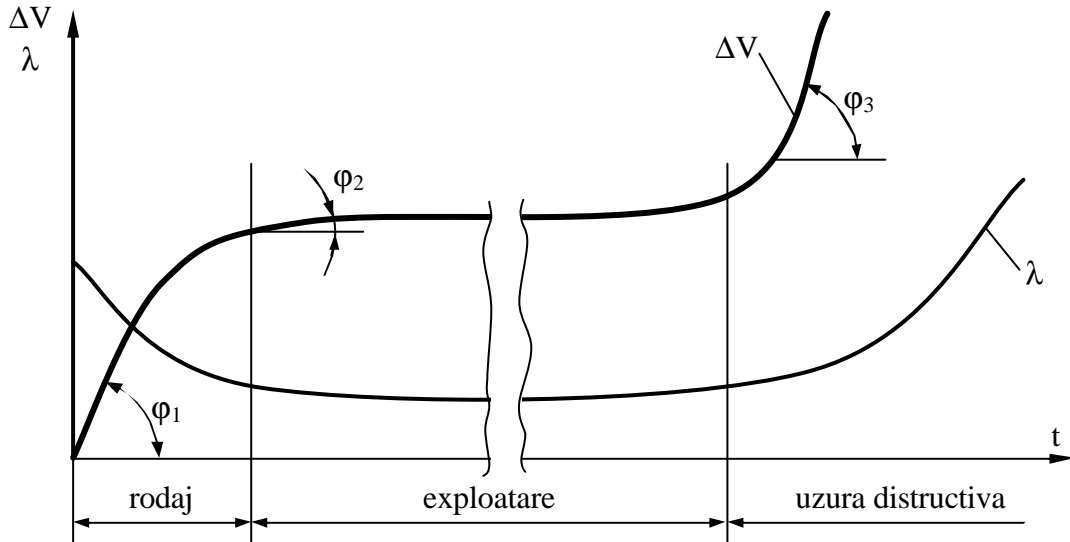


Figura 4.21

$$U_v = K_u \cdot \frac{N \cdot L_f}{HB} \quad (4.31)$$

$$h_m = \frac{U_v}{A_n} = \frac{K_u \cdot \sigma_m \cdot L_f}{HB} \quad (4.32)$$

$$I_{uh} = \frac{U_v}{L_f} = \frac{K_u \cdot \sigma_m}{HB} \quad (4.33)$$

$$v_{uh} = \frac{U_v}{t} = \frac{K_u \cdot N \cdot v}{HB} \quad (4.34)$$

$$\eta_t = \eta_0 \cdot e^{-\beta(t-t_0)} \quad (4.35)$$

$$\mu_{ak} = \frac{S_m \cdot \tau_r + (1 - S_m) \cdot \tau_{rf}}{\sigma_c} \quad (4.36)$$

Tipuri de uzare	Natura uzarii	Tipuri de cuple de frecare
<i>Adeziune</i> Gripaj incipient. Transfer de material Adeziune moderata. Adeziune severa: gripaj total	Mecanica, metalurgica si termica	Majoritatea cuplelor de frecare, lagare, asamblari demontabile, glisiere, ghidaje, piston-cilindru, angrenaje, variatoare, scule aschietoare etc.
<i>Abraziune.</i> Microaschiere. Rizare. Eroziune abraziva. Brazdare. Zgâriere	Mecanica	Organele de masini functionând în mediu abraziv, lanturi de antrenare, cuple de frecare insuficient protejate (piston-cilindru, lagare cu alunecare, rulmenti, angrenaje etc).
<i>Oboseala</i> Oboseala mecanica. Pitting. Exfoliere. Oboseala termo-mecanica	Mecanica. Termo-mecanica	Cuple hertziene lubrificate (angrenaje, rulmenti, suruburi cu bile, cama-tachet, role de lant). Cuple hertziene cu frecare uscata sau supuse unui tratament termic defectuos (rola, sina-bandaj, angrenaje etc.
<i>Coroziune</i> Coroziune chimica Ruginire	Chimica	Organele de masini în medii corozive, neprotejate sau în prezenta lubrifiantului degradat, a apei (piston-cilindru, lagare cu alunecare, rulmenti).
Coroziune galvanica Ciupire electrica	Electrochimica	Cuple de frecare unse si sub actiunea curentului electric: Flancurile unor angrenaje, bandaj-sina, contacte electrice.
Coroziune biochimica	Biochimica	Ghidaje si conductele lichidului de ungere-racire de la masini- unelte.
Tribocoroziune Coroziune de fretare	Mecanochimica	Cuple de frecare în prezenta lubrifiantului degradat: piston- cilindru, ghidaje, lagare etc. Cuple de frecare cu deplasari mici în medii corozive: fuzete, rulmenti, caneluri, asamblari filetate.
Cavitatie Impact	Mecanotermo- chimica	Suprafetele supuse imploziilor de gaze, în apa sau ulei (paleta de turbine, pompe, elice de nave, lagare cu alunecare, angrenaje etc.). Organe de maruntire, angrenaje etc.
Cojire Deformare la rece	Mecanica	Suprafetele unor organe de masini deformat plastic în urma unor puternice solicitari mecanice (angrenaje, rulmenti etc.).
Încetire		Flancuri de angrenaje solicitate si imperfect unse.
Brinelare		Cai de rulare la rulmenti, flancuri de angrenaje.
Interferenta		Angrenaje nedeplasate sau imperfect deplasate.
Fisurare de rectificare	Termomecanica	Organe de masini cu defecte de rectificare, angrenaje etc.
Fisurare de tratament termic		Organe de masini tratate termic necorespunzator (angrenaje, role, arbori etc.).
Deformare la cald	Termica	Organe de masini puternic solicitate mecanic si termic: rulmenti, angrenaje, ghidaje, discuri de frâna etc.
Decolorare (patare)		Suprafete supraîncalzite: camasi de cilindru, angrenaje, discuri de frâna etc.

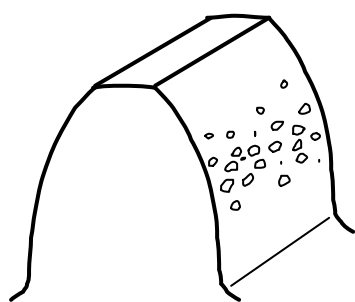


Figura 4.22

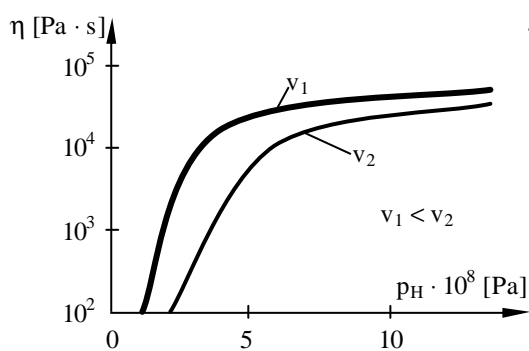


Figura 4.23

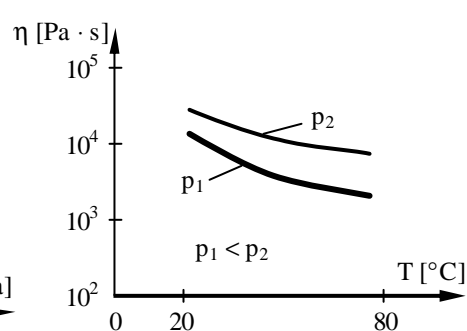


Figura 4.24