Deformacijski tenzor

$\vec{u}(\vec{r})$ ... vektor premika

$$dl'^2 - dl^2 = 2u_{ij}\,dx_i\,dx_j$$

$$u_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} + \underbrace{\frac{\partial u_k}{\partial x_i}\frac{\partial u_k}{\partial x_j}}_{\text{zanemarimo}}\right)$$

$$u_{ij} = \frac{1}{2}\left((\nabla\vec{u})_{ij} + (\nabla\vec{u})_{ji}\right) \quad \text{splošno}$$

Splošne deformacije

σ_{ij} ... napetostni tenzor

površinske sila

$$f_i = \frac{\partial}{\partial x_j}\sigma_{ij}$$

i-ta komp. površinske gostote sile na j-to komp. površine

$$F_i = \oint \sigma_{ij}\, \underset{\text{normala}}{dS_j}$$

Sprememba volumne v last. sist.

$$\frac{\Delta V}{V} = u_{kk}$$

Izotropni tlak $\sigma_{ij} = -p\delta_{ij}$

Hookov zakon

$$\sigma_{ij} = 2\mu\, u_{ij} + \lambda u_{kk}\delta_{ij}$$

$$u_{ij} = \frac{1}{2\mu}\left(\sigma_{ij} - \frac{\lambda}{(2\mu+3\lambda)}\sigma_{kk}\delta_{ij}\right)$$

$$\rho\ddot{\vec{u}} = \vec{f}^{zun} + \mu\nabla^2\vec{u} + (\mu+\lambda)\nabla\nabla\cdot\vec{u}$$

Navierova enačba

$$\mu = \frac{E}{2(1+\sigma)} \qquad \lambda = \frac{E\sigma}{(1-2\sigma)(1+\sigma)}$$

$$E = \frac{\mu(2\mu+3\lambda)}{\mu+\lambda} \qquad \sigma = \frac{1}{2(1+\mu/\lambda)}$$

$$\sigma_{ij} = \frac{E}{1+\sigma}\left(u_{ij} + \frac{\sigma}{1-2\sigma}u_{kk}\delta_{ij}\right)$$

$u_{kk} = \nabla\cdot\vec{u}$

$$u_{ij} = \frac{1}{E}\left((1+\sigma)\sigma_{ij} - \sigma\sigma_{kk}\delta_{ij}\right)$$

Navierova enačba

$$\rho\ddot{\vec{u}} = \vec{f}^{zun} + \frac{E}{2(1+\sigma)}\left(\nabla^2\vec{u} + \frac{1}{1-2\sigma}\nabla\nabla\cdot\vec{u}\right)$$

telesno porazdeljena gostota sile

RP.

- napetost na pov. je nič ker nanjo ne deluje površinska sila

Nihanje: na steni velja $u = u_0 e^{i\omega t}$

Tanke plošče

u... odmik v z smeri

$$K\nabla^2\nabla^2 u - P = 0$$

$$K = \frac{Eh^3}{12(1-\sigma^2)}$$

P → površinska gostota sile (tlak) [$\rho g h$]

Za okrogle plošče $u(r)$

$$\nabla^2\nabla^2 = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right)\right)\right)$$

RP

n

togo vpeta $u=0 \quad \frac{\partial u}{\partial n} = 0 \Big|_{\text{na robu}}$

podprta $u=0 \quad \frac{\partial^2 u}{\partial n^2} + \sigma\underbrace{\frac{\partial \varphi}{\partial l}}_{1/R}\frac{\partial u}{\partial n} = 0$

Upogib palic

K... dolžinska gostota zun. sil

$$M = EI\left(-\frac{d^2y}{dz^2}, \frac{d^2x}{dz^2}, 0\right) = EI(-\ddot{y}, \ddot{x}, 0)$$

$$F_{x,y} = -EI\dddot{x}_{,y} + F_z\dot{x}_{,y}$$

$$EI x^{(4)}_{,y} - F_z\ddot{x}_{,y} - \dot{F}_z\dot{x}_{,y} - K_{x,y} = 0$$

Krog $I = \frac{\pi R^4}{4}$

Kvader a, b $\quad I_x = \frac{b^3 a}{12} \quad I_z = \frac{a^3 b}{12}$

RP.

vpeta $x=0 \quad \dot{x}=0$

prosta $F=0 \quad M=0$

vrtljivo vpeta $x=0 \quad M=0$

Struna $u = u_0 \sin kx\, e^{i\omega t}$

Rešitve DE

polinomi in racionalne funkcije (za sferne)

$x^{(4)} = C \rightarrow$ pol. 4. st.

$x^{(4)} + k^2\ddot{x} = 0 \rightarrow A\sin kz + B\cos kz + Cz + D$

$x^{(4)} - \alpha^4 x = 0 \rightarrow A\sin + B\cos + C\,\mathrm{sh} + D\,\mathrm{ch}\ \alpha z$

$\ddot{x} - k^2 x = 0 \rightarrow$ hiperbolične

$$\frac{F}{S} = E\frac{\Delta l}{l} \qquad \frac{\Delta l}{l} = \alpha\Delta T$$

$$E = \frac{\sigma_{zz}}{u_{zz}} \qquad \sigma = -\frac{u_{xx}}{u_{zz}} \qquad G = \frac{\sigma_{xy}}{2u_{xy}}$$

Matematične zveze

$$\varepsilon_{ijk}\varepsilon_{ijl} = 2\delta_{kl}$$

$$\varepsilon_{ijk}\varepsilon_{nmk} = \delta_{in}\delta_{jm} - \delta_{jn}\delta_{im}$$

$$\varepsilon_{ijk}\varepsilon_{ijk} = 6$$

$$\nabla\nabla\cdot = \nabla^2 + \nabla\times\nabla\times$$

Besslova DE

$$\frac{\partial^2 j_l}{\partial r^2} + \frac{2}{r}\frac{\partial j_l}{\partial r} + \left(1 - \frac{l(l+1)}{r^2}\right)j_l = 0$$

$\nabla\nabla\cdot\vec{u} + k^2\vec{u} = 0$ → Sferne Besslove

$$-x^l j_{l+1} = (x^{-l}j_l)' \qquad j_0(x) = \frac{\sin x}{x}$$

$$x^{l+1}j_{l-1} = (x^{l+1}j_l)'$$

$$\int f(x)H(x-x_0) = (F(x) - F(x_0))H(x-x_0) + C$$

Cilindrične koordinate

$$d^3r = r\,dr\,d\phi\,dz,$$

$$\nabla f = \frac{\partial f}{\partial r}\mathbf{e}_r + \frac{1}{r}\frac{\partial f}{\partial \phi}\mathbf{e}_\phi + \frac{\partial f}{\partial z}\mathbf{e}_z,$$

$$\nabla\cdot\vec{v} = \frac{1}{r}\frac{\partial(rv_r)}{\partial r} + \frac{1}{r}\frac{\partial v_\phi}{\partial \phi} + \frac{\partial v_z}{\partial z},$$

$$\nabla\times\vec{v} = \left(\frac{1}{r}\frac{\partial v_z}{\partial \phi} - \frac{\partial v_\phi}{\partial z}\right)\mathbf{e}_r + \left(\frac{\partial v_r}{\partial z} - \frac{\partial v_z}{\partial r}\right)\mathbf{e}_\phi + \frac{1}{r}\left(\frac{\partial(rv_\phi)}{\partial r} - \frac{\partial v_r}{\partial \phi}\right)\mathbf{e}_z,$$

$$\nabla^2 f = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial f}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2},$$

$$\nabla^2\vec{v} = \left(\nabla^2 v_r - \frac{v_r}{r^2} - \frac{2}{r^2}\frac{\partial v_\phi}{\partial \phi}\right)\mathbf{e}_r + \left(\nabla^2 v_\phi - \frac{v_\phi}{r^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \phi}\right)\mathbf{e}_\phi + \nabla^2 v_z\,\mathbf{e}_z,$$

Sferične koordinate

$$d^3r = r^2\,dr\,d(\cos\theta)\,d\phi,$$

$$\nabla f = \frac{\partial f}{\partial r}\mathbf{e}_r + \frac{1}{r}\frac{\partial f}{\partial \theta}\mathbf{e}_\theta + \frac{1}{r\sin\theta}\frac{\partial f}{\partial \phi}\mathbf{e}_\phi,$$

$$\nabla\cdot\vec{v} = \frac{1}{r^2}\frac{\partial(r^2 v_r)}{\partial r} + \frac{1}{r\sin\theta}\left(\frac{\partial(\sin\theta\, v_\theta)}{\partial\theta} + \frac{\partial v_\phi}{\partial\phi}\right),$$

$$\nabla\times\vec{v} = \frac{1}{r\sin\theta}\left(\frac{\partial(\sin\theta\, v_\phi)}{\partial\theta} - \frac{\partial v_\theta}{\partial\phi}\right)\mathbf{e}_r + \frac{1}{r}\left[\left(\frac{1}{\sin\theta}\frac{\partial v_r}{\partial\phi} - \frac{\partial(rv_\phi)}{\partial r}\right)\mathbf{e}_\theta + \left(\frac{\partial(rv_\theta)}{\partial r} - \frac{\partial v_r}{\partial\theta}\right)\mathbf{e}_\phi\right],$$

$$\nabla^2 f = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial f}{\partial r}\right) + \frac{1}{r^2}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial f}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2 f}{\partial\phi^2}\right].$$

Elastomehanika

Kinematika deformacije

$\mathbf{u}(\mathbf{r}) = \mathbf{r}'(\mathbf{r}) - \mathbf{r}$ (vektor premika)

$$u_{ik} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_k} + \frac{\partial u_k}{\partial x_i} + \frac{\partial u_l}{\partial x_i}\frac{\partial u_l}{\partial x_k}\right) \approx \frac{1}{2}\left(\frac{\partial u_i}{\partial x_k} + \frac{\partial u_k}{\partial x_i}\right)$$

(deformacijski tenzor)

$$\mathrm{d}\mathbf{r}'^2 = \mathrm{d}\mathbf{r}^2 + 2u_{ik}\,\mathrm{d}x_i\,\mathrm{d}x_k$$

$$\frac{\mathrm{d}V' - \mathrm{d}V}{\mathrm{d}V} = \operatorname{tr}\mathbf{u} = u_{ii}$$

$$\begin{bmatrix} u_{rr} & u_{r\vartheta} & u_{r\varphi} \\ & u_{\vartheta\vartheta} & u_{\vartheta\varphi} \\ & & u_{\varphi\varphi} \end{bmatrix} =$$

$$\begin{bmatrix} \frac{\partial u_r}{\partial r} & \frac{1}{2}\left(\frac{\partial u_\vartheta}{\partial r} - \frac{u_\vartheta}{r} + \frac{1}{r}\frac{\partial u_r}{\partial \vartheta}\right) & \frac{1}{2}\left(\frac{\partial u_\varphi}{\partial r} - \frac{u_\varphi}{r} + \frac{1}{r\sin\vartheta}\frac{\partial u_r}{\partial \varphi}\right) \\ & \frac{1}{r}\frac{\partial u_\vartheta}{\partial \vartheta} + \frac{u_r}{r} & \frac{1}{2}\left(\frac{1}{r}\frac{\partial u_\varphi}{\partial \vartheta} - \frac{u_\varphi}{r\tan\vartheta} + \frac{1}{r\sin\vartheta}\frac{\partial u_\vartheta}{\partial \varphi}\right) \\ & & \frac{1}{r\sin\vartheta}\frac{\partial u_\varphi}{\partial \varphi} + \frac{u_r}{r} + \frac{u_\vartheta}{r\tan\vartheta} \end{bmatrix}$$

$$\begin{bmatrix} u_{rr} & u_{r\varphi} & u_{rz} \\ & u_{\varphi\varphi} & u_{\varphi z} \\ & & u_{zz} \end{bmatrix} =$$

$$\begin{bmatrix} \frac{\partial u_r}{\partial r} & \frac{1}{2}\left(\frac{\partial u_\varphi}{\partial r} - \frac{u_\varphi}{r} + \frac{1}{r}\frac{\partial u_r}{\partial \varphi}\right) & \frac{1}{2}\left(\frac{\partial u_r}{\partial z} + \frac{\partial u_z}{\partial r}\right) \\ & \frac{1}{r}\frac{\partial u_\varphi}{\partial \varphi} + \frac{u_r}{r} & \frac{1}{2}\left(\frac{1}{r}\frac{\partial u_z}{\partial \varphi} + \frac{\partial u_\varphi}{\partial z}\right) \\ & & \frac{\partial u_z}{\partial z} \end{bmatrix}$$

Mehanična napetost

Predpostavimo, da sile delujejo le preko stične ploskve.

$$F_i = \int f_i(\mathbf{r})\,\mathrm{d}^3\mathbf{r} + \int f_i^{(z)}(\mathbf{r})\,\mathrm{d}^3\mathbf{r}$$

$$\int_V f_i(\mathbf{r})\,\mathrm{d}^3\mathbf{r} = \oint_{\partial V} p_{ik}\,\mathrm{d}A_k \qquad \text{(def. napetostnega tenzorja)}$$

$$f_i = \frac{\partial p_{ik}}{\partial x_k}$$

Iz poljubnega napetostnega tenzorja lahko vedno tvorimo enakovreden napetostni tenzor, ki je simetričen.

$$\rho\ddot{u}_i = f_i^{(z)} + \frac{\partial p_{ik}}{\partial x_k} \qquad \text{(Cauchyeva enačba)}$$

$$\delta W = \int f_i\,\delta u_i\,\mathrm{d}^3\mathbf{r} = -\int p_{ik}\,\delta u_{ik}\,\mathrm{d}^3\mathbf{r}$$

$$\mathrm{d}f = \mathrm{d}\left(\frac{f}{V}\right) = -s\,\mathrm{d}T + \mathrm{d}w = -s\,\mathrm{d}T + p_{ik}\,\mathrm{d}u_{ik}$$

$$p_{ik} = \left(\frac{\partial f}{\partial u_{ik}}\right)_T$$

Hookov zakon

$$f = f_0 + \frac{1}{2}u_{ik}C_{iklm}u_{lm}$$

$$p_{ik} = C_{iklm}u_{lm}$$

Izotropno sredstvo

$$p_{ik} = \lambda u_{ll}\delta_{ik} + 2\mu u_{ik} = \frac{E}{1+\sigma}\left(u_{ik} + \frac{\sigma}{1-2\sigma}u_{ll}\delta_{ik}\right)$$

$$u_{ik} = \frac{1}{2\mu}\left(p_{ik} - \frac{\lambda}{3\lambda+2\mu}p_{ll}\delta_{ik}\right) = \frac{1}{E}[(1+\sigma)p_{ik} - \sigma p_{ll}\delta_{ik}]$$

$$\lambda = K - \frac{2\mu}{3} = \frac{\sigma E}{(1+\sigma)(1-2\sigma)}$$

$$\mu = \frac{E}{2(1+\sigma)}$$

$$\sigma = \frac{\lambda}{2(\lambda+\mu)}$$

$$E = \frac{\mu(3\lambda+2\mu)}{\mu+\lambda}$$

$$K = \frac{E}{3(1-2\sigma)}$$

Prosta energija

$$f = f_0 + \frac{\lambda}{2}u_{ll}^2 + \mu u_{ik}u_{ki} = f_0 + \mu\left(u_{ik} - \frac{1}{3}u_{ll}\delta_{ik}\right)^2 + \frac{K}{2}u_{ll}^2 =$$

$$= f_0 + \frac{E}{2}\left[\frac{\sigma}{(1+\sigma)(1-2\sigma)}u_{ll}^2 + \frac{1}{1+\sigma}u_{ik}u_{ki}\right]$$

$$\rho\ddot{\mathbf{u}} = \mathbf{f}^{(z)} + (\lambda+\mu)\boldsymbol{\nabla}\boldsymbol{\nabla}\cdot\mathbf{u} + \mu\nabla^2\mathbf{u} = \qquad \text{(Navierova enačba)}$$

$$= \mathbf{f}^{(z)} + \frac{E}{2(1+\sigma)}\left[\nabla^2\mathbf{u} + \frac{1}{1-2\sigma}\boldsymbol{\nabla}\boldsymbol{\nabla}\cdot\mathbf{u}\right]$$

Plošče

Nevtralna ploskev je ploskev v materialu, ki ne doživi ne raztega ne skrčka.

Mongeva reprezentacija: z $\zeta(x,y)$ podamo premik nevtralne ploskve vzdolž osi z.

Zaradi tankosti je $\mathbf{p}$ enak po celi snovi.

Zunanje sile so mnogo manjše od notranjih napetosti $\Longrightarrow$ $p_{xz} = p_{yz} = p_{zz} = 0$.

$$\mathbf{u} = \begin{bmatrix} -z\frac{\partial^2\zeta}{\partial x^2} & -z\frac{\partial^2\zeta}{\partial x\partial y} & 0 \\ & -z\frac{\partial^2\zeta}{\partial y^2} & 0 \\ & & \frac{\sigma}{1-\sigma}z\left(\frac{\partial^2\zeta}{\partial x^2} + \frac{\partial^2\zeta}{\partial y^2}\right) \end{bmatrix}$$

$$f = f_0 +$$

$$+\frac{Ez^2}{2(1-\sigma^2)}\left\{\left(\frac{\partial^2\zeta}{\partial x^2} + \frac{\partial^2\zeta}{\partial y^2}\right)^2 + 2(1-\sigma)\left[\left(\frac{\partial^2\zeta}{\partial x\partial y}\right)^2 - \frac{\partial^2\zeta}{\partial x^2}\frac{\partial^2\zeta}{\partial y^2}\right]\right\}$$

$$D = \frac{Eh^3}{12(1-\sigma^2)}$$

$$D\nabla^2\nabla^2\zeta - P = 0 \qquad \text{(enačba ravnovesja)}$$

Robni pogoj prislonjene plošče: $\frac{\partial^2\zeta}{\partial\mathbf{n}^2} + \sigma\frac{\partial\varphi}{\partial l}\frac{\partial\zeta}{\partial\mathbf{n}} = 0$

Palice

Torzija

$$\tau = \frac{\mathrm{d}\varphi}{\mathrm{d}z}$$

$$\mathbf{u} = \tau(-yz, xz, \psi(x,y))$$

$$u_{xz} = \frac{\tau}{2}\left(-y + \frac{\partial\psi}{\partial x}\right)$$

$$u_{yz} = \frac{\tau}{2}\left(x + \frac{\partial\psi}{\partial y}\right)$$

$$p_{xz} = \mu\tau\left(-y + \frac{\partial\psi}{\partial x}\right) = 2\mu\tau\frac{\partial\chi}{\partial y}$$

$$p_{yz} = \mu\tau\left(x + \frac{\partial\psi}{\partial y}\right) = -2\mu\tau\frac{\partial\chi}{\partial x}$$

Vsi ostali u_{ij}, p_{ij} so enaki nič.

Ravnovesje

$$\nabla^2\psi = 0$$

$$\nabla^2\chi = -1$$

Prost robni pogoj ($\mathbf{f} = 0$) vzdolž roba preseka: $\chi\big|_{\text{rob}} = konst.$

$$M_z = -2\mu\tau\int\mathbf{r}\cdot\boldsymbol{\nabla}\chi\,\mathrm{d}S = G\tau$$

$$C = 4\mu\int(\boldsymbol{\nabla}\chi)^2\,\mathrm{d}x\,\mathrm{d}y$$

$$F = \frac{1}{2}\int C\tau^2\,\mathrm{d}z$$

Upogib

$$u_{zz} = \frac{x}{R}$$

$$u_{xx} = u_{yy} = -\sigma\frac{x}{R}$$

$$p_{zz} = E\frac{x}{R}$$

Vsi ostali u_{ij}, p_{ij} so enaki nič.

$$\mathbf{u} = \left(-\frac{1}{2R}\left[z^2 + \sigma(x^2 - y^2)\right], -\frac{\sigma xy}{R}, \frac{xz}{R}\right)$$

$$I = \int x^2\,\mathrm{d}x\,\mathrm{d}y$$

$$F = \frac{1}{2}\int EI\frac{1}{R^2}\,\mathrm{d}z$$

Globalna teorija palic

$$\hat{\mathbf{t}}(l) = \frac{\partial\mathbf{r}(l)}{\partial l} \qquad \text{(tangenta)}$$

$$\hat{\mathbf{n}}(l) = R\frac{\partial\hat{\mathbf{t}}(l)}{\partial l} \qquad \text{(normala)}$$

$$\frac{1}{R} = \hat{\mathbf{n}}\cdot\frac{\partial\hat{\mathbf{t}}}{\partial l} = \left|\frac{\partial\hat{\mathbf{t}}}{\partial l}\right|$$

$$\hat{\mathbf{t}} \parallel \hat{\mathbf{e}}_\zeta, \qquad \hat{\mathbf{t}} \perp \hat{\mathbf{e}}_\xi, \hat{\mathbf{e}}_\eta$$

$$\frac{\partial\hat{\mathbf{t}}}{\partial l} = \boldsymbol{\Omega}\times\hat{\mathbf{t}}$$

$$I_{ij} = \iint\left(r^2\delta_{ij} - r_ir_j\right)\mathrm{d}x_\eta\,\mathrm{d}x_\xi, \qquad \mathbf{r} = (x_\eta, x_\xi)$$

$$F = \frac{1}{2}\int\left[E\left(I_{\eta\eta}\Omega_\eta^2 + 2I_{\eta\xi}\Omega_\eta\Omega_\xi + I_{\xi\xi}\Omega_{\xi\xi}\right) + C\Omega_\zeta^2\right]\mathrm{d}l$$

Ravnovesje

$$\frac{\mathrm{d}\mathbf{F}}{\mathrm{d}l} = -\mathbf{K}$$

$$\frac{\mathrm{d}\mathbf{M}}{\mathrm{d}l} + \hat{\mathbf{t}}\times\mathbf{F} = 0$$

Samo upogib (tudi velike deformacije): $EI\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}l}\times\frac{\mathrm{d}^3\mathbf{r}}{\mathrm{d}l^3} = \mathbf{F}\times\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}l}$

Majhen upogib pravokoten na os z

Pišemo vektorje samo v xy ravnini. $t \doteq (\dot{x}, \dot{y}, 1)$

$$\mathbf{M} = EI\left(-\frac{\mathrm{d}^2y}{\mathrm{d}z^2}, \frac{\mathrm{d}^2x}{\mathrm{d}z^2}\right)$$

$$\mathbf{F} = -EI\frac{\mathrm{d}^3\mathbf{r}}{\mathrm{d}z^3} + F_z\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}z}$$

$$EI\frac{\mathrm{d}^4\mathbf{r}}{\mathrm{d}z^4} - F_z\frac{\mathrm{d}^2\mathbf{r}}{\mathrm{d}z^2} - \frac{\mathrm{d}F_z}{\mathrm{d}z}\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}z} - \mathbf{K} = 0 \qquad = -\rho\frac{\partial^2 u}{\partial t^2}$$

Elastični valovi

Longitudinalni val: $\boldsymbol{\nabla}\times\mathbf{u} = 0$

$$c_l^2 = \frac{E(1-\sigma)}{\rho(1+\sigma)(1-2\sigma)} = \frac{\lambda+2\mu}{\rho} = \frac{K+4\mu/3}{\rho}$$

Transverzalni val: $\boldsymbol{\nabla}\cdot\mathbf{u} = 0$

$$c_t^2 = \frac{E}{2\rho(1+\sigma)} = \frac{\mu}{\rho} < c_l^2$$

$$\ddot{\mathbf{u}} = -c_t^2\boldsymbol{\nabla}\times\boldsymbol{\nabla}\times\mathbf{u} + c_l^2\boldsymbol{\nabla}\boldsymbol{\nabla}\cdot\mathbf{u}$$

$$p_{ik} = 2\rho c_t^2u_{ik} + \rho(c_l^2 - 2c_t^2)u_{ll}\delta_{ik}$$

Odboj in lom:

$$k_\parallel^{\text{vpadni}} = k_\parallel^{\text{odbiti}} = k_\parallel^{\text{lomljeni}}$$