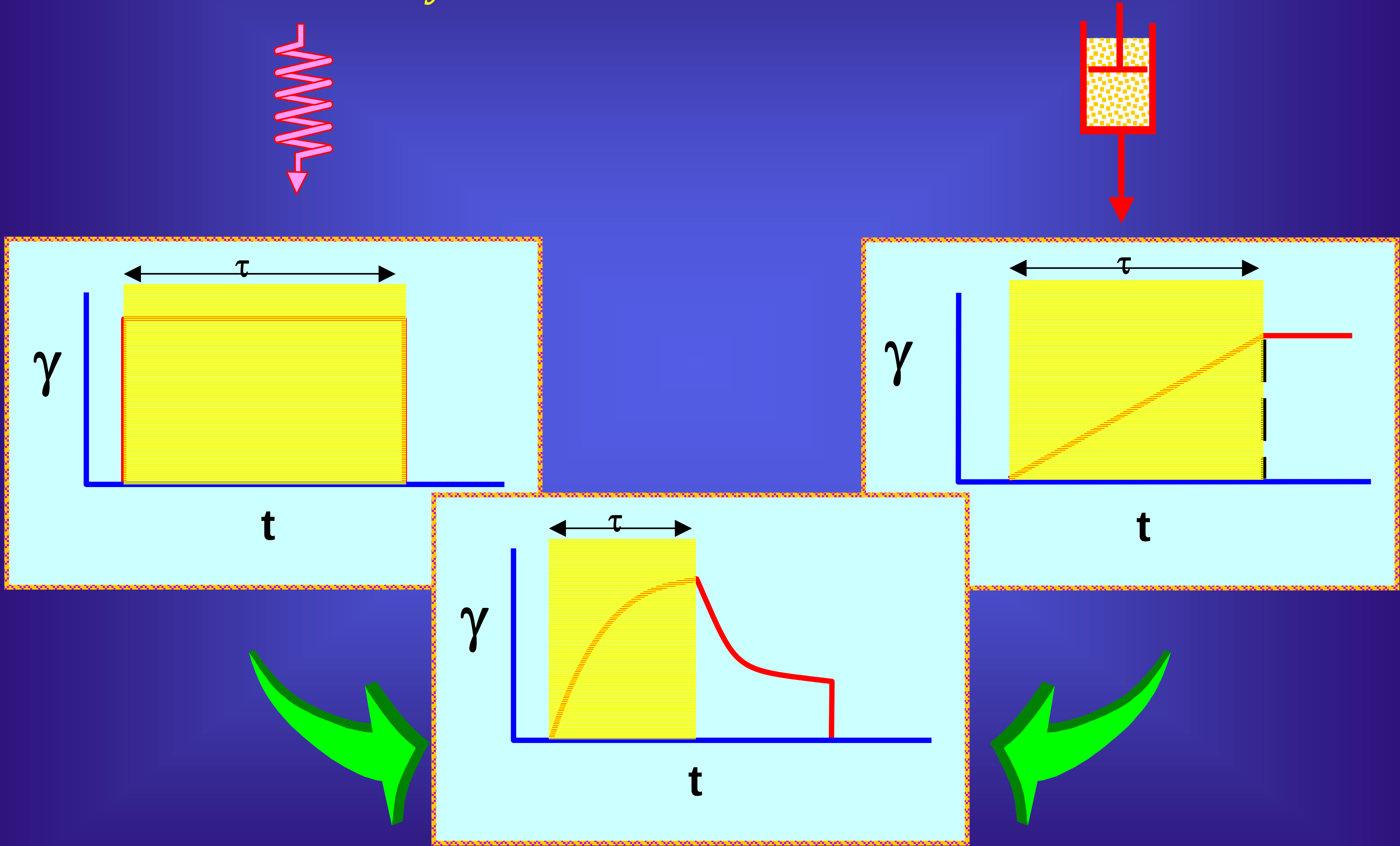
INTRODUCCIÓN

Extremos clásicos

Sólido Elástico -*Ley de Hooke*

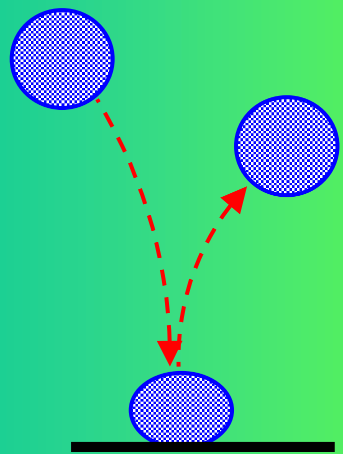
Fluido Viscoso-*Ley de Newton*

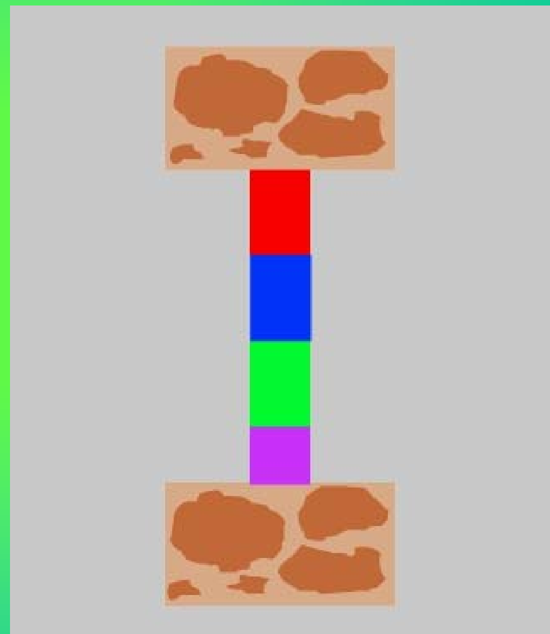


Material Viscoelástico

Número de Debora [De] = τ / T

Tiempo de relajación

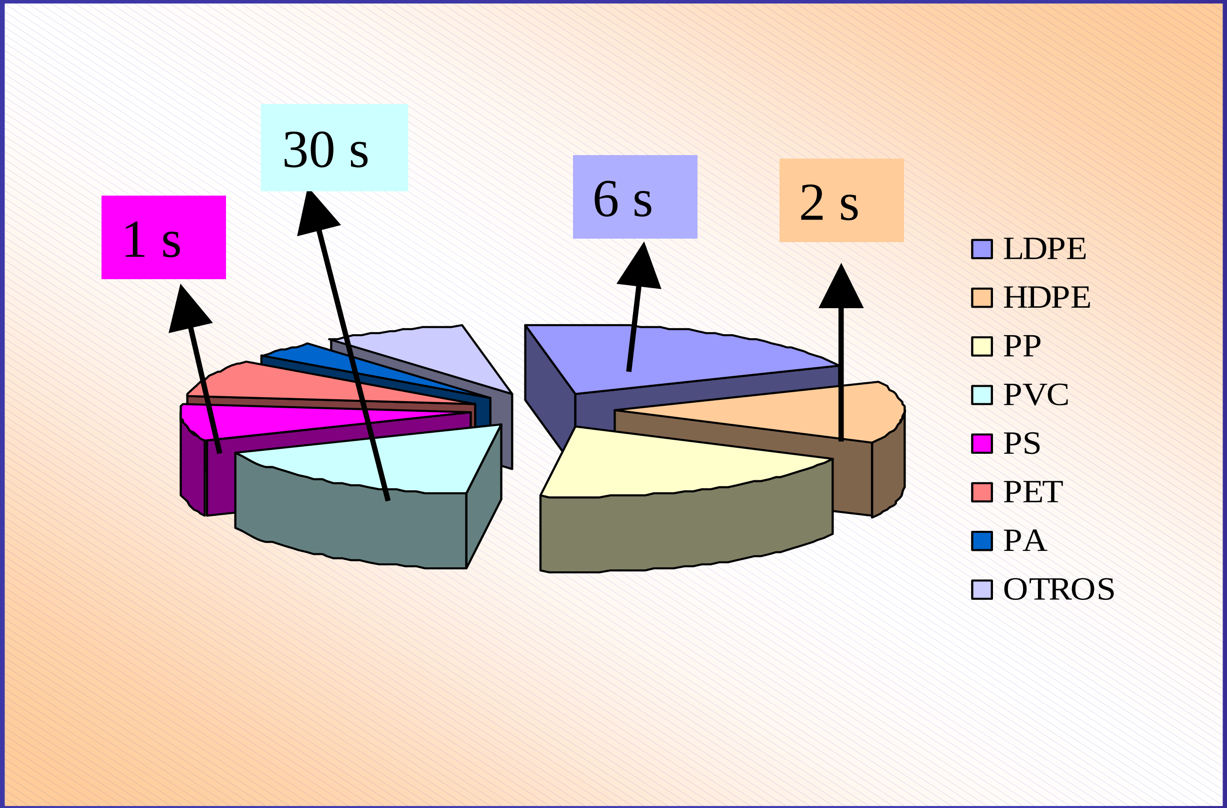




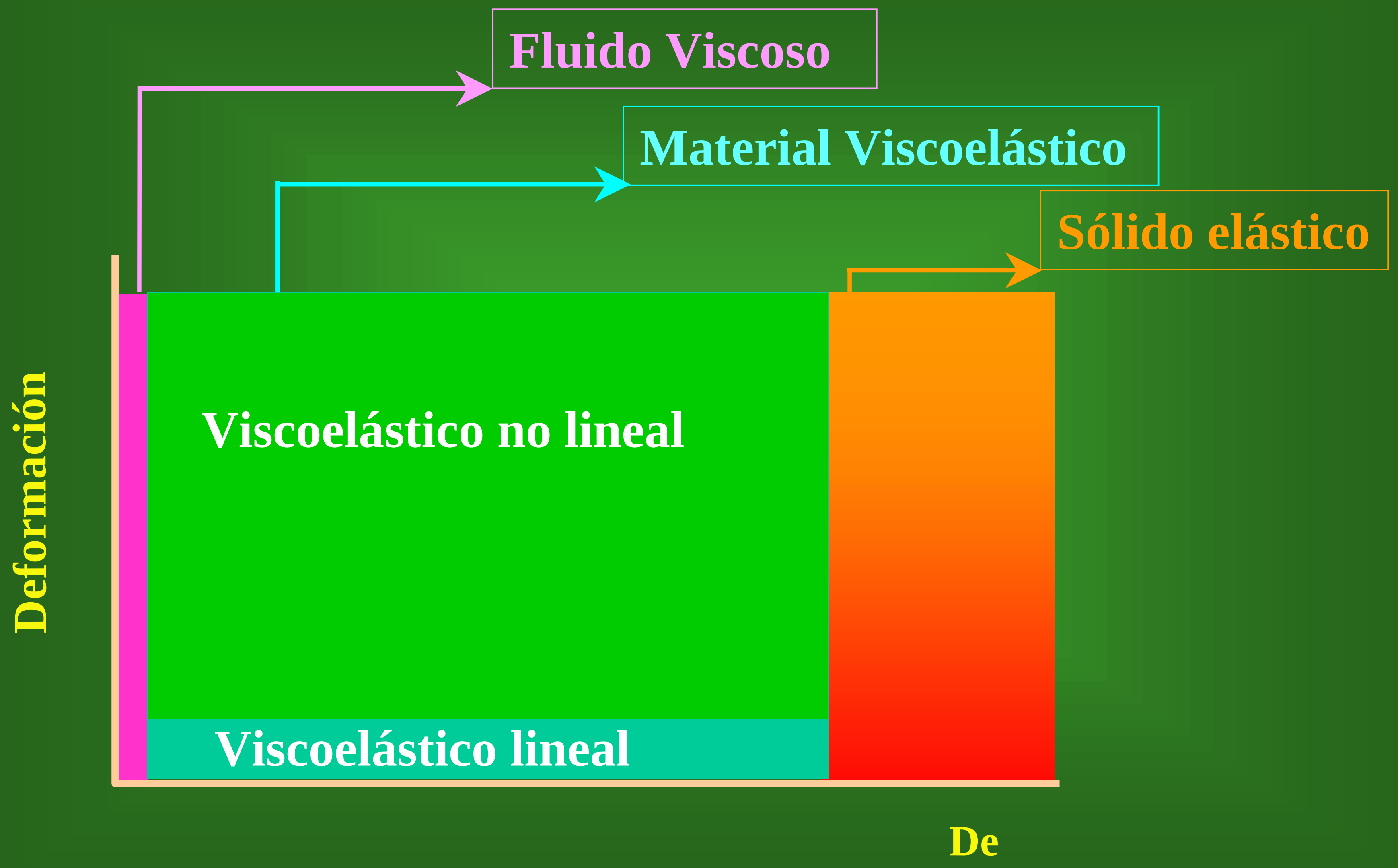
De $\rightarrow \infty$

De $\rightarrow$ 0

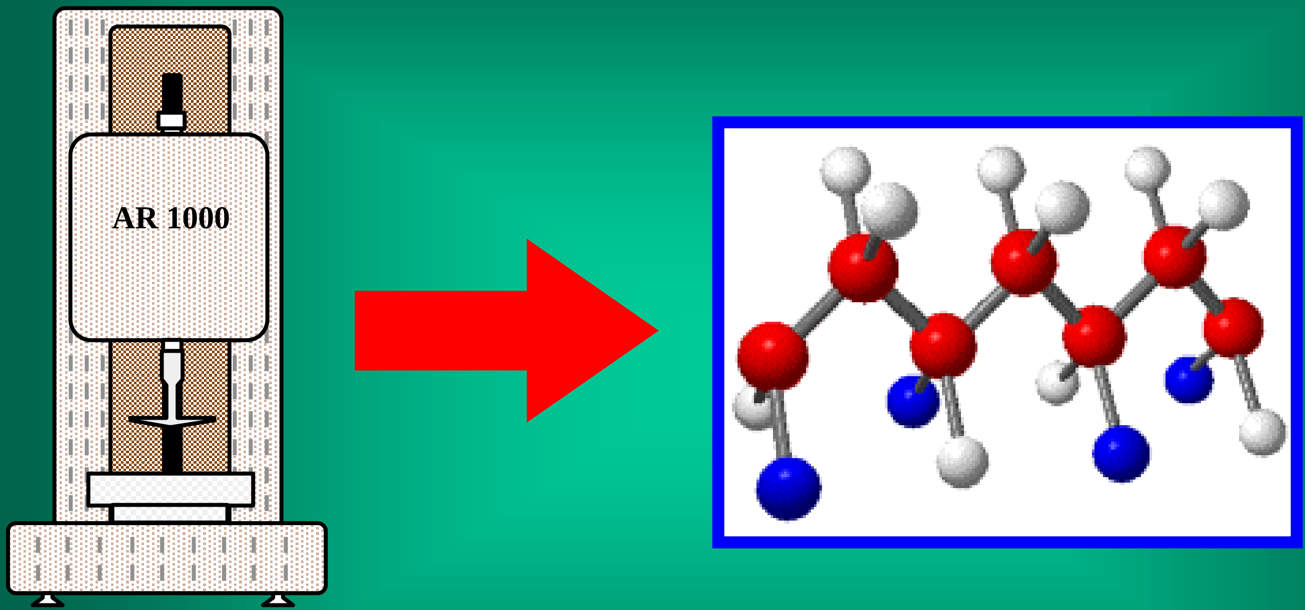
Valores de algunos tiempos de relajación característicos

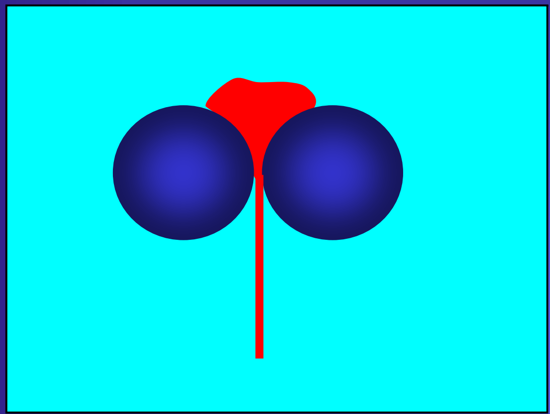


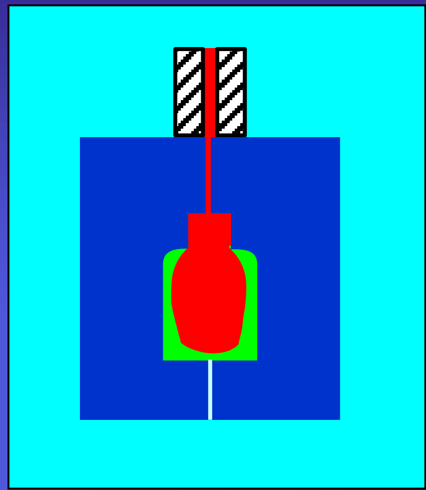
Uso de Polímeros en Europa durante 1999
(Asociación Europea de Fabricantes de Polímeros)

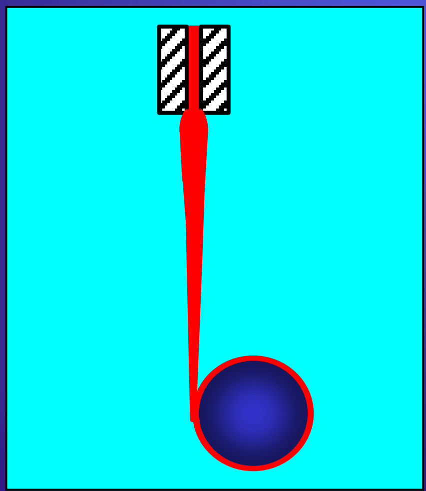

Fluido Viscoso
Material Viscoelástico
Sólido elástico
Viscoelástico no lineal
Viscoelástico lineal
Deformación
De

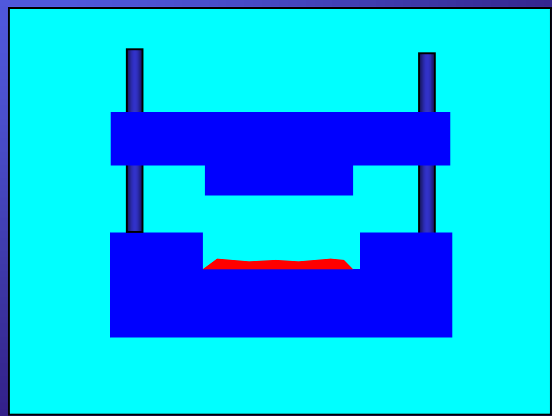
Viscoelasticidad lineal: Régimen de aplicación



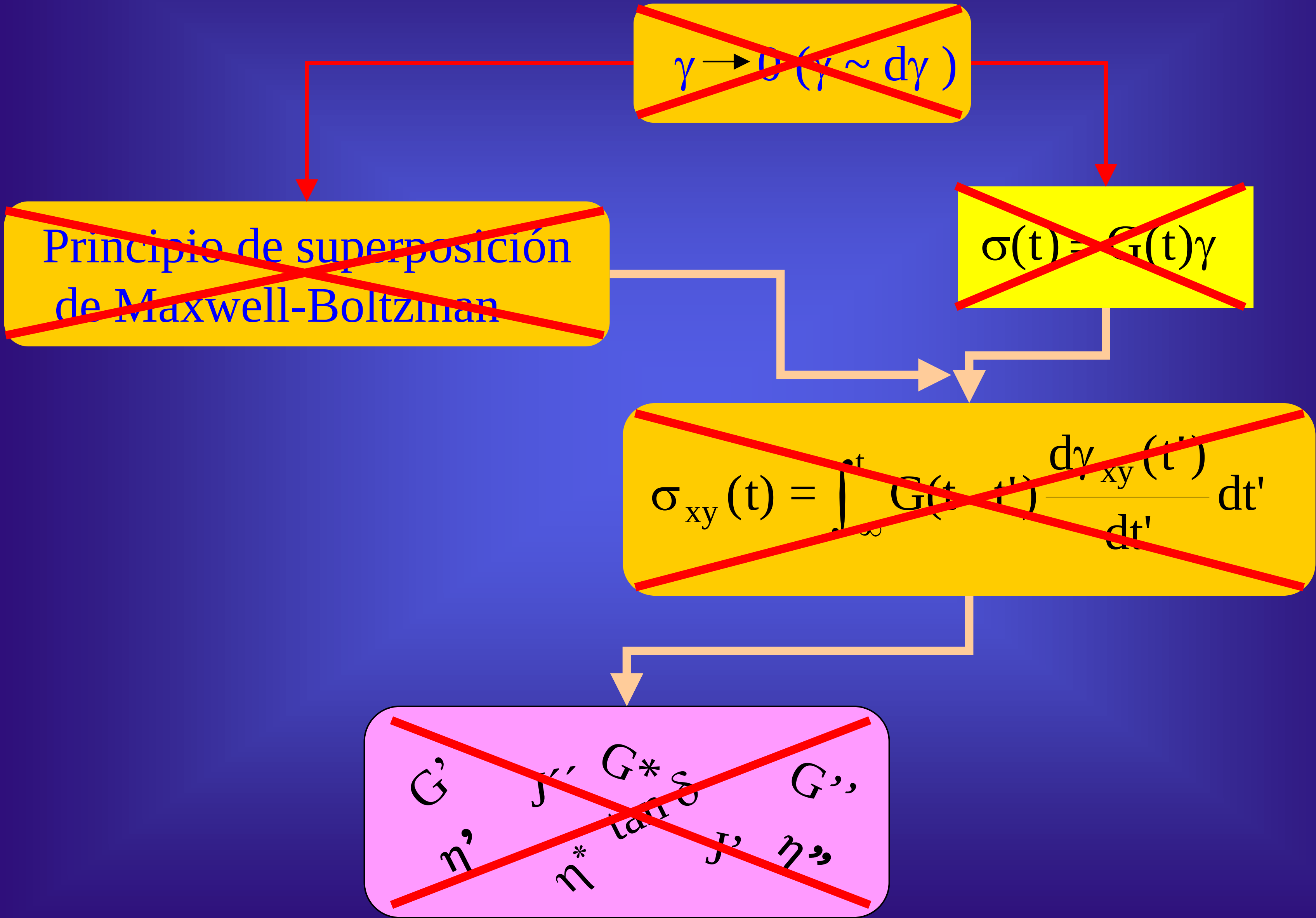




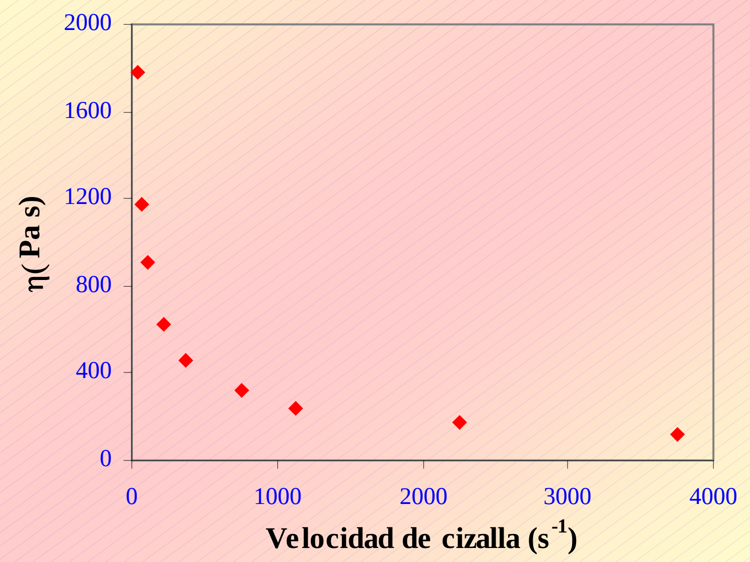




Ecuaciones basadas en viscoelasticidad lineal

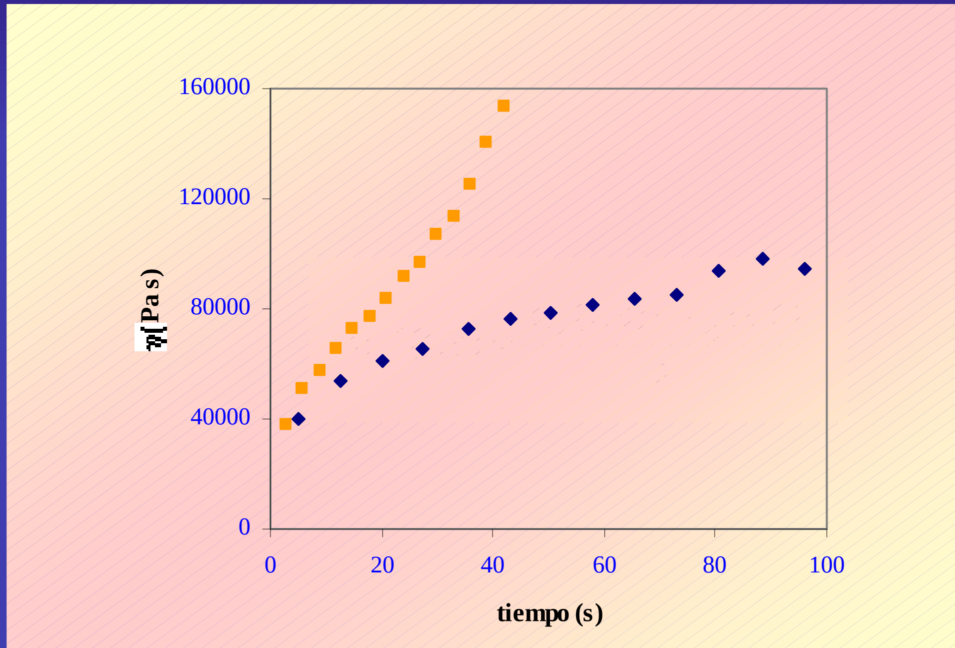


1. FENÓMENOS NO LINEALES

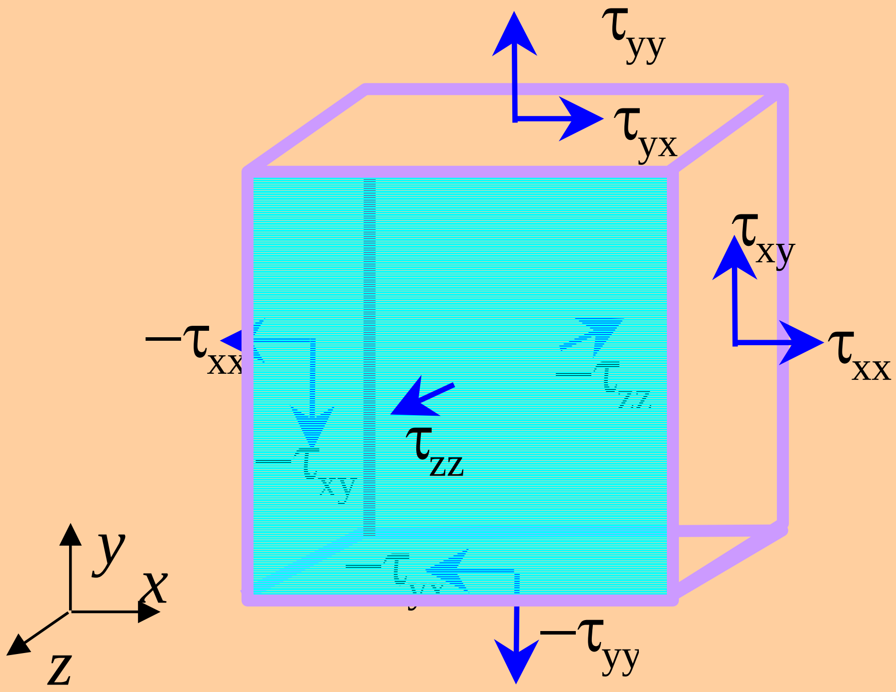


2000
1600
1200
800
400
0
η(Pa s)
0
1000
2000
3000
4000
Velocidad de cizalla (s-1)

LDPE,170ºC



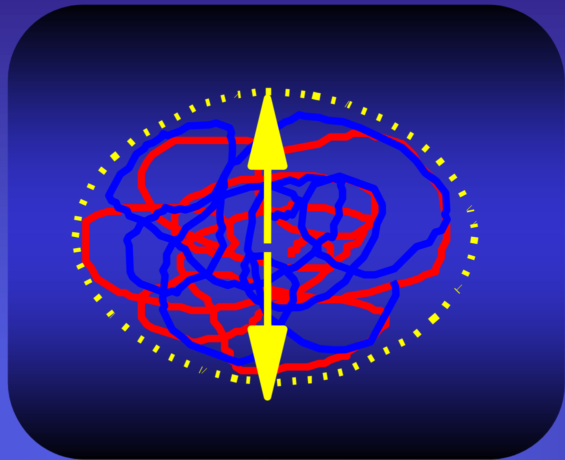
LDPE,170ºC



$$\vec{\vec{\tau}} = \begin{pmatrix} \tau_{xx} & \tau_{xy} & 0 \\ \tau_{yx} & \tau_{yy} & 0 \\ 0 & 0 & \tau_{zz} \end{pmatrix}$$

$$\tau_{xx} = \tau_{yy} = \tau_{zz} = P$$

$$\tau_{xx} \neq \tau_{yy} \neq \tau_{zz}$$



Diferencias esfuerzos normales:

- **Principal** $N_1 = \left(\tau_{xx} - \tau_{yy}\right)$
- **Secundaria** $N_2 = \left(\tau_{yy} - \tau_{zz}\right)$

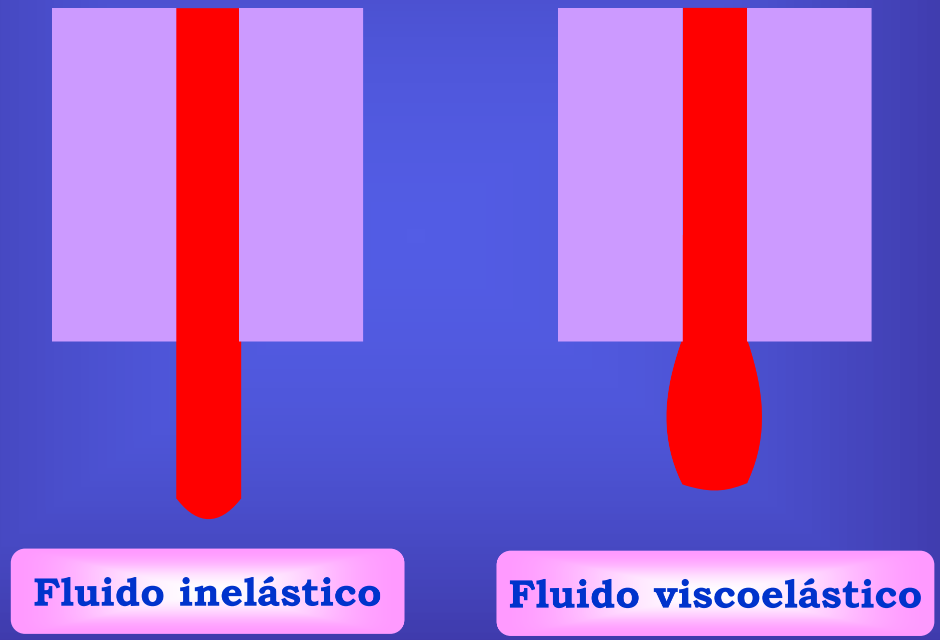
Coeficientes de esfuerzos normales:

- **Principal** $\Psi_1(\gamma) = \left(\left(\tau_{xx} - \tau_{yy}\right) \Big/ \left(\dot{\gamma}\right)^2 \right)$
- **Secundario** $\Psi_2(\gamma) = \left(\left(\tau_{yy} - \tau_{zz}\right) \Big/ \left(\dot{\gamma}\right)^2 \right)$

Consecuencias observables de los esfuerzos normales

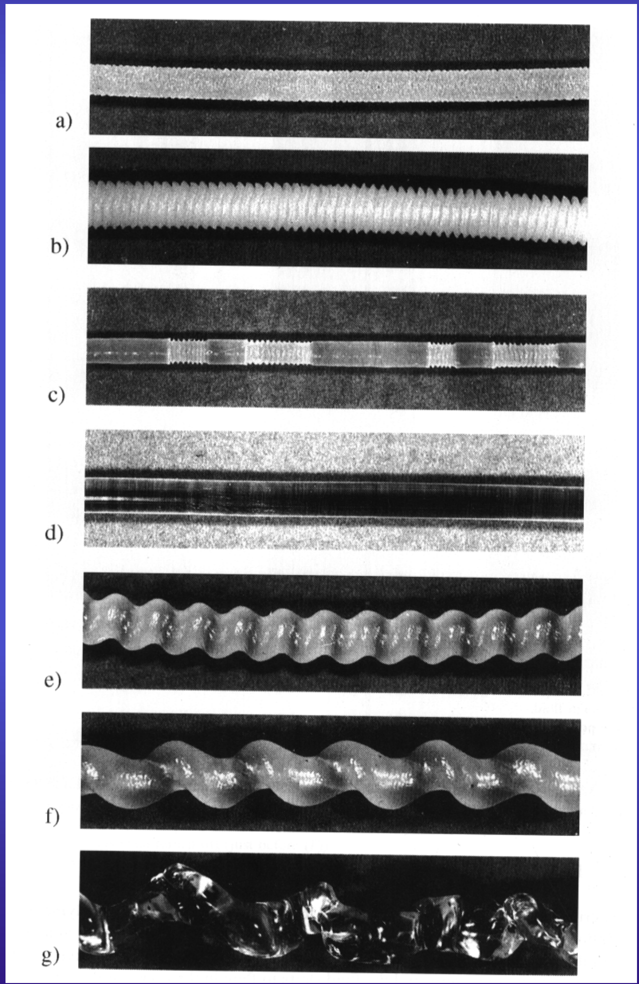
CONSECUENCIAS OBSERVABLES

- **Hinchamiento post-extrusión**



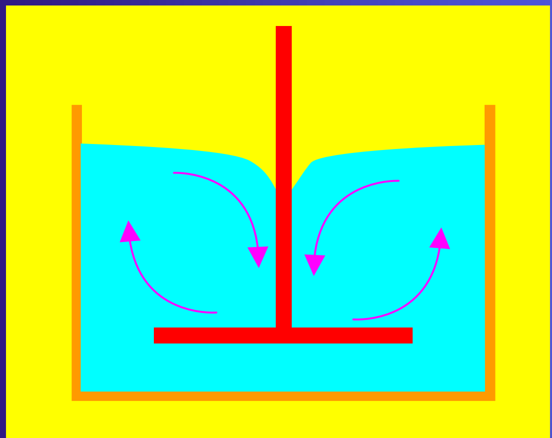
Consecuencias observables de los esfuerzos normales

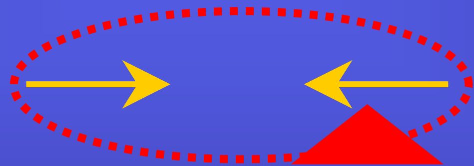
Inestabilidades del flujo



Consecuencias observables de los esfuerzos normales

Efecto Weisenberg

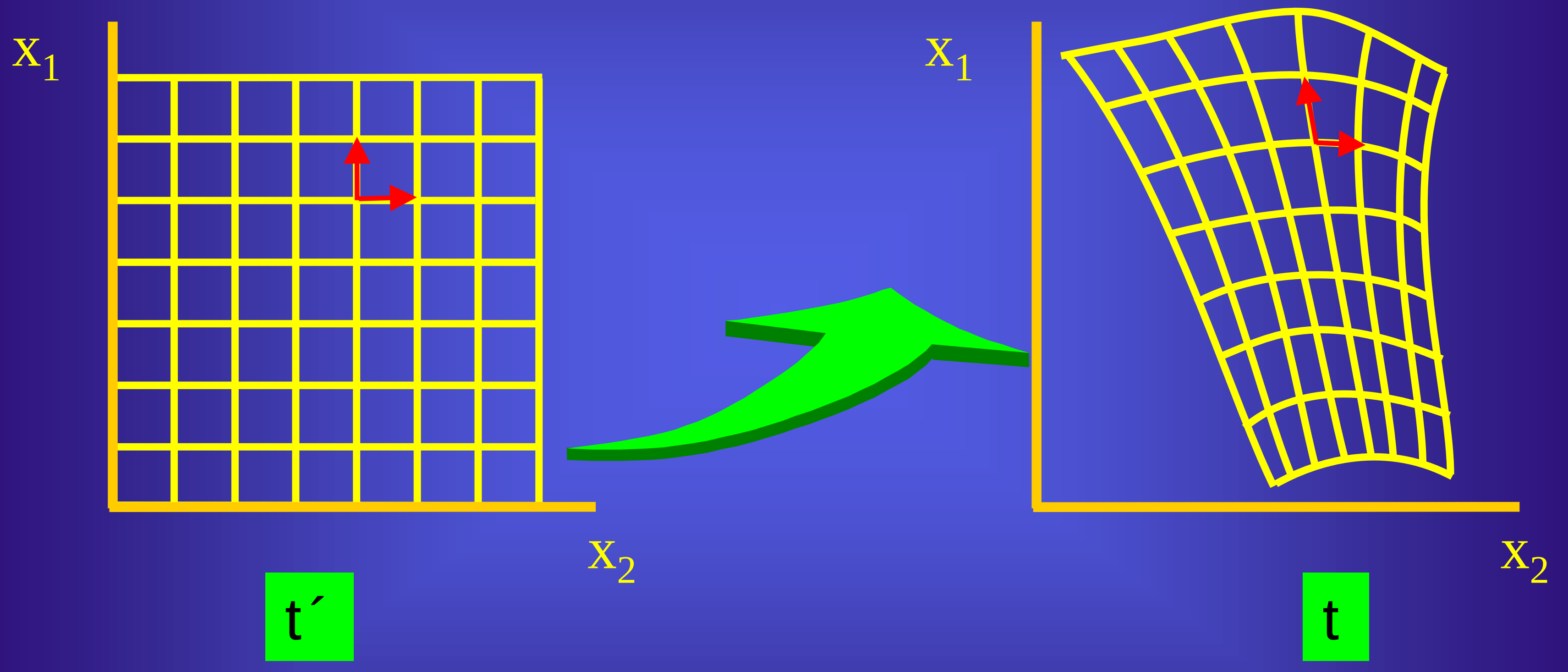




Poliacrilamida en agua/glicerina

2. ECUACIONES CONSTITUTIVAS PARA LA VISCOELASTICIDAD NO LINEAL

Sistema de coordenadas inmerso en el fluido



Expresión matemática de la adopción de un sistema de ejes móviles

Viscoelasticidad lineal | ***Viscoelasticidad no lineal***

$$B_{ij} = \sum_m \left(\frac{\partial x_i}{\partial x'_m} \frac{\partial x_j}{\partial x'_m} \right)$$

$$\vec{\vec{\gamma}}$$

$$\vec{\vec{\gamma}}_0 = \vec{\vec{\delta}} - \vec{\vec{B}} = \vec{\vec{\delta}} - \vec{\vec{C}}^{-1}$$

$$\frac{\partial \vec{\vec{\pi}}}{\partial t}$$

$$\vec{\vec{\pi}}_{(1)} = \frac{D \vec{\vec{\pi}}}{Dt} - \left\{ (\vec{\nabla} \vec{v})^T \bullet \vec{\vec{\pi}} + \vec{\vec{\pi}} \bullet (\vec{\nabla} \vec{v}) \right\}$$

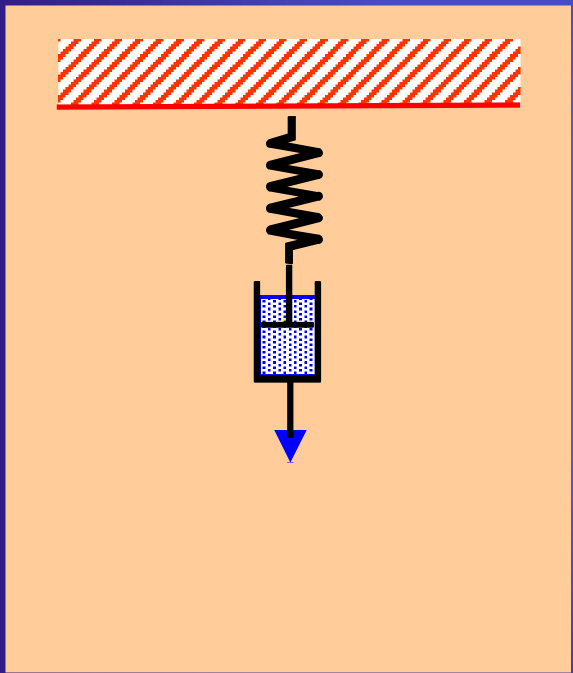
$$\frac{D}{Dt} = \frac{\partial}{\partial t} + v \bullet \nabla$$

$$\frac{\partial^n \vec{\vec{\gamma}}}{\partial t^n}$$

$$\vec{\vec{\gamma}}_{n+1} = \frac{D \vec{\vec{\gamma}}_n}{Dt} - \left\{ (\vec{\nabla} \vec{v})^T \bullet \vec{\vec{\gamma}}_n + \vec{\vec{\gamma}}_n \bullet (\vec{\nabla} \vec{v}) \right\}$$

$$\vec{\vec{\gamma}}_1 = \dot{\vec{\vec{\gamma}}}$$

Modelo de White-Metzner



$$\vec{\vec{\tau}} + \frac{\eta_0}{G}\frac{\partial \vec{\vec{\tau}}}{\partial t} = -\eta_0 \frac{\partial \vec{\vec{\gamma}}}{\partial t}$$

$$\vec{\vec{\tau}} + \frac{\eta_0}{G}\vec{\vec{\tau}}_{(1)} = -\eta(\dot{\gamma})\,\vec{\vec{\gamma}}_{(1)}$$