FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

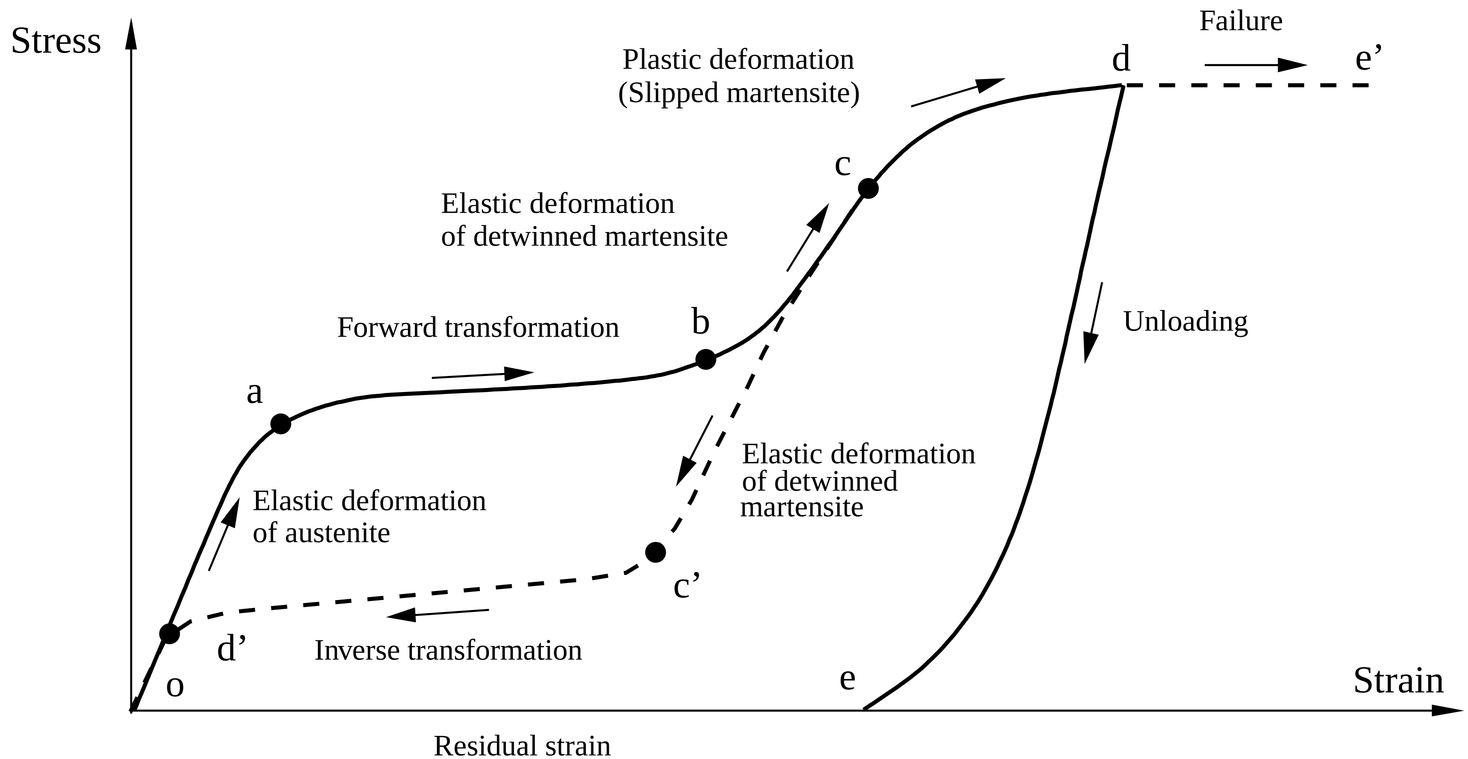
Vibration control with shape memory alloys in civil engineering strutctures

Filipe Amarante dos Santos

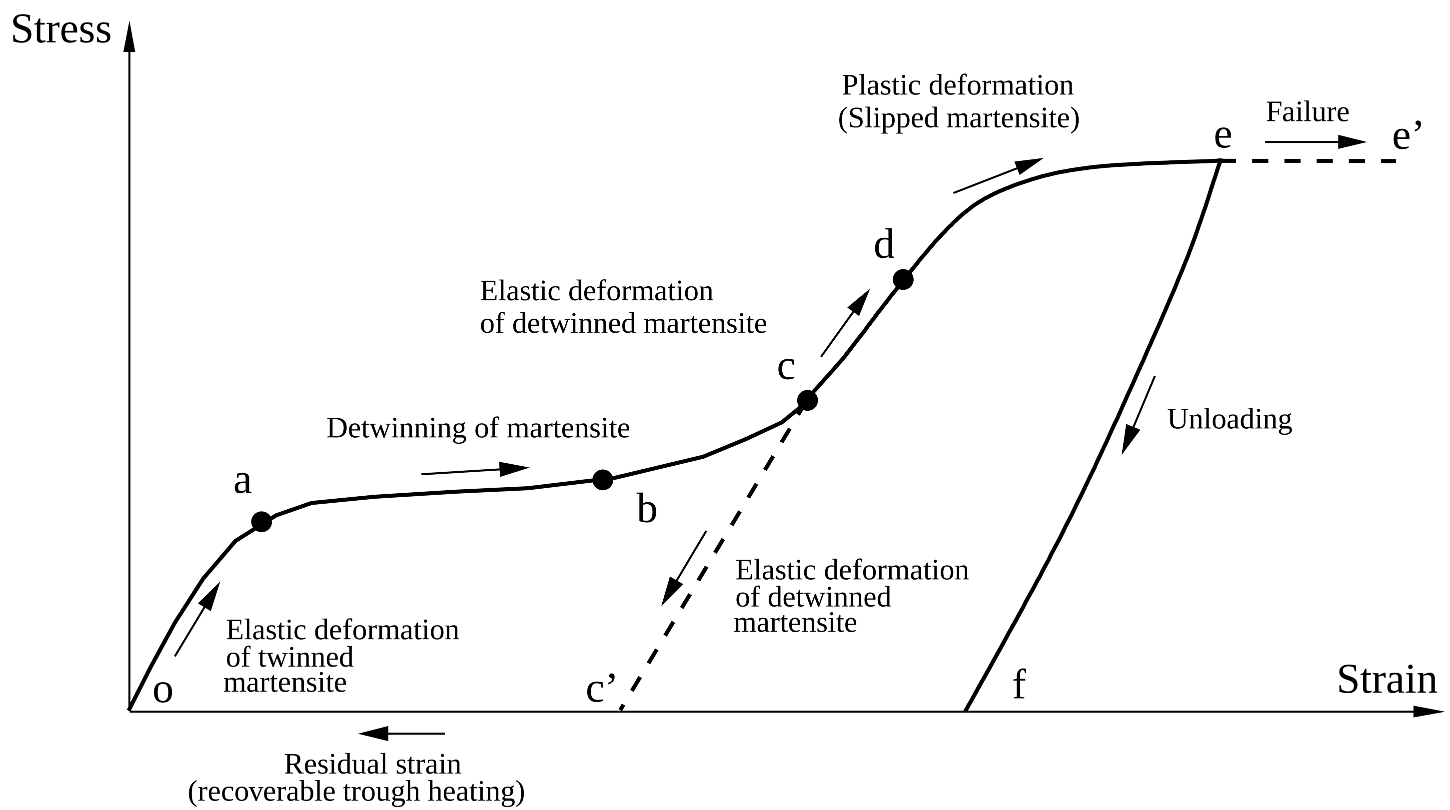
Processing, characterization and applications of shape memory alloys

June 14, 2013

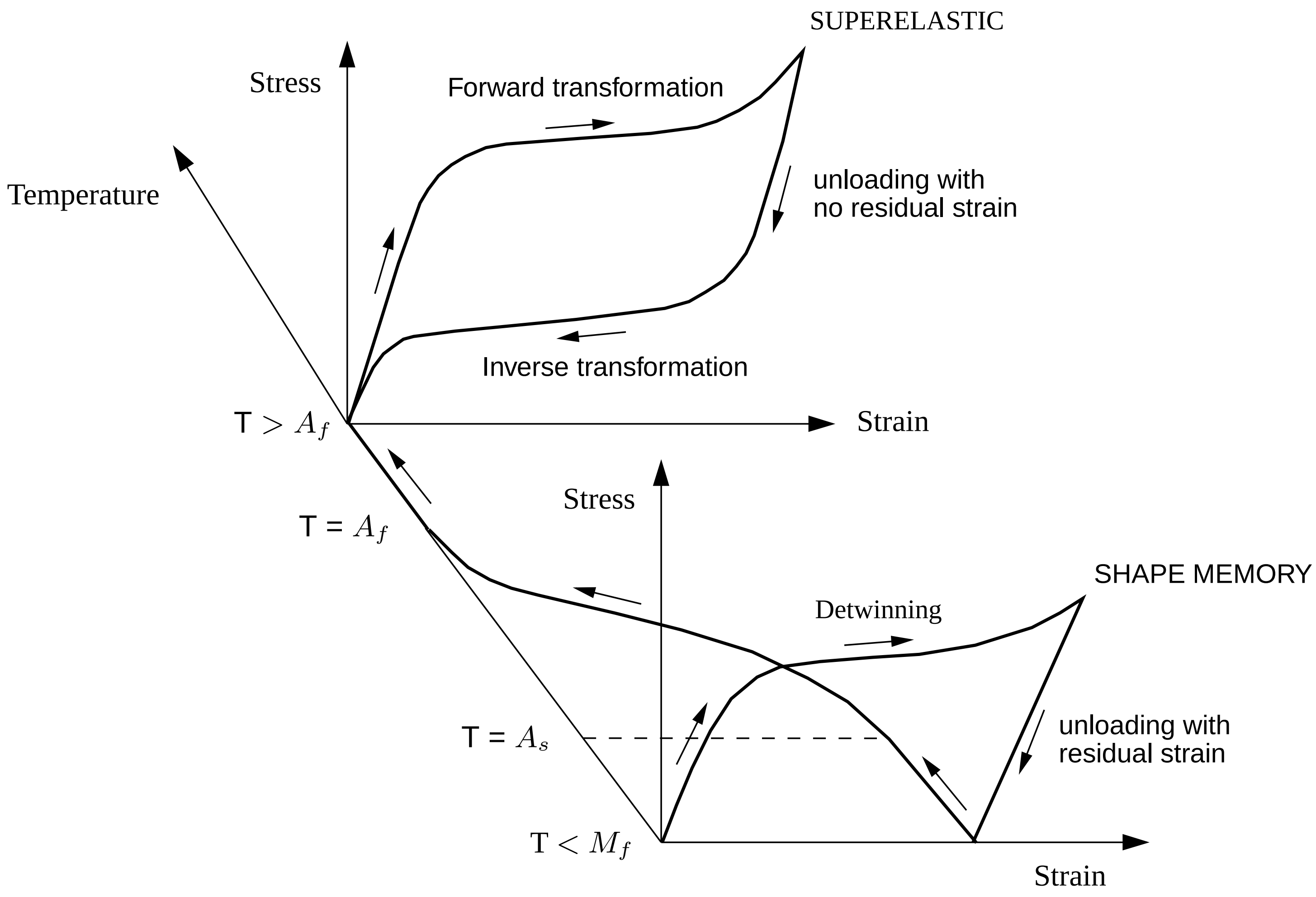
Generic stress-strain response of a SMA above A_f



Generic stress-strain response of a SMA below M_f

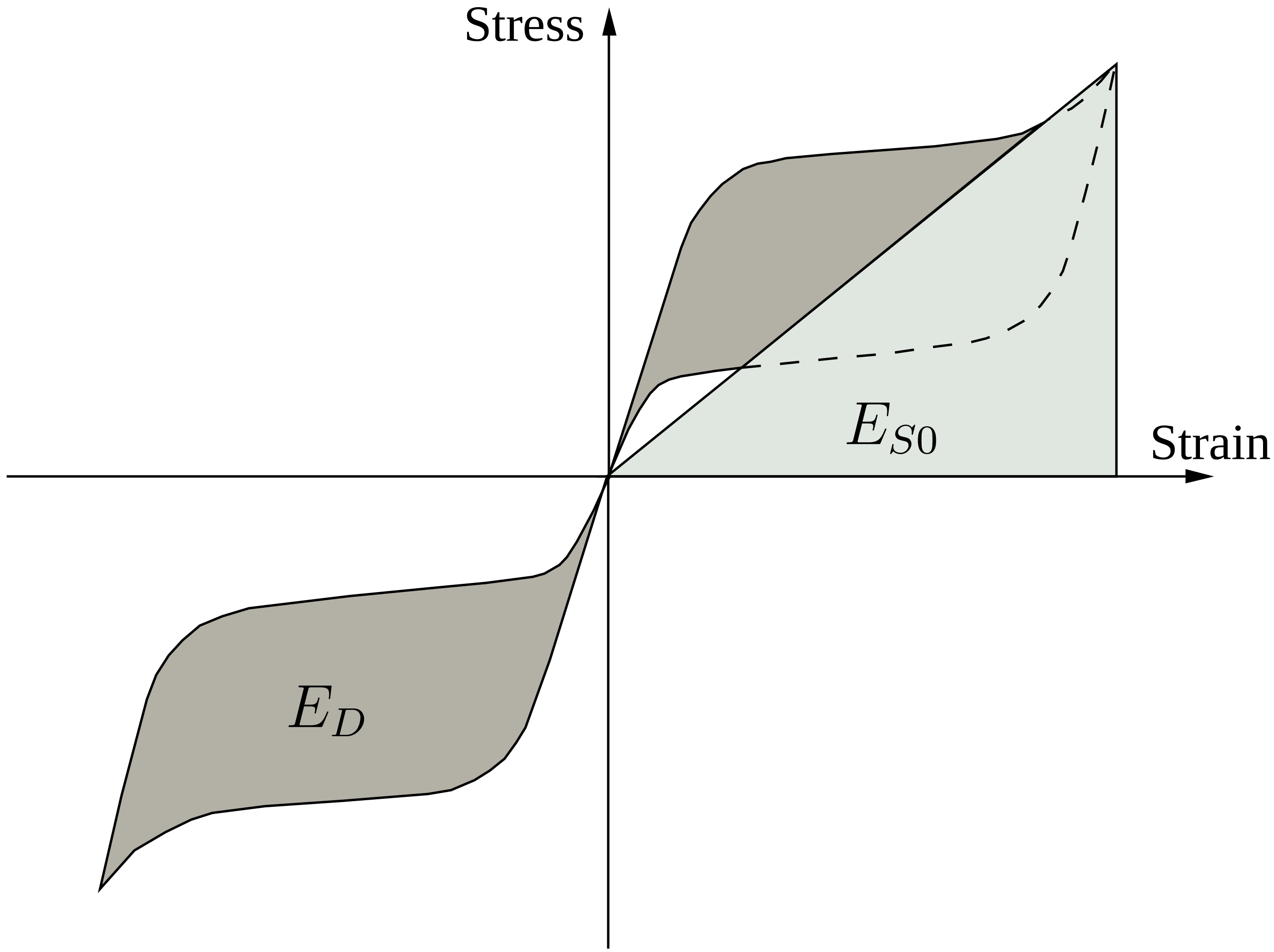


Shape-memory and superelastic sequence. Three dimensional stress, strain and temperature diagram



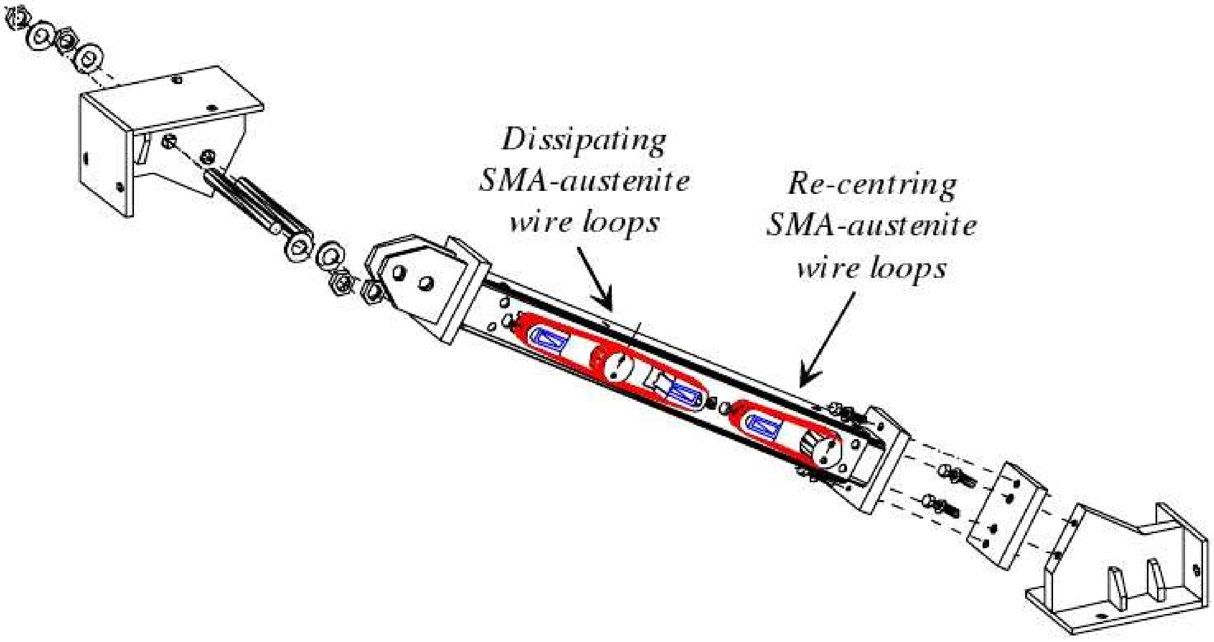
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Definition of energy dissipated E_D in a superelastic loading cycle and maximum strain energy E_{S0}

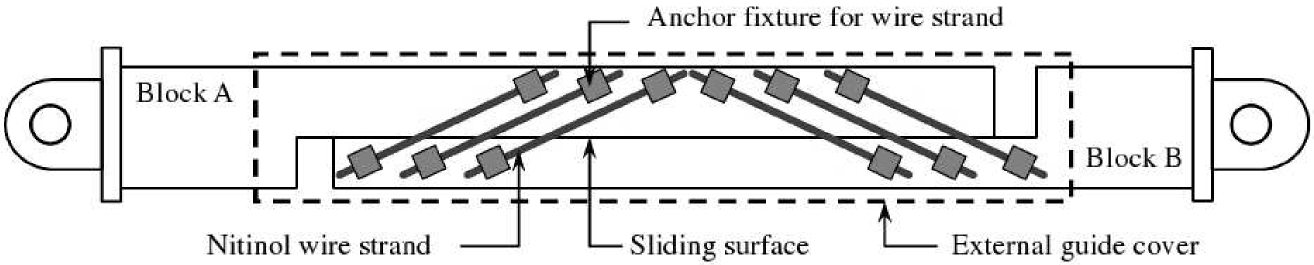


Small-scale steel framed prototype with SMA braces (adapted from Boroscheck)

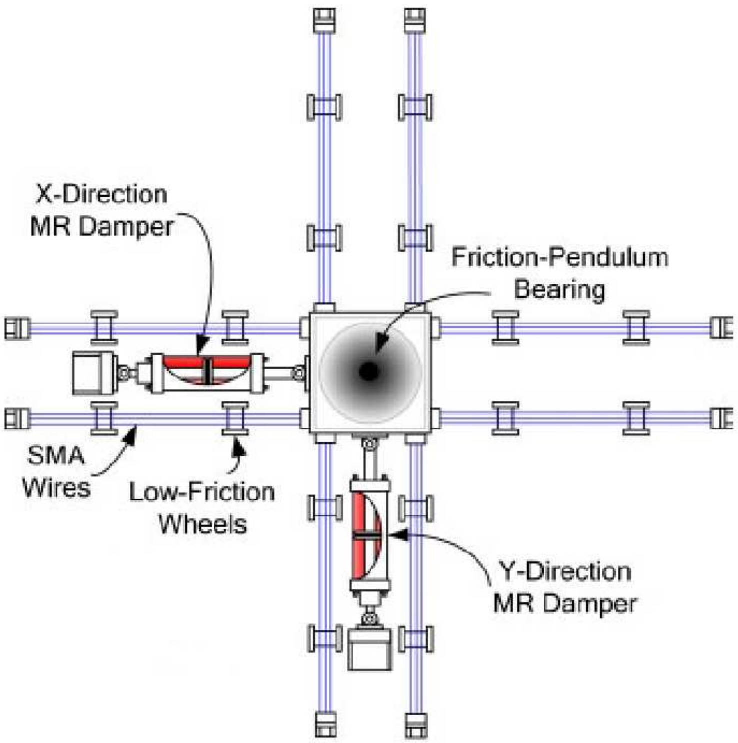
SMA-based energy dissipating and re-centering brace (adapted from Dolce)

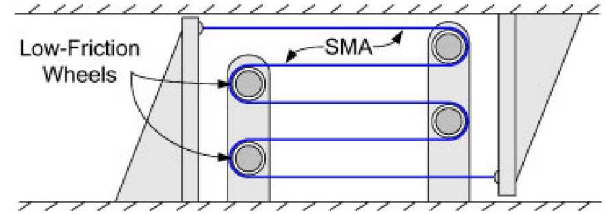


Adaptive vibration control device for bracing systems (adapted from Zhang and Zu)

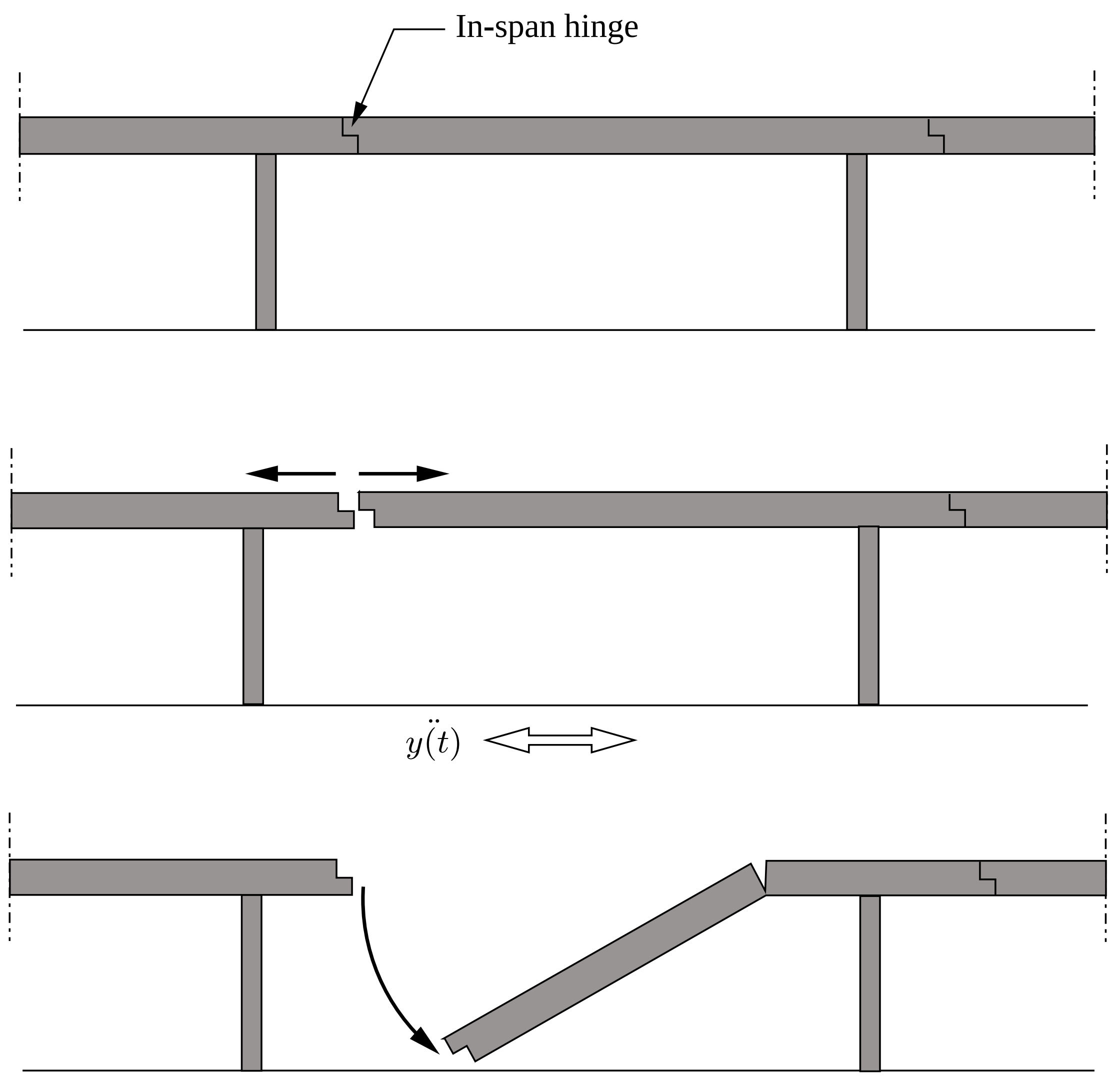


Configuration of elastomeric bearings, friction-pendulum bearings, SE austenitic wires and MR dampers. Low-friction wheels for SMA wire installation (adapted from Shook)





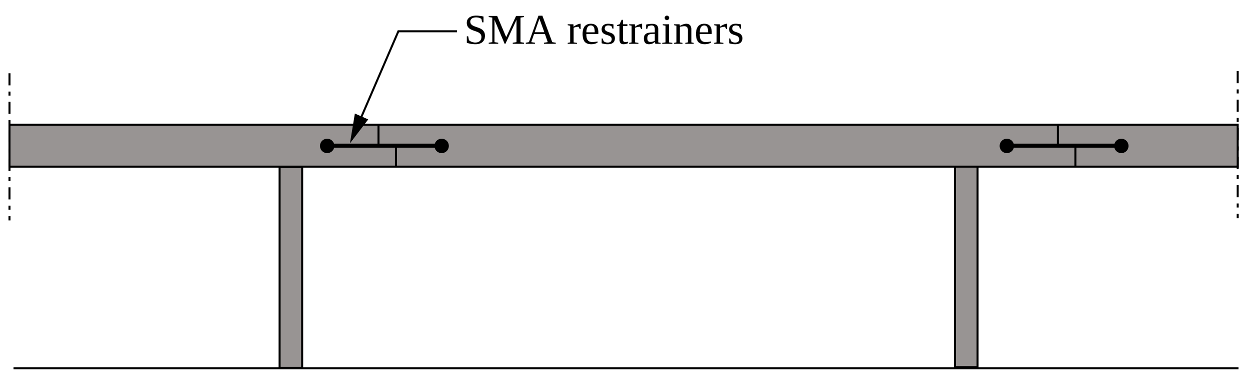
Unseating of bridge at in-span hinge during an earthquake



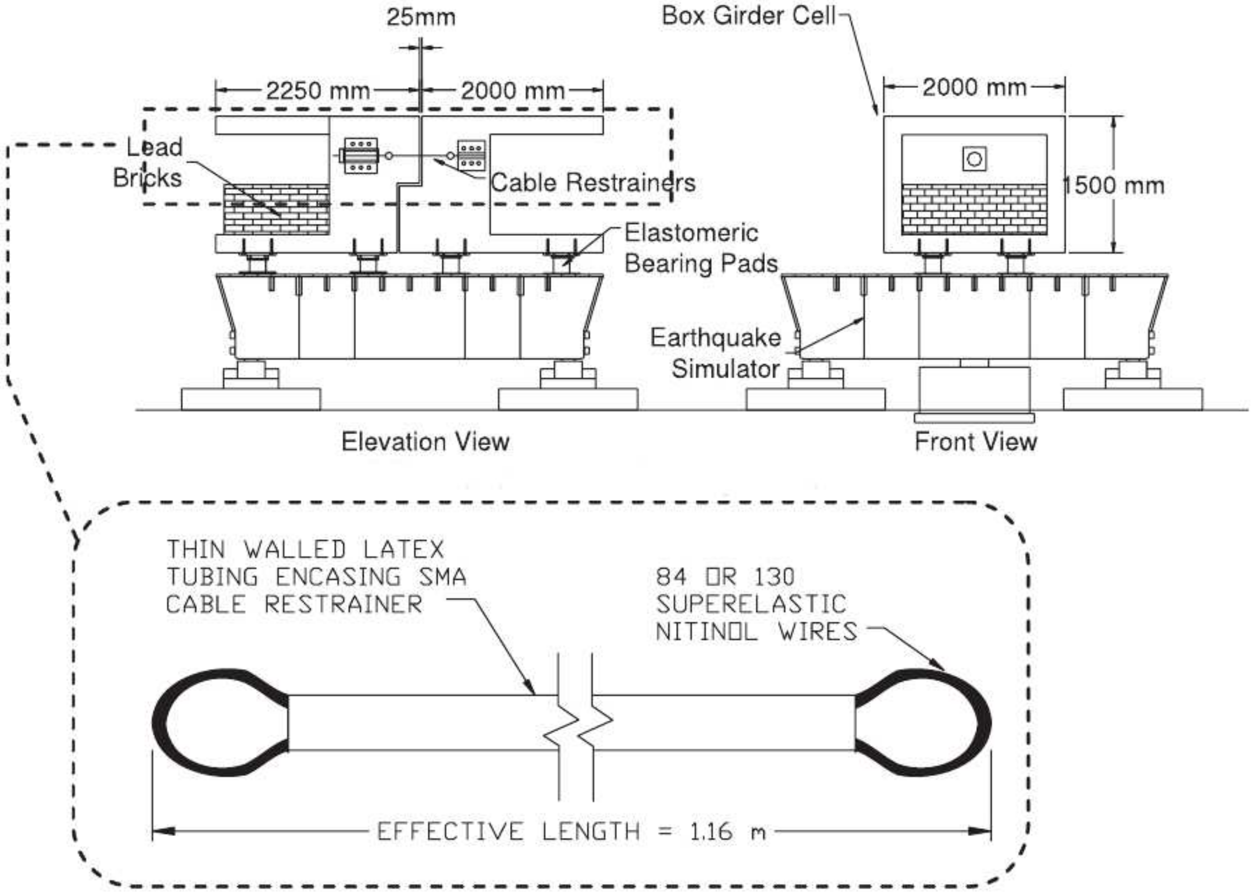
Colapso de ponte durante o sismo de Northridge (1994)(Johnson et al.)

Colapso de ponte reforçada com elementos tradicionais de retenção, em aço, durante o sismo de Northridge (1994) (Johnson et al.)

Restraining solution with SMA elements in a multi-span simply supported bridge

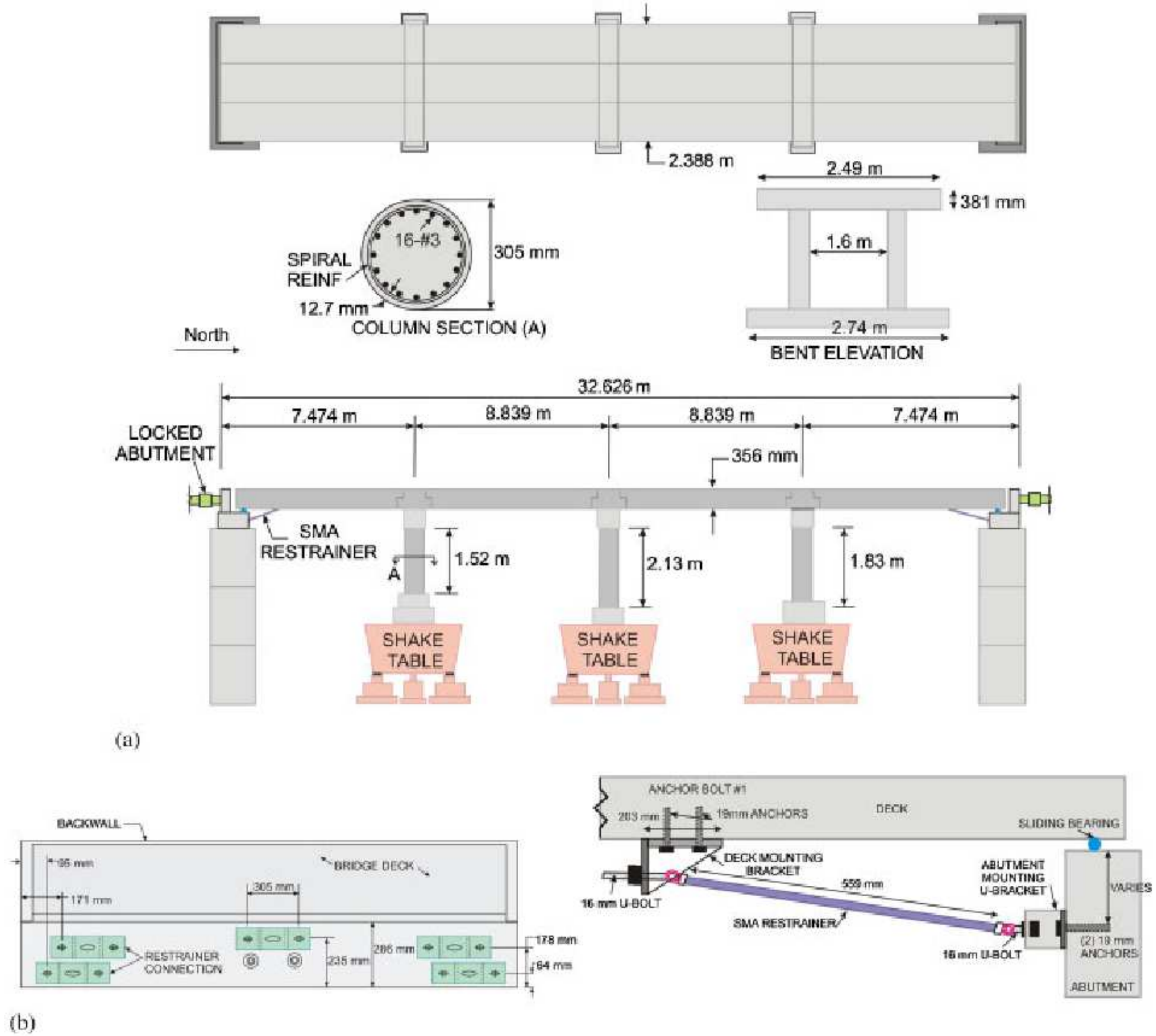


Schematic of the test setup and SMA restrainer cable (adapted from Johnson)



SMA restrainer test setup (adapted from Johnson)

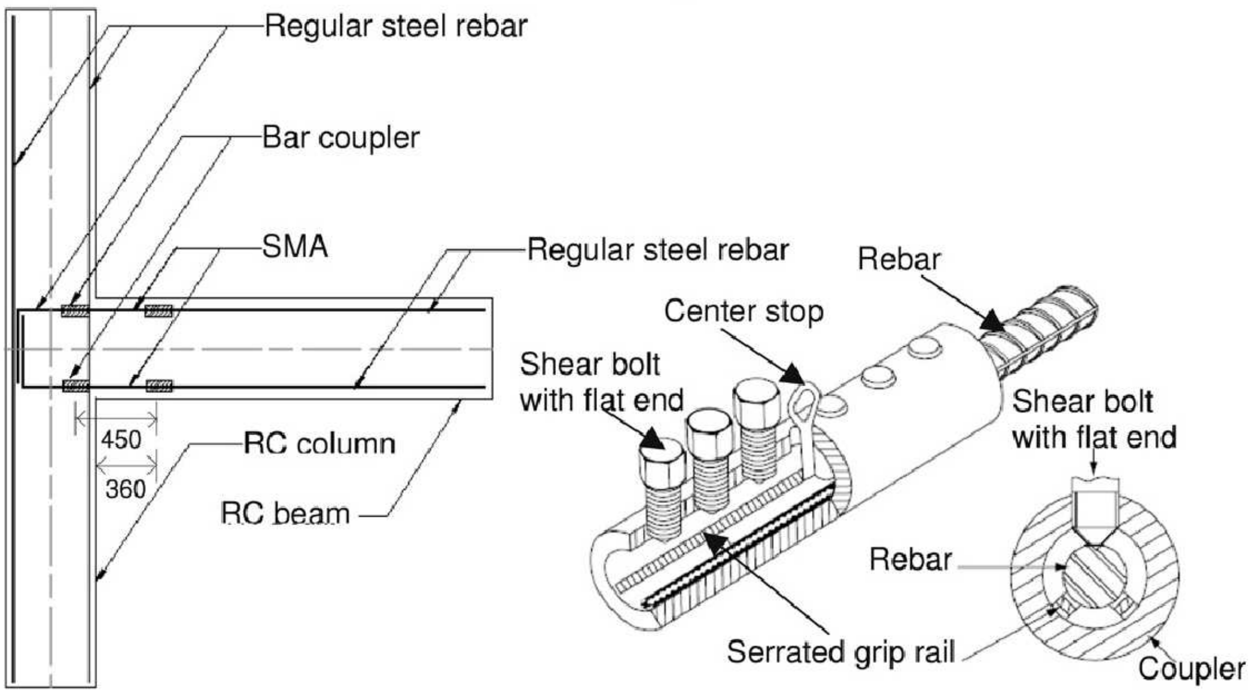
Schematic of the test setup and SMA restrainer cable (adapted from Padgett)



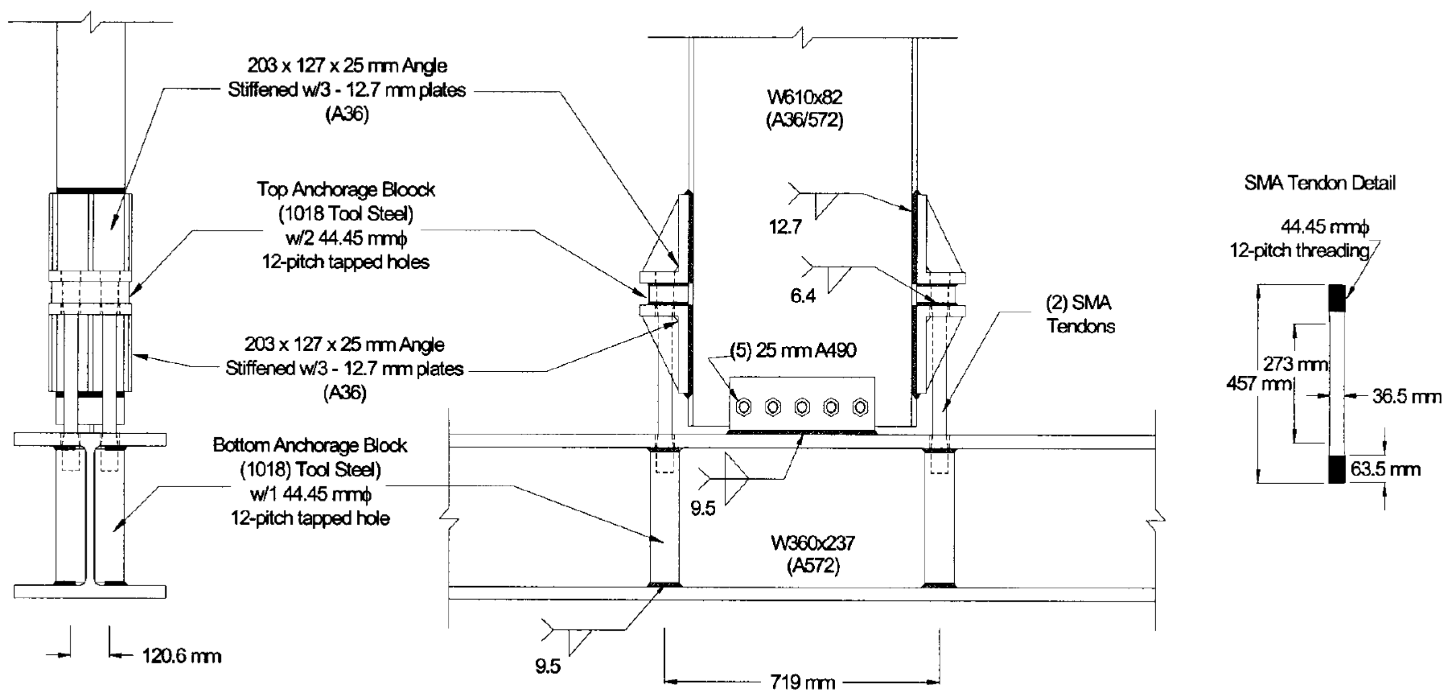
SMA restrainer test setup (adapted from Johnson)

Reinforcement details of beam-column element with coupler (dimensions in mm) (adapted from Alam)



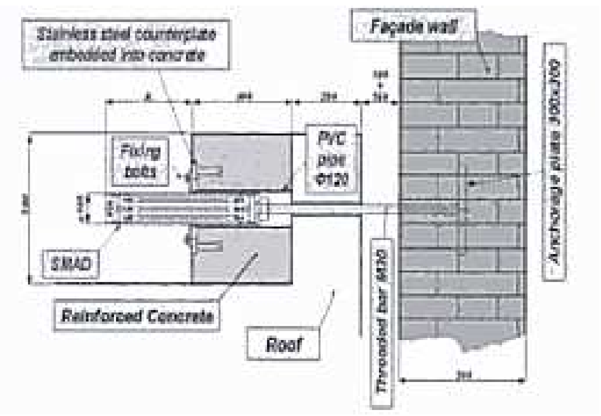
Schematic of the SMA-based connection test setup (adapted from Ocel)



SMA-based full-scale connection test setup (adapted from Ocel)

Basilica of St. Francis of Assisi in Italy

(a) General view.



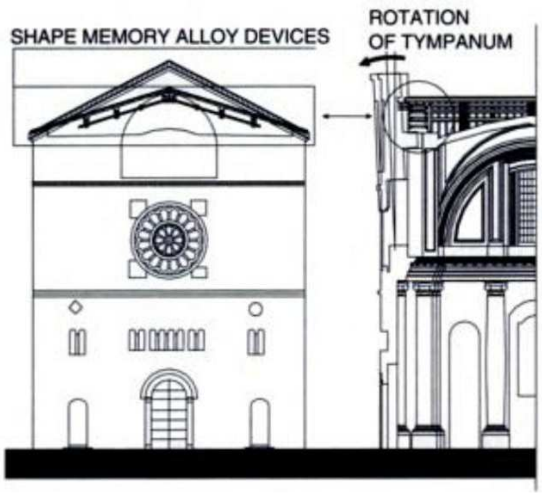
(b) Anchorage detail of SMAD.

(c) SMAD application.

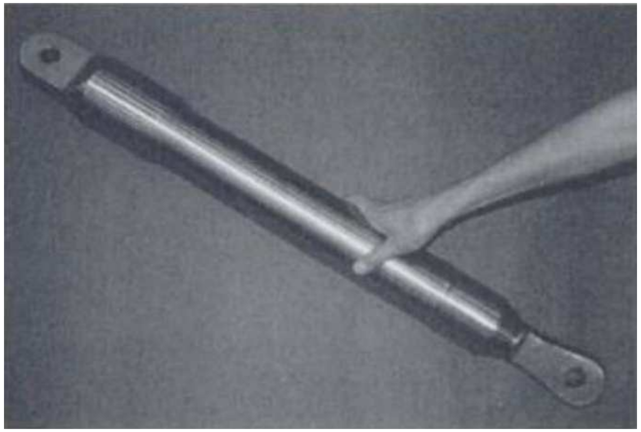
(d) SMADs arrangement.

St. Feliciano Cathedral in Italy

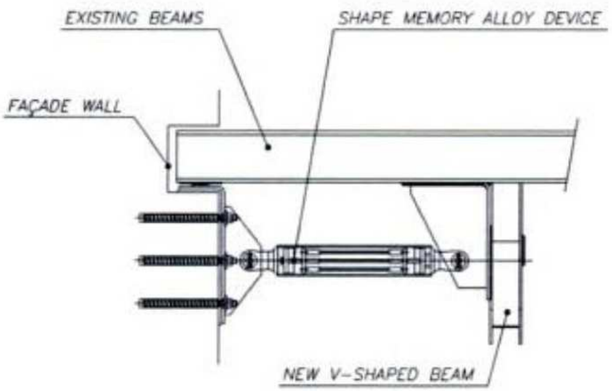
(a) General view



(b) SMADs arrangement



(c) SMAD ($F = 27$ kN, $\Delta u = \pm 20$ mm)



(d) Anchorage detail of SMAD

S. Giorgio Church Bell-Tower in Italy

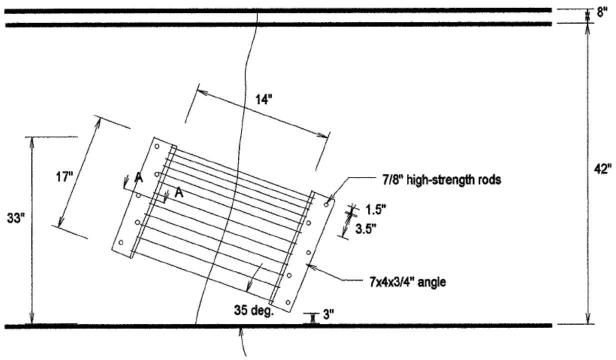
(a) General view

(b) SMAD application

Bridge carrying Sherman Road over US-31, USA

(a) General view

(b) Shear cracks on beam stem



(c) SMA rods

(d) Heating of SMA rods

Experimental equipment: (a-b) testing machine and temperature controlled chamber; (c) gripping jaws

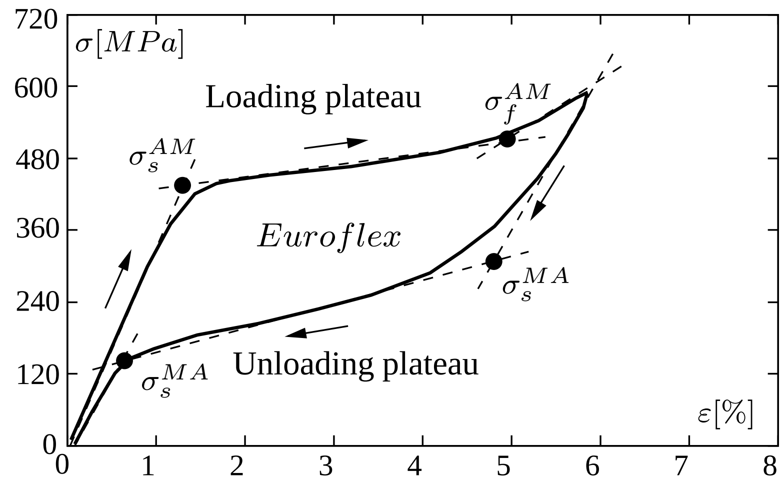
(a)

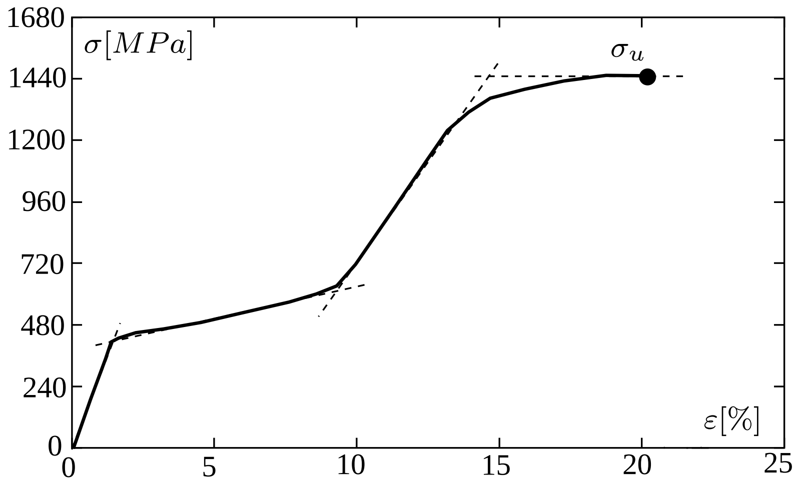
(b)

(c)

CARACTERIZAÇÃO DA SUPERELASTICIDADE

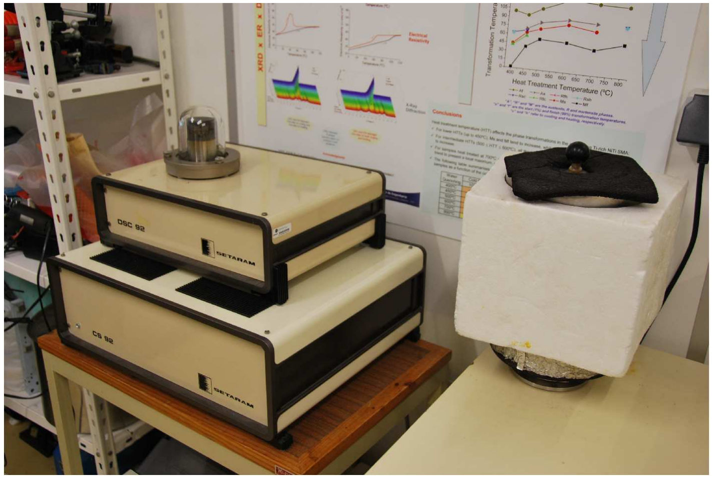
Ensaios de tracção

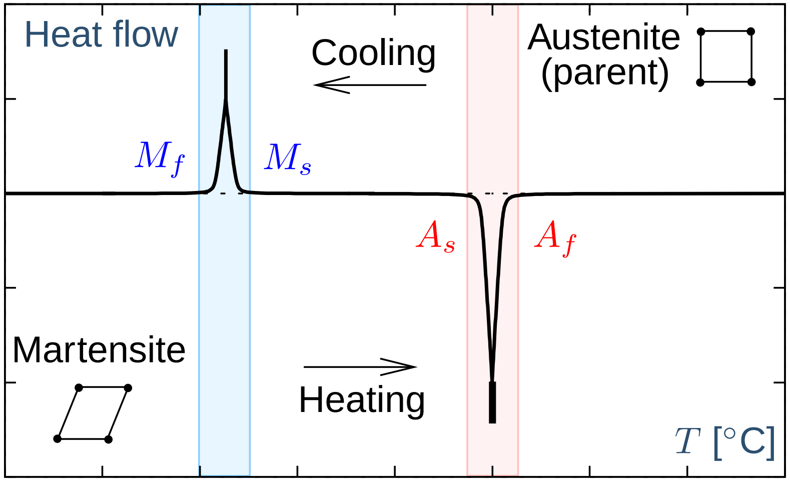




CARACTERIZAÇÃO DA SUPERELASTICIDADE

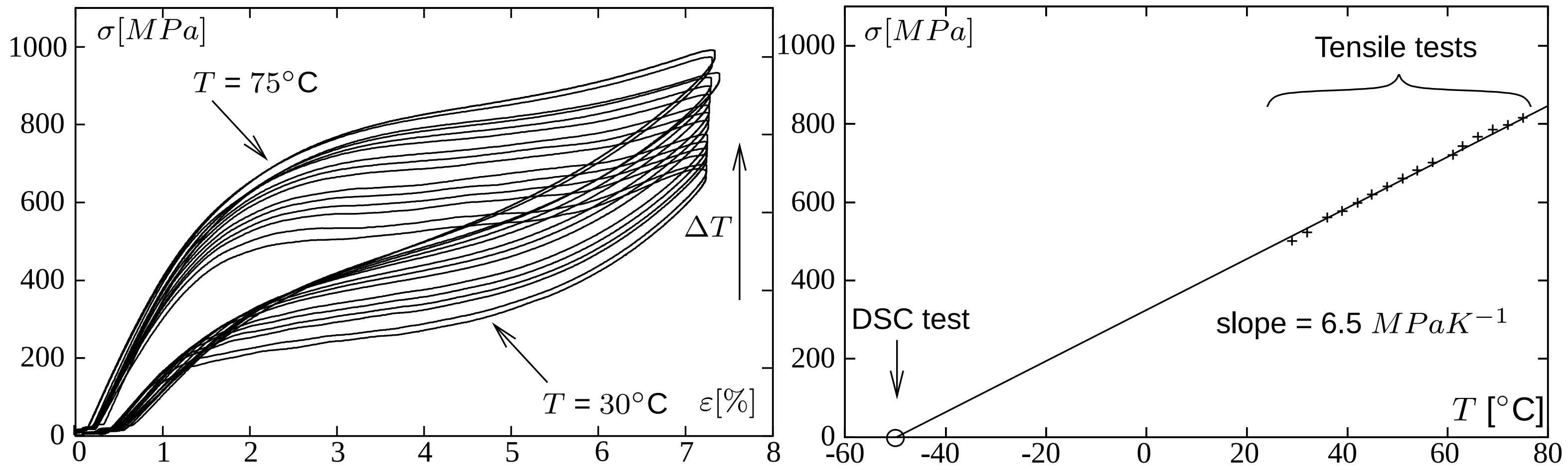
Ensaio DSC (Differential Scanning Calorimetry)





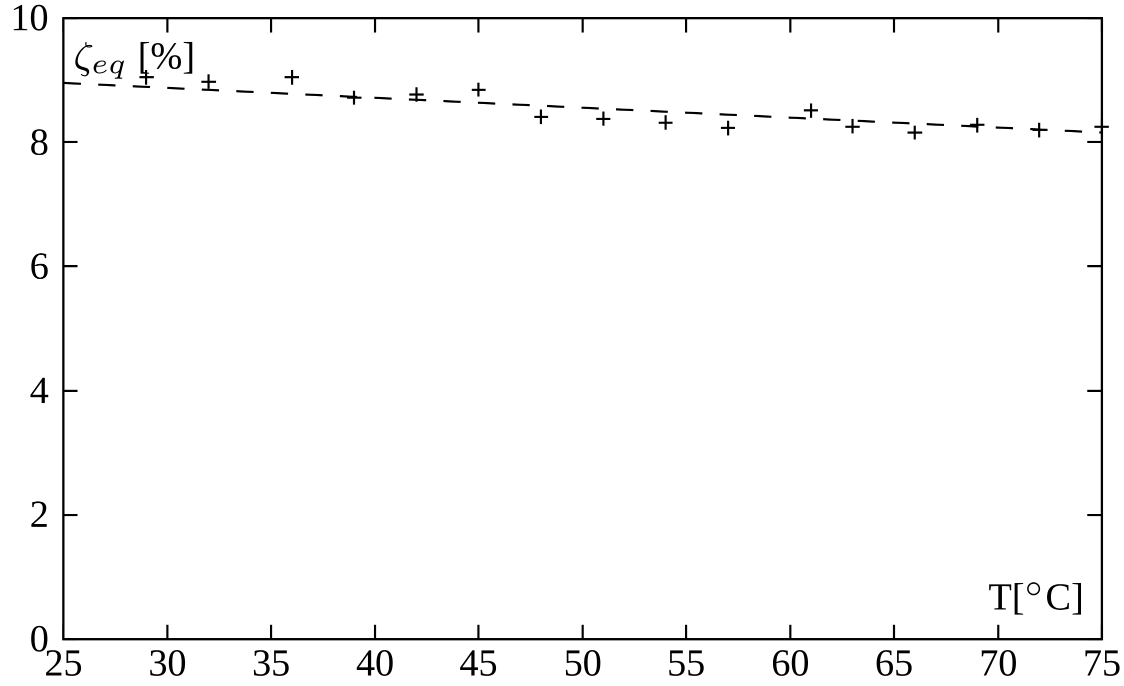
CARACTERIZAÇÃO DA SUPERELASTICIDADE

Ensaios de tracção com temperatura variável (CCC)



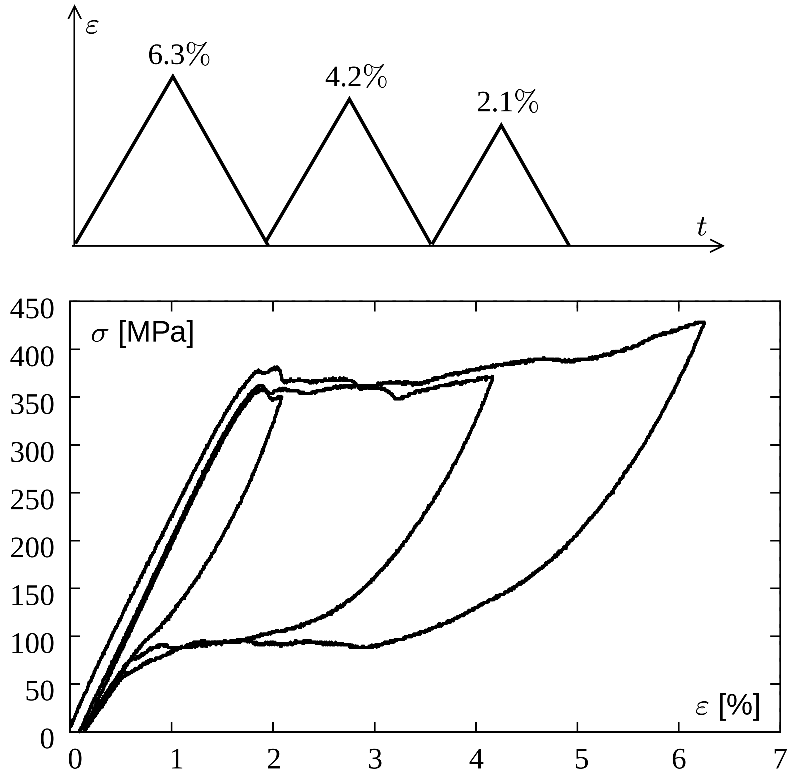
CARACTERIZAÇÃO DA SUPERELASTICIDADE

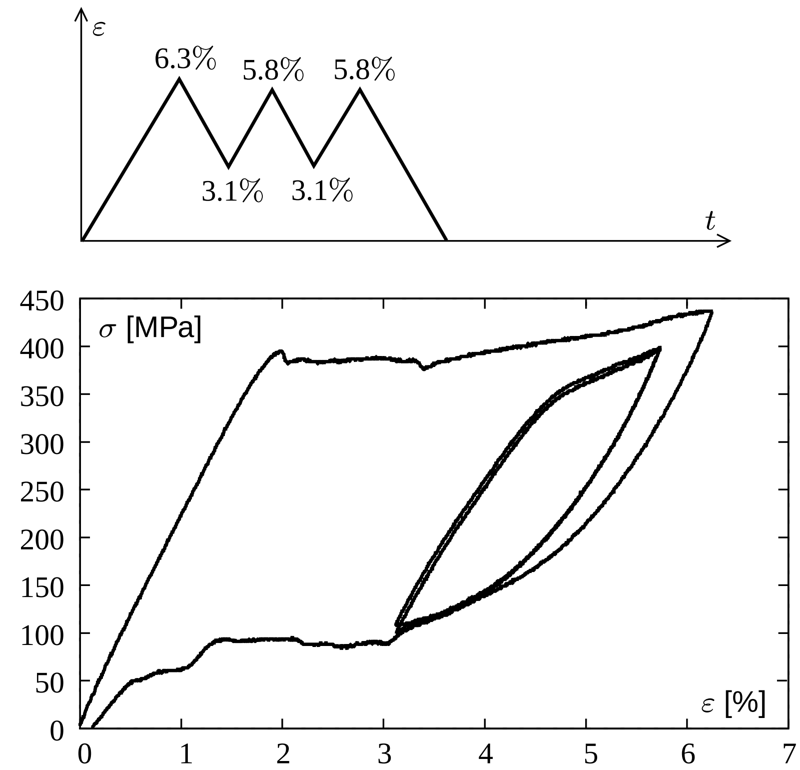
Influência da temperatura ambiente no amortecimento



CARACTERIZAÇÃO DA SUPERELASTICIDADE

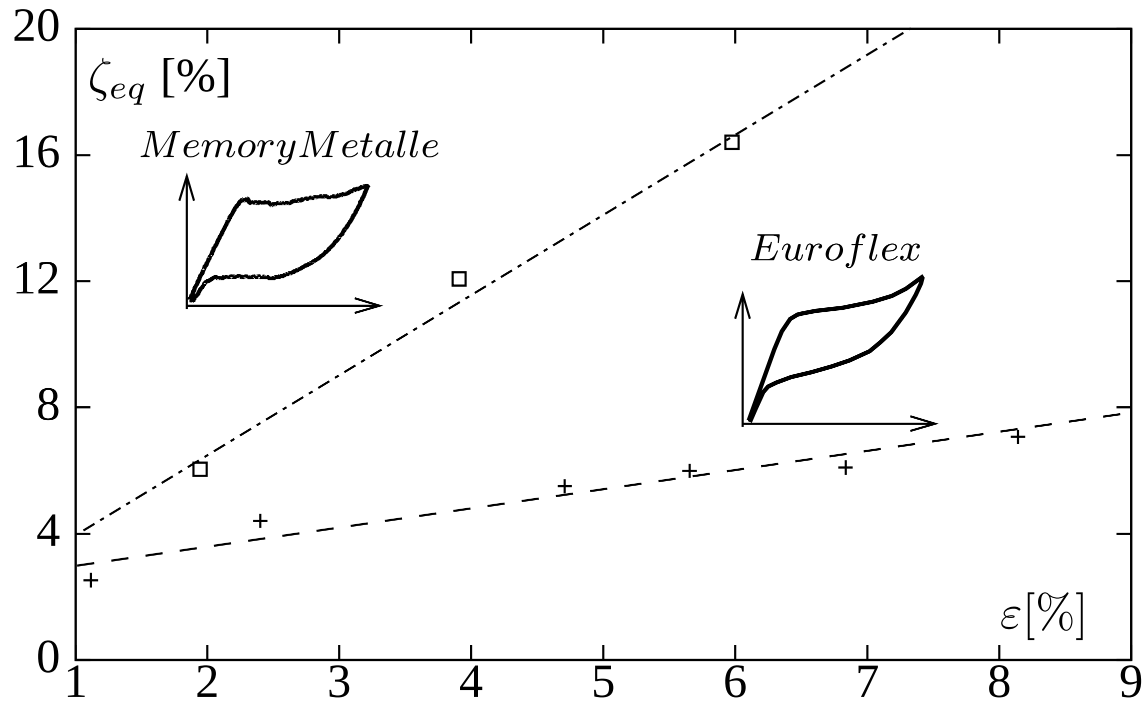
Ensaios de tracção com ciclos parciais



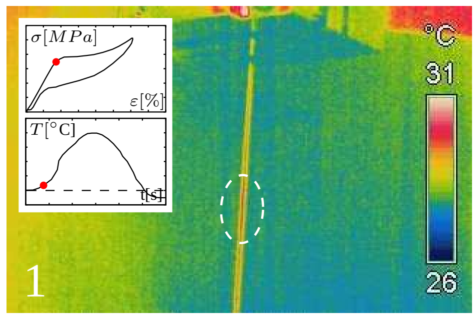


CARACTERIZAÇÃO DA SUPERELASTICIDADE

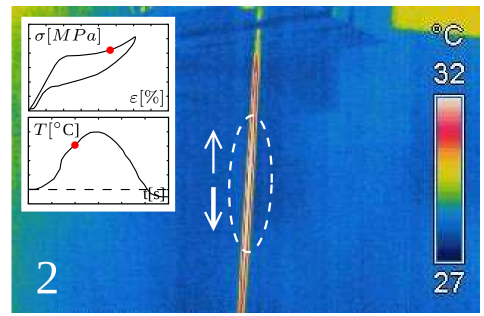
Influência da amplitude da extensão no amortecimento



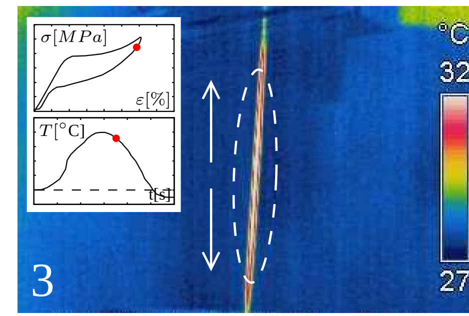
Temperature patterns within the SE wire specimen, during the loading-unloading tensile test at a strain rate of 0.250%/s



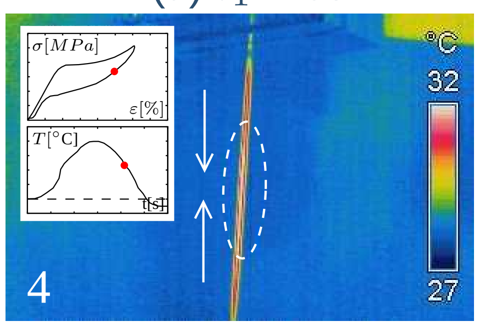
(a) t_1 = 6s



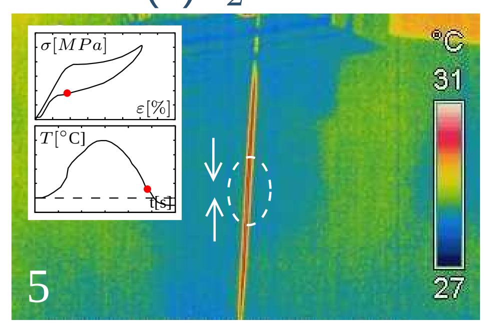
(b) t_2 = 16s



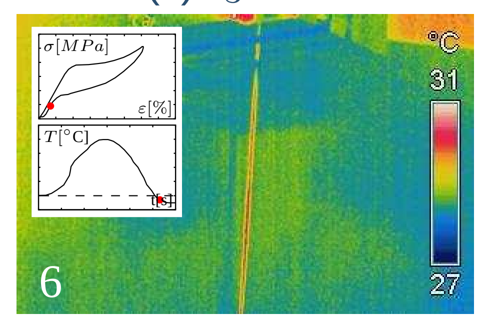
(c) t_3 = 28s



(d) t_4 = 34s

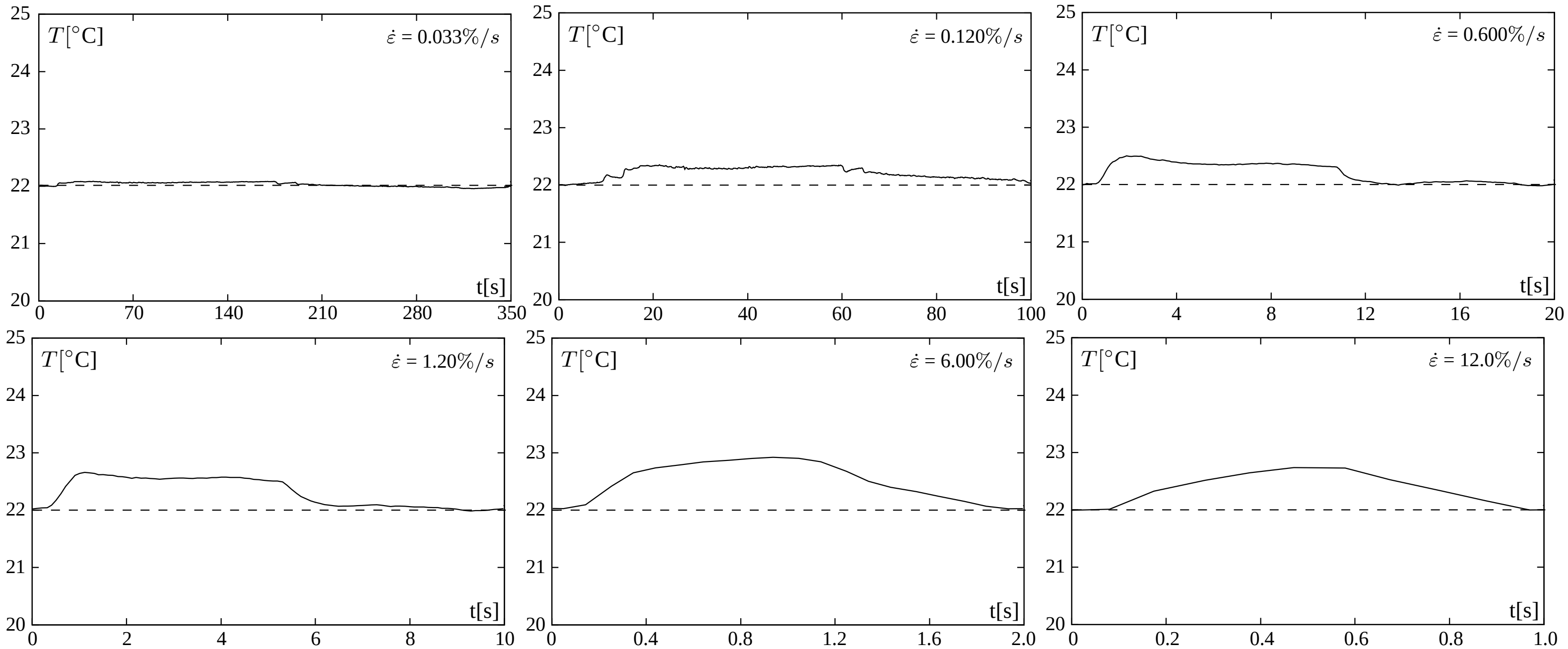


(e) t_5 = 39s

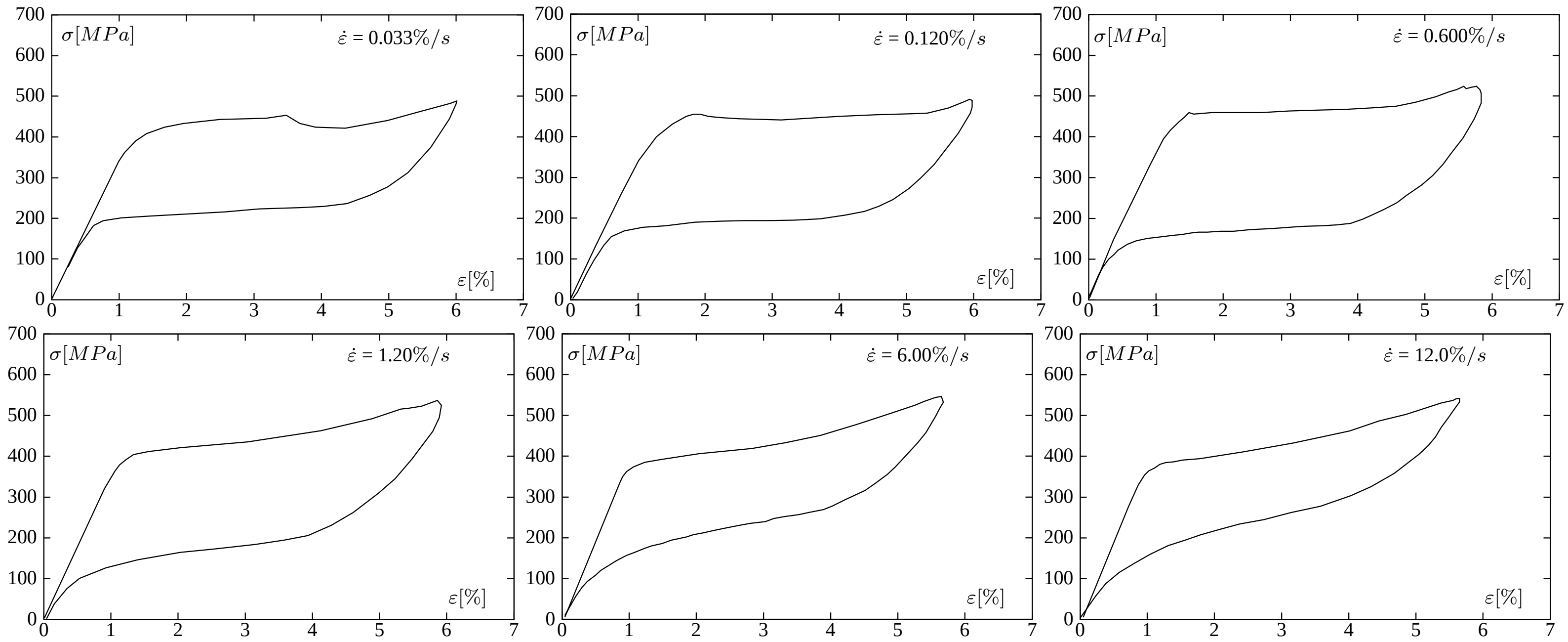


(f) t_6 = 44s

Dynamic tensile tests: strain-rate influence on temperature time-history

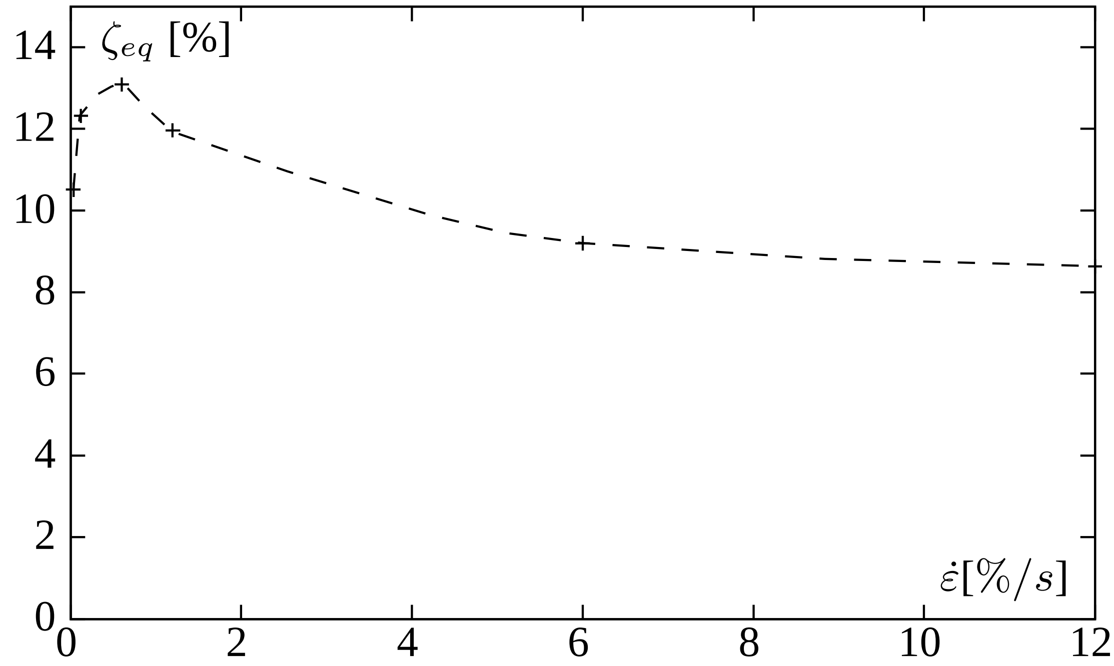


Dynamic tensile tests: strain-rate influence on temperature time-history



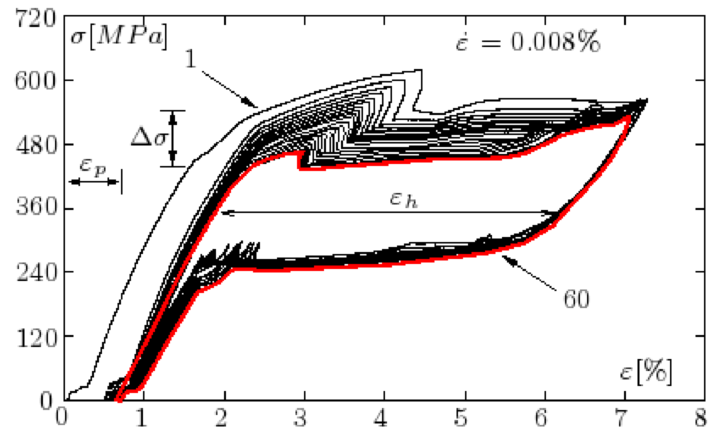
MODELO EXPERIMENTAL

Influência da velocidade no amortecimento)

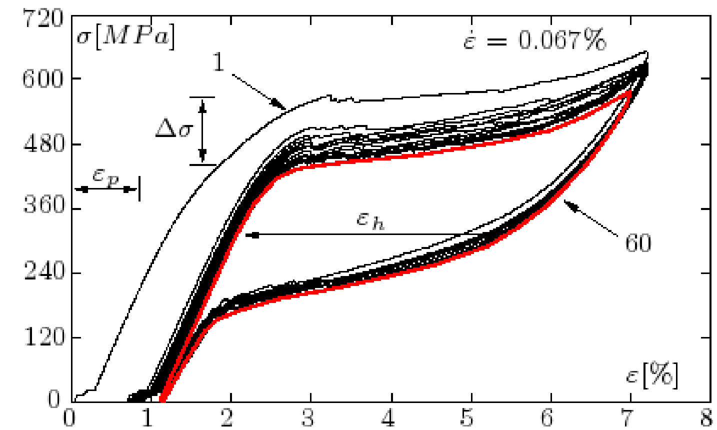


CARACTERIZAÇÃO DA SUPERELASTICIDADE

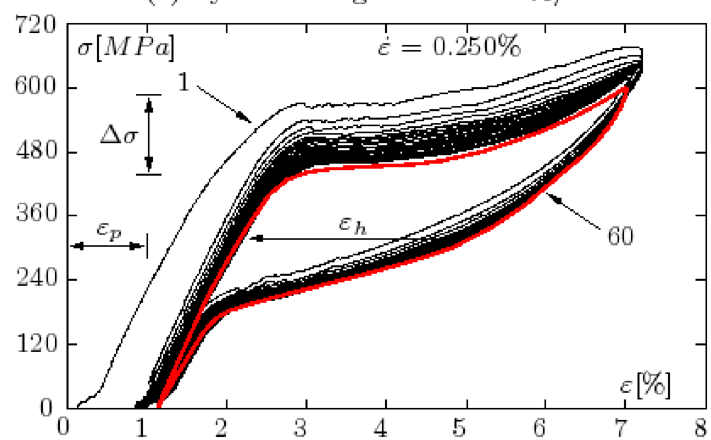
Ensaios de tracção cíclicos



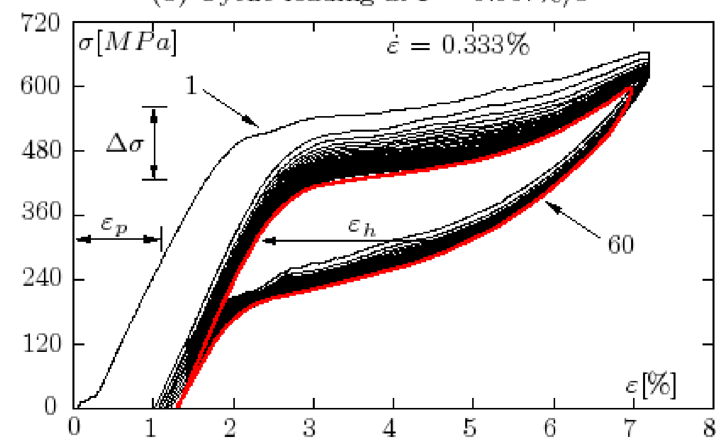
(a) Cyclic loading at $\dot{\varepsilon} = 0.008\%/s$



(b) Cyclic loading at $\dot{\varepsilon} = 0.067\%/s$



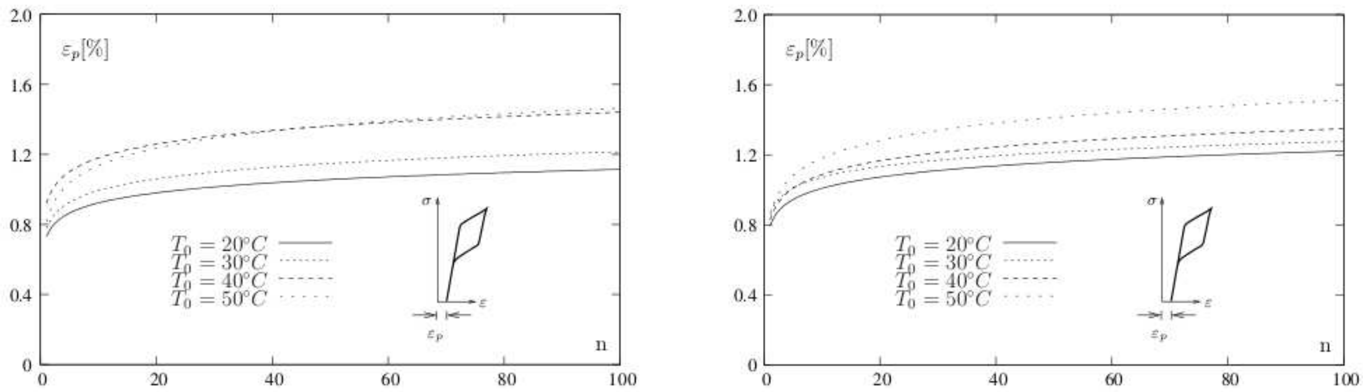
(c) Cyclic loading at $\dot{\varepsilon} = 0.250\%/s$



(d) Cyclic loading at $\dot{\varepsilon} = 0.333\%/s$

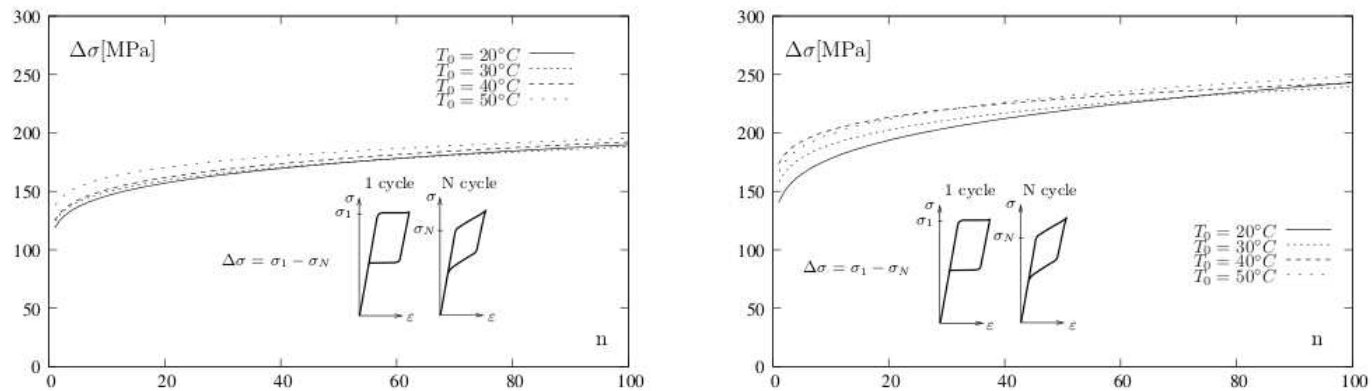
CARACTERIZAÇÃO DA SUPERELASTICIDADE

Ensaios de tracção cíclicos



(a) $\dot{\varepsilon} = 0.10\%/s$. (b) $\dot{\varepsilon} = 0.30\%/s$.

Evolution of the cumulative creep deformation due to cycling.

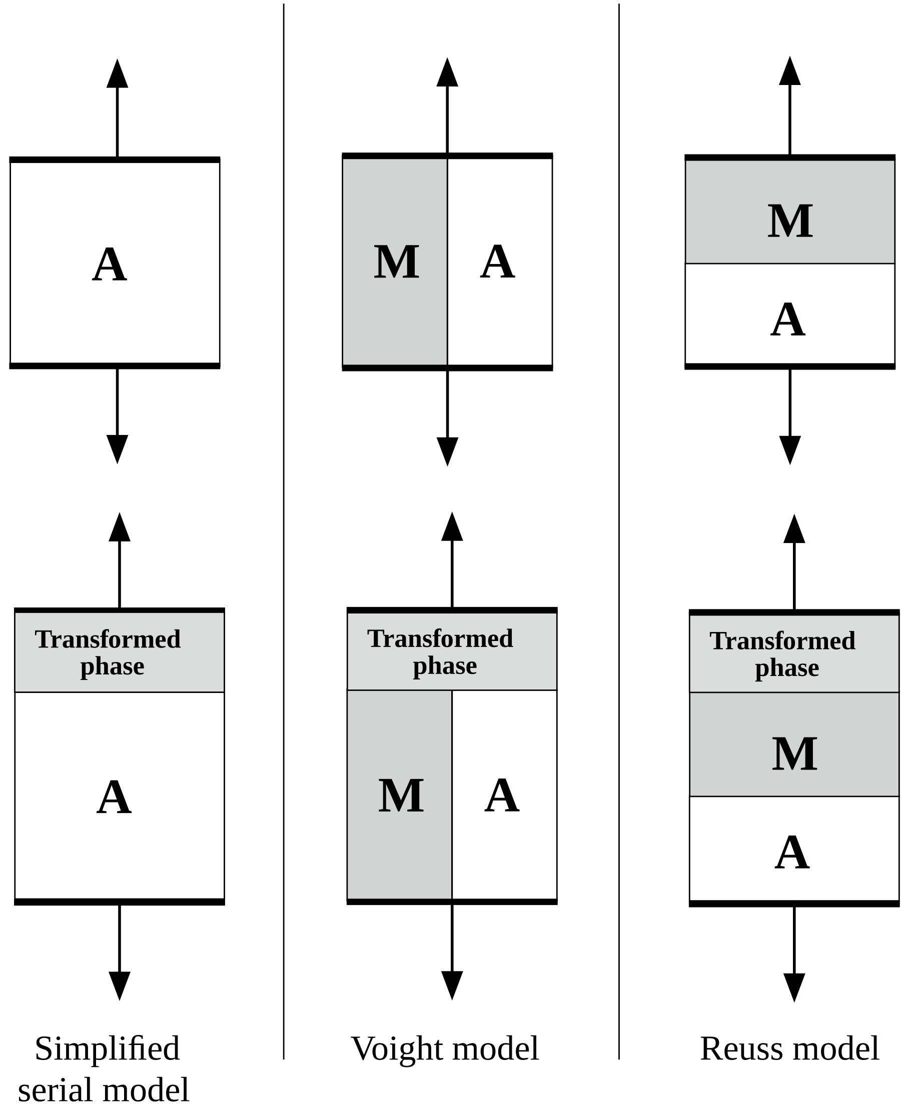


(a) $\dot{\varepsilon} = 0.10\%/s$. (b) $\dot{\varepsilon} = 0.30\%/s$.

Evolution of the variation of the critical stress to induce martensite with cycling.

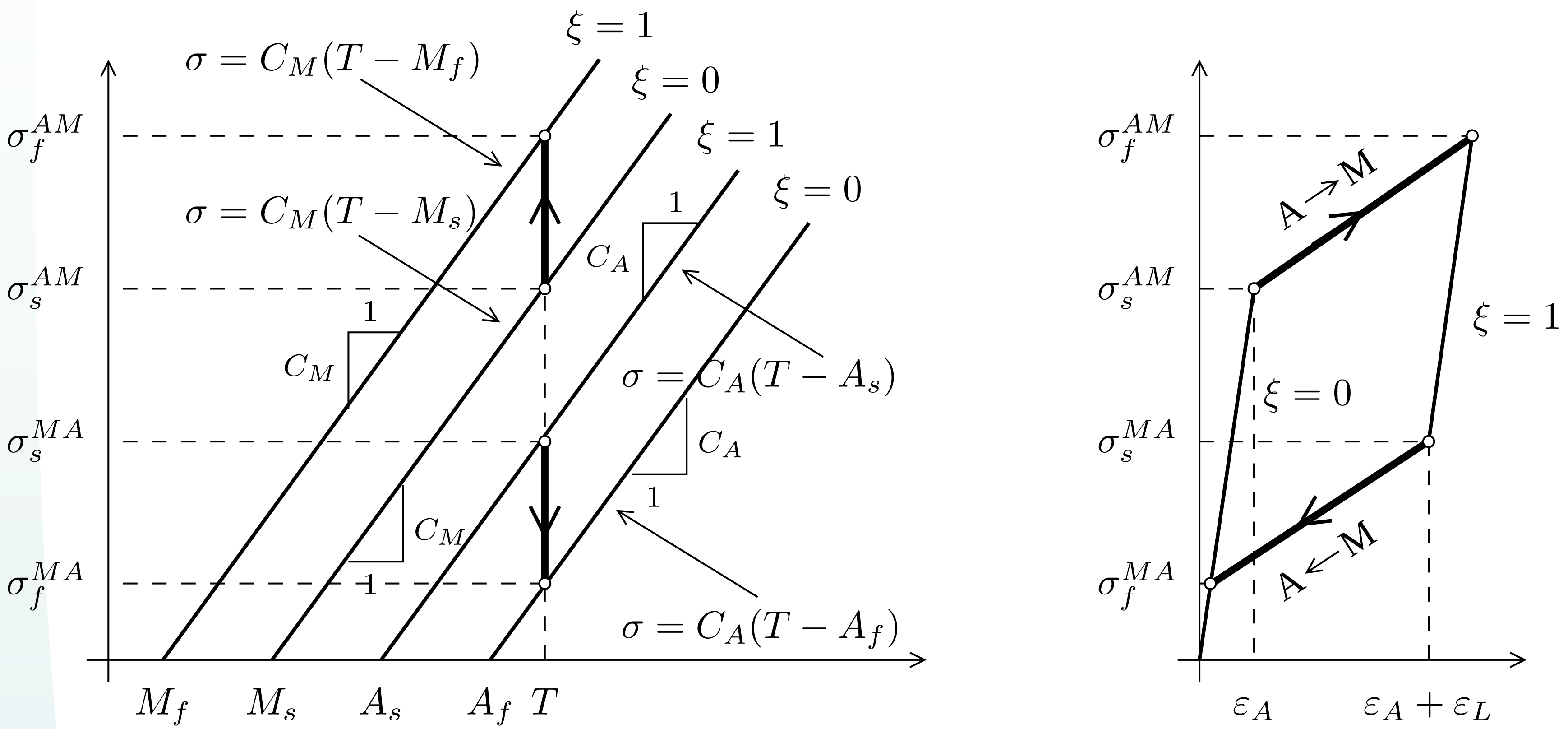
MODELAÇÃO DA SUPERELASTICIDADE

Lei mecânica: $\sigma(\varepsilon, T, \xi)$



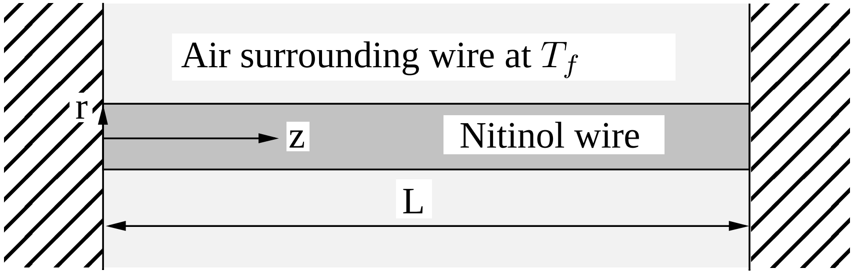
MODELAÇÃO DA SUPERELASTICIDADE

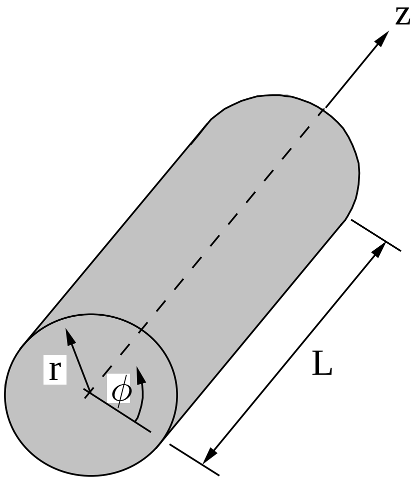
Lei cinética: $\xi(\sigma, T)$



MODELAÇÃO DA SUPERELASTICIDADE

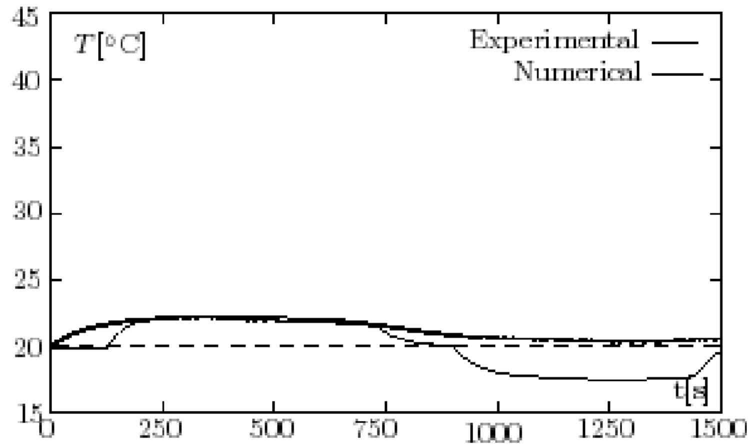
Lei de balanço energético: $q_{gen}(\xi, W)$



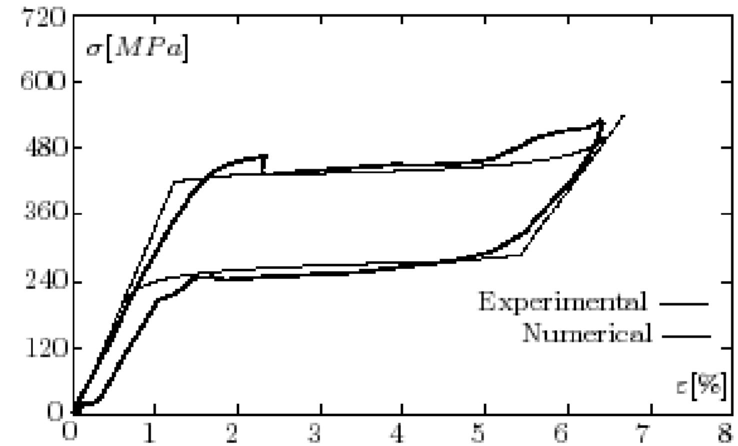


MODELAÇÃO DA SUPERELASTICIDADE

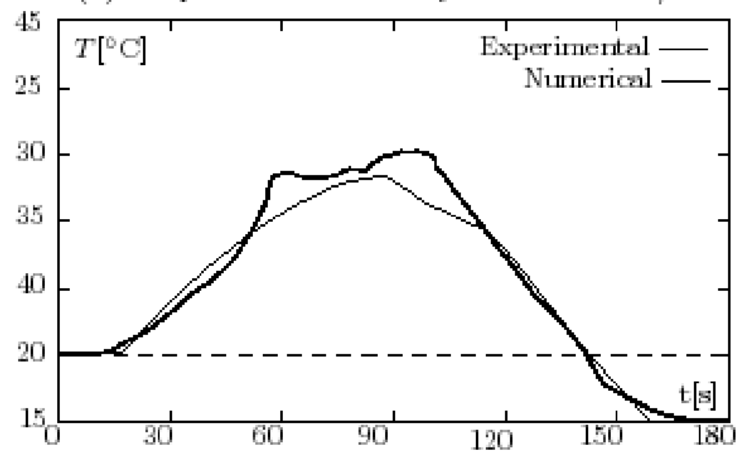
Validação do modelo numérico



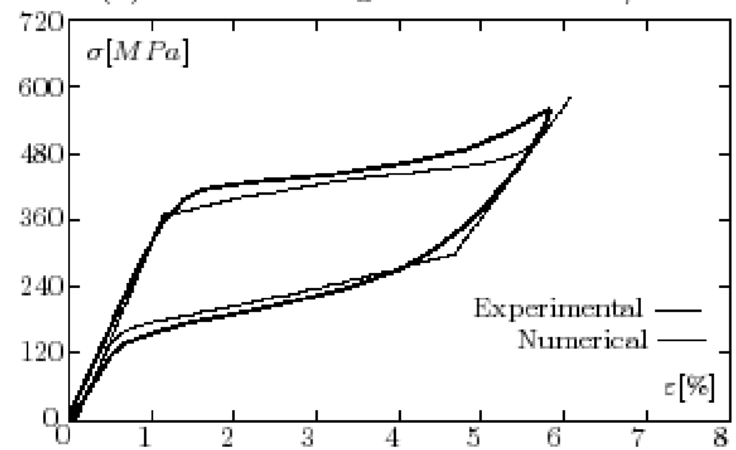
(a) Temperature time-history for $\dot{\varepsilon} = 0.008\%/s$



(b) Stress-strain diagram for $\dot{\varepsilon} = 0.008\%/s$



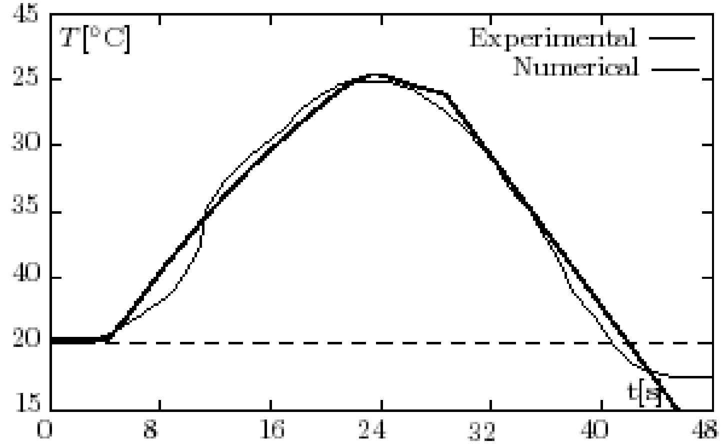
(c) Temperature time-history for $\dot{\varepsilon} = 0.067\%/s$



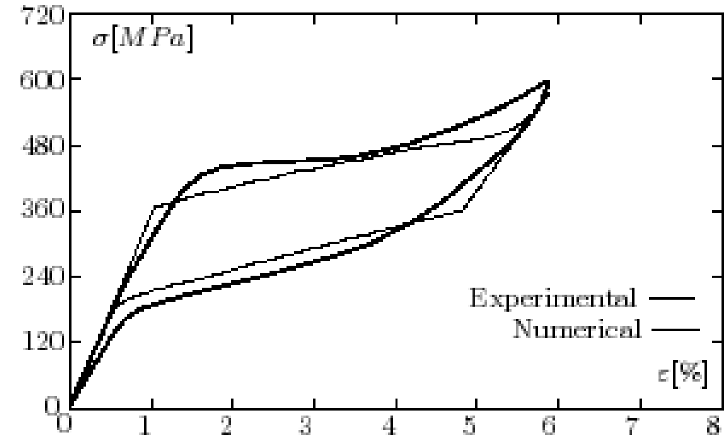
(d) Stress-strain diagram for $\dot{\varepsilon} = 0.067\%/s$

MODELAÇÃO DA SUPERELASTICIDADE

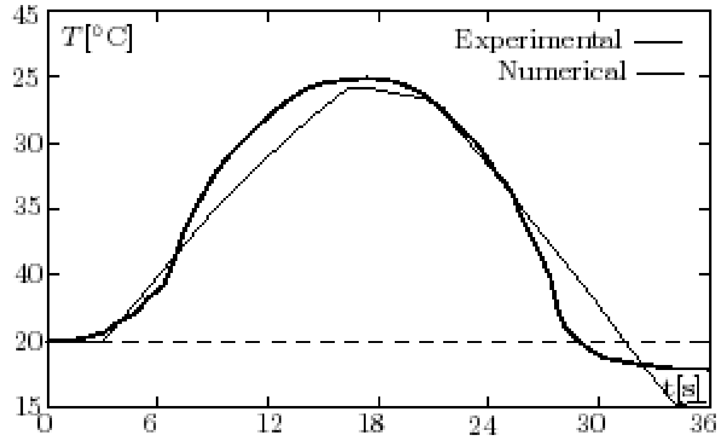
Validação do modelo numérico



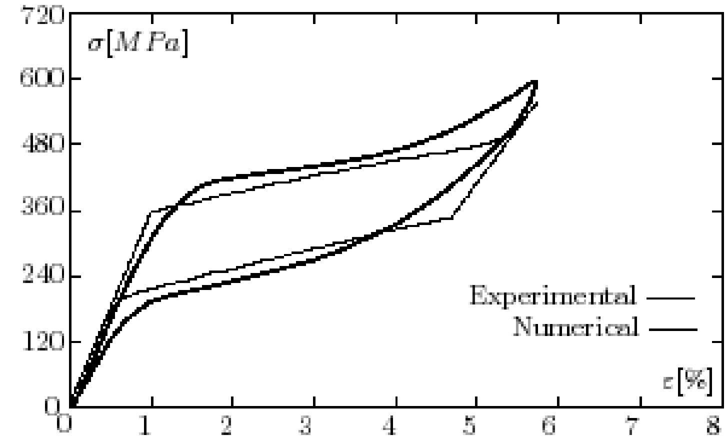
(e) Temperature time-history for $\dot{\varepsilon} = 0.250\%/s$



(f) Stress-strain diagram for $\dot{\varepsilon} = 0.250\%/s$

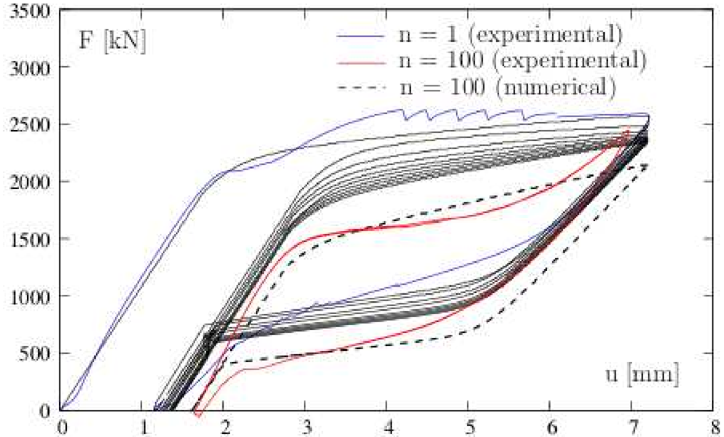


(g) Temperature time-history for $\dot{\varepsilon} = 0.333\%/s$

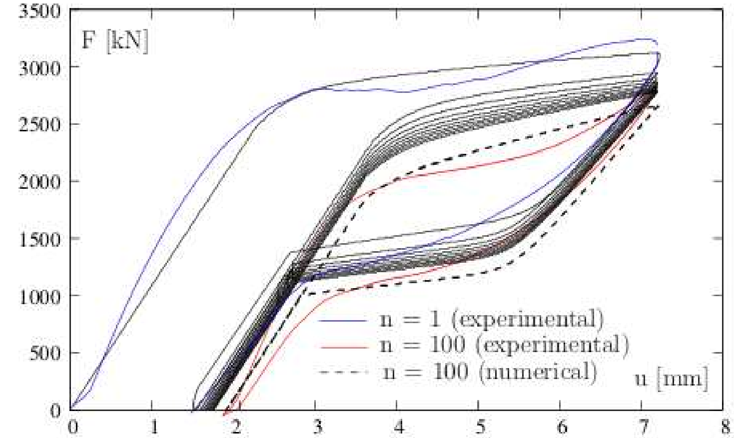


(h) Stress-strain diagram for $\dot{\varepsilon} = 0.333\%/s$

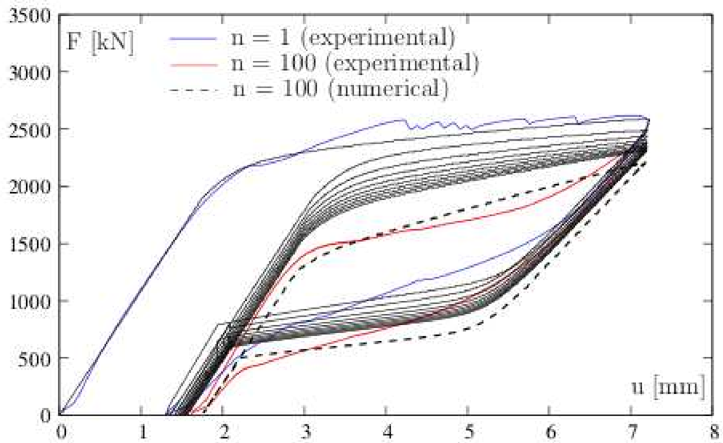
MODELAÇÃO DA SUPERELASTICIDADE
Validação do modelo numérico



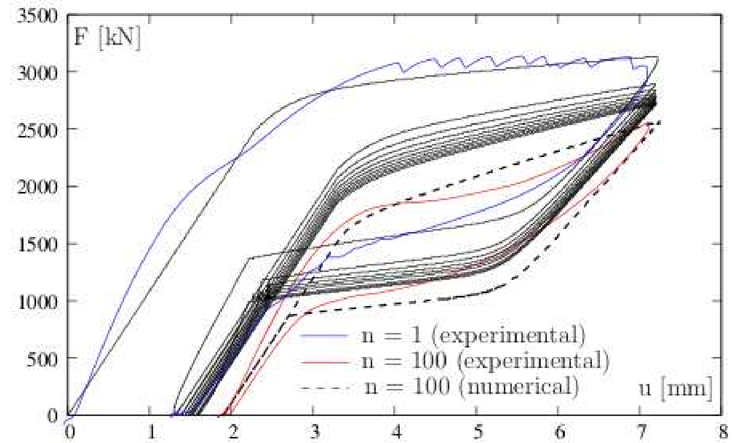
(a) $T_0 = 20°\text{C}$ and $\dot{\varepsilon} = 0.15\%/s$.



(b) $T_0 = 40°\text{C}$ and $\dot{\varepsilon} = 0.15\%/s$.

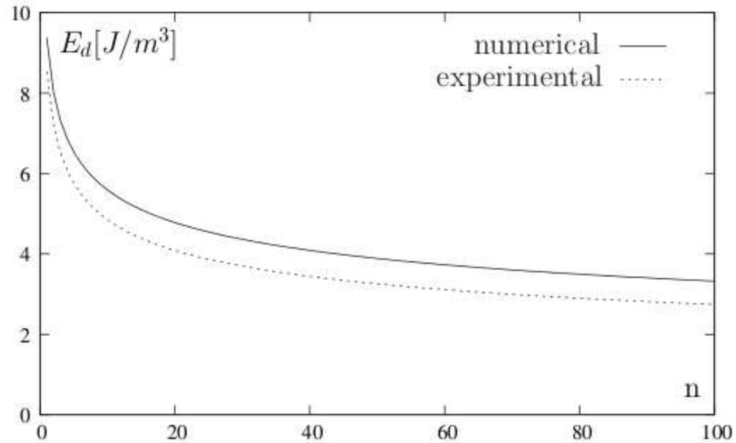


(c) $T_0 = 20°\text{C}$ and $\dot{\varepsilon} = 0.30\%/s$.

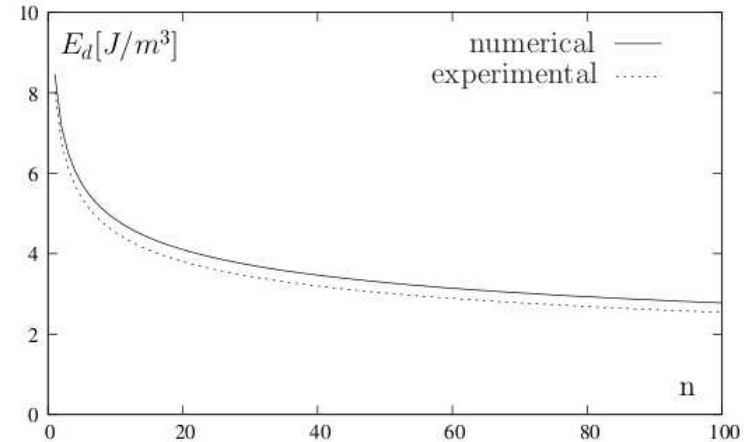


(d) $T_0 = 40°\text{C}$ and $\dot{\varepsilon} = 0.30\%/s$.

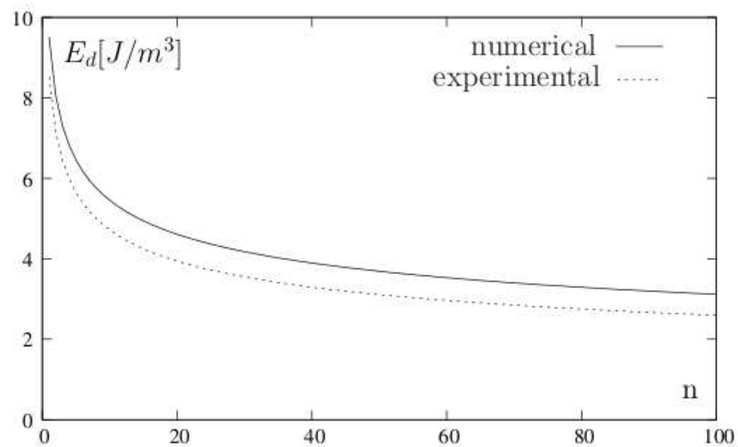
MODELAÇÃO DA SUPERELASTICIDADE
Validação do modelo numérico



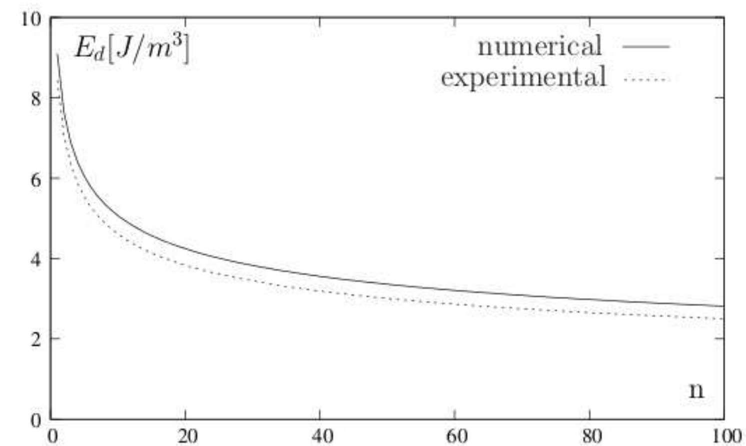
(a) $T_0 = 20°C$ and $\dot{\varepsilon} = 0.15\%/s$.



(b) $T_0 = 40°C$ and $\dot{\varepsilon} = 0.15\%/s$.



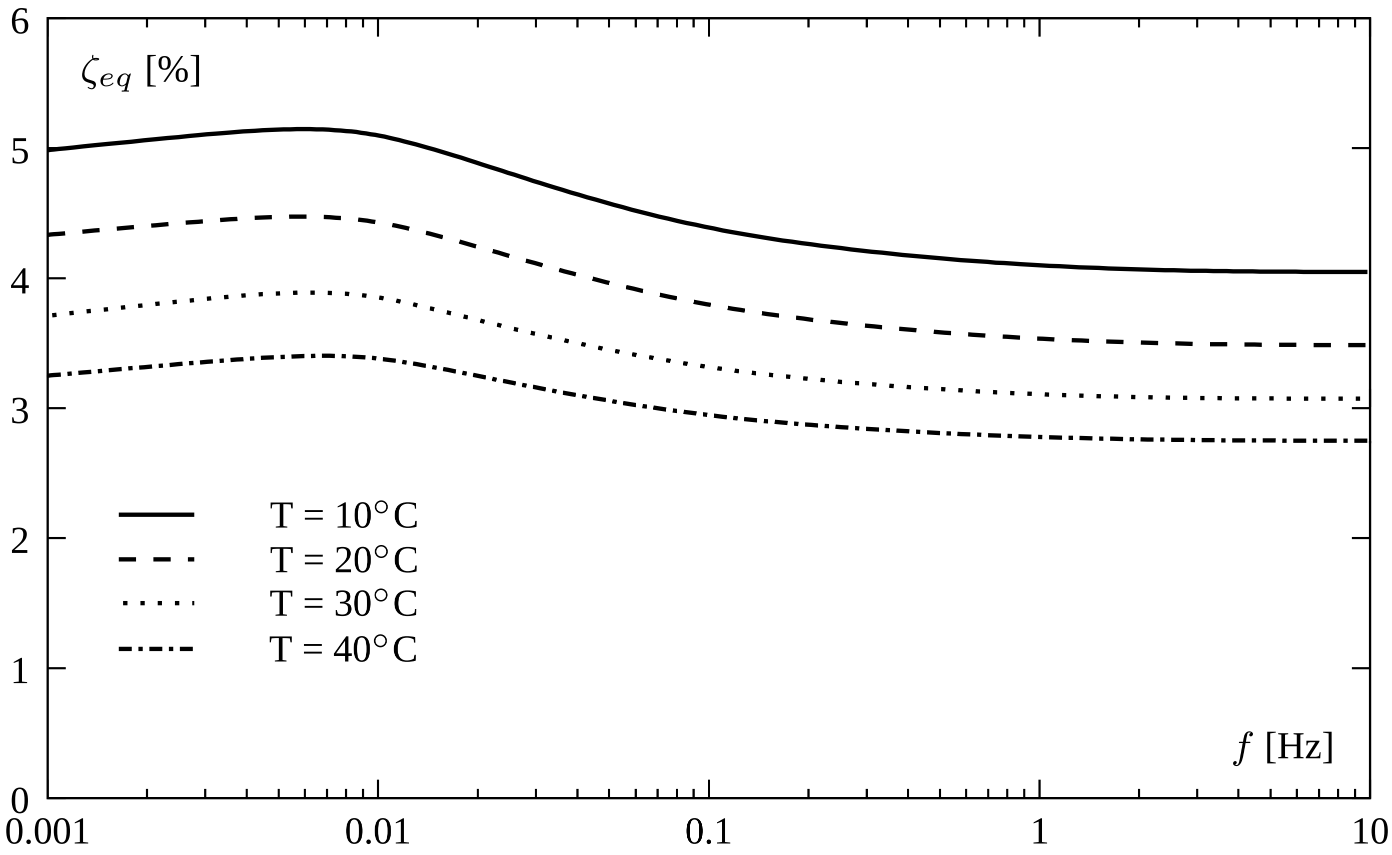
(c) $T_0 = 20°C$ and $\dot{\varepsilon} = 0.30\%/s$.



(d) $T_0 = 40°C$ and $\dot{\varepsilon} = 0.30\%/s$.

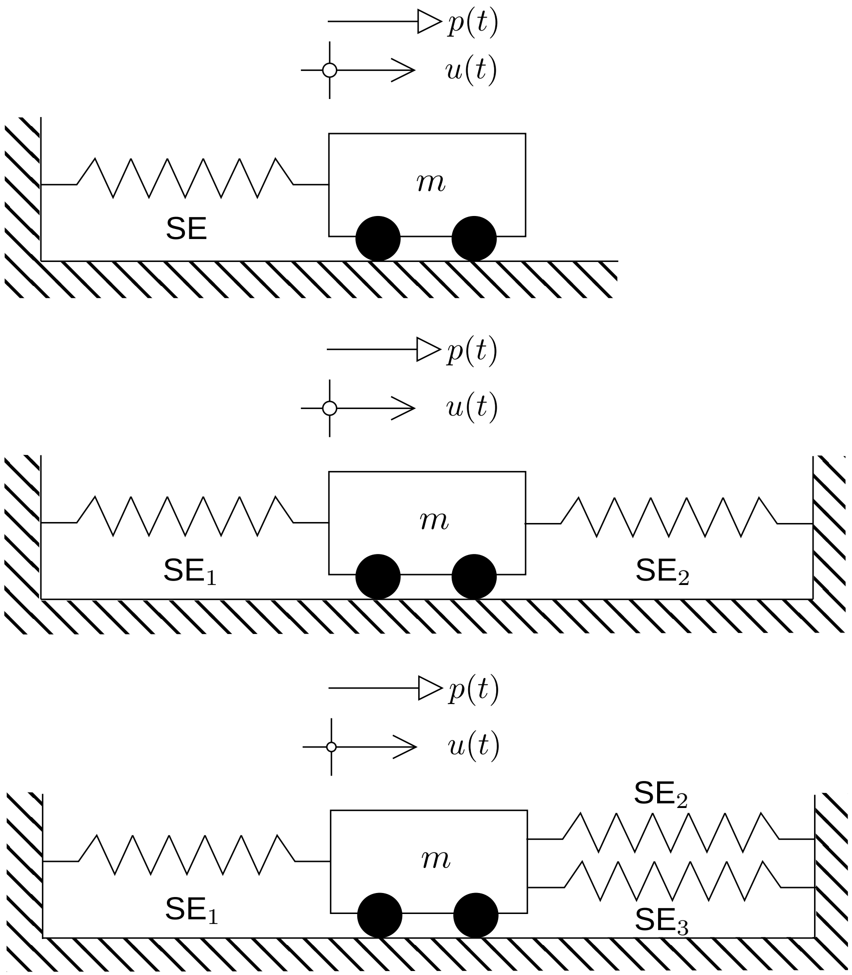
MODELAÇÃO DA SUPERELASTICIDADE

Estudo paramétrico: $\zeta_{eq}(f)$



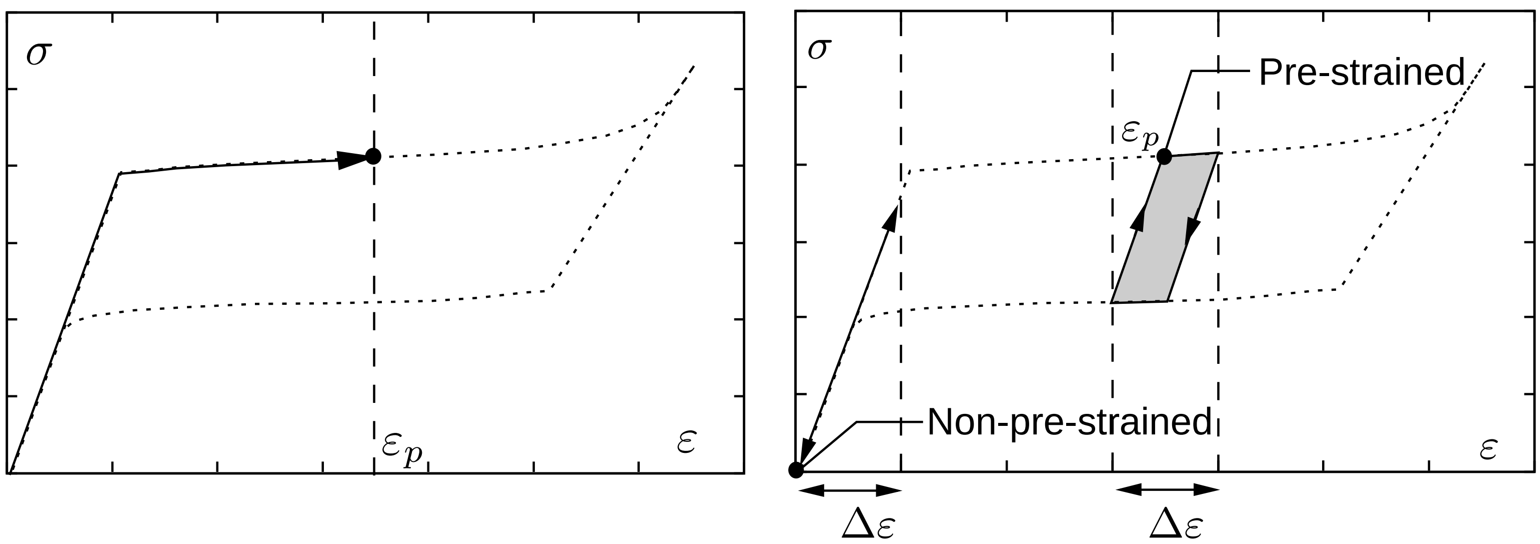
MODELAÇÃO DA SUPERELASTICIDADE

Sistema dinâmico superelástico com 1 grau de liberdade: método de Newmark



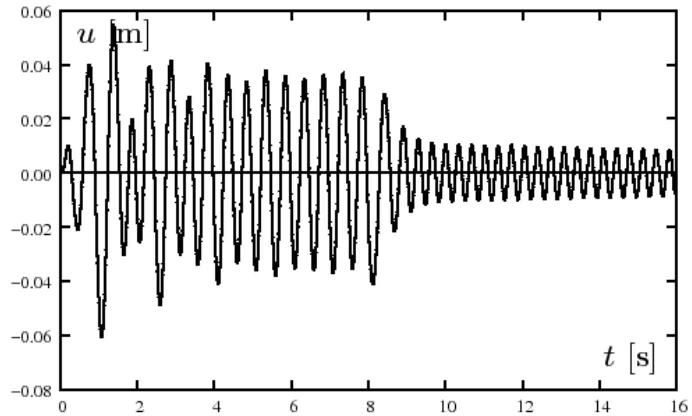
MODELAÇÃO DA SUPERELASTICIDADE

Pré-esforço em aplicações superelásticas

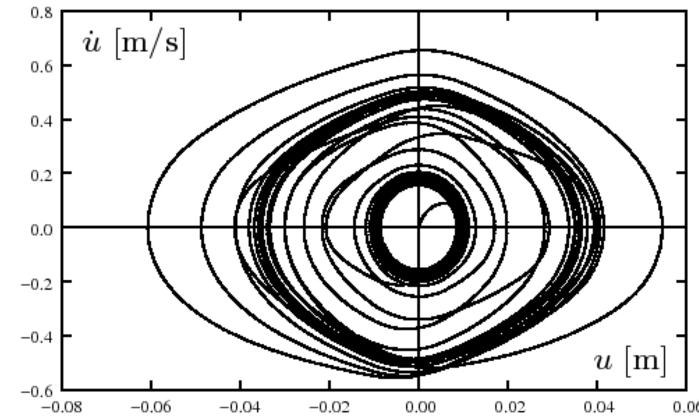


MODELAÇÃO DA SUPERELASTICIDADE

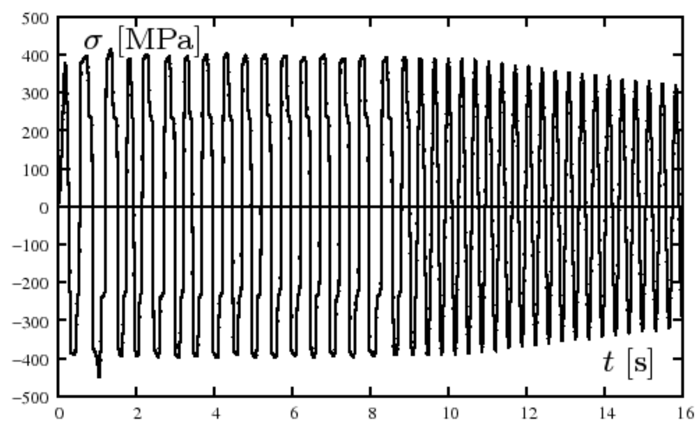
Sistema com um elemento SE ($T = 20°$C, $f = 2$ Hz)



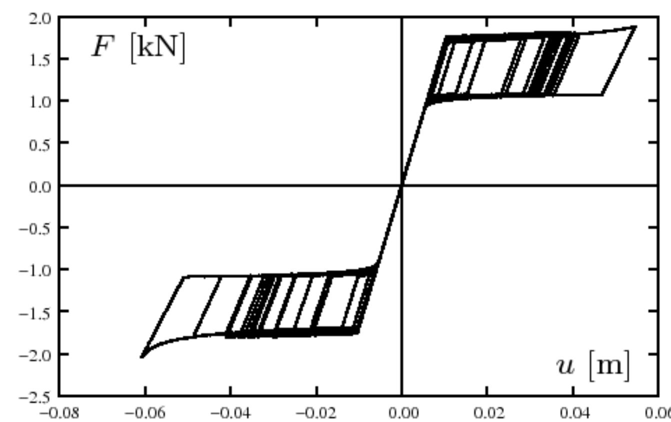
(a) Displacement time-history



(b) Phase plane



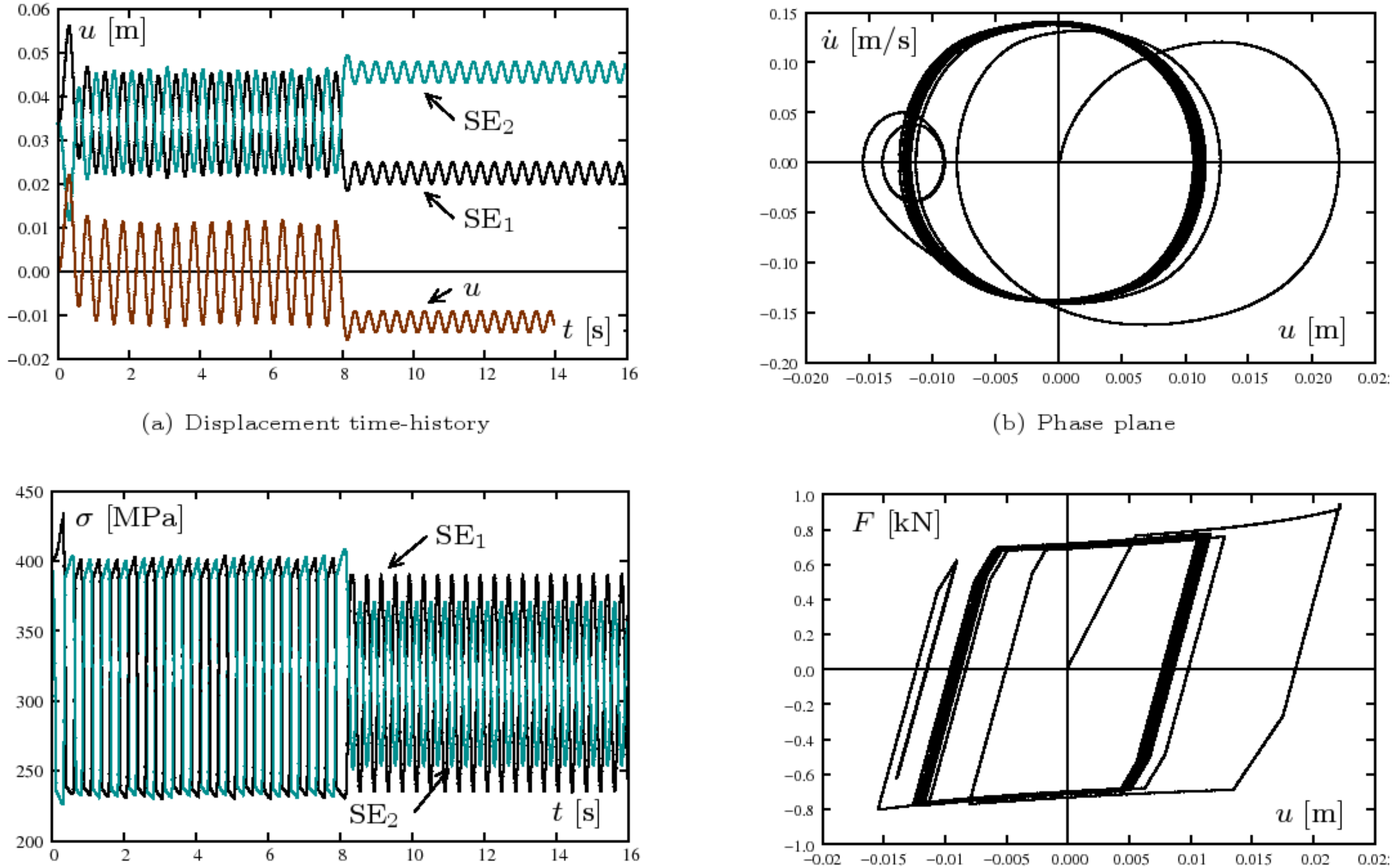
(c) Stress time-history



(d) Force-displacement

MODELAÇÃO DA SUPERELASTICIDADE

Sistema com dois elementos SE ($T = 20°$C, $f = 2$ Hz)



(a) Displacement time-history

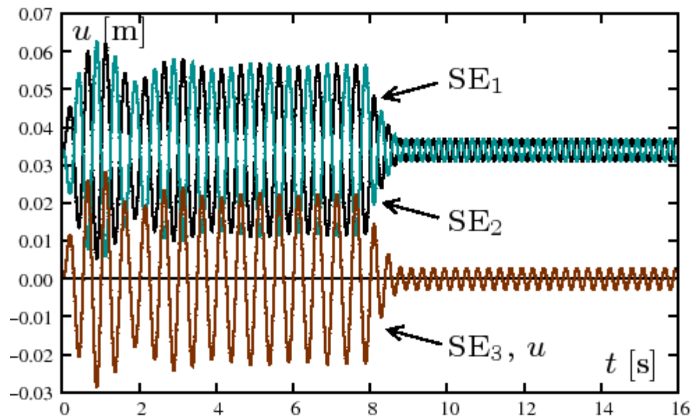
(b) Phase plane

(c) Stress time-history

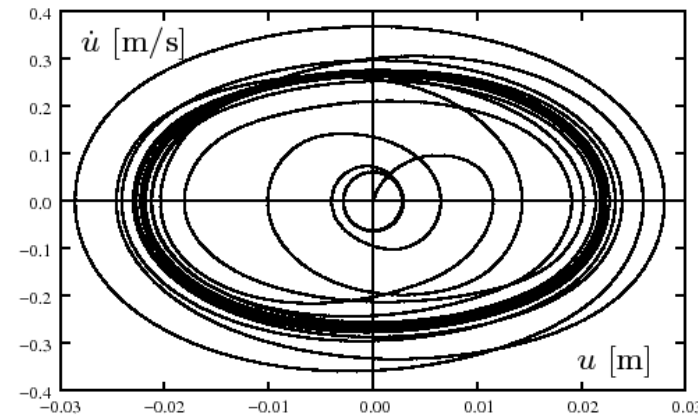
(d) Force-displacement

MODELAÇÃO DA SUPERELASTICIDADE

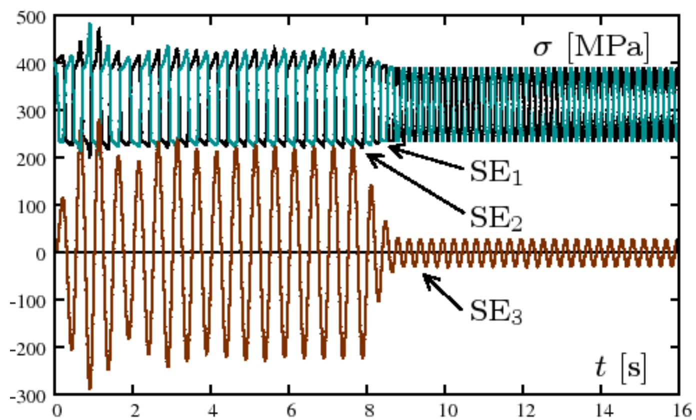
Sistema com três elementos SE ($T = 20$°C, $f = 2$ Hz)



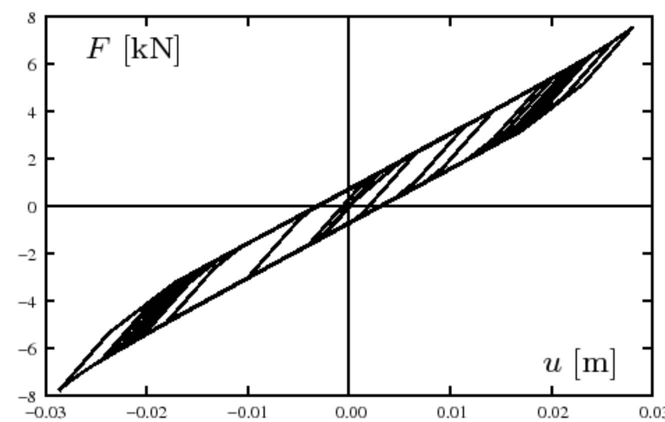
(a) Displacement time-history



(b) Phase plane



(c) Stress time-history

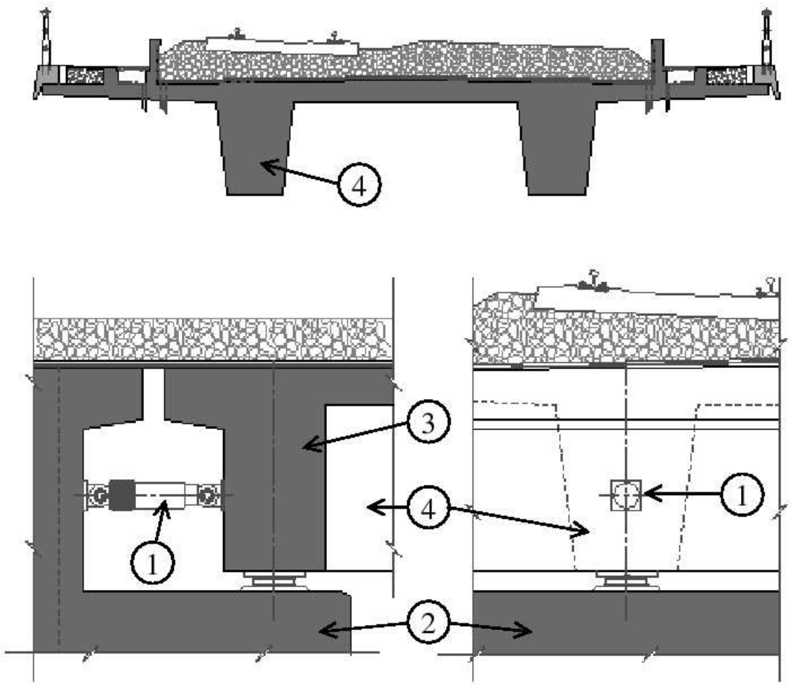


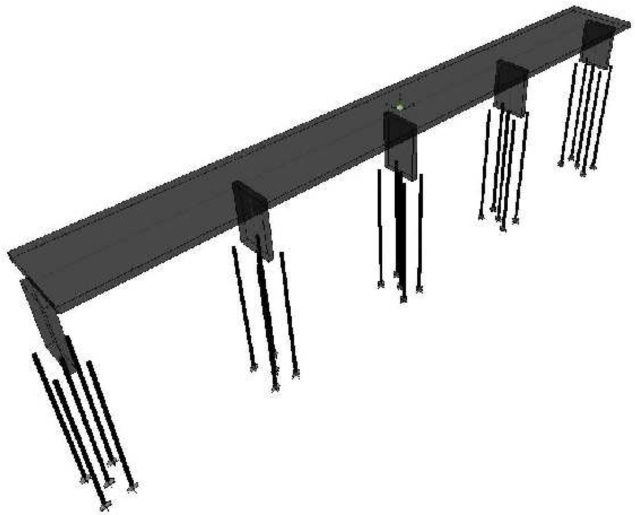
(d) Force-displacement

MODELAÇÃO DA SUPERELASTICIDADE

Sistema de retenção para pontes baseado em elementos superelásticos

MODELAÇÃO DA SUPERELASTICIDADE
Viaduto de São Martinho

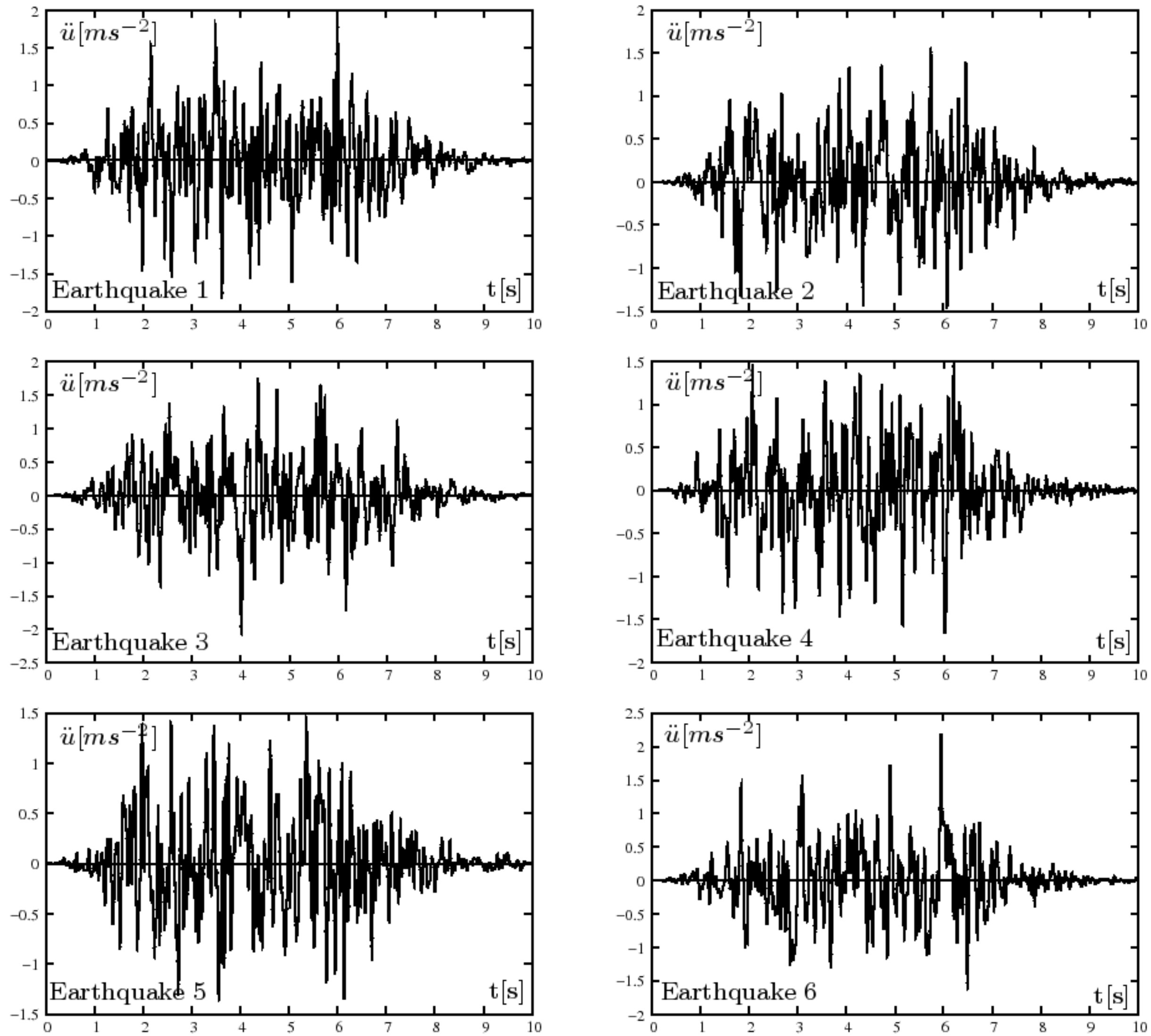




Legend: 1. SMA device, 2. Abutment, 3. Transverse girder, 4. Main girder

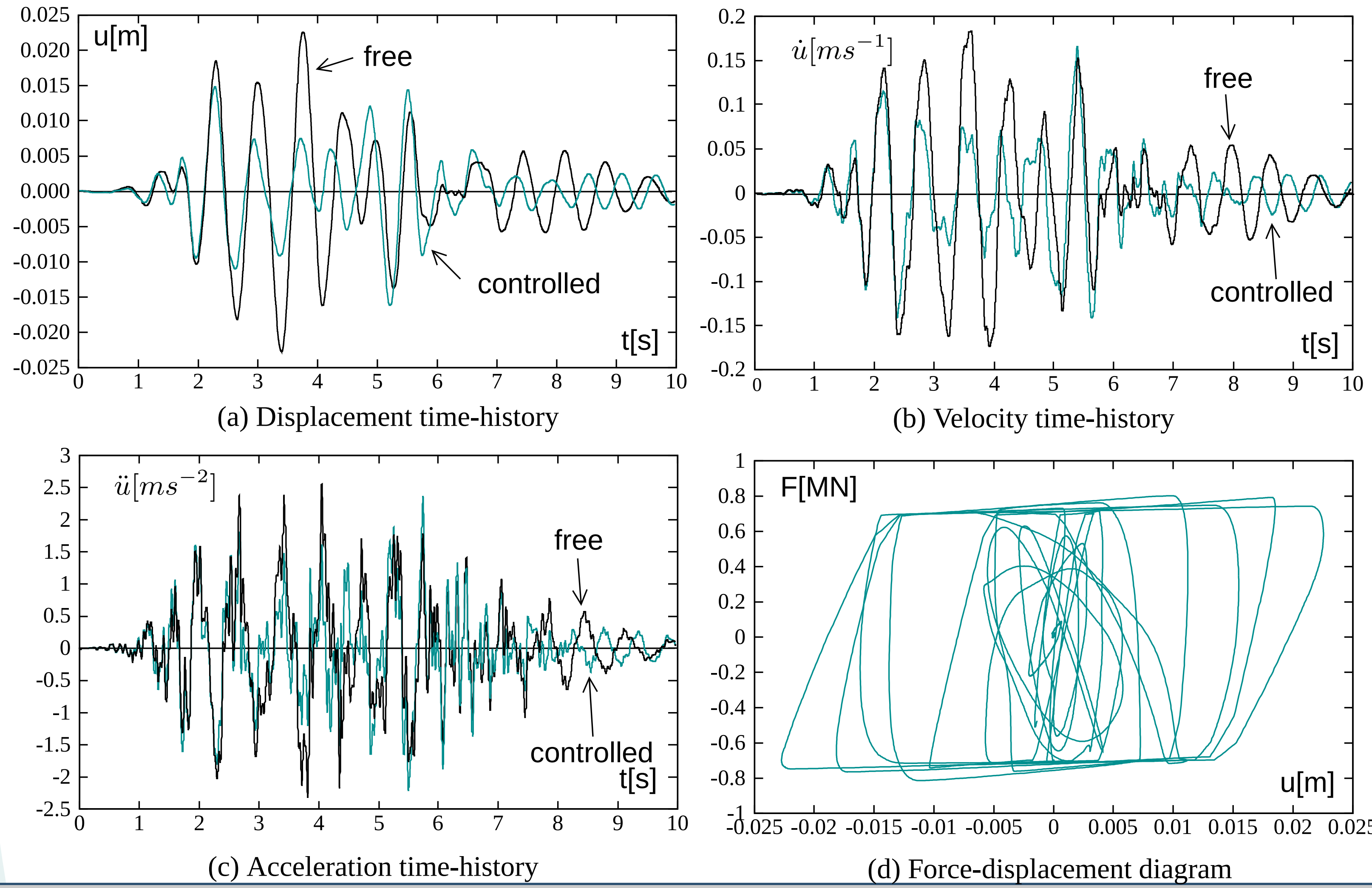
MODELAÇÃO DA SUPERELASTICIDADE

Histograma da acção sísmica



MODELAÇÃO DA SUPERELASTICIDADE

Seismic response of a viaduct with f = 1.0 Hz and A = 5% A_{max}



(a) Displacement time-history

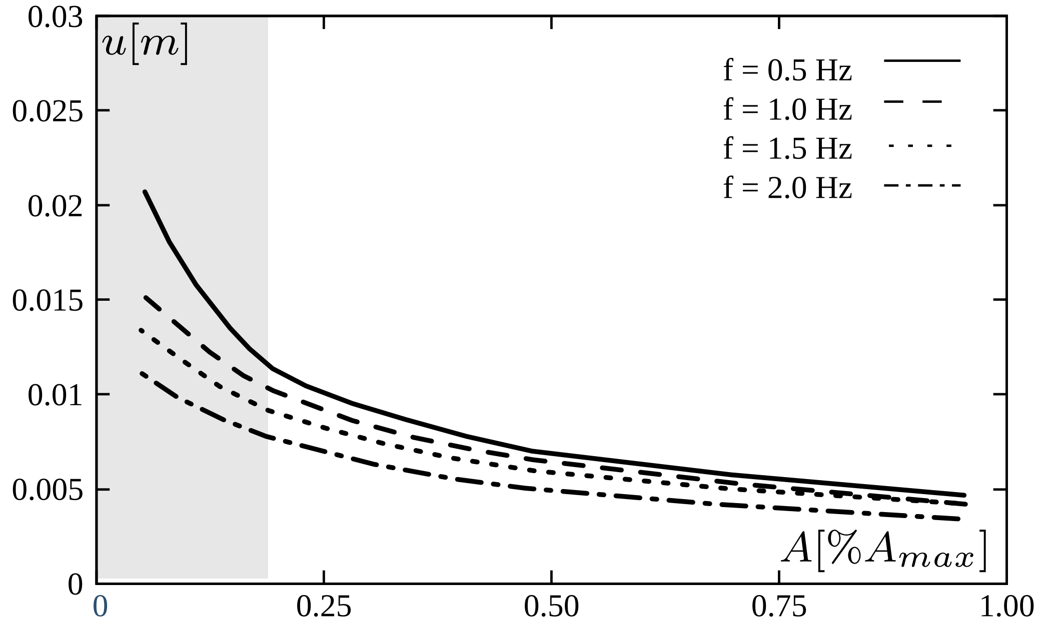
(b) Velocity time-history

(c) Acceleration time-history

(d) Force-displacement diagram

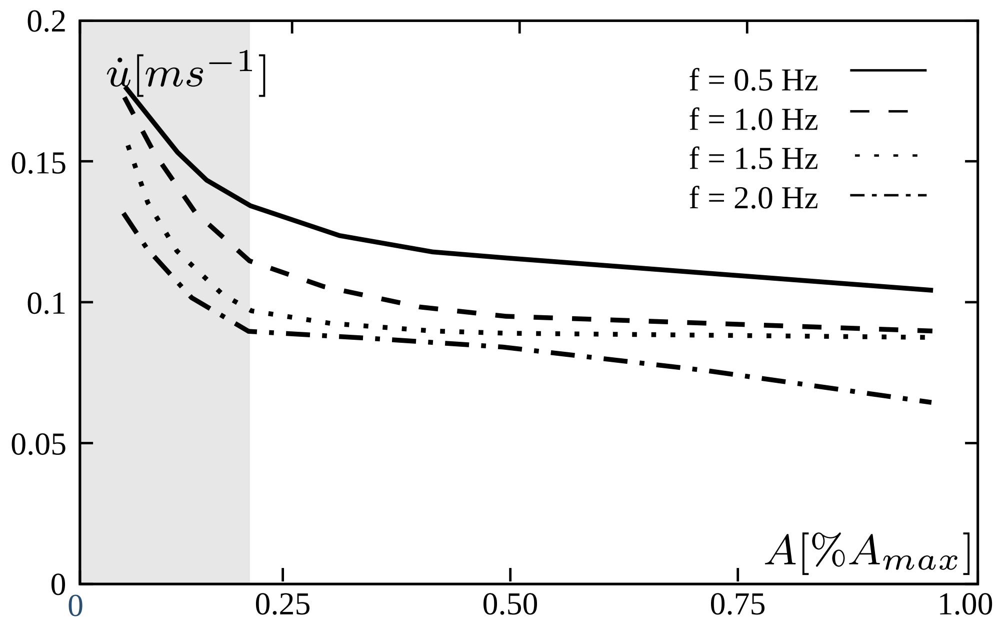
MODELAÇÃO DA SUPERELASTICIDADE

Parametric curves in function of the SE restraining area: displacement



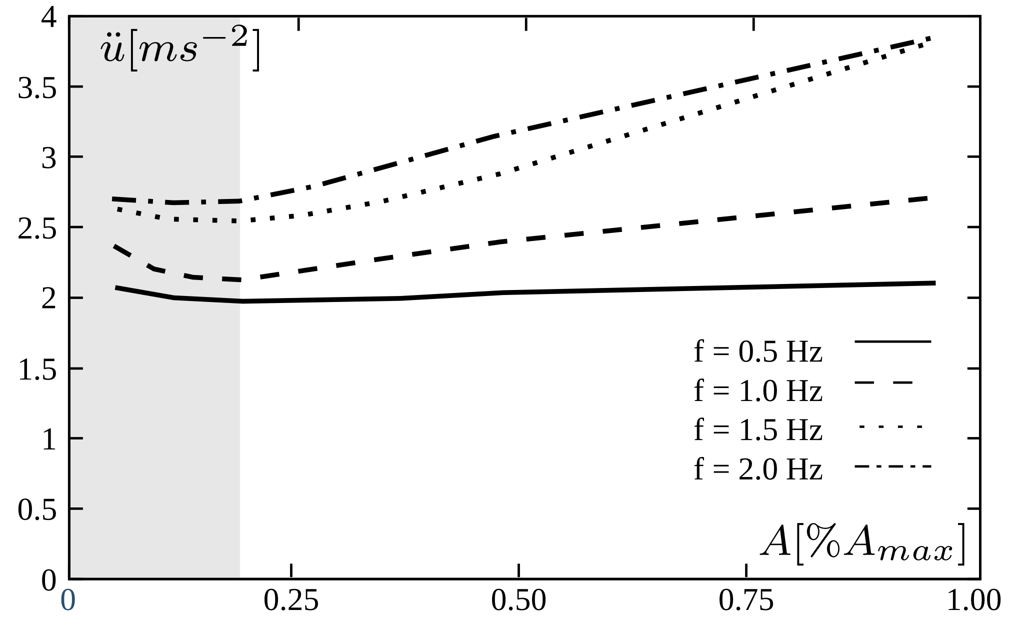
MODELAÇÃO DA SUPERELASTICIDADE

Parametric curves in function of the SE restraining area: velocity



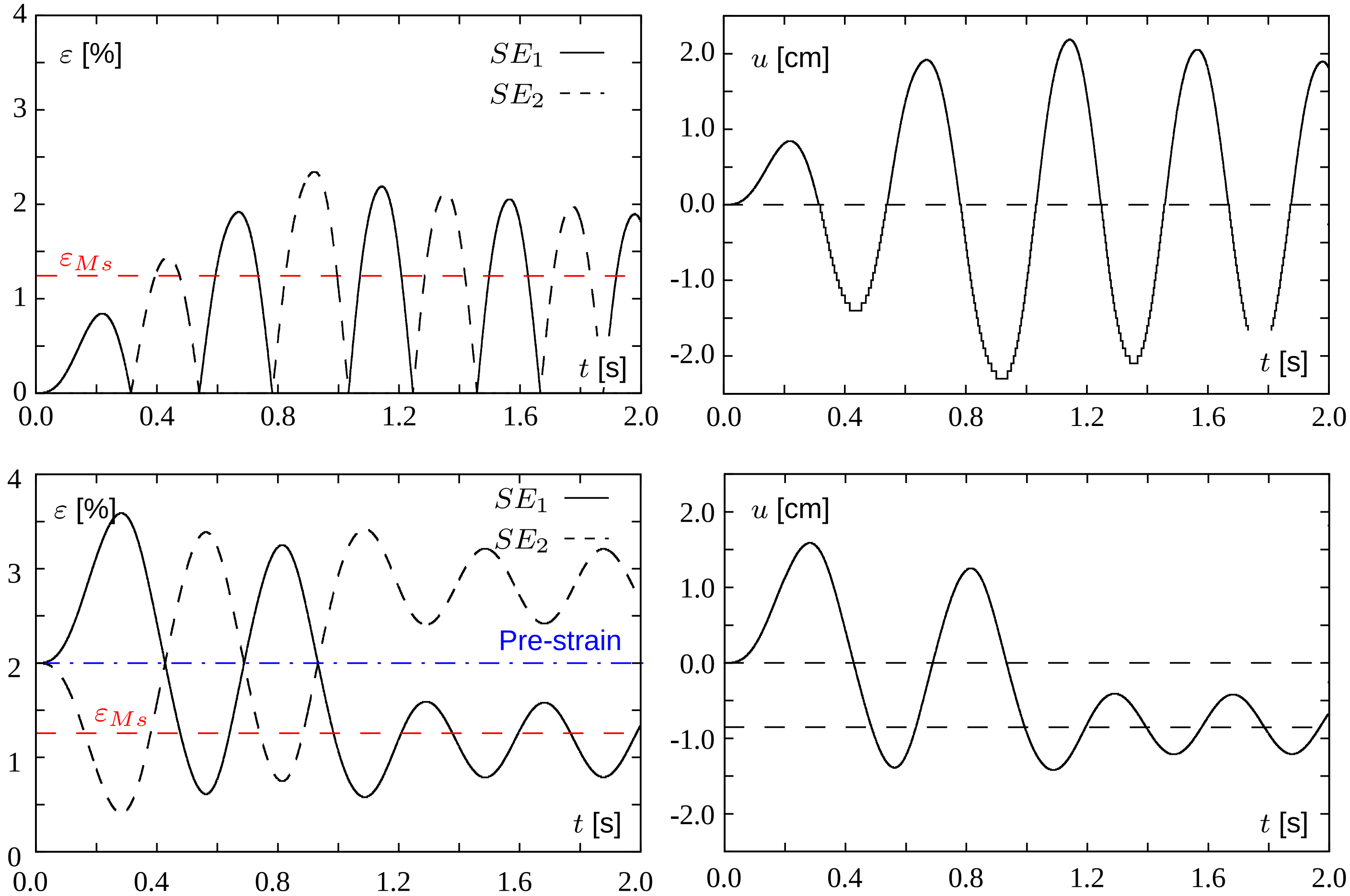
MODELAÇÃO DA SUPERELASTICIDADE

Parametric curves in function of the SE restraining area: acceleration



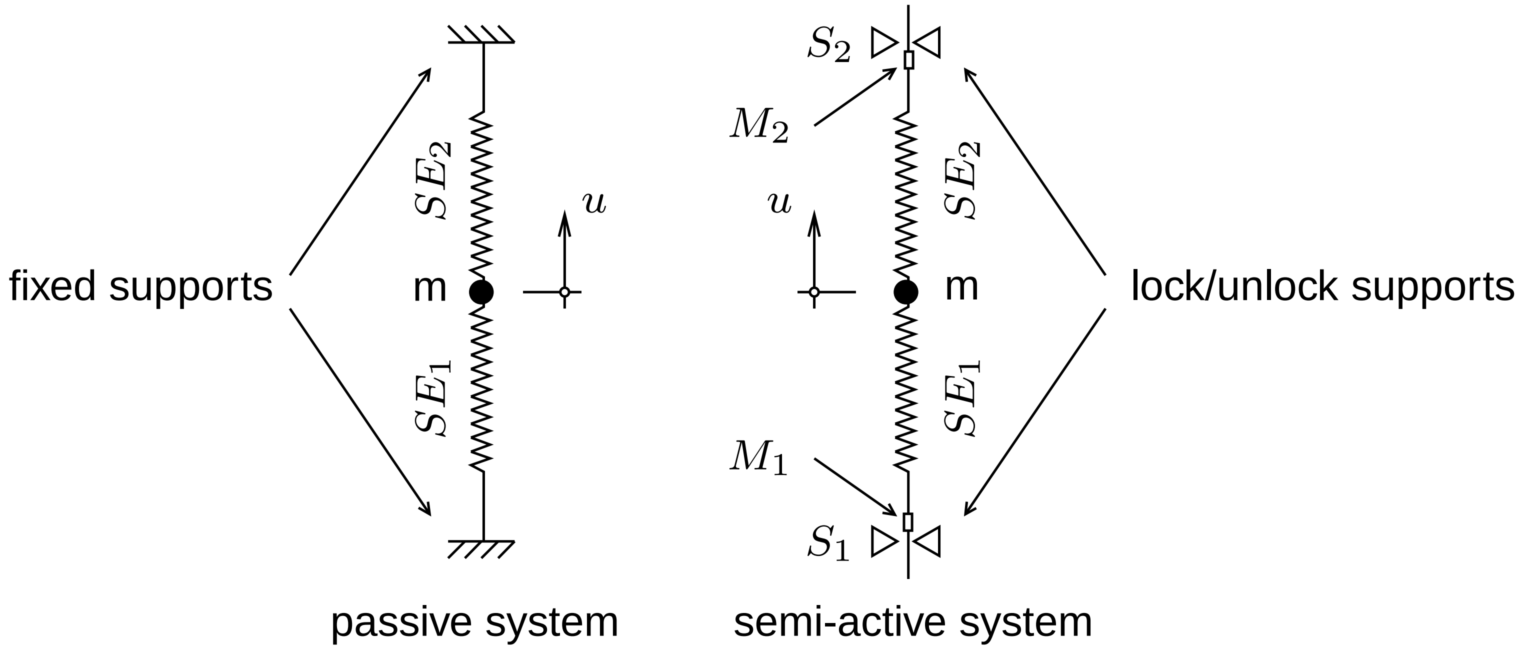
NOVO DISPOSITIVO DE CONTROLO

Sistema passivo sem pré-esforço e com pré-esforço



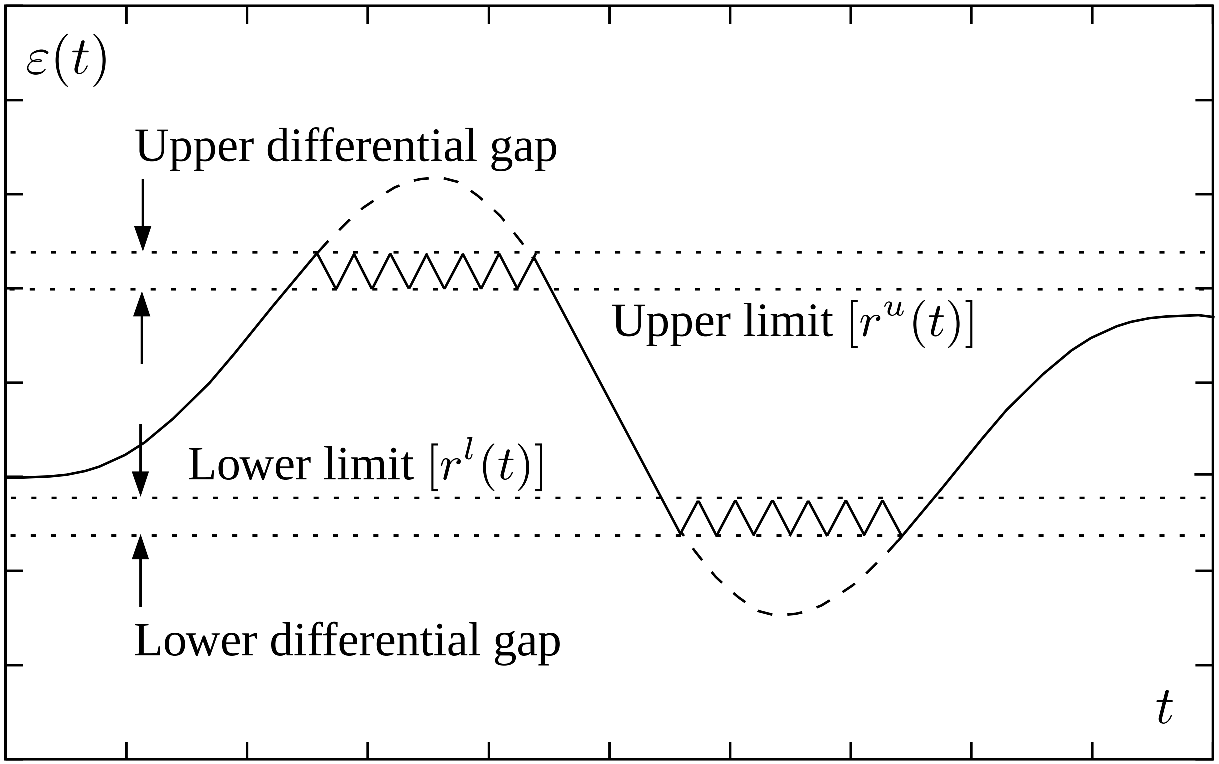
NOVO DISPOSITIVO DE CONTROLO

Esquema funcional do novo dispositivo



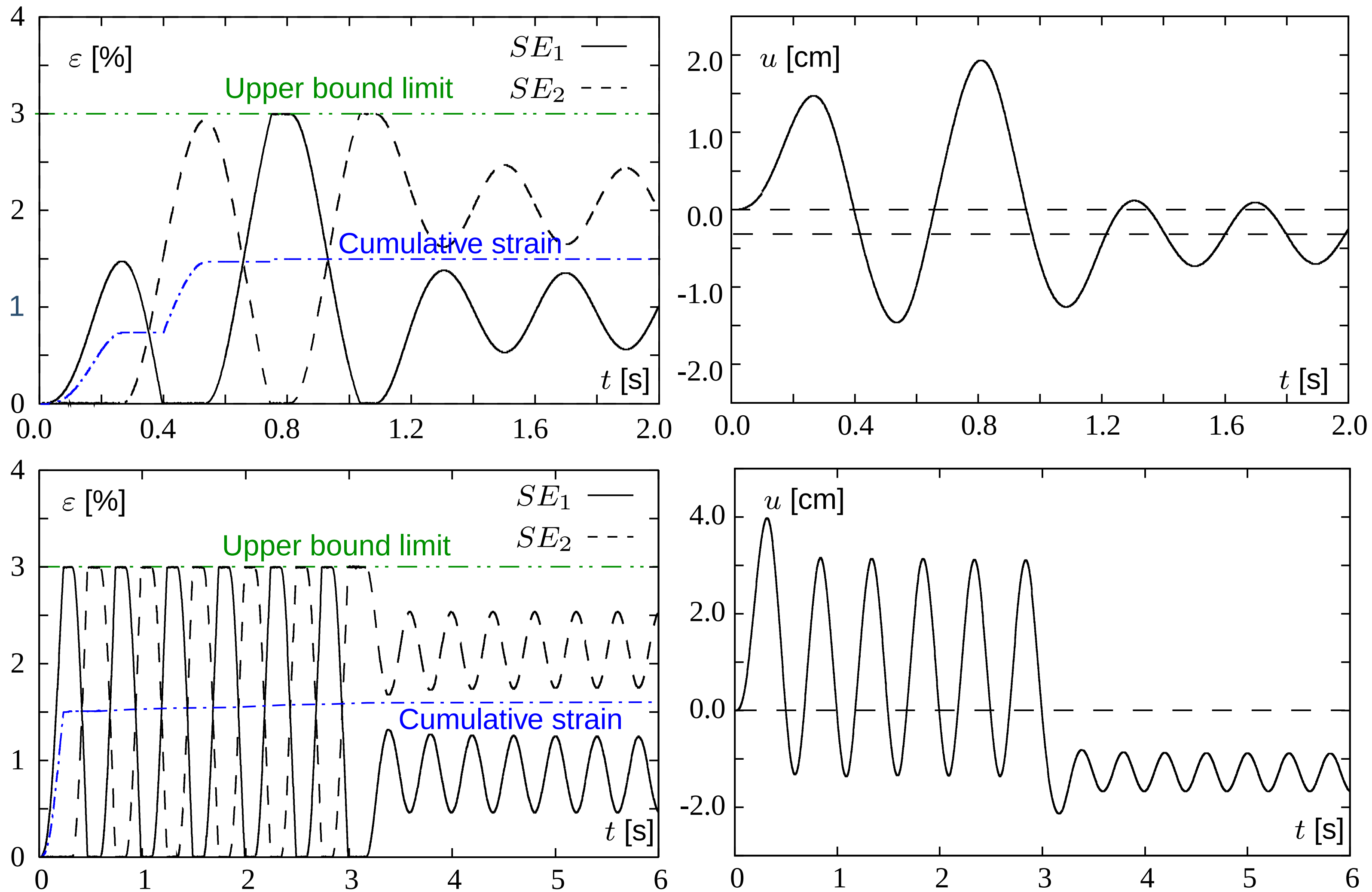
NOVO DISPOSITIVO DE CONTROLO

Funcionamento do controlador on-off



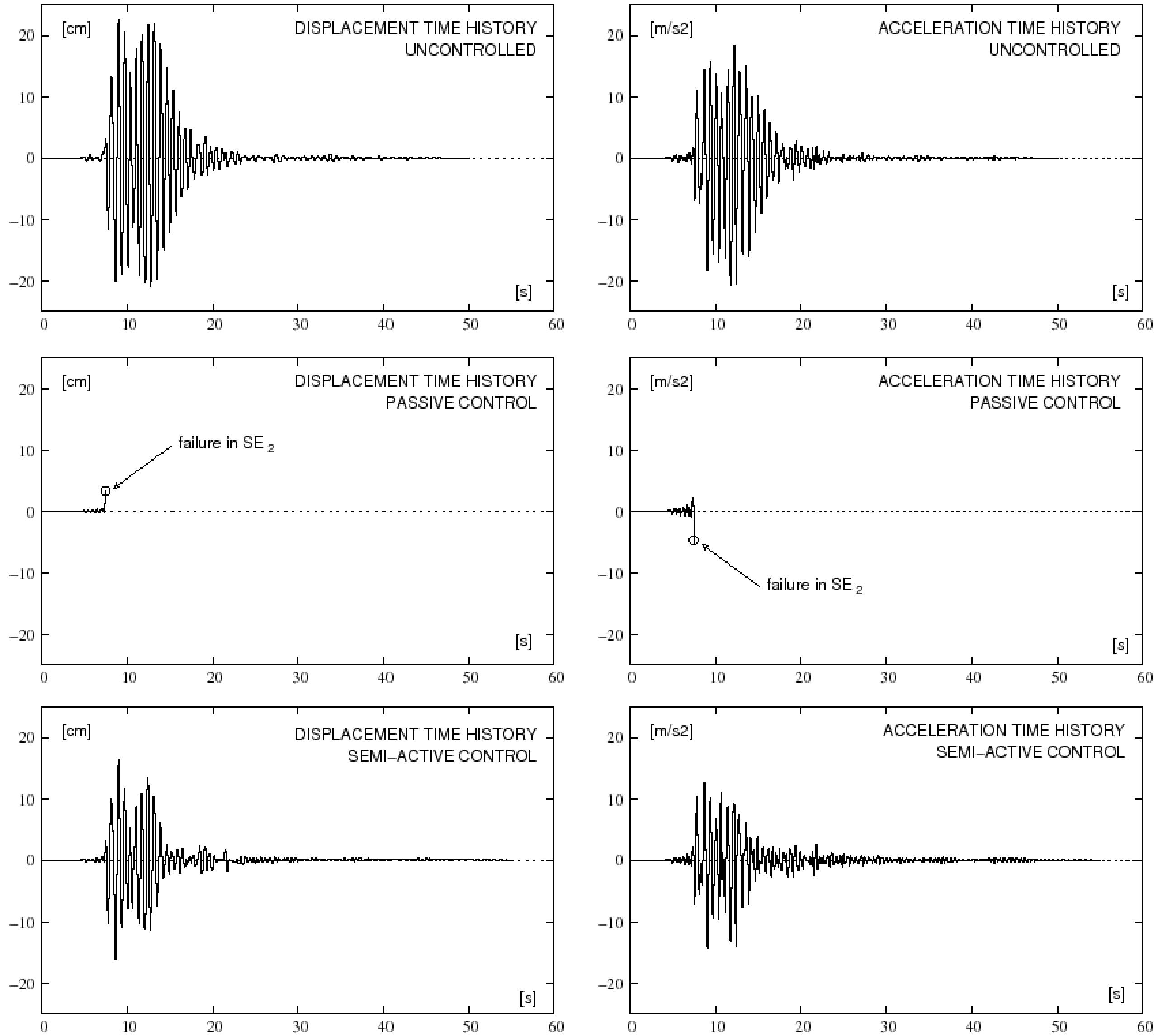
NOVO DISPOSITIVO DE CONTROLO

Novo dispositivo submetido a solicitações harmónicas

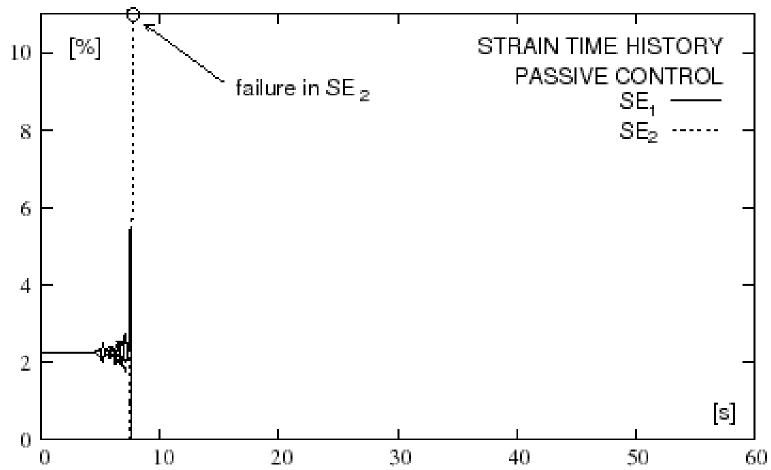


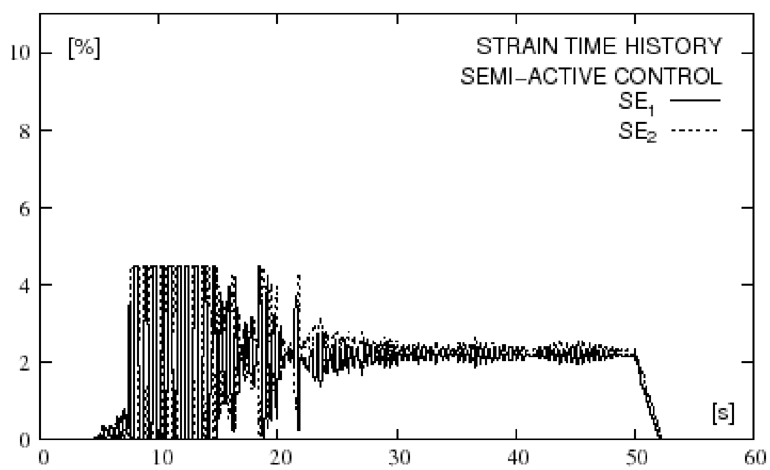
NOVO DISPOSITIVO DE CONTROLO

Estudo comparativo: sismo “kobe”



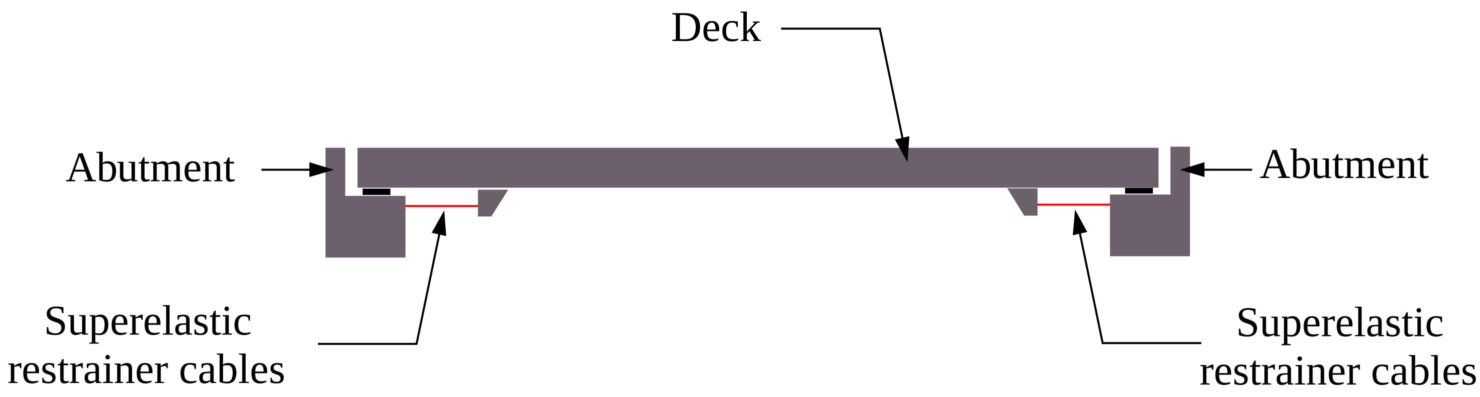
NOVO DISPOSITIVO DE CONTROLO
Estudo comparativo: sismo “kobe”





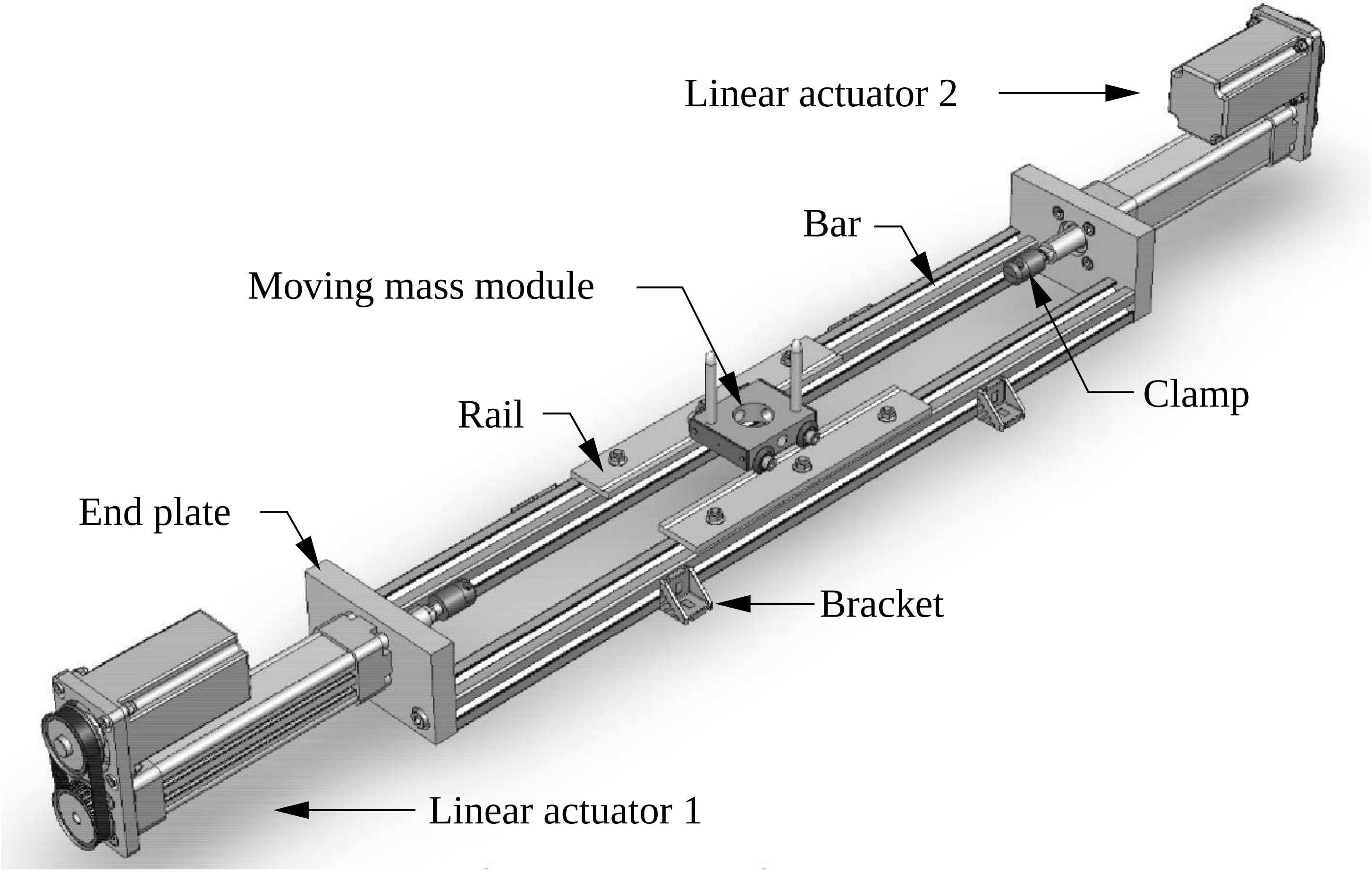
MODELO EXPERIMENTAL

Ponte simplesmente apoiada com sistema de retenção superelástico



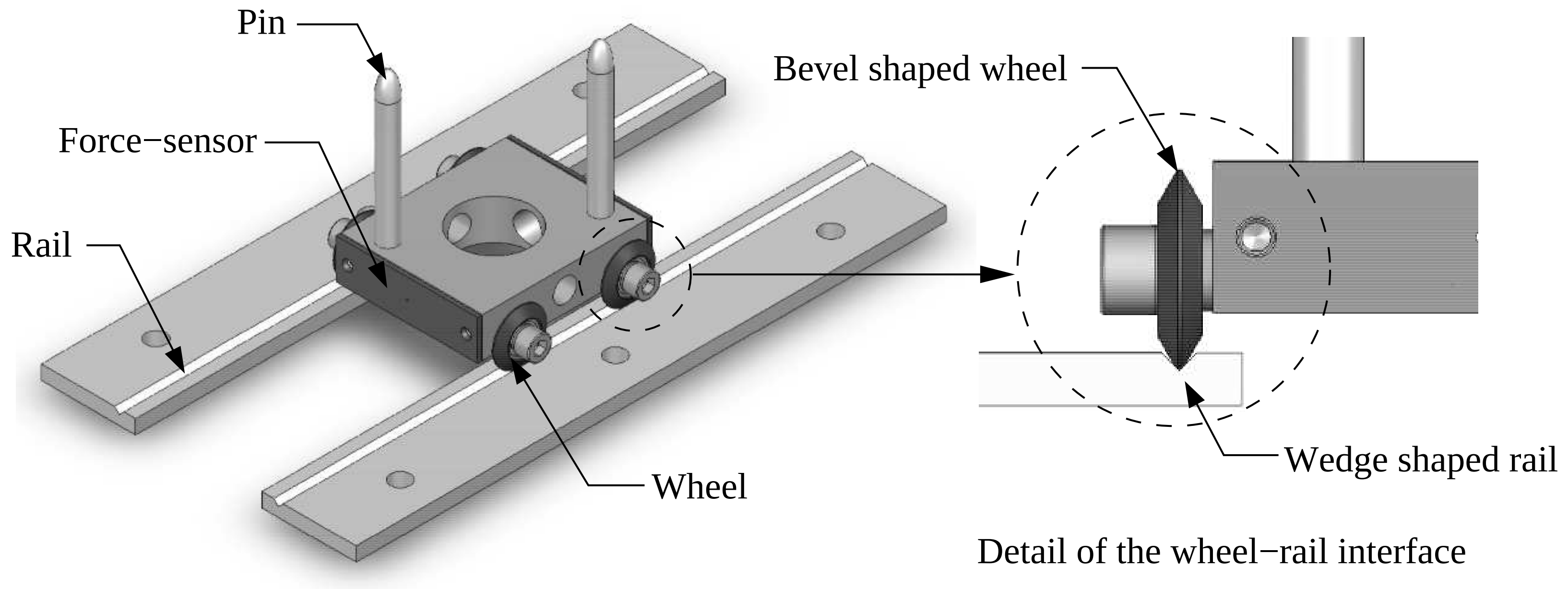
MODELO EXPERIMENTAL

Fase de projecto: conceito geral do dispositivo



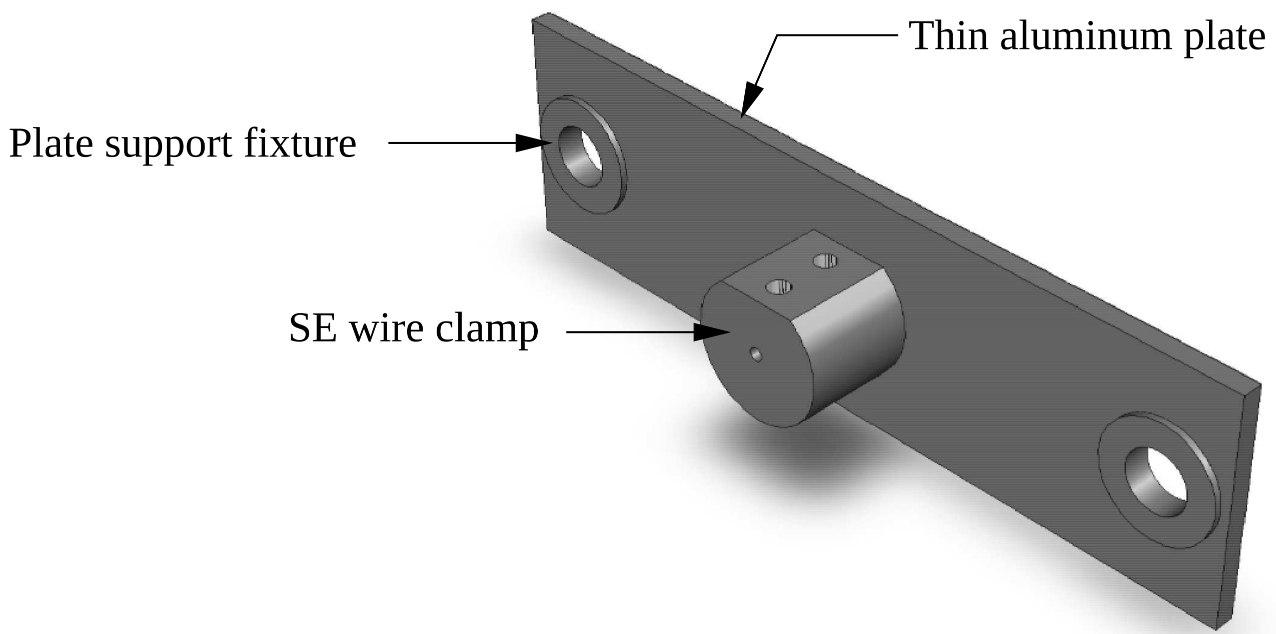
MODELO EXPERIMENTAL

Fase de projecto: módulo com massa móvel



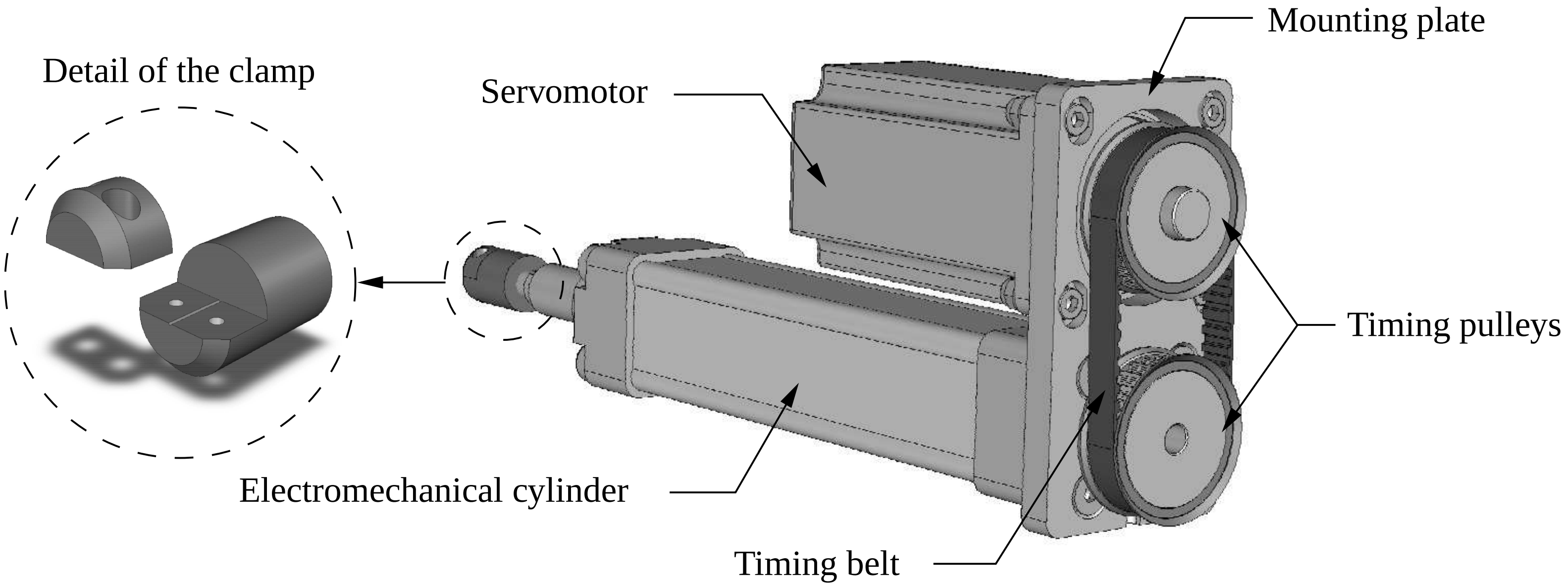
MODELO EXPERIMENTAL

Fase de projecto: sensor de força



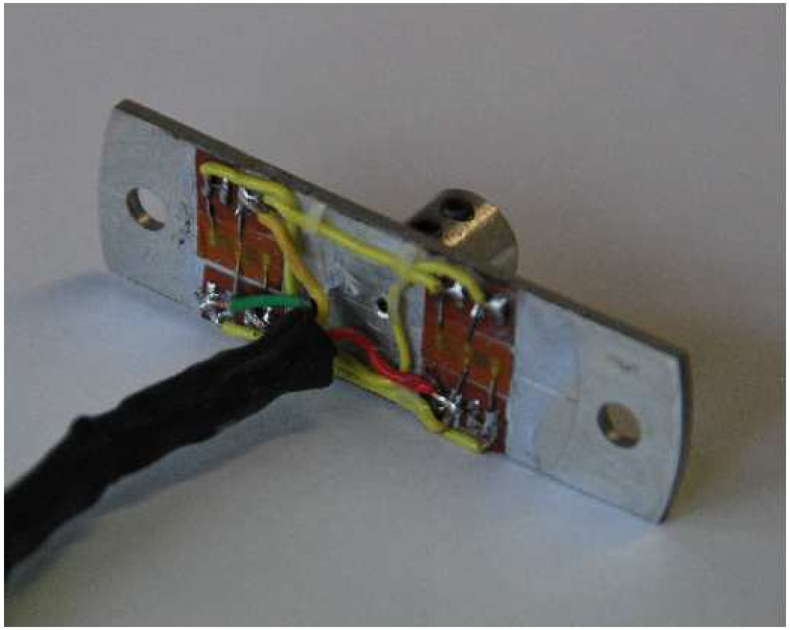
MODELO EXPERIMENTAL

Fase de projecto: actuador linear



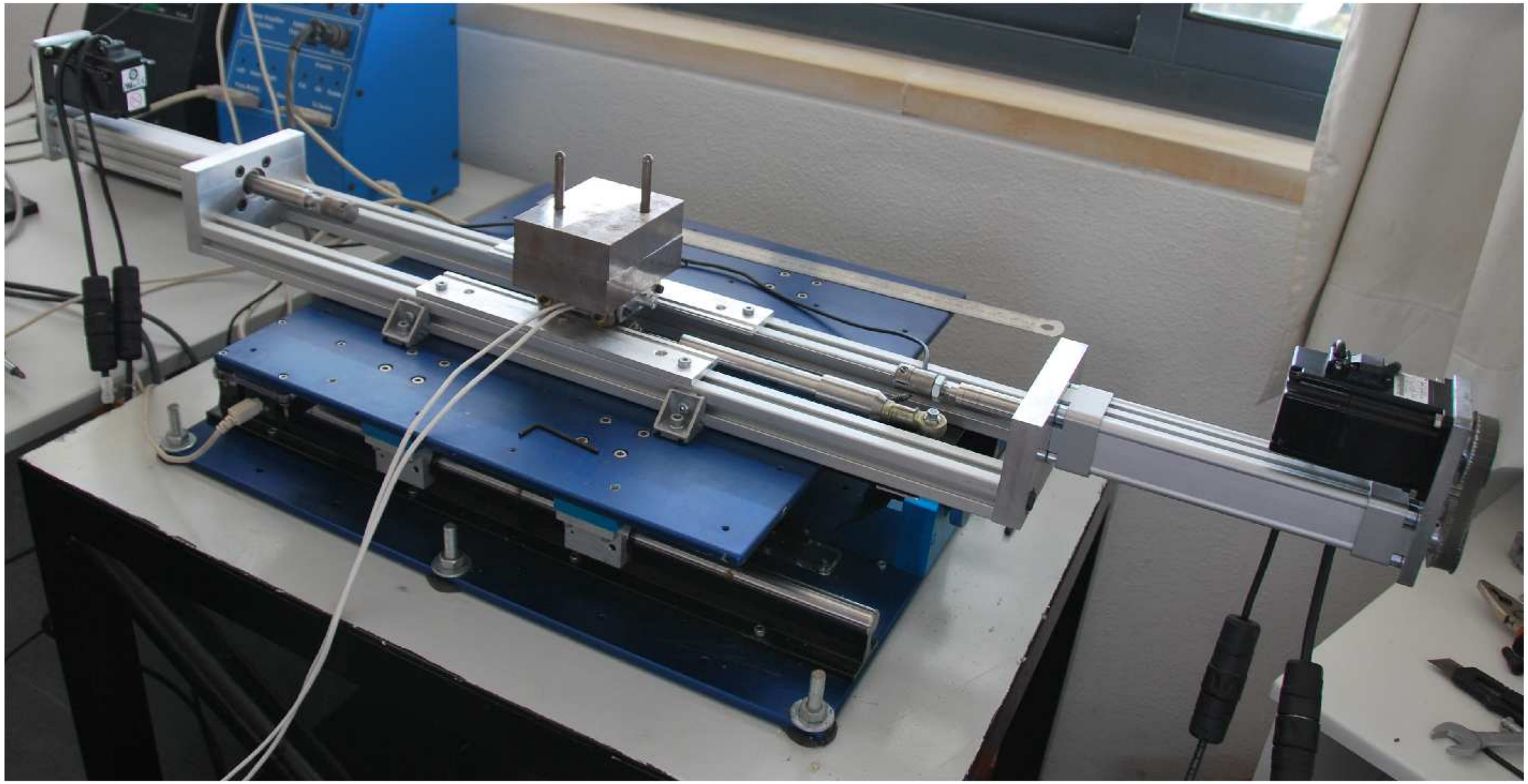
MODELO EXPERIMENTAL

Sensor de força



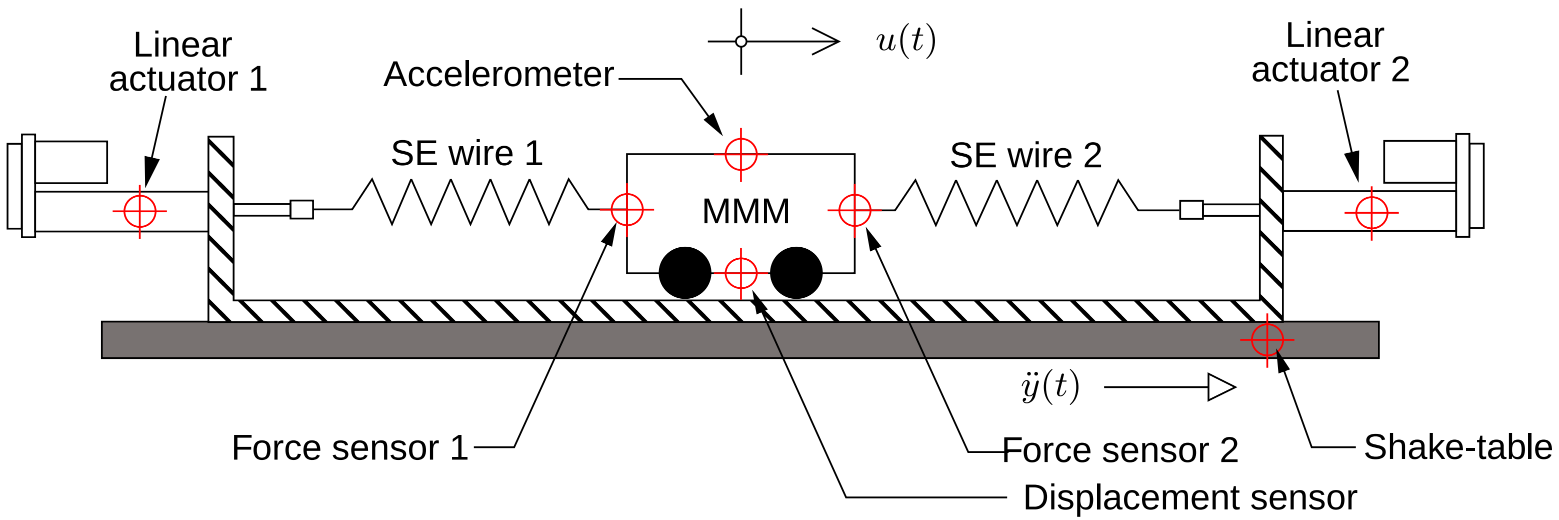
MODELO EXPERIMENTAL

Protótipo completo



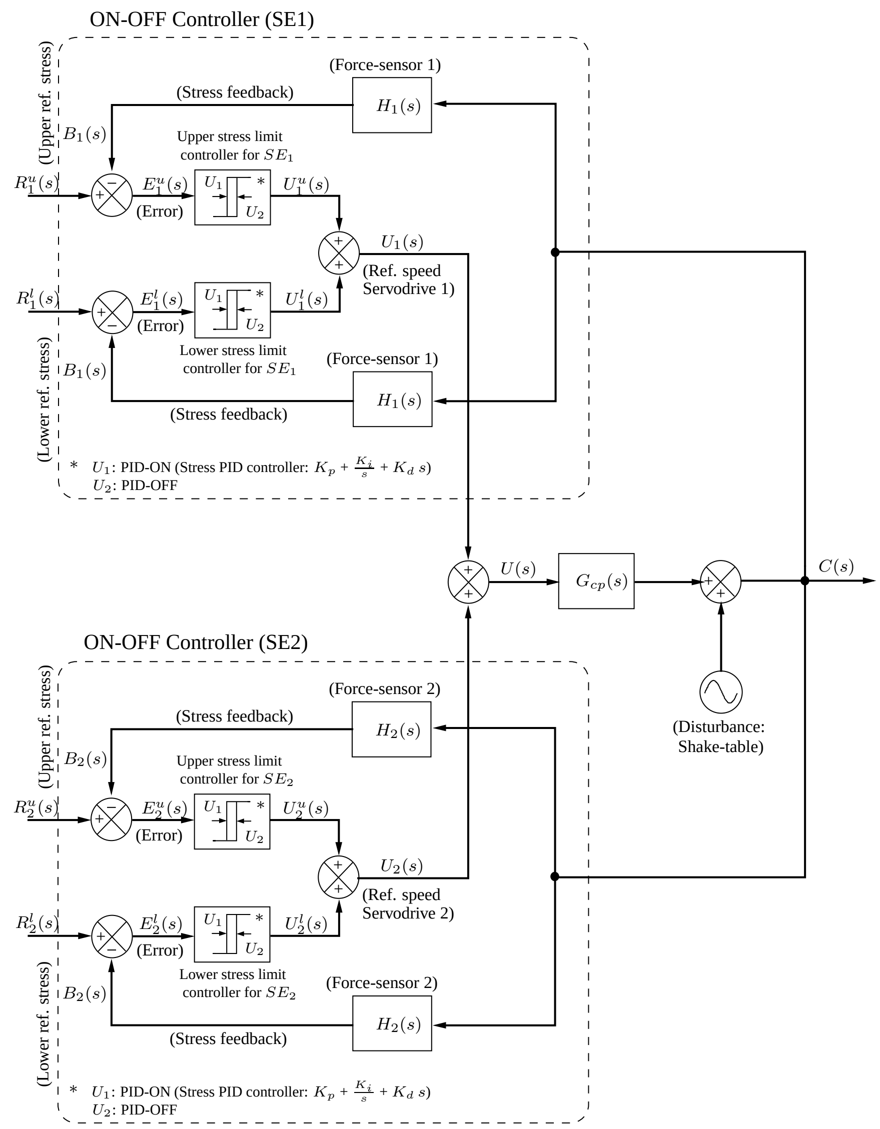
MODELO EXPERIMENTAL

Ensaio do protótipo completo



MODELO EXPERIMENTAL

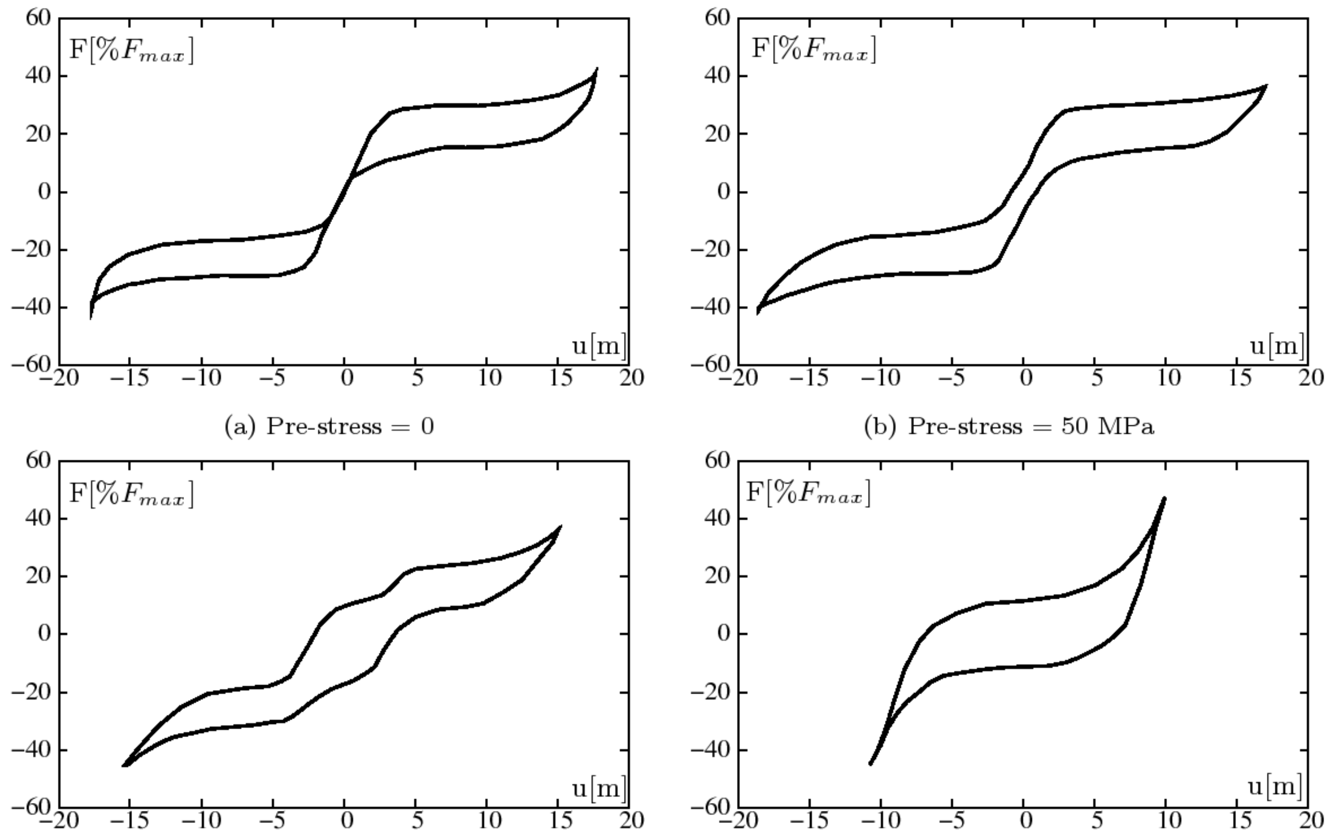
Diagrama de blocos do protótipo



MODELO EXPERIMENTAL

Estudo paramétrico: pré-esforço no protótipo

$(\zeta_{eq} = 10\% \rightarrow \zeta_{eq} = 23\%)$



(a) Pre-stress = 0

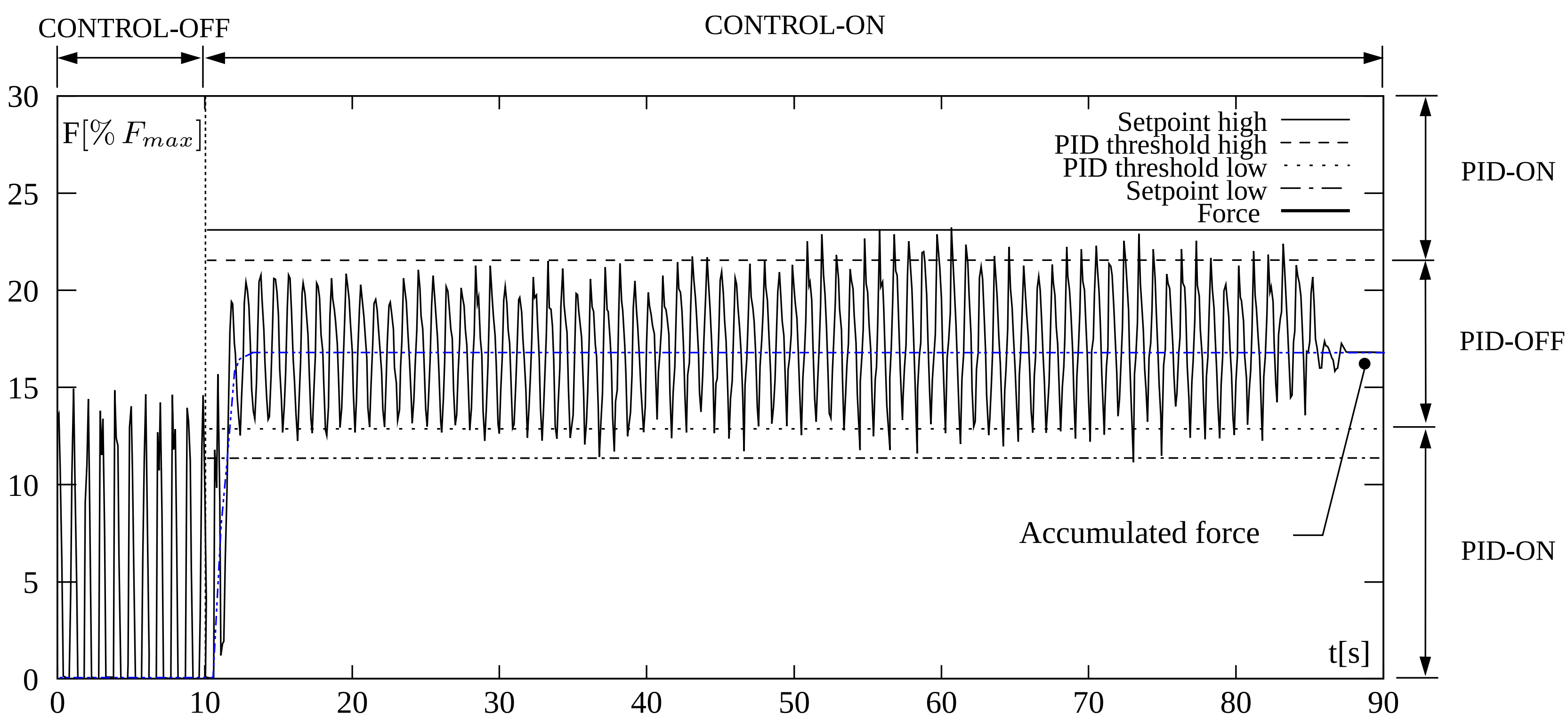
(b) Pre-stress = 50 MPa

(c) Pre-stress = 100 MPa

(d) Pre-stress = 200 MPa

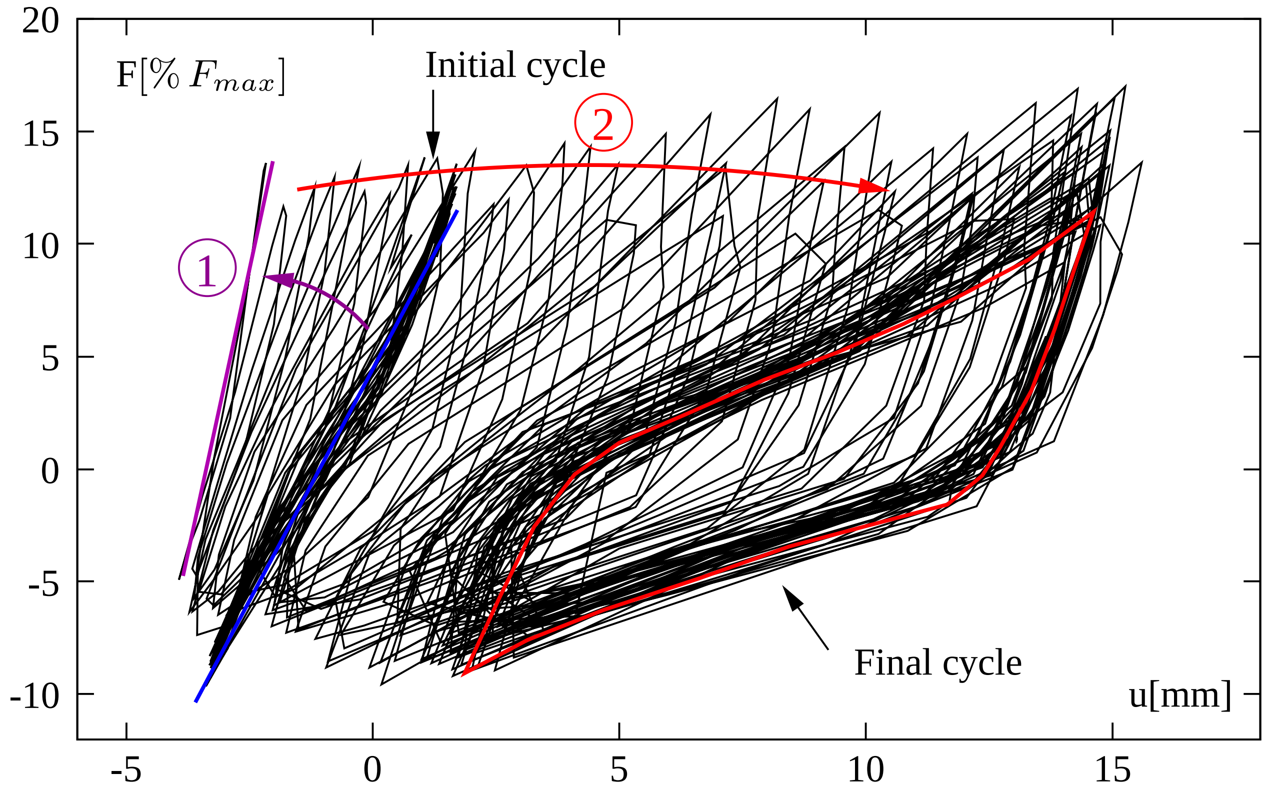
MODELO EXPERIMENTAL

Resultados: histograma da força em SE1



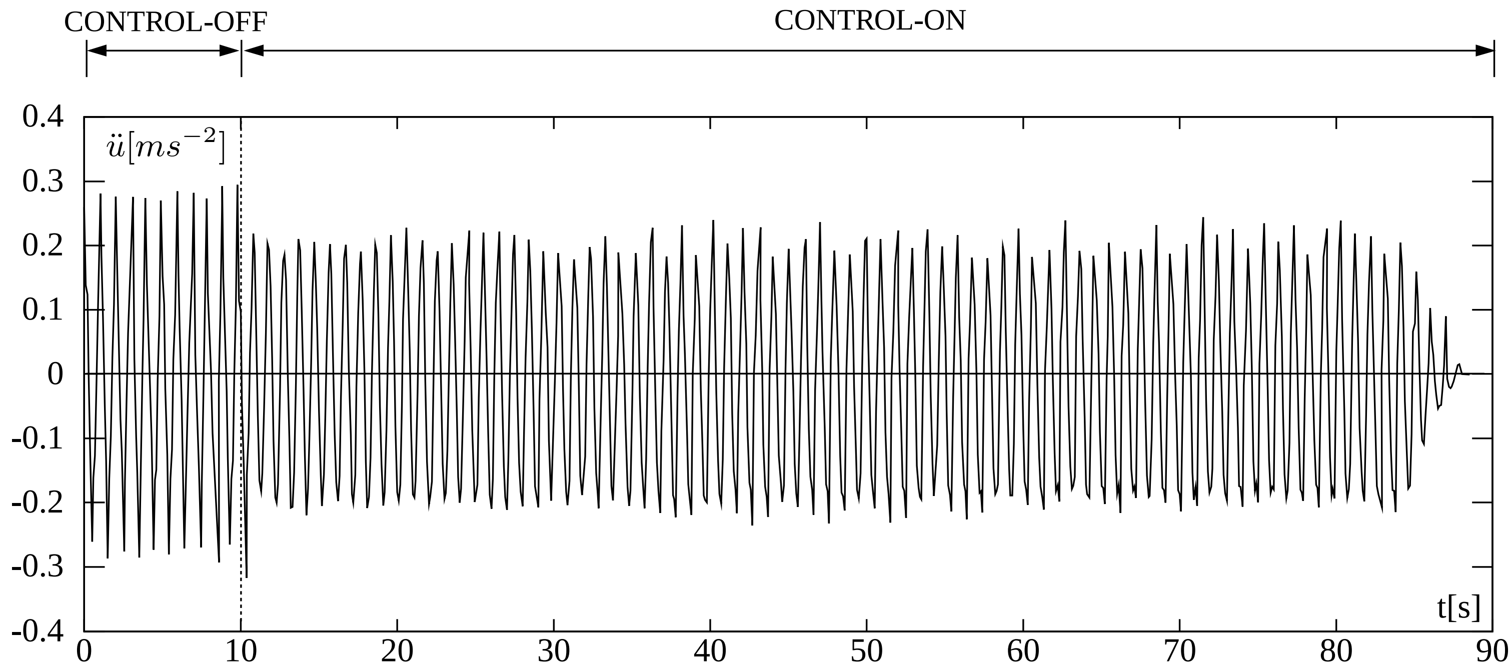
MODELO EXPERIMENTAL

Resultados: evolução do diagrama força-deslocamento



MODELO EXPERIMENTAL

Resultados: histograma da aceleração



SUPERB

Seismic Unseating Prevention. Elements for Retrofitting of Bridges: PTDC/ECM/117618/2010

http://cornel.dec.fct.unl.pt/SUPERB/index.php

Obrigado pela atenção.