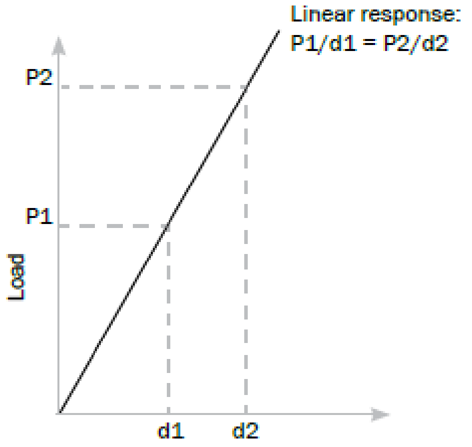
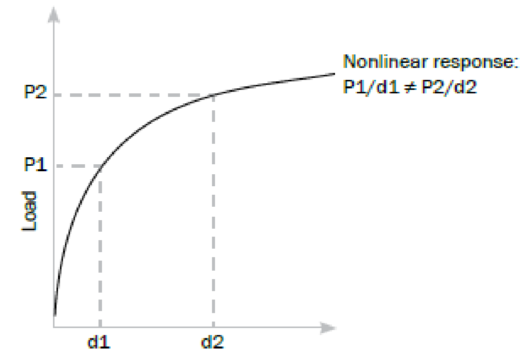
CAE Non Linear Analysis

Strategie di modellazione per l'analisi agli elementi finiti

Annotazioni con riferimento a Hyperworks

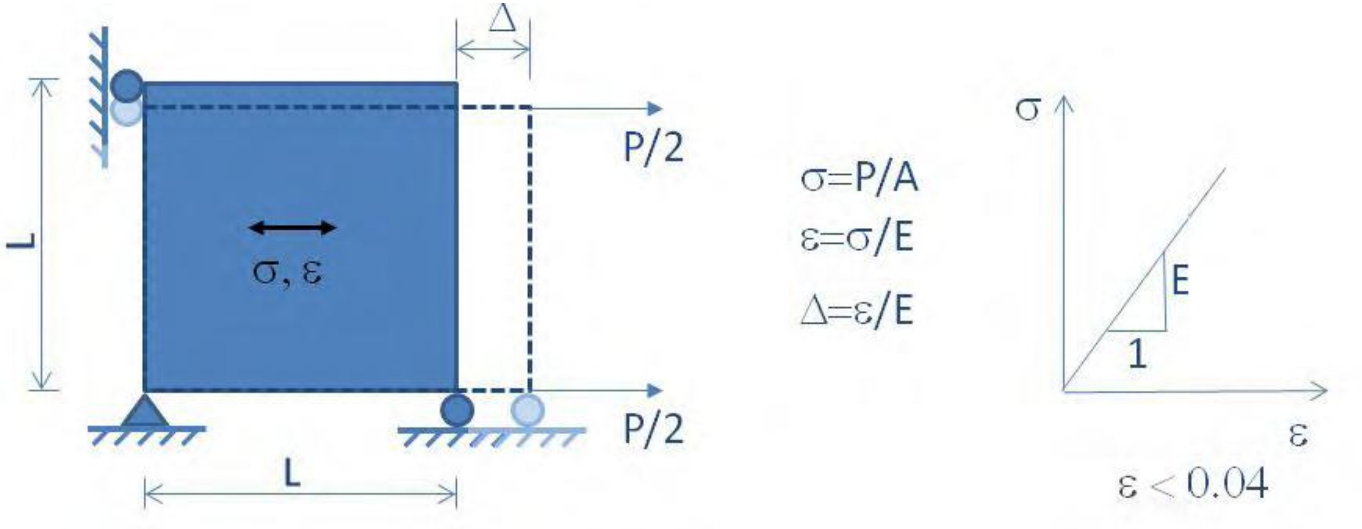
Characteristic Feature	Linear Problems	Nonlinear Problems
Load - Displacement Relation	Displacements vary linearly with applied loads. Thus Stiffness is constant. Changes in geometry due to displacement are assumed to be small and hence are ignored. Original or undeformed state is always used as a reference state.	It is nonlinear. Thus stiffness varies as a function of load. Displacements can be very large and changes in geometry cannot be ignored. Thus stiffness varies as a function of load.
Stress-Strain Relation	Linear up to the proportional / elastic limit. Properties such as Young's Modulus are easily available.	It is nonlinear function of stress-strain and time. These are difficult to obtain and requires lot of additional experimental material testing. Mind the differences between true stress and engineering stress
Scalability	Applicable. That is if a 1 N force causes x units of displacement , then 10 N magnitude of force will cause 10x displacement	Not applicable.
Superposition	Applicable. That is a combination of load cases is possible.	Not applicable .
Reversibility	The behaviour of the structure is fully reversible upon the removal of external loads. This also means that loading sequence is not important and the final state is unaffected by the load history.	The final state after removal of loads is different from the initial state. Due to this superposition of load cases is not possible. Load history is very important.
Solution scheme	The load is applied in one step with no iterations .	Load is split into small increments with iterations performed to ensure that equilibrium is satisfied at every load increment.
Computational Time	Small	Large
User's Interaction with the software	Least required	Requires lot of monitoring as the software may fail to converge sometimes.





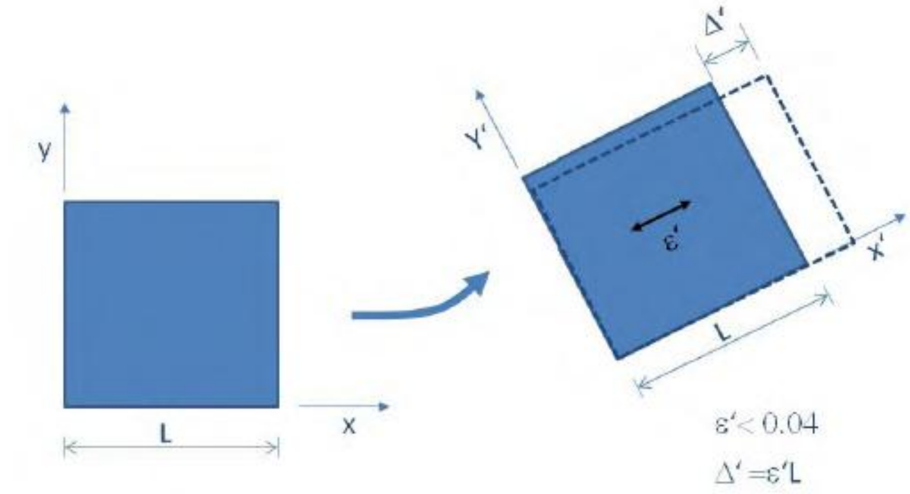
Le non linearità possibili si distinguono in tre categorie:

- Non linearità geometriche
- Non linearità del materiale
- Non linearità di contatto



In caso di ipotesi elastico lineare con piccole deformazioni, lo stress è proporzionale alle deformazioni

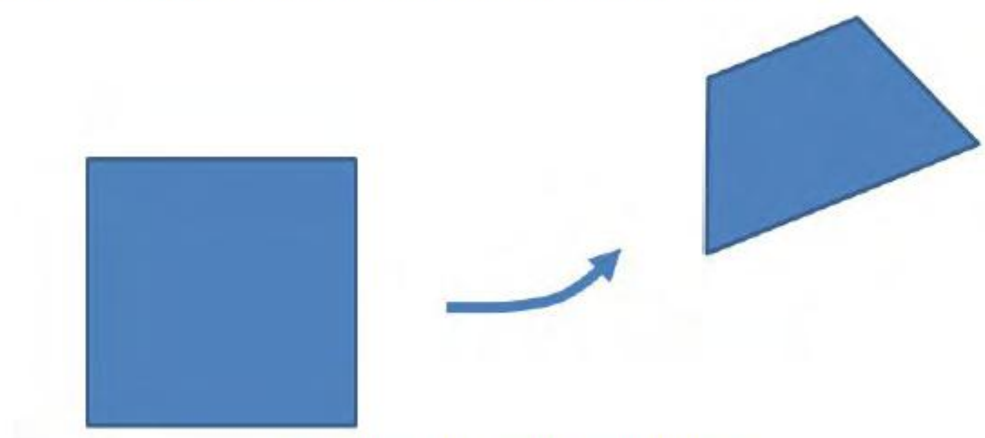
Large Displacements And Rotations (small strain; linear or nonlinear material)



Le non linearità geometriche possono essere legate a: grandi spostamenti, grandi rotazioni, grandi deformazioni

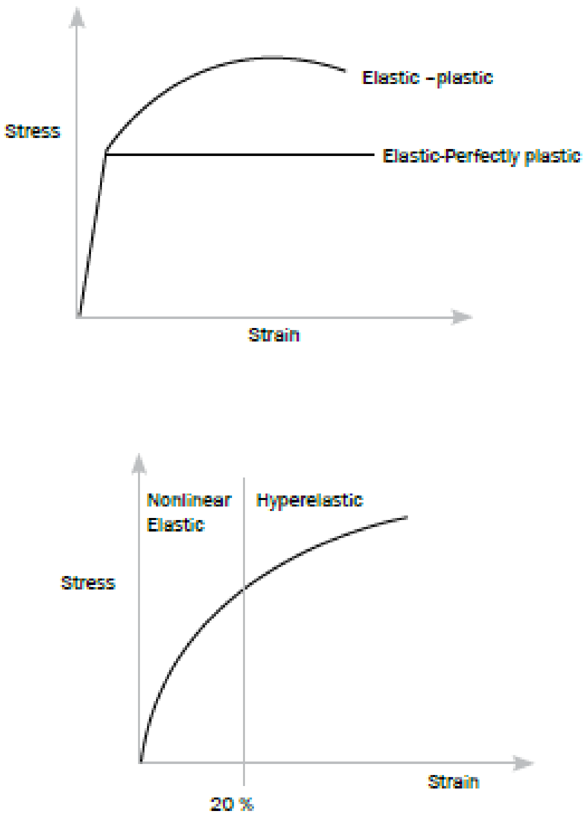
In questi casi la geometria delle sezioni che reagiscono alle sollecitazioni oppure i punti/modi di applicazione dei carichi cambiano configurazione durante la deformazione

Large Displacements, Rotations, And Large Strain (linear or nonlinear material)



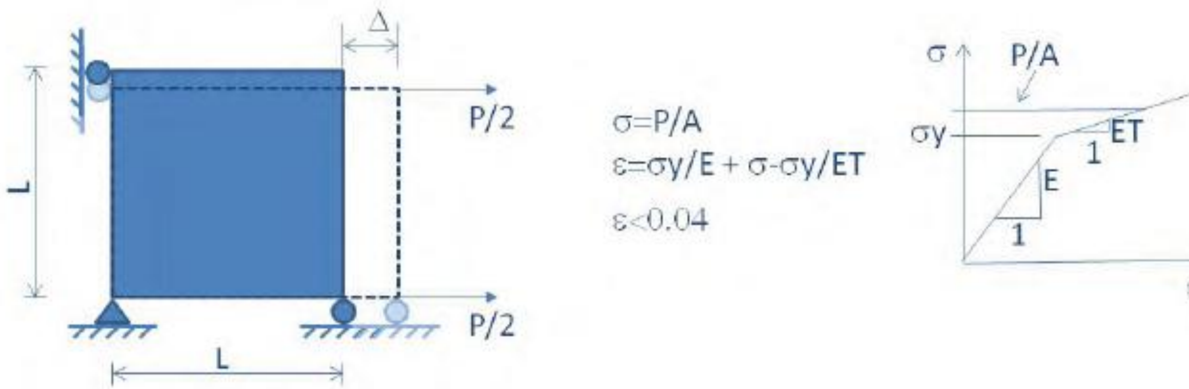
Images after K.J. Bathe, Finite Elemente Methoden

Le non linearità del materiale riguardano fenomeni di iperelasticità o plasticità e sono tenuti in conto mediante opportuni legami costitutivi (o modelli di materiale)



Features of Material Nonlinearity

Piccole deformazioni, materiale in campo plastico modellato come bilineare



Images after K.J. Bathe, Finite Elemente Methoden

Esempi di modelli costitutivi (sai trovare i nomi delle card in Hyperworks Optistruct? E in Ansys?)

1. Nonlinear elastic

2. Hyperelastic

3. Elastic-perfectly plastic

4. Elastic-time independent plastic

5. Time dependent plastic (Creep)

6. Strain rate dependent elasticity – plasticity

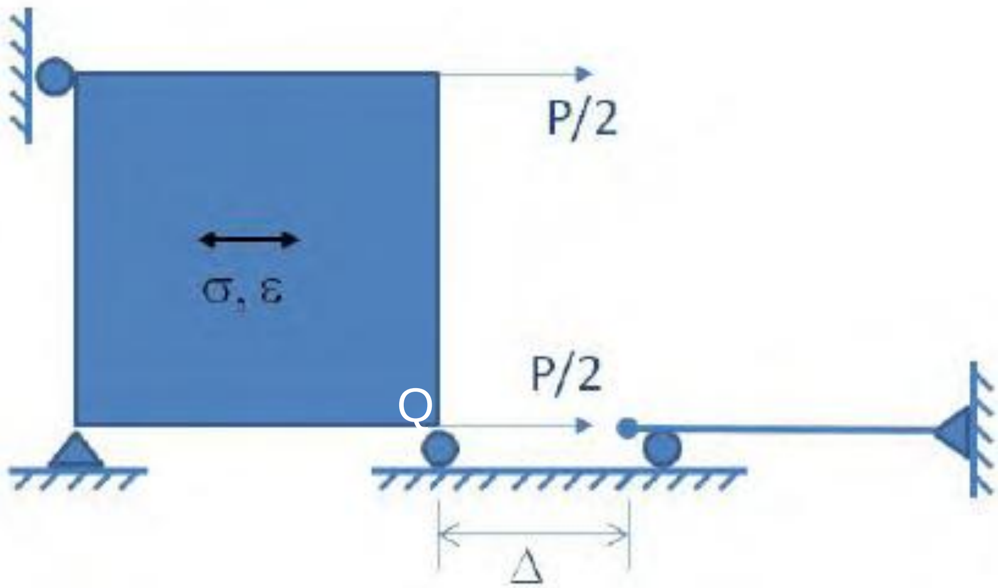
7. Temperature dependent elasticity and plasticity

Type	Description	Model	Law (MID)
Elastic-plasticity of Isotropic Materials	MATX02 von Mises hardening without damage MATX36	Johnson-Cook	(2)
		Zerilli-Armstrong	(2)
		Zhao	(48)
		Cowper-Symonds	(44)
		Piecewise linear	(36)
		Drucker-Prager for rock or concrete	(10), (21)
	von Mises hardening with brittle damage	Aluminum, glass, etc	(27)
		Predit rivets	(54)
		Reinforced concrete	(24)
	von Mises hardening with ductile damage	Ductile damage for solids and shells	(22)
		Ductile damage for solids	(23)
	von Mises with viscoplastic flow	Ductile damage for porous materials, Gurson	(52)

Metallic alloys	Rubber
Law 1: elastic material	Law 42: Ogden-Mooney-Rivlin
Law 2: elasto-plastic material	Law 62: Hyper Visco Elastic material
Law 27: elasto-plastic brittle material	
Law 36: tabulated elasto-plastic material	**Plastic**
Law 60: ~36 + quadratic stain rate interpolation	Law 36: tabulated elasto-plastic material
Law 66: Visco Elastic Plastic Piecewise Linear Material	Law 65: Elastomer material
	Law 76: SAMP
Austenitic and Stainless Steels	
Law 63: Hansel material	**Glass**
Law 64: Ugine and ALZ material	Law 27: elasto-plastic brittle material
	Law 36: tabulated elasto-plastic material
Crushable foams (Honeycomb)	
Law 28: Honeycomb	**Composite**
Law 50: Crushable foam	Law 36: tabulated elasto-plastic material
Law 68: Cosserat medium	Law 15: Tsai Wu plasticity + Chang & Chang failure
	Law 25: Tsai Wu plasticity model
Foams	
Law 33: Closed Cell visco-elastic-plastic	**Fabric**
Law 35: Generalized Kelvin-Voigt open/closed cells	Law 19: linear elastic orthotropic material
Law 38: Tabulated visco-elastic material	Law 58: nonlinear elastic material
Law 70: Tabulated hyper visco elastic material	
	Special
	Law 5: Jones Wilkins Lee Material (Explosives e.g. TNT)

Overview on some of the supported material models in OptiStruct / RADIOSS.

Le nonlinearità di contatto riguardano cambiamenti nello stato di vincolo tra le superfici o i nodi



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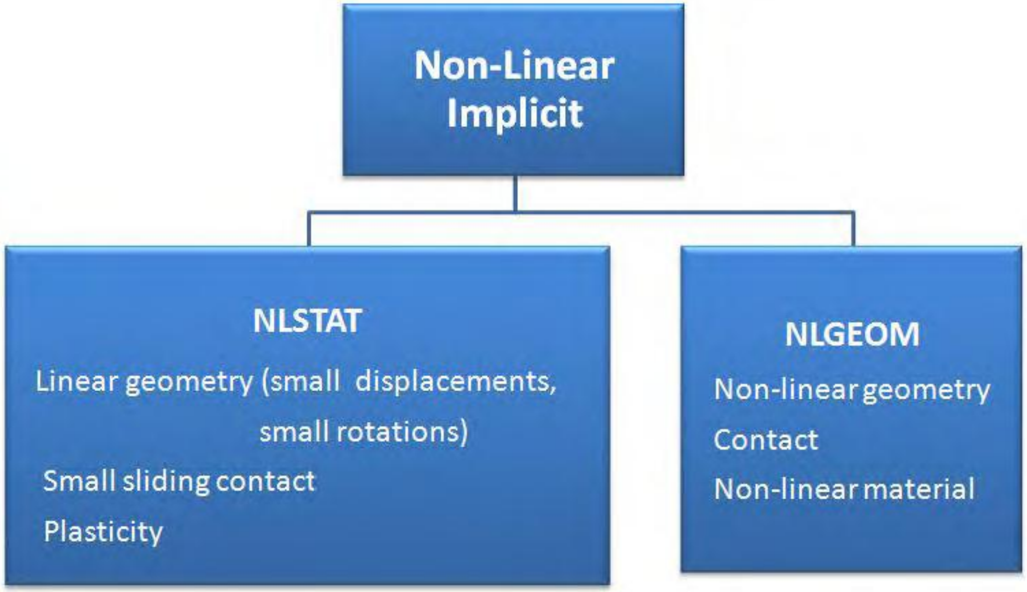
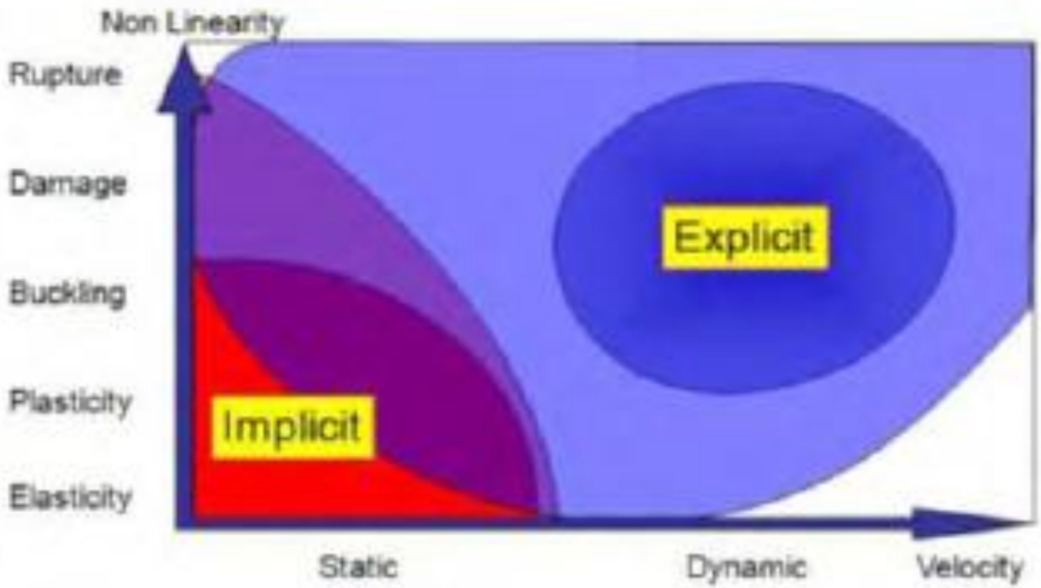
Il punto Q a partire da un certo spostamento Delta risulterà bloccato





A comparison of explicit and implicit solution domains