Polytechnic University of Catalonia

Msc. in Numerical Methods

Computational Mechanic Tools

Homework 3: "Non-linear Elastic Block"

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1 Code identification

- The definition of the example (loading, geometry)
  File= preprocessing.m
  Example selection= from line 8 to 59
  Mesh generation = from line 61 to 75
  Element type= from line 78 to 83
  Model parameters= from line 85 to 101
  Boundary conditions= from line 108 to 125
  Forces= from line 127 and 136

- The choice of solution method (Newton's method with or without line-search).
  File= main_incremental_iterative.m
  Method= line 20
  Line-search option= line 21
  File= main_buckling.m
  Method= line 18
  Line-search option= line 20

- The implementation of the solution method.
  File= equilibrate.m
  The hole function is the implementation, using different parts depending on the method chosen

- The implementation of the incremental-iterative strategy, with smart initial guesses for imposed displacements.
  File= main_incremental_iterative.m
  Implementation with smart initial guess= line 44 to 48

- The introduction of random perturbations in the initial guesses of the solution method.
  File= main_buckling.m
  Perturbations in geometry= from line 53 to 57
  File=main_incremental_iterative.m
  Perturbations= line 50

2 Tests

The following examples were run

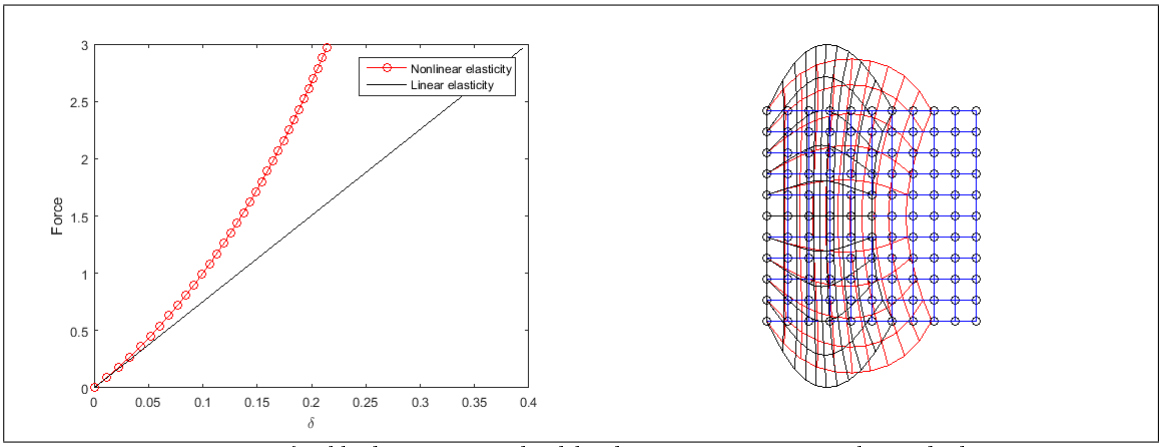
- Example 0 without line-search and for mod1.force = -3e0 and mod1.force = 3e0.
- Example 1 without line-search and for lambda=[1:.025:2] and lambda=[1:-.01:0.5].
- Examples 2 and 3 with and without line-search, with and without random perturbations.
- Examples 4 and 5 with and without line-search, without random perturbations.

Too many plots were obtained when the examples were run. Instead of enclosing all of them, only a few will be used to compare the linear and the non-linear model.

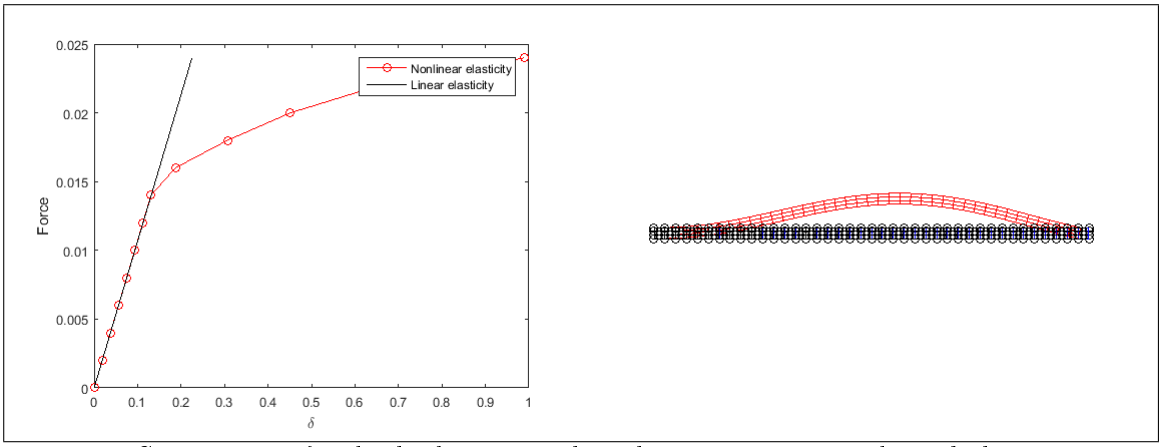
3 Linear model vs. Non-Linear model

- Proportionality of the response with respect to the loads

  Hook's law of proportionality between strains and stresses (displacements and forces) only holds when displacements are sufficiently small. In the case of large displacements, linear elasticity keeps using Hook's Law and is no longer representative of reality. That's why in the following figures, the curves for linear elasticity and non-linear elasticity are together in the beginning of the loading but detach in the following figures.



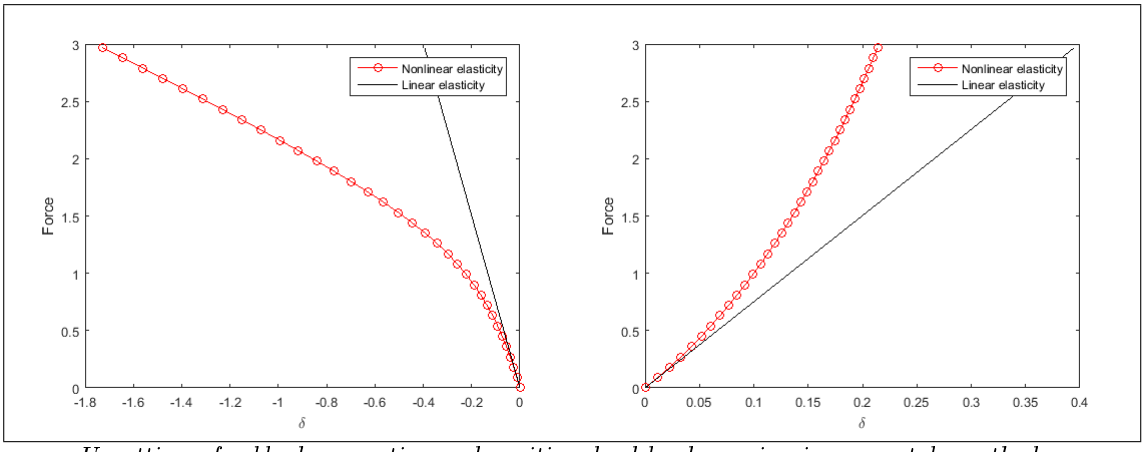
Upsetting of a block - Positive dead load - main_incremental_method



Compression of a slender beam - Dead Load - main_incremental_method

- Symmetry of the response with respect to the sign of the loads.

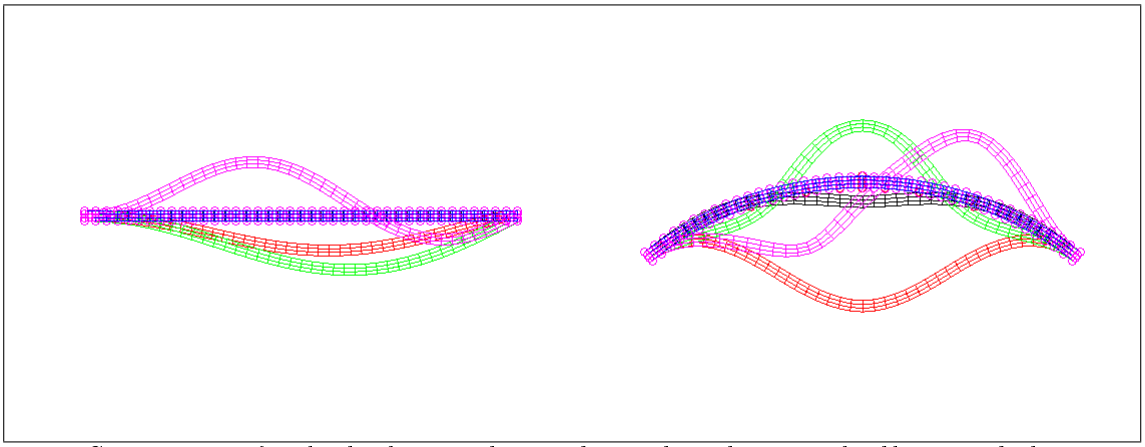
  As shown in the following figure, when two loads with same modulus but different sign are applied to the block, the linear response is symmetric while the non-linear isn't.



Upsetting of a block - negative and positive dead load - main_incremental_method

- Uniqueness of solutions

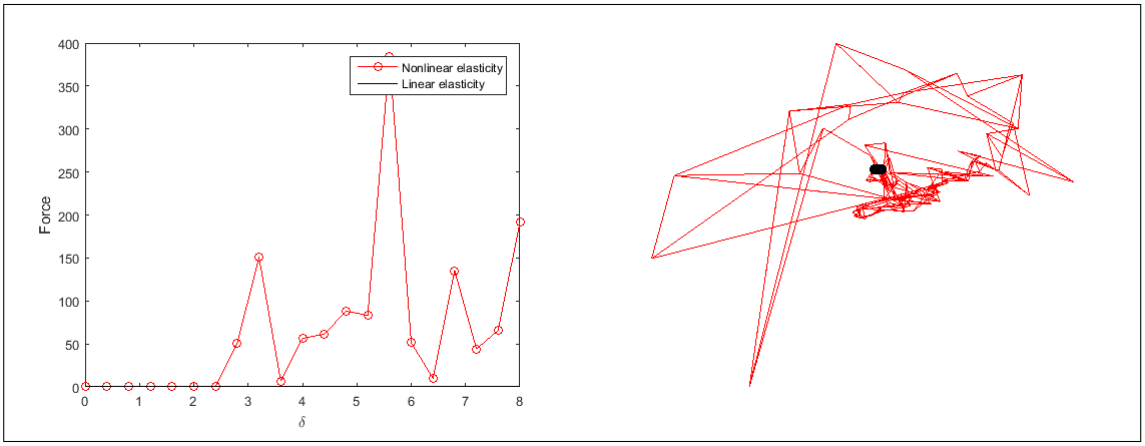
  Buckling is an example of a non-linear phenomena that can result in different configurations (buckling modes) while a linear analysis would result in an unique solution.



Compression of a slender beam and an arch- Dead Load - main_buckling_method

- Stability of the solutions

  Linear problems are in general stable, while non-linear methods use algorithms that are conditionally stable. This means that some methods work only under some specific configurations and equilibrium is not reached in a reasonable amount of iterations, usually giving chaotic results.



Compression of a slender beam - Imposed displacement - main_incremental_method (no linesearch)

4 Conclusions

Some phenomenon in nature, in fact most of them, are intrinsically non-linear (when geometry, material, and boundary conditions behave non-linearly). Linear analysis are useful for getting partial understanding of them, under many unrealistic hypothesis, but are insufficient when more deep and precise result are needed. Non-linear methods are more complex (depending on more parameters) and, a priori, doesn't guarantee convergence, and when they do, the solution may not be unique. That's why non-linear analysis should be done by experienced engineers with deep knowledge of the problem behaviour, the model and numerical methods techniques.