Name: ……..… Date: …….. Signature ……

Universitat Politècnica de Catalunya, Barcelona, April 15–19, 2013

Numerical Simulation of Fast Transient Dynamic Phenomena in Fluid-Structure Systems

Questions/Exercises on Part I

Note: some questions may admit more than one answer. You may mark all answers you think are appropriate, and eventually add some comments of your own.

1. In explicit transient dynamics the fundamental governing equation for a Lagrangian formulation is:
    a. The principle of virtual work
    b. The conservation of momentum
    c. The conservation of mass
    d. The conservation of energy
2. In the approach chosen here, equilibrium is expressed:
    a. In the initial configuration
    b. In the previous configuration
    c. In the current configuration
3. In explicit time integration by the Central Difference scheme, the fundamental quantity is:
    a. The (full-step) velocity
    b. The mid-step velocity
    c. The acceleration
    d. The displacement
4. The Central Difference integration scheme is:
    a. First-order accurate and introduces some numerical damping
    b. First-order accurate and without numerical damping
    c. Second-order accurate and introduces some numerical damping
    d. Second-order accurate and without numerical damping
5. The Central Difference integration scheme is:
    a. Unconditionally stable
    b. Conditionally stable
    c. Unconditionally unstable
6. In the chosen implementation of the Central Difference integration scheme, during a generic time step (not the first one!) one obtains:
    a. First the (new) displacements, then the accelerations and finally the velocities
    b. First the velocities, then the accelerations and finally the displacements
    c. First the accelerations, then the velocities and finally the displacements
    d. First the displacements, then the velocities and finally the accelerations

7. Which of the following combinations is preferable in transient numerical analyses?
    a. Explicit time integrator and consistent mass matrix
    b. Implicit time integrator and lumped mass matrix
    c. Explicit time integrator and lumped mass matrix
    d. Implicit time integrator and consistent mass matrix
8. In the chosen explicit strategy, stress update is conveniently expressed in:
    a. Total form, based upon the total strains
    b. Rate form, based upon the strain increments
    c. Rate form, based upon the total strains
9. The radial return algorithm for plasticity:
    a. Always requires iterations to find the new stress state
    b. Requires iterations only if the trial stress state lies outside the yield surface
    c. Never requires iterations, but possibly just a projection of the trial stress state
10. A so-called co-rotational formulation may simplify the treatment of geometric nonlinearities:
    a. In continuum-like elements
    b. In structural elements such as bars and beams
    c. In plate and shell elements
11. Which of the following strain measures is more appropriate?
    a. Engineering strain in small-strain analyses
    b. Natural strain in small-strain analyses
    c. Engineering strain in large-strain analyses
    d. Natural strain in large-strain analyses
12. During the transient solution, checking the energy balance is:
    a. Redundant, because the chosen method ensures it *a priori*
    b. Necessary, because it is used in the algorithm to advance in time the solution
    c. Useful, because it gives a hint on the quality of the numerical solution obtained
13. The method of Lagrange multipliers used to impose the essential boundary conditions:
    a. Is always completely explicit, like the rest of the chosen solution strategy
    b. Leads in general to an implicit treatment of the constrained degrees of freedom
    c. Requires an implicit treatment of all degrees of freedom in the model
14. The basic "ingredients" used by the Lagrange multipliers method are:
    a. The constraint equation and the chosen time integration scheme
    b. The constraint equation and the constitutive law in the material(s)
    c. Only the constraint equation
    d. Only the time integration scheme
15. The Lagrange multipliers method:
    a. Yields the reaction forces, which are then treated as externally applied loads
    b. Does not provide the reactions, but ensures that the constraints are satisfied
    c. Yields the reaction forces, which then need a special treatment

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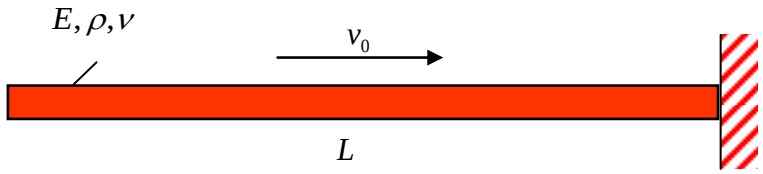
Exercise 1

An elastic bar of length $L = 1$ m, constant cross-section and homogeneous material impacts a rigid wall at an initial velocity v_0. We want to compute the transient behavior of the bar from time $t_0 = 0$ up to time $t_f = 2.0 \times 10^{-3}$ s.



The relevant material properties are: Young's modulus $E = 1.0 \times 10^9$ Pa, density $\rho = 1.0 \times 10^3$ Kg/m^3 and Poisson's coefficient $\nu = 0$. Assume a linear analysis since $v_0 \ll c$, where c is the sound speed in the material.

The bar is uniformly discretized in space by a certain number N of 2-node bar elements.

A. Estimate the sound speed in the bar:

$$c \approx ...$$

B. Estimate the stability step Δt^{crit} as a function of the number N of elements:

N	Δt^{crit}
10	
100	
1000	

C. Estimate the total number of steps n needed in the transient calculation, by assuming a stability safety factor $\varphi = 0.5$ (i.e. by using a time increment $\Delta t = \varphi \cdot \Delta t^{\text{crit}}$):

N	n
10	
100	
1000	

D. Estimate the total cost of the calculation in terms of memory size and of CPU time, by arbitrarily letting 1.0 be the cost of the solution with the coarsest mesh ($N = 10$):

N	Memory	CPU time
10	1.0	1.0
100		
1000		

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Facultative additional questions:

Imagine now that the bar material is elasto-plastic and that the initial velocity is sufficiently high to produce quite some plastification (a longitudinal strain, say, of the order of 10%) in the bar. Which of the following statements is correct, and why?

E. The stability step:

   a. Is not affected at all
   b. Varies because the sound speed in the material changes
   c. Varies because the length of the elements changes
   d. Varies because both the sound speed and the elements length change

[Hint: consider the onset of plastic waves in addition to elastic waves]

Comments/discussion:

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F. Assuming the radial return algorithm to treat plasticity, the CPU cost of the calculation with respect to a purely elastic solution:

   a. Is not affected at all
   b. Increases only slightly and in a fairly predictable way
   c. May no longer be estimated

Comments/discussion:

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G. With respect to an elastic solution, the elasto-plastic solution is expected:

   a. To be smoother, because the time integration scheme dissipates some energy
   b. To be smoother, because the material law dissipates some energy
   c. To present roughly the same numerical oscillations as in the elastic case

Comments/discussion:

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H. In the elasto-plastic solution:

   a. The total energy should not be conserved
   b. The total energy should be conserved

Comments/discussion:

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