The influence of time integrator on contact/impact problems using the positional finite element method

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Abstract. The dynamic structural problems involving contact/impact are strongly nonlinear, and can lead to spurious numerical oscillations, generating unsatisfactory results or even convergence problems depending on the applied temporal and spatial discretization techniques. The use of Newmark method with traditional parameters is proven to be inefficient in this case, making necessary the application of specialized time integration techniques. Some authors propose alternative values for the Newmark parameters to circumvent this problem, introducing a numerical damping in the system, and reducing artificially the high frequency oscillations. However, this strategy is highly sensitive to the time discretization, decreasing the accuracy of the results when the time steps are not sufficiently refined. As an alternative, one can employ the alpha-generalized time integration method, which allows the control of numerical dissipation by using appropriate parameters. In this work, we apply different combinations of said parameters, including the ones which reproduce the Newmark method and its variations, in order to analyze the numerical stability of two-dimensional impact problems. The applied computational framework is the positional finite element method, which is characterized by using positions as nodal parameters, instead of displacements, and naturally considering geometrical nonlinearities in its formulation. The applied constitutive model is the Neo-Hookean, for large strain. For the numerical implementation of structural contact, we make use of a node-to-segment model with Lagrange multipliers, employing a contact detection algorithm based on the intersection of trajectories. Finally, a representative numerical example is proposed with different time integration techniques. The results indicate that the adequate choice of alpha-generalized parameters can lead to quite significant improvements to the numerical stability when compared to the traditional Newmark method and its modifications.

Keywords: Time integrator, Structural contact, Positional Finite Element Method

1 Introduction

The Finite Element Method has been applied to nonlinear problems for a significant time, as can be seen in works such as Hughes and Carnoy [1], with shell elements, Schulz and Filippou [2] with beam elements in Lagrangian formulation and Crisfield [3] with solid elements. Seeking an alternative approach, Coda [4] introduces the positional finite element method, which employs degrees of freedom in positions, instead of traditional displacements. This approach has been successfully applied to static and dynamic problems with trusses elements [5] and shells [6] in several applications, including structural contact cases [7, 8]. This formulation is more compact, as can be seen in Avancini and Sanches [9], making its writing simpler and more straightforward. Furthermore, the position-based formulation is naturally and truly isoparametric, since its nodal parameters (problem unknowns) are the current coordinates of the solid.

The contact between deformable solids can be numerically modeled in two steps: detection of the intersection point and imposition of non-penetration conditions, with the solution procedure being directly affected by the discretization technique. One of these techniques is the node-to-node (NTN), used by Mashayekhi et al. [10], characterized by having only a nodal base and requiring an appropriate coincidence of the meshes, therefore unsuitable for general large displacement problems. By means of the node-to-segment (NTS) scheme, or node-to-surface for 3 dimensions, introduced by Hughes et al. [11], it is possible to distinguish the contact interfaces