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NEW DEVELOPMENTS IN SURFACE-TO-SURFACE DISCRETIZATION STRATEGIES FOR ANALYSIS OF INTERFACE MECHANICS

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Summary. *This talk will summarize recent developments pertaining to new discretization methods for large deformation frictional contact problems, in which ideas from so-called mortar projection are used to represent contact conditions in an integral sense within the (finite element) discretized framework. As might be anticipated from the mortar literature, this approach produces numerical techniques which are much more accurate than historical node-to-surface contact treatments; in particular, they preserve optimal convergence rates inherited from the underlying finite element method. Additionally, however, an important and to some degree unanticipated feature of these methods is their greatly enhanced robustness in comparison with node-to-surface treatments, which arises primarily from spatial smoothing characteristics inherited from the non-local mortar contact operators.*

1 INTRODUCTION

Most traditional approaches to finite element analysis of contact phenomena rely on some notion of node-to-surface kinematics for discrete representation of contact phenomena (see, for example, [1]). Although such methods are intuitive and relatively straightforward to implement, they suffer from many practical and theoretical shortcomings, including lack of patch test passage under general circumstances, susceptibility to locking, degraded spatial convergence characteristics, and in highly nonlinear applications, a decided lack of robustness due to non-smoothnesses in contact geometry.

This work will describe the development of a class of *surface-to-surface* based techniques for description of contact phenomena in finite element applications, derived in recent years from the class of mortar methods introduced originally primarily for the domain decomposition problem, in such references as [2]. We have described these methods in a series of papers in recent years [3, 4, 5, 6], and have demonstrated their effectiveness in two and three dimensional applications, in large and small deformations, and with and without friction. The key idea of these approaches is that rather than enforcing constraints in a local pointwise fashion (in what might be termed as a collocation approach), the surface-to-surface descriptions rely on a non-local representation of contact constraints. In this representation, the surface node shape functions are used to produce least-squares projections of displacement fields from potentially non-conforming grids onto a single discretization, where the contact constraints are readily and unambiguously enforced in a stable manner. Theoretically, the mortar literature tells us that this technique preserves the optimal convergence rates expected from the finite element method even when the discretizations across contact surfaces are non-conforming. Practically speaking, the effect of the non-local constraint representations is significant smoothing of contact interactions, giving rise to greatly enhanced robustness over what is typically observed with traditional node-to-surface approaches.

This presentation will give the basic approach behind extension of the traditional mortar element method to contact problems, will discuss in detail the development of a framework in which large deformation friction problems may be solved, and will review some recent work in which highly efficient contact searching schemes have been developed for both body-to-body and self-contact applications. Very new extensions of the methodology to lubricated friction problems will also be discussed.

2 NUMERICAL EXAMPLE

The figure depicts an example where two neo-Hookean toroids impact each other in a manner producing significant deformation and relative sliding. This example is typical of many we have examined, which run only with great difficulty and user intervention using more traditional strategies, but which execute routinely using the new surface-to-surface framework.

3 CONCLUSIONS

A new class of contact-impact algorithms, derived from the mortar element framework for imposition of kinematic constraints between dissimilarly meshed domains, has been conclusively demonstrated to be effective in quasistatic and implicit dynamic solid and structural mechanics applications. Surface-to-surface discretization methods are fully developed for both frictionless and frictional applications, and have recently been enhanced through incorporation of efficient bounding volume hierarchies for contact searching, and effective extension to encompass self-contact. Current work is focusing on the development of mortar-based strategies for the treatment of lubricated contact phenomena.

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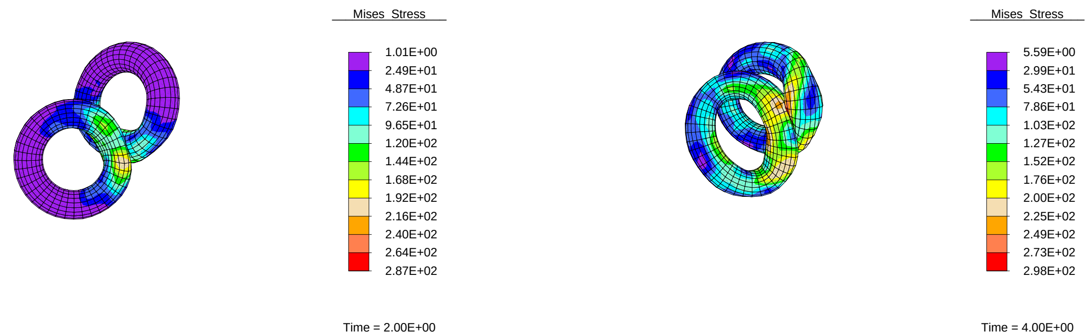

Figure 1: Selected time steps from a two torus impact problem, demonstrating effectiveness of the surface-to-surface contact algorithm in a transient, neo-Hookean impact simulation.

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