Geometrically exact contact theory as a fundamental basis for isogeometric computational modeling of contact

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ABSTRACT

The advantages of the isogeometric method as the usage of the full geometrical features of the structure for contact analysis can be exploited if the contact kinematics is well understood for all geometrically possible contact pairs. Contact interaction between bodies from a geometrical point of view can be seen as an interaction between deformable surfaces with arbitrary geometry and smoothness, whereas various smoothness gives the surface itself as well as surface edges and vertexes. Therefore, contact pairs can be hierarchically split into a set of the following geometric pairs: Surface-To-Surface (STS), Curve-To-Surface (CTS), Point-To-Surface (PTS), Curve-To-Curve (CTC), Point-To-Curve (PTC) and Point-To-Point (PTP). The shortest distance between these geometrical objects is a natural measure of the contact interaction and gives a rise to the Closest Point Projection (CPP) procedure in each situation. The first fundamental basis is a set of theorems for existence and uniqueness of the corresponding CPP procedure, which allows to split the space surrounding the contacting body into so-called projection domains in which the corresponding contact pairs can be considered. These domains are constructed in the special coordinate system inherited from the differential geometry of the corresponding object: in the Gaussian coordinate system for surfaces (STS and PTS contact pairs), in the Frenet-Serret coordinate system for curves (CTC and PTC contact pairs) and in the Darboux coordinate system for curves on a surface (CTS contact pair). The second fundamental issue is a covariant description of the contact kinematics for each contact pair. This gives in due course a set of measures for contact interaction including not only the standard penetration for the non-frictional contact, but also various tangential measures arising from the analysis of the relative motion in the corresponding coordinate system. The full apparatus of the differential geometry for surfaces, curves and curves on surfaces should be exploited in order to prepare all necessary objects for the computational analysis in a covariant form without the involvement of the approximation explicitly: weak forms, their linearization in the form of covariant derivatives, contact interfaces laws in the form far more general than the standard Coulomb friction law as well as their computational realizations e.g. in the form of return-mapping algorithms. A special consideration for the mechanical models such as curvilinear beams is necessary leading to the combination of a special isogeometric family of solid-beam finite elements together with contact – Curve-To-Solid Beam (CTSB) contact element. All these transformations have been provided in the closed covariant form for each contact pairs, which gives to the researcher a large possibility to chose any class of isogeometric approximations depending on the mechanical model.

REFERENCES

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