Space–Time Slip Interface (ST-SI) Method and Its ST Friends

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ABSTRACT

We present a space–time (ST) computational method that brings together three ST methods in the framework of the ST-VMS [1] method: the ST Slip Interface (ST-SI) [2] and ST Topology Change (ST-TC) [3] methods and ST Isogeometric Analysis (ST-IGA) [4]. The "friendship" of these methods enables computational analysis in the presence of multiple challenges, such as those in heart valve flow. The challenges include accurate representation of boundary layers near moving solid surfaces, including the leaflets, even when they come into contact, and handling a high level of geometric complexity. The ST-VMS, as a moving-mesh method, maintains high-resolution boundary layer representation near solid surfaces. The ST-TC method enables moving-mesh computation of flow problems with TC, such as contact between heart valve leaflets, maintaining high-resolution representation near the leaflets. The ST-SI method was introduced for high-resolution representation of the boundary layers near spinning solid surfaces. The mesh covering a spinning surface spins with it, and the SI between the spinning mesh and the rest of the mesh accurately connects the two sides. For heart valves, the SI connects the mesh sectors containing the leaflets, enabling a more effective mesh moving. Integrating the ST-SI and ST-TC methods [5] enables high-resolution representation even when the contact is between leaflets covered by meshes with SI. It also enables handling contact location change and contact and sliding on the SI. Integrating the ST-IGA with the ST-SI and ST-TC methods increases flow solution accuracy while keeping the element density in narrow spaces near contact areas at a reasonable level. Computations for a realistic aortic-valve model with prescribed leaflet motion show the effectiveness of the ST-SI-TC-IGA method [6].

REFERENCES

[1] K. Takizawa and T.E. Tezduyar, "Multiscale space–time fluid–structure interaction techniques", *Computational Mechanics*, **48** (2011) 247–267, doi: 10.1007/s00466-011-0571-z.

[2] K. Takizawa, T.E. Tezduyar, H. Mochizuki, H. Hattori, S. Mei, L. Pan, and K. Montel, "Space–time VMS method for flow computations with slip interfaces (ST-SI)", *Mathematical Models and Methods in Applied Sciences*, **25** (2015) 2377–2406, doi: 10.1142/S0218202515400126.

[3] K. Takizawa, T.E. Tezduyar, A. Buscher, and S. Asada, "Space–time interface-tracking with topology change (ST-TC)", *Computational Mechanics*, **54** (2014) 955–971.

[4] K. Takizawa, T.E. Tezduyar, Y. Otoguro, T. Terahara, T. Kuraishi, and H. Hattori, "Turbocharger flow computations with the Space–Time Isogeometric Analysis (ST-IGA)", *Computers & Fluids*, **142** (2017) 15–20, doi: 10.1016/j.compfluid.2016.02.021.

[5] K. Takizawa, T.E. Tezduyar, S. Asada, and T. Kuraishi, "Space–time method for flow computations with slip interfaces and topology changes (ST-SI-TC)", *Computers & Fluids*, **141** (2016) 124–134, doi: 10.1016/j.compfluid.2016.05.006.

[6] K. Takizawa, T.E. Tezduyar, T. Terahara, and T. Sasaki, "Heart valve flow computation with the integrated Space–Time VMS, Slip Interface, Topology Change and Isogeometric Discretization methods", *Computers & Fluids*, November 2016, doi: 10.1016/j.compfluid.2016.11.012.