Particle Simulation Interacting with Moving Flexible Bodies through Standard Particle Interface

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In Computational dynamics, analysis of moving body can be performed by many kinds of simulation methods[1]. And the advancement in simulation methods enables a mechanical researcher to deal with special body types, not only rigid bodies, but also flexible bodies, fluid or granular materials, and much more. If various types of materials are treated simultaneously, actual state of nature can be modelled and simulated, which leads to more realistic and valuable results. For accurate simulation results, methodology for coupled simulation between different types of bodies should be established. It can be done by several ways, for example, by defining the correlation formulas governing the material behaviors between different type of bodies, or by coupling each simulation with different material type, by exchanging data and information that is required for each simulations. By integrating the body types in one simulation and setting up the multidisciplinary methods, the scope of dynamic simulation field will be expanded, which makes the coupled simulation one of the most important issue in the computational dynamics field.

In this topic, coupled contact simulation between flexible body and particles is studied. Coupling of this two different type can be applied in many kind of mechanical field or situations such as interactions between moving machine and particles or fluids, such as lubrication system, liquid coolant injected to the engines, transportation of granular materials, and many other examples. For multi flexible body dynamics (MFBD), movement of body can be simulated. So body geometries are generated in MFBD solver and should be transferred to particle solver, which is considered as boundary that particles cannot pass through. And particle geometries, shape, and material, contact properties are defined in particle solver. And in MFBD, applied force is required both for rigid and flexible body[2]. With the multi flexible body dynamic simulation, position and orientation, and shape of the body is determined with each time step. While in general particle solver, position and movement of particles and contact data is obtained for each time step. Contact is defined between particle and boundaries, and between particles itself. Boundaries, which is called as 'wall' is mostly considered as rigid and fixed on the designated position. When contact occurs, contact forces are applied for each particle and wall. In the point of coupling between this two simulations, wall in particle solver is regarded as a moving body in multibody dynamics simulation. So additional considerations for both side is quite obvious. In multibody dynamics, additional applied force from particle contact should be considered so that the collision between particle and wall could affect the behavior of wall. And for particle simulation, position and shape of wall should be changed over time. This data should be calculated and transferred from MFBD solver to particle solver.

In consideration of flexible wall, contact force on the wall should be treated differently with the case of rigid wall[3]. To get the behavior of rigid wall in dynamic simulation, solver only needs the total force from particle to wall. But for flexible wall, FEA (finite element analysis) is integrated. So the wall geometries are discretized into small patches and nodes. And for FEA, contact forces from particle collision should be equivalently converted to nodal forces applied on each discretized node, which enables to obtain the deformation of flexible body. So the converting process of particle contact forces to nodal forces should be implemented.

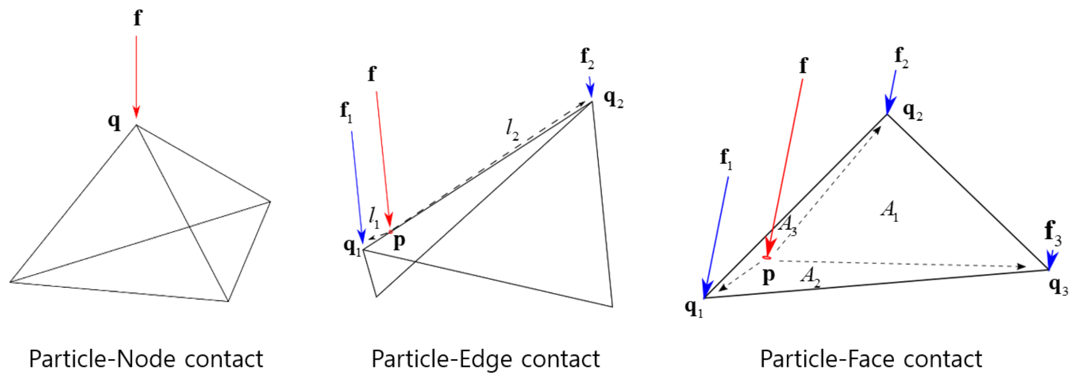

Fig. 1: Contact between particle and patch geometry

For this study RecurDyn is used as MFBD solver[4], which also provides the communication environment from particle solver and RecurDyn itself. SPI (Standard Particle Interface) is introduced, composed of generalized API functions and standardized format for communication between two individual solver[5]. API functions defined in SPI enables an efficient data exchange and time stepping control, and nodal force calculations, etc. The timing of data exchange between two solvers should be controlled correctly, which can affect the whole simulation result. So several options are suggested in SPI. Post-processing is also possible in RecurDyn through SPI, which shows the coupled result data such as wall forces acting from the particle, and force distribution on the wall. By exporting result data for particle and wall, direct visualization is available and the interaction between particles and flexible bodies can be easily checked and analyzed.

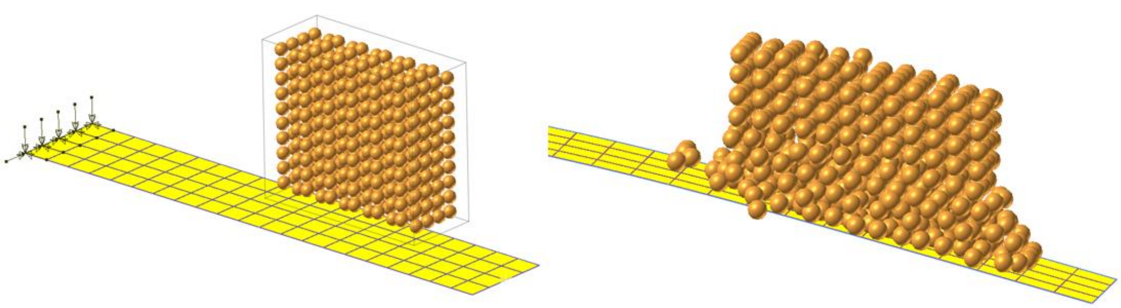

Fig. 2: Coupled simulation with flexible shell specimen and particles

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