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”SPH - Finite Element” coupling in explicit dynamics.

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ABSTRACT

The SPH or Element Free Galerkin methods are very efficient to simulate perforations with fragmentation. But, the computation effort is heavy and this type of model is not necessary in the whole domain for the most industrial applications. Very often the perforations and fragmentations are limited to a geometrically confined zone. This observation naturally leads to couple a usual FE model in the non-fragmented zone and a SPH method in the zone which could be damaged and fragmented.

This geometrical partition of space introduces the concept of subdomains, already developed in dynamics, in the FETI method by Farhat [1], and its extension by Gravouil and Combescure [2]. The method used in the preceeding approaches is not directly transposable to the ”SPH - FE” coupling because of the difficulty to impose constrains on the boundarys SPH domain.

A classification of the methods currently used for coupling meshless and meshed methods is given in the publication of Rabczuk, Xiao and Sauer [3]. A volume gluing method with an overlapping zone of subdomains is developped in this paper which relies on the Arlequin method (Ben Dhia [4] and Rateau [5]). One zone is discretized with finite elements and the other with SPH particles.

Thus, the domain is divided into two subdomains which overlap on a part of volume. So, the restriction of velocities in the overlapping zone are imposed identical. This method is based on :

- a space mediator constituted by the velocities vector,
- a coupling operator in order to project the comparative vectors on space mediator.
- a distribution of the strain and the kinetic energies between the two sets of discretisation in the overlapping zone. We choose linear weight parameter functions in the thickness direction of the overlapping zone.
- a one-order ”Moving Least Square” interpolation [6] gives the value of the SPH displacement vector at the FE Gauss points (noted GP).

- the coupling matrices,

$$W^{int} = \sum_{q=1}^{N_{GP}} \left[\sum_{k=1}^{n} N_k \Lambda_k \left(\underline{\xi}_q \right) \left(\sum_{i=1}^{m} M_i u_i^{SPH} \left(\underline{\xi}_q \right) - \sum_{k=1}^{n} N_j u_j^{FE} \left(\underline{\xi}_q \right) \right) w_q det \left\{ J \left(\underline{\xi}_q \right) \right\} \right]$$

$$W^{int} = 0 \Rightarrow \underline{\underline{P}}_{kj}^{FE} = - \sum_{q=1}^{N_{PG}} N_k \left(\underline{\xi}_q \right) N_j \left(\underline{\xi}_q \right) w_q \; \& \; \underline{\underline{P}}_{ki}^{SPH} = - \sum_{q=1}^{N_{PG}} N_k \left(\underline{\xi}_q \right) M_i \left(\underline{\xi}_q \right) w_q$$

In a second part, a comparison between EF, SPH and mixed methods show the efficiency on simple analytical benchmarks. Finally, the validity of the approach is demonstrated to simulations of experimental perforations of concrete slabs [7] where simulations with a concrete model and "SPH - FE" coupling are compared to experimental results.

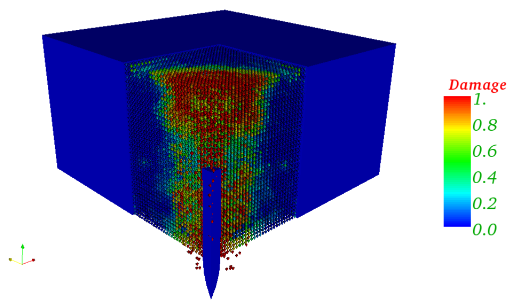

Figure 1: Final damage for an impact at 750 $m.s^{-1}$ on a concrete slab.

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