X-DMS 2015
eXtended Discretization MethodS
September 9-11, 2015, Ferrara, Italy

SPH-modeling of fast impacts with adhesion

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Key Words: SPH solid mechanics, adhesion forces, Large strains, High strain-rates, Explicit dynamics.

ABSTRACT

This paper is devoted to the simulation of cold spray metal or ceramics deposition process. The process consists in sending small spherical particulates at a high velocity (300 to 1000 ms^{-1}) on a substrate. The experimental observation is that these particulates are stuck on the substrate under very special conditions. First they must be small enough: if one sends at the same speed a particulate of material A onto a substrate of material B (which may be the same as A) the good sticking only occurs if the particulate is small enough. This simple observation indicates that surface adhesion forces play a significant role in this process. The object of this presentation is to show how these forces can be taken into account and modeled in a fast transient computation.

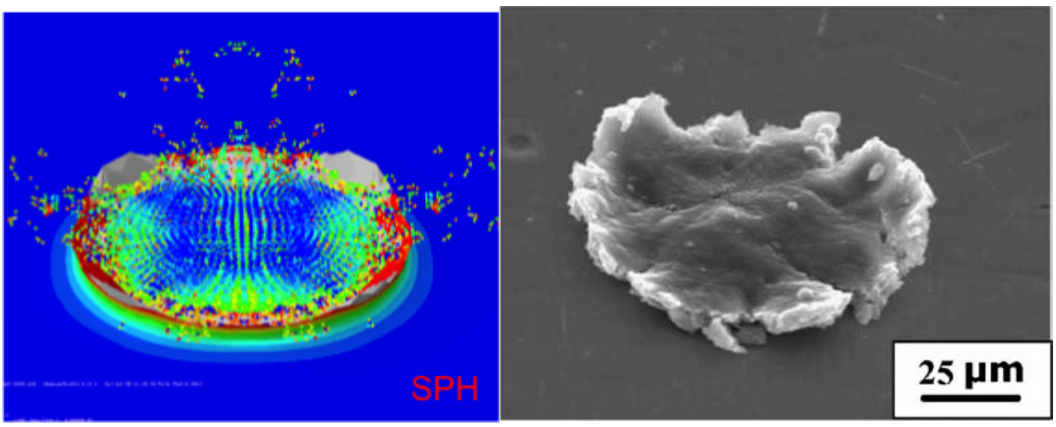

Figure 1: SPH Computation and Experiment of Cold Spray soft particle deformed particulate.

The particulates undergo huge deformations if the substrate is stiff and the particle soft, and the reverse case is also possible which induce large deformations of the substrate. Hence SPH formulation is chosen for both bodies. One knows that solid SPH present severe drawbacks if their formulation is based on updated Lagrangian method [1, 2, 3]. Hence the total Lagrangian formulation is used with usual renormalization procedures and special treatment of the boundary "nodes" [2]. The contact impact is treated with the Pinball methods [4] and Lagrange multiplier techniques. The material is highly non-linear strain and temperature sensitive and may damage. It is represented with a damaging Johnson Cook model which includes strain rate and temperature dependency. The damage model if of ductile of brittle nature as proposed in Lemaitre J Book on mechanical modeling of materials.

The usual pinball [pin-bely] contact algorithm detects collisions between two SPH nodes. The pinballs are attached to the SPH contact candidates. When collision is detected all contacts are solved simultaneously using the Lagrange multiplier vision of contacts. This approach has the great interest not to eat any energy as well as taking into account the contacts interactions, but the price to pay is the solution of a linear system which is changing with time as contact geometry is changing.

In case of adhesion the problem is slightly more complex. The adhesion forces are active during the opening of the gap between the two pinballs until the adhesion surface energy is dissipated (as in fracture mechanics, this surface energy is the product of a surface adhesion energy density $G_{Adhesion}$ by the corresponding glued surface). The glued surface has to be decided for a couple of interacting pinballs. This surface is given by equation:

$$S_{Adhesion} = 0.5\pi(R_1^2 + R_2^2) \qquad (1)$$

where R_i is the (evolving) radii of SPH nodes i on which the pinballs are attached. A Dugdale cohesive model has been used to model adhesion: it supposes that the adhesion stress $\sigma_{Adhesion}$ is constant during the opening until the critical gap $[u]_{Adheion}$ is reached. These parameters are related by the following equation:

$$G_{Adhesion} = \sigma_{Adhesion}[u]_{Adhesion} \qquad (2)$$

The adhesion forces applied on the link into the direction of the pinball couple is then:

$$F_{Adhesion} = \sigma_{Adhesion}S_{Adhesion} \qquad (3)$$

This force only acts when the gap opens ($[\dot{u}] > 0$). Once the adhesion energy is dissipated (or the gap totally opened) the corresponding force is set to zero, and the two pinballs are free to move. Simulations examples will show the importance of adhesion modeling onto the prediction of the gluing of spheres of different sizes and thrown at different velocities onto a substrate.

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