Modelling wood anisotropy by the mean of the Discrete Element Method for cutting process simulation

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When modelling wood at mesoscopic scale in order to simulate processing operations such as wood cutting, one may face strong barriers using the straightforward methodology. Indeed, traditional cutting simulations use Finite Element Model (FEM) to represent the material (often metal) and the cutting tool. When the material machined is wood, and the attention is focused on the chip as well as the final product (for material value enhancement) the simulation must be able to robustly consider multiple cracks, fragmentations, and contacts. In this case, the method starts to lose in efficiency to the benefice of the Discrete Element Method (DEM) which display much better performances in modelling robustly these phenomena.

Formerly designed to model granular media [1], the Discrete Element Method is now also used for continuous material modeling. The material is discretized into small discrete elements (DE), usually spheres. The DEs are linked one to another thanks to bonds. Bonds behavior are set to reproduce the media behavior. DEM has shown today its ability to model isotropic materials faithfully, however it is not yet the case for anisotropic media such as wood at mesoscopic scale. This study, based on a very recently published paper [2] highlights the obstacles encountered when modeling wood-like orthotropic media.

Two different modeling approaches are considered: cubic regular arrangement, where discrete elements are placed on a regular Cartesian lattice (an approach already implemented once in a wood cutting simulation [3]), and random sphere-packed arrangement, where elements are randomly packed. As the second approach is initially favoring isotropy of the domain, a new method to affect orientation-dependent Young's modulus of bonds is proposed to create orthotropy. Domains created by both approaches are loaded in compression in-axis (along the material orthotropic directions) and off-axis to determine their effective Young's modulus according to the loading direction.

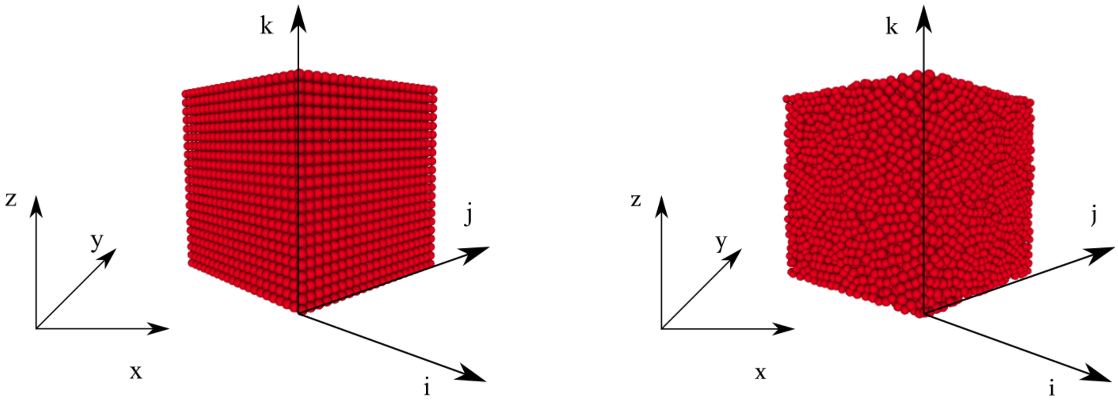

Figure 1: Discrete models based on cubic regular arrangement (left) and on packed arrangement (right) [2]

Results are compared to an estimation given by the Hankinson formula which is often used to represent high orthotropic behavior such as encountered in wood or synthetic fiber materials. For this class of materials, it is shown that, contrary to cubic regular arrangement, the random sphere-packed arrangement exhibits difficulties to reach highly orthotropic behavior. This prevent from the modelling of wood from most of the tree species. Conversely, this latter arrangement displays results closer to continuous orthotropic material during off-axis tests. Therefore, in the case of modelling of only radial-tangential planar phenomena or woods with low anisotropy, the random sphere-packed arrangement is to prefer, while cubic regular arrangement should be used for modelling of longitudinal-transversal phenomena, but with peculiar care.

References

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