Planetary Ball Milling Model for optimal 2-D Materials Exfoliation

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Abstract

Planetary ball milling is a versatile technique for the tuning of structural and microstructural properties of almost any kind of material. Interestingly, it has been demonstrated to be an effective and promising method for mechanical exfoliation of 3D bulk systems leading to the production of large quantities of two-dimensional nanostructured materials (such as graphene and boron nitride nanosheets), of primary scientific and technological interest [1, 2].
Success of the process closely relates to the choice of a multitude of milling variables, e.g. number and size of balls, jar geometry and velocity of revolving parts, strongly influencing balls movements and, in turn, the nature of impulsive forces applied by milling media collisions, that can be either prevalently normal or shear type [3].

Due to the importance of milling parameters fine tuning, as an alternative to time-consuming and barely-controllable experimental testing, a dynamic-mechanical model for planetary ball-milling has been developed within a multibody dynamics software [4]. Indeed, simulations provide full control over kinematic and dynamic quantities for each milling body as well as quantities associated to each contact event, therefore allowing an outright understanding of balls motion regimes, intensity of impacts and energy exchange for both normal and tangential components, highlighting the preferential direction of force transfer [5]. Predictions on best milling conditions that, for the exfoliation process, have to be identified with the enhancing of shear actions transfer, become thus possible. The predicted optimal conditions will be presented and discussed around the relevant case study of large scale graphene production.

References

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Figures

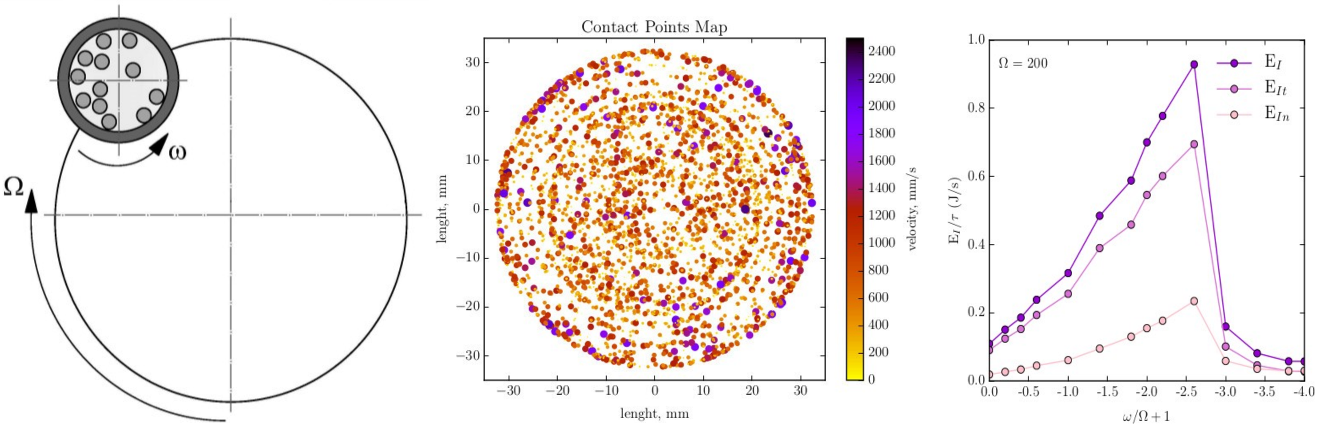

Fig: *left, 2-D representation of planetary ball mill; middle, map of impact points of balls against jar wall; right, impact specific kinetic energy as a function of jar to plate velocity broken down into normal and tangential components.*