The Global COE Program

"The Next Generation of Physics, Spun from Universality and Emergence"

Bilateral International Exchange Program (BIEP, invite) report

Send report to: Your responsible Professor in Kyoto University

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(Year/Month/Day) 2009/09/17

Invited Student

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Responsible Researcher in Kyoto University

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Research Project

Title	Oblique collision of nanoclusters
Duration	From 2009/07/06 to 2009/09/12

Please summarize your activities and results during your stay in Kyoto University.
Also please describe how your stay has been beneficial to the graduate students in the institute. You can add a sheet, if you need more space.
You can also write any comments and requests to the GCOE program.

The main goal of my collaboration with Prof. Hisao Hayakawa was to develop a simple theoretical model of oblique collisions of small soft spheres and to compare the theoretical prediction with results of molecular dynamics simulation of oblique collision of nanoclusters, performed by Kuniyasu Saitho, PhD student of Prof. Hisao Hayakawa.

Normal tangential restitution coefficient is equal to ratio between moduli of normal components of relative velocity of particles after and before collision. The normal direction is determined with respect to the orientation of contact area. The tangential restitution coefficient is equal to ratio between tangential components after and before collision. They can be calculated by solving a system of Newtonian equations, which describe evolution of normal and tangential components of relative velocity. The normal force is assumed to consist of three parts: Herzian force, describing pure repulsion of particles, viscoelastic force, accounting for loss of velocity due to viscous interactions and attractive adhesive force, obtained in the framework of JKR theory.

To account for tangential interactions we propose a simple microscopic model of tangential force, namely we assume, that the contact surfaces of colliding particles are not flat, but contain asperities in the form of half-spheres. The tangential force then represents a projection of sum of forces, acting between all asperities, on the tangential direction. Force, acting between asperities is also assumed to consist of Herzian, viscoelastic and adhesive parts. The number of contacts between different asperities depends on normal deformation, radius of contact area, dimensions of asperities and their surface number density.

Nanoclusters represent soft and small spheres, and in the oblique impact the contact surface area changes its orientation. We proposed a new algorithm for solution of system of Newtonian equations, taking into account the effect of surface reorientation at each time step. We calculated shift angle of normal unit vector and found good qualitative agreement with simulation results.

In the case of soft spheres a question arises: how to determine the normal restitution coefficient, should we take the projection of relative velocity on fixed normal unit vector before collision or on time-dependent unit vector after collision. In the first case the normal restitution coefficient can surprisingly take negative values, which was confirmed by computer simulation. The second definition describes the collision has more pronounced physical meaning, however, it requires rigorous determination of the end of collision, which is difficult even in computer simulation, and much more complicated in the experiment.

We performed calculation of normal restitution coefficient according to both definitions and got good qualitative agreement with MD simulation.

Additional purpose of my stay in YITP was the exchange of knowledge with colleagues in the field of Statistical Physics. I gave three seminars at the group meeting of Prof. Hayakawa, concerning my research of Brownian motion in the granular media, aggregation and fragmentation processes in astrophysical systems and the collaboration project with Prof. Hayakawa. I also presented a poster at the Workshop “Frontiers in Nonequilibrium Physics”, which took place during my stay in YITP. I had numerous mutually beneficial private communications with graduate students and colleagues of Prof. Hayakawa.

Now we are writing joined paper, containing the results of research, performed during my stay in YITP, and will continue our collaboration in the future.