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MASTER THESIS

The validity of current contact force models for the collision of viscoelastic spheres

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Abstract

An important model for granular particles are elastic and viscoelastic spheres. The macroscopic interaction forces for such objects are commonly obtained from the continuum mechanical equations of motion for elastic and viscoelastic material in quasi static approximation. The same holds true for the coefficients of restitution of colliding spheres which are, in turn, obtained from the macroscopic interaction forces. The quasi static assumption implies that the characteristic deformation rate is much smaller than the speed of sound in the material and that the relaxation time of the particle's material is negligible compared to the duration of the contact. In this work the validity of these assumptions is probed for realistic impact scenarious by comparing to a direct numerical solution of the underlying continuum mechanical equations of motion by means of finite elements.

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1 INTRODUCTION

Some intro

1.1 Granulates

A granular material is a conglomeration of discrete solid, macroscopic particles characterized by a loss of energy whenever the particles interact (the most common example would be friction when grains collide). The constituents that compose granular material must be large enough such that they are not subject to thermal motion fluctuations. Thus, the lower size limit for grains in granular material is about $1\mu m$. On the upper size limit, the physics of granular materials may be applied to ice floes where the individual grains are icebergs and to asteroid belts of the Solar System with individual grains being asteroids. [1]

1.2 Particle Simulations of Granulates

1.3 Particle Models

1.4 Aims

1.5 Acknowledgements

A big thank you for the support to Dr.Patric Mueller

2 BACKGROUND

3

SIMULATION METHOD

3.1 FEM

3.2 Simulation Setup

3.2.1 Sphere vs Rigid Plane

In this simulation the collision of two viscoelastic spheres is studied. Both the spheres have the same magnitude of velocity but opposite directions. Therefore to simplify the model and computation, instead of simulation two spheres colliding, a single sphere colliding against a rigid plane can be simulated. This setup would be equivalent to the original problem as both the spheres are the same in all aspects except for having different directions of velocities.

3.2.2 Symmetry

To further simplify the model, instead of considering the complete sphere, only a 2D semi-circular cross-section is considered. As the spheres are symmetric about the central rotational axis and the angle of contact is 90 degrees, there would not be any velocity in the Y direction.

3.2.3 Mesh

The 3.1 shows the mesh used in the simulation. We can see that the mesh is finer at the bottom of the sphere as it is the point of contact and would undergo massive deformation during the impact.

The 3.2 shows an enlarged image of the bottom half of the mesh. We can see the degree of fineness of the mesh compared to the other half of the sphere.

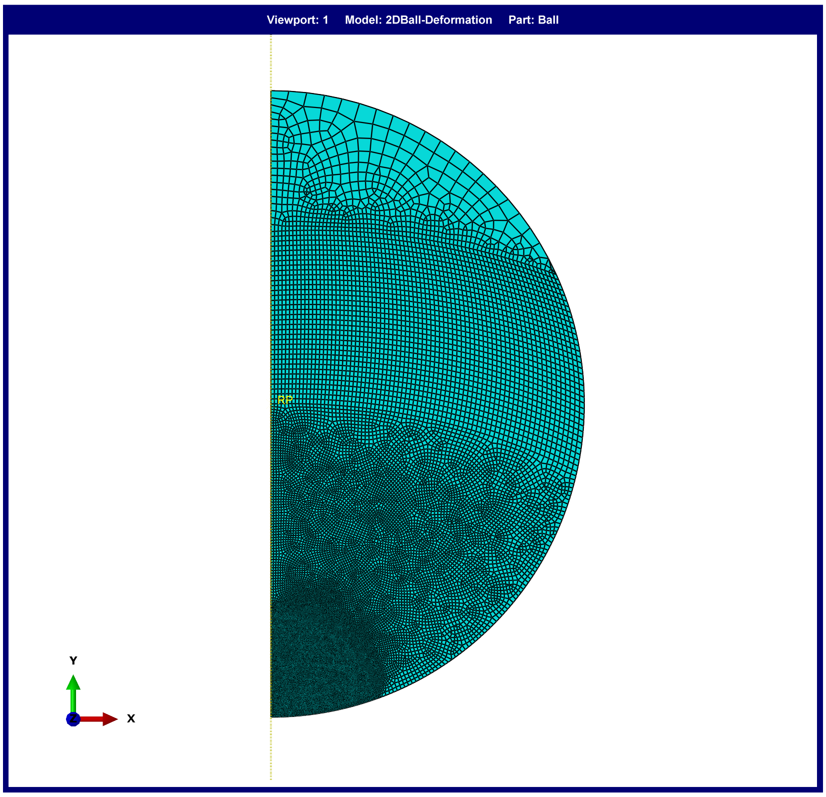

Figure 3.1: Mesh

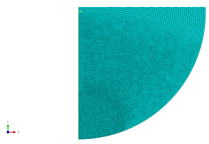

Figure 3.2: Bottom Half of Mesh

3.2.4 Rigid Plane

The figure shows the rigid plane against which the sphere would be colliding.

3.3 Measurement Quantities

3.3.1 Displacement

To measure the displacement of the body, the displacement of the center of mass was measured. The center of mass of the of a sphere is located at the sphere. The figure shows the center of the 2D semi-circle which was considered as the sphere of the model. To measure the displacement center of mass of the sphere, the displacement of center of the semicircle was considered.

3.3.2 Kinetic Energy

The kinetic energy of an object is the energy that it possesses due to its motion. As the aim of the thesis is to measure the co-efficient of restitution, which is directly related to the restitution kinetic energy in the body after the collision is completed.

$$KineticEnergy(KE) = \frac{mv^2}{2} \tag{3.1}$$

where m is the mass of the object and v is the velocity of the object.

3.3.3 Strain Energy

The strain energy is the energy stored by a system undergoing deformation. During a collision, a part of the kinetic energy is converted into strain energy. This strain energy can also be observed as vibration on the body of the object. When the load is removed,

$$StrainEnergy(U) = \frac{V\sigma\epsilon}{2} \tag{3.2}$$

where V is volume, σ is stress and ϵ is strain.

3.3.4 Co-efficient of Restitution

The co-efficient of restitution describes the energy transfer

3.4 Verification

To verify the correctness of the simulation setup, various meshes were tried. As Abaqus CAE has an option to automatically choose a suitable timestep, the automatic option was chosen.

4 RESULTS

5 CONCLUSION AND FUTURE WORK

In this chapter we want to draw conclusions about the work, which has been done during this thesis. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

5 BIBLIOGRAPHY

[1] Jacques Duran. *Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials (Partially Ordered Systems)*. Springer, 1999. ISBN 0387986561.