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A New Frequency Domain Approach to Modelling of Discrete Element Method Applications 

Abstract: 
A new frequency domain approach to the discrete element method (DEM) is proposed. The approach is based on an analogy between the frequency domain formulation of the Navier-Stokes equations and a Hamilton-Jacobi system. The approach is used to model the flow of granular materials in a channel and in a porous medium.

Introduction

The discrete element method (DEM) is a powerful tool for simulating the behavior of granular materials. However, the computational cost of DEM simulations can be very high, especially for complex geometries and large systems. Therefore, there is a need for more efficient and accurate modeling techniques.

In this paper, we propose a new frequency domain approach to modeling the flow of granular materials using the discrete element method. The approach is based on an analogy between the frequency domain formulation of the Navier-Stokes equations and a Hamilton-Jacobi system.

The main advantage of the frequency domain approach is that it can significantly reduce the computational cost of simulations. This is because the solution of the frequency domain equations is obtained by numerical integration, which is much faster than solving the time domain equations.

The frequency domain approach is also more accurate than traditional time domain approaches. This is because it is able to capture the effects of non-linearities and dispersion that are often present in granular flows.

Results

We have applied the frequency domain approach to model the flow of granular materials in a channel and in a porous medium. The results show that the approach is able to accurately predict the behavior of the granular materials.

Conclusion

In conclusion, the frequency domain approach to modeling granular materials using the discrete element method is a promising new technique. It offers significant advantages over traditional time domain approaches, including lower computational cost and higher accuracy.

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References

Rubinstein et al. 34

FEM

DEM

as discussed in (2) Rubinstein et al. et al. 10.1007 focusing on the methodological aspects. Yet, it is important to note that the presented models and methods are not intended to be a comprehensive overview of the field. Instead, the focus is on presenting a specific methodological approach that can be applied to various research questions in fluid dynamics.

The presented models and methods are based on the principles of DEM and FEM. DEM is a discrete element model that simulates the behavior of granular materials, while FEM is a continuous model that simulates the behavior of deformable solids. The combination of these two models allows for the simulation of complex fluid-structure interactions, which are common in many real-world applications.

One of the key features of the presented models is their ability to handle large deformations and contacts between different materials. This is achieved through the use of advanced contact algorithms and contact force models. Additionally, the models are capable of handling complex geometries and boundary conditions, which is important for realistic simulations.

The presented models and methods are validated through a series of benchmark tests, which demonstrate their accuracy and robustness. These tests include simulations of simple geometries as well as more complex scenarios, such as the simulation of fluid-structure interactions in natural disasters.

Overall, the presented models and methods provide a powerful tool for the simulation of fluid-structure interactions. However, it is important to note that the accuracy and reliability of these simulations depend on the quality of the input data and the assumptions made in the models. Therefore, it is crucial to carefully choose the appropriate model and input parameters for each specific application.

DEM

Penetration energy

Sinkage

Figure 3. Penetration energy as a function of sinkage for DEM and FEM simulations.

Figure 4. Comparison of the simulations with and without contact force models.

Figure 5. Comparison of the simulations with and without contact force models.

Table 1. Comparison of the computational times for DEM and FEM simulations.

Table 2. Comparison of the computational times for DEM and FEM simulations.

Table 3. Comparison of the computational times for DEM and FEM simulations.


The force-extension relationship is given by the equation:

\[ c_e = \frac{E}{p} \]

where \( c_e \) is the elongation, \( E \) is the modulus of elasticity, and \( p \) is the applied pressure. For small pressures, the relationship is linear.

The stress-strain relationship is also important, given by:

\[ \sigma = \frac{F}{A} \]

where \( \sigma \) is the stress, \( F \) is the force, and \( A \) is the cross-sectional area.

The Young's modulus, \( E \), is the ratio of stress to strain:

\[ E = \frac{\sigma}{\epsilon} \]

where \( \epsilon \) is the strain.

The Poisson's ratio, \( \nu \), is the ratio of lateral to axial deformation:

\[ \nu = \frac{\text{Lateral Strain}}{\text{Axial Strain}} \]

For isotropic materials, \( \nu \) is typically around 0.3. The effect of Poisson's ratio on stress-strain behavior is significant, especially at high strains.

The von Mises criterion, \( \sigma_v \), is a measure of the stress state that defines yielding:

\[ \sigma_v = \sqrt{\frac{3}{2}} \left( \sigma_x^2 + \sigma_y^2 + \sigma_z^2 + 2\tau_{xy}^2 + 2\tau_{yz}^2 + 2\tau_{xz}^2 \right) \]

where \( \sigma_x, \sigma_y, \sigma_z \) are the principal stresses and \( \tau_{xy}, \tau_{yz}, \tau_{xz} \) are the shear stresses.

The failure criterion is often expressed in terms of the yield stress, \( \sigma_y \), or the ultimate tensile strength, \( \sigma_u \), which defines the maximum stress that a material can withstand without rupture.

In conclusion, the mechanical behavior of materials is complex and depends on various factors, including the material type, stress state, and deformation rate. Understanding these relationships is crucial for designing and predicting the performance of materials in various applications.
A. Rothe: All the plots show the generalized-α method of time integration.

B. Rothe: All the plots show the generalized-α method of time integration.

C. Rothe: All the plots show the generalized-α method of time integration.

D. Rothe: All the plots show the generalized-α method of time integration.