Discrete Element Method (DEM) simulations are a promising approach to accurately predict agglomeration and deposition of micron-sized adhesive particles. However, the mechanistic models in DEM combined with high particle stiffness for most common materials require time step sizes in the order of nanoseconds, which makes DEM simulations impractical for more complex applications. In this study, analytically derived guidelines on how to reduce computational time by using a reduced particle stiffness are given. The guidelines are validated by comparing simulations of particles with and without reduced particle stiffness to experimental data. Then two well-defined test cases are investigated to show the applicability of the guidelines. When introducing a reduced particle stiffness in DEM simulations by reducing the effective Young’s modulus from $E$ to $E_{\text{mod}}$, the surface energy density $c$ in the adhesive Johnson-Kendall-Roberts (JKR) model by Johnson et al. [1] should be modified as $c_{\text{mod}} = c(E_{\text{mod}}/E)^{2/5}$. Using this relation, the stick/rebound threshold remains the same but the collision process takes place over a longer time period, which allows for a higher time step size. When rolling
motion is important, the commonly used adhesive rolling resistance torque model proposed by Dominik and Tielens [2,3], Krijt et al. [4] can be used by modifying the contact radius ratio \( (a/a_0)3/2 \) to \( (a_{\text{mod}}/a_{0,\text{mod}})3/2 \), while keeping the other terms unaltered in the description of the rolling resistance torque \( Mr,\text{mod} = -4FC(a/a_0)3/2n \). Furthermore, as the particle stiffness is reduced from \( E \) to \( E_{\text{mod}} \), the time period for collisions (or oscillations when particles stick upon impact) \( Dt_{\text{col}} \) is found to vary as \( Dt_{\text{col},\text{mod}} = Dt_{\text{col}}(E/E_{\text{mod}})^{2/5} \). As the collision duration and the collision time step size are directly related, this criterion can be used to estimate how much the time step size can be changed when a reduced particle stiffness is introduced. Introducing particles with a reduced particle stiffness has some limitations when strong external forces are acting to break-up formed agglomerates or re-entrain particles deposited on a surface out into the free stream. Therefore, care should be taken in flows with high local shear to make sure that an external force, such as a fluid drag force, acting to separate agglomerated particles, is several orders of magnitude lower than the critical force required to separate particles.

Stichworte: Discrete Element Method; Reduced particle stiffness; Adhesive particles; JKR adhesive model; Rolling resistance torque; Computational efficiency

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