ICCES, 2026, vol.26, no.2

DOI: 10.32604/icces.2026.013226

PROCEEDINGS

A Numerical Manifold Method Study of Granular Material Compression Molding

Xuezhen Zhai[1], Pengwan Chen[1,*], and Ge Kang[1,*]

[1]State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, Beijing, 100081, China

[*]Corresponding Author: Pengwan Chen; Ge Wang. Email: pwchen@bit.edu.cn; kangge@bit.edu.cn

ABSTRACT

Compaction and molding of Granular materials are critical processes that govern the uniformity of density and the final mechanical properties of the material. However, the underlying mechanisms controlling particle evolution during densification remain poorly understood. To address this issue, a two dimensional granular material compaction model was developed using the numerical manifold method (NMM). The entire densification process, from particle rearrangement and plastic deformation to crack initiation and fragmentation, was simulated based on realistic particle morphologies. Through model validation and mesoscale analysis, the evolution of particle breakage rate, crack length, and various failure modes during compaction was quantitatively characterized. The results indicate that the compaction of granular materials can be divided into four distinct stages: rearrangement, deformation, fragmentation, and densification. Within the strain range of 30-45%, crack length increases rapidly, and the proportion of fractured particles rises from 10% to 80%, marking the most intense phase of energy dissipation and structural transformation. When strain exceeds 45%, crack propagation tends to saturate, leading to the formation of a stable interlocking structure. From the perspectives of structural evolution and damage development, this study elucidates the internal mechanisms governing density evolution and damage behavior in granular materials during compression molding, thereby providing a theoretical foundation for optimizing compaction processes and enhancing the quality of molded products.

KEYWORDS

Numerical manifold method; Granular materials; compression molding; densification evolution; force chain

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declares no conflicts of interest to report regarding the present study.

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