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# An introduction to Distinct Lattice Spring Model (DLSM)

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## 1 INTRODUCTION

There are a large number of numerical methods which have been applied to rock mechanics and rock engineering. Yet, none can tackle all the problems encountered in rock mechanics and rock engineering. This is particularly the case in dealing with phenomena emanating from the micro structure such as sensitivity to size and distribution of flaws and cracks and their evolution with imposed deformation and loading. Indeed, a successful numerical method must be able to fully consider the microstructure of a material when studying its macroscopic mechanical properties and failure behaviors. These requirements have resulted in renewed and increased interest in discrete or framework/lattice numerical modeling techniques in recent years. In this paper, we introduce a new micromechanical numerical model: Distinct Lattice Spring Model (DLSM) (Zhao et al, 2010 and Zhao, 2010), which is proposed to overcome some of the limitations of the existing discrete micromechanical models and may become an alternative tool for rock mechanics study. The context of this paper covers the theoretical basis, formulation, verification and application of the model using several numerical examples.

## 2 REAL MULTI-DIMENSIONAL INTERNAL BOND MODEL

In recent years, a number of attempts have been made to develop the so-called micromechanical models by explicitly accounting of the micro-discontinuous structures in the medium. The first micromechanical model in this context may be attributed to the pioneering work of Gao and Klein (1998), who proposed the virtual internal bond (VIB) model to simulate crack growth in an isotropic solid. At the continuous state, VIB corresponds to a linear elastic solid with a fixed Poisson ratio, namely, 0.25 for three-dimensional cases and 0.33 for two-dimensional cases. To represent the diversity of the Poisson's ratio, Zhang and Ge (2005) developed the virtual multi-dimensional internal bond (VMIB) model, in which a shear constraint was added into the interaction between two coupled particles. In both VIB and VMIB, materials are discretized into mass particles linked through randomly distributed bonds. The bond here is a virtual concept rather than a real existence. In this work, a micromechanical model which takes into account the advantages of VMIB and Lattice Spring model is proposed and named as the real multi-dimensional internal bond model (RMIB).

## 3 DISTINCT LATTICE SPRING MODEL (DLSM)

In DLSM, material is discretized into mass particles with different sizes. Whenever the gap between the two particles is smaller than a given threshold value, the two particles are linked together through a bond between their center points , which consists of normal and shear springs (see Fig 2(a)). The particles and bonds form a network system representing the material. The system equation of motion is solved by using the explicit central finite difference scheme (see Fig 2(b)). Different from the conventional LSMs, the shear spring is introduced making possible handling of problems with a variable Poisson's ratio. For the shear spring, the relative shear displacement between the two particles is obtained through a local strain based method which ensures that the model preserves the rotational invariance of LSM consisting of normal springs only, details can be found in (Zhao et al, 2010; Zhao 2010). Another distinct feature of DLSM is that during calculation, the micromechanical parameters are automatically calculated based on formulation provided in the RMIB model.

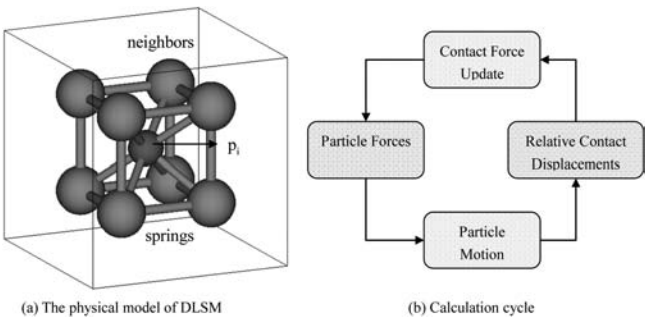


Figure 1. The physical model and the calculation cycle of DLSM.

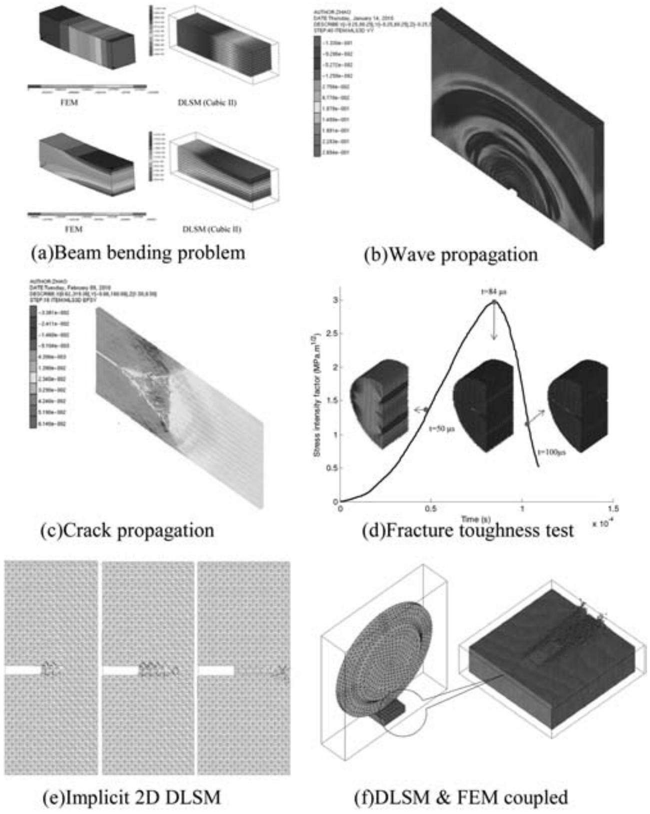


Figure 2. Numerical Examples of DLSM.

## 4 VALIDATION AND APPLICATION

Examples are presented to highlight the abilities of the DLSM for static modeling, wave propagation through joints and dynamic fracturing (see Fig 2). For the beam bending problem, results of the DLSM model with different lattice structures are analysed and compared with the FEM solution (see Fig 2(a)). Fig 2(b) shows the application of DLSM on modeling wave propagation problem. The results are compared well with UDEC and analytical solutions (Zhu et al, 2011). The DLSM is also used to predict the dynamic cracking propagation velocity of PMM plate by Kazerani et al (2010) (see Fig 2(c)) and dynamic fracture toughness of rock material (see Fig 2(d)). New developments of the DLSM, e.g. Implicit DLSM (see Fig 2(e)) and DLSM and FEM coupled model (see Fig 2(f)), are also presented. Other applications of DLSM include: Zhao and Zhao (2010) to study the cutting process of coal under single blade and You et al (2010) to analyze the anisotropic failure of rock material.

## 5 CONCLUISION

DLSM is different from the conventional lattice spring models in that a shear spring is introduced to capture multi-body forces that develop due to spring deformation. Compared with traditional numerical methods, DLSM has the advantages: it directly uses macroscopic parameters without a calibration process, unlike particle based discrete element methods (DEM), it has half as many degrees of freedom as DEM and it is stable, does not require a numerical integration technique, and is well suited to the analysis of contact and heterogeneity problems. These advantages may lead the DLSM become an alternative choice in rock mechanics study.

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