8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

COMPARISON BETWEEN TWO MATERIAL POINT METHODS FOR APPLICATIONS IN GEOTECHNICS

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Key Words: *Material Point Method, Generalized Material Point Method, Geotechnics.*

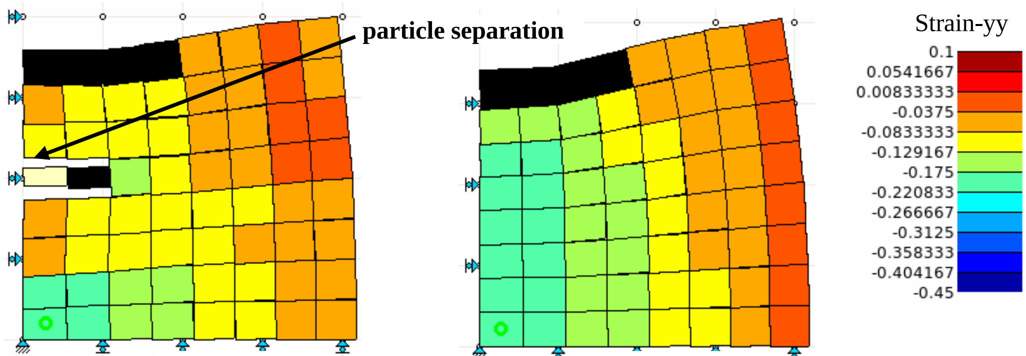
ABSTRACT

The relatively recent material point method (MPM) is an improvement of the particle-in-cell method used in fluid mechanics. The MPM can be used for dynamic analysis of the mechanical behaviour of geotechnical structures, including explosions, impact, penetration, fracture, and crack growth, and has advantages over conventional methods, such as the finite element method. Here, we present a comparison between the original MPM [1] with a more recent method named 'the generalized material point method' (GMPM). The GMPM was presented in [2], but referred as GIMP in that paper. The principal difference between the MPM and GMPM is the selection of the particle characteristic and grid shape functions. The GMPM reduces to the MPM when a specific particle characteristic function is selected. Contrary to the MPM, the GMPM can have C^1 weighting functions, even with C^0 grid shape functions. This higher degree of smoothness provided by the GMPM over the MPM allows for simulations with better accuracy and less noise. In addition, as illustrated here, a typical problem which arises in MP methods, specifically the particle separation, is highly minimised in the GMPM. The example presented is a (flexible) footing problem in a linear elastic medium.

The two main hypotheses of the MP methods concern the particle characteristic and the grid shape functions. Generally, standard FEM element shape functions are used as grid shape functions. However, while the MPM adopts a Dirac delta function for the particle characteristic function, the GMPM generalizes by means of contiguous particles leading to characteristic functions of finite extent. The main impact of this generalization, based on a Petrov-Galerkin discretization scheme, is the increase of the support of the weighting functions, leading to a higher computational effort. Actually, in the absence of a regular grid, construction of the weighting functions is only achieved at considerable effort and computational cost.

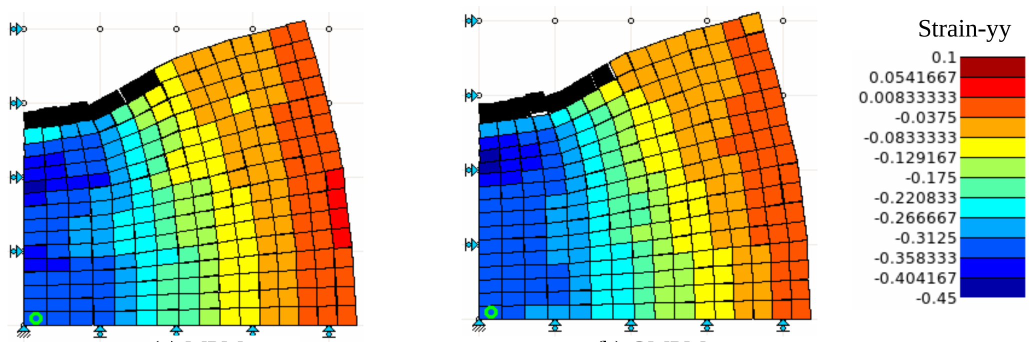
The example is an elastic body (Young's modulus E = 100, Poisson's ratio ν = 0.25, density ρ = 1, dimensions = 1×1) with a footing and 2D plane-strain situation. The loading q is set as a function of time ($q(t) = 5t$) and the time increment for the two first simulations was 0.01 and for the last one (refined grid) was 0.001. It is possible to observe that with a relative coarse discretization, the MPM may lead to particle separation (Fig. 1), contrary to the simulations with the GMPM. Additionally, the simulations using the MPM exhibit a bit of noise, as indicated by the strain field shown

in Figs. 2 and 3. The particle separation problem is a challenge for these two methods, and is mainly related with the particle deformation-update scheme. In order to solve this problem, we are also investigating better weighting functions for the GMPM, since the particle volume and shape have great influence in those functions.



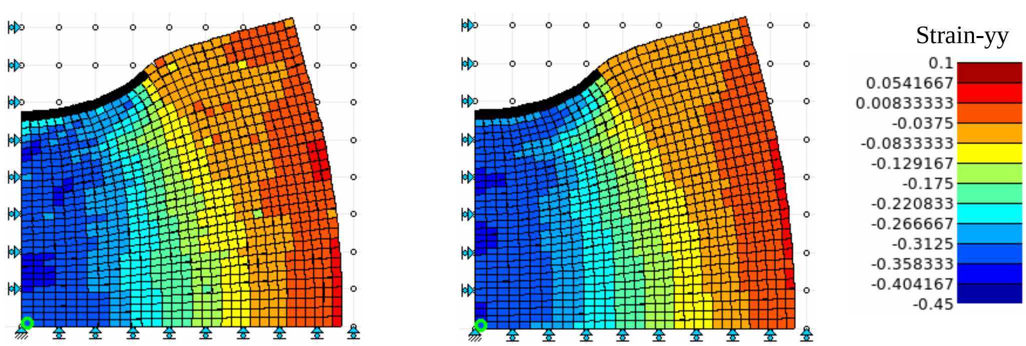
(a) MPM (b) GMPM

Figure 1. Results from the footing problem with a coarse grid (Δt = 0.01, t_f = 4).



(a) MPM (b) GMPM

Figure 2. Results from the footing problem with a coarse grid and more material points (Δt = 0.01, t_f = 8).



(a) MPM (b) GMPM

Figure 3. Results from the footing problem with a finer grid and more material points (Δt = 0.001, t_f = 8).

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