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Treatments of Fractures Intersection in the Enriched-Embedded Discrete Fracture Model (nEDFM) for Porous Flow

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ABSTRACT

Motivated by the fractures being very thin compared to the size of rock matrix, utilizing the non-conforming grid is an efficient approach to simulate fluid flow in fractured porous media. The embedded discrete fracture model (EDFM) is the typical one that using the conforming grid and modelled based on the finite volume method (FVM) framework. The EDFM maintains advantages of mass conservation and low computational complexity, but it cannot characterize blocking fractures and has a low accuracy on the mass exchange between fractures and matrix [1]. In our previous work [2], we developed the enriched-EDFM (nEDFM) to address the two limitations of the classical EDFM. The main feature of the nEDFM is the approximation of pressure distribution inside interaction regions by the local shape function, which introduces two enriched degrees of freedoms (DOF) for each fracture cell and can depict the discontinuities of pressure and its gradient across blocking fractures. However, the original local shape function only applies to the configuration that no more than one fracture line crosses a matrix cell. The function format and the related number of enriched DOF should be modified to handle the more complex discontinuities inside matrix cells crossed by more than one fracture line. This study develops the treatments for matrix cells crossed by two fracture lines, include the situations where fracture lines intersect or do not intersect with each other inside the cell. Five configurations are divided to cover all situations about the fractures distribution inside one cell, and customized local shape functions are proposed for each configuration. Furthermore, the treatment of flow interaction between two fracture lines is also developed to fit the situation that the permeabilities of two fractures have a large difference. The comparison results of a classical case [3] show that the nEDFM still has a high efficiency and accuracy for the case with fractures intersections and has a better performance than the EDFM, projected-EDFM, and extended finite element method (XFEM).

KEYWORDS

Fractured porous media; enriched embedded fracture model; fractures intersection; local shape function

Figures 1 and 2 present the pressure distributions of situation (i) and situation (ii) of a classical case. The results obtained by mimetic finite differences (MFD) are regarded as a reference. It can be observed that for situation (i), the nEDFM and pEDFM both can describe correct pressure distributions, but for situation (ii), only the nEDFM gets the correct solution because it can properly calculate the mass exchange between blocking and conductive fractures.

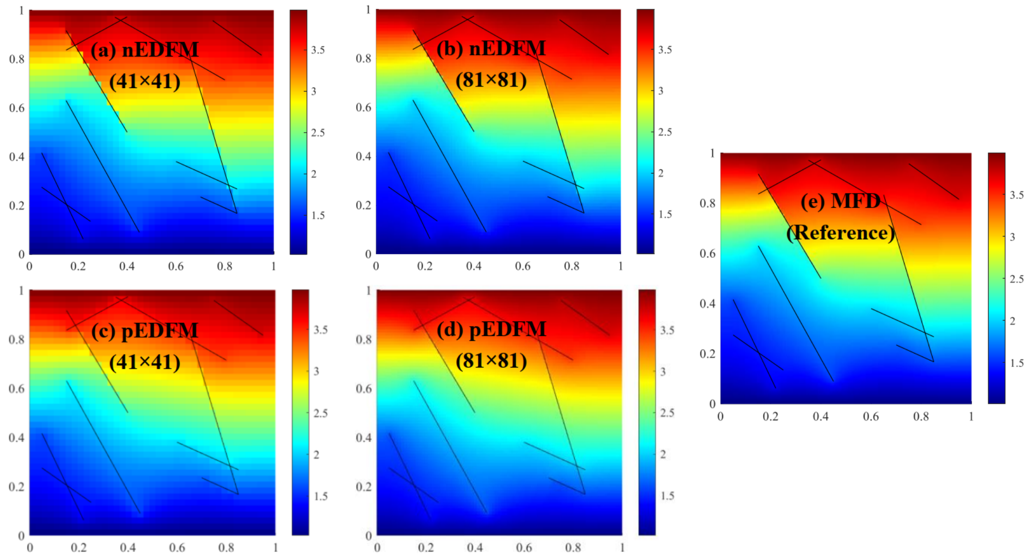

Fig. 1. Pressure distributions of the situation (i) obtained by nEDFM, pEDFM, and MFD (for reference).

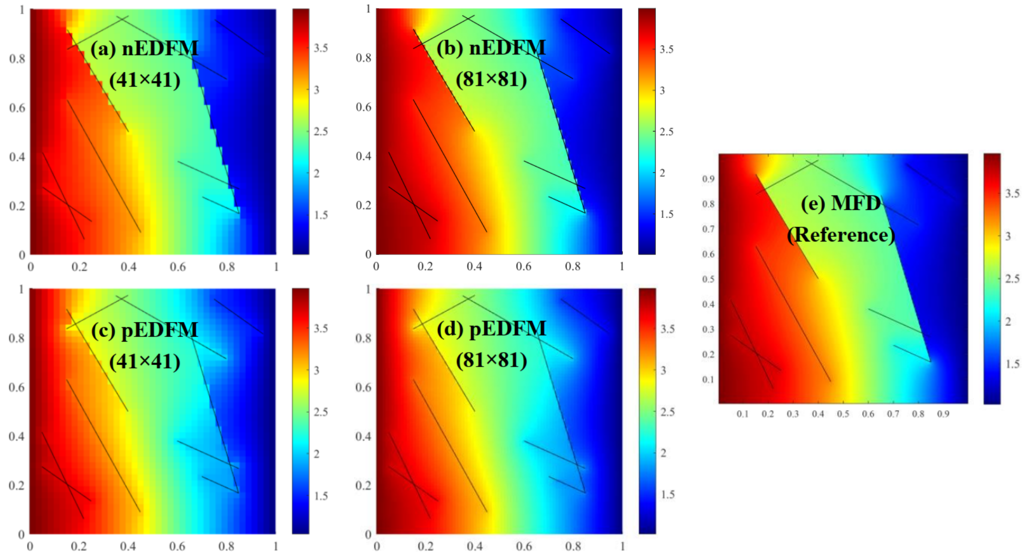

Fig. 2. Pressure distributions of the situation (ii) obtained by nEDFM, pEDFM, and MFD (for reference).

Table 1 presents a quantitative comparison of the performance of different non-conforming methods. The nEDFM simultaneously has a low number of DOF and low error in matrix and fracture domains, making it a promising numerical method.

Table 1. DOF and errors of different non-conforming methods.

Methods	Cells number		Number of DOF	Error in matrix domain		Error in fracture domain	
	Matrix	Fracture		situation (i)	situation (ii)	situation (i)	situation (ii)
MFD	2,260,352	52608	3,471,040	-	-	-	-
nEDFM	**1681**	**234**	**2383**	**0.018**	**0.024**	**0.013**	**0.045**
pEDFM	1681	223	1904	0.039	0.067	0.049	0.079
EDFM	1681	234	1915	0.053	0.078	0.038	0.072
D-XFEM	1922	199	7180	0.019	0.022	0.029	0.036
RDFM	1600	219	32000	0.018	0.023	0.031	0.051

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