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Free convection with diffusion in a fractured porous medium: Experimental, numerical and analytical studies

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Despite the major role of free convection process in fractured porous media, the significant studies for this process have not been accomplished. In this study, experimental, numerical and analytical studies of free convection in fracture porous media were investigated. First, by using computational fluid dynamics (CFD), free convection inside vertical and tilted fractures was studied and it was shown that the convection for tilted fracture occurs in Rayleigh number (Ra) of about 20, which is less than that value for a vertical fracture. Moreover, fracture orientation and fracture size affect velocity and temperature distribution inside the fracture because of free convection. In the next step, free convection in a porous medium with a vertical fracture across it was studied by an experimental setup and CFD. The thickness of the formed boundary layer, the onset of convection and the size of the convection cells were measured. The boundary layer thickness was estimated about 3 cm and 11 plumes observed in the onset of the convection. After analyzing the results and explaining their shortcomings, the idea of correcting the minimum Rayleigh number for such systems was described. The results showed that by using this idea, linear stability analysis equations can be used for such media. In the last part, the free convection with molecular diffusion in the presence of cross diffusion-convection effects in heterogeneous porous media was studied analytically and a number of equations for calculating the minimum Rayleigh number for these media were introduced. The results of these equations were compared with CFD results. The Soret and Dufour effects on the boundary layer flow were investigated. Moreover, the effects of some important parameters such as the Rayleigh number, Soret and Dufour numbers on free convection were analyzed and indicated that the Dufour number was a major parameter in heterogeneous porous media.

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