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ARTIFICIAL COMPRESSIBILITY CBS SCHEME FOR THE GENERALIZED POROUS MEDIUM MODEL

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ABSTRACT

In this work, the authors developed an artificial compressibility (AC) version of the characteristic-based split (CBS) algorithm for the solution of the generalized model for the description of convection in porous media. In particular, the efficiency of this method is verified through comparison with the semi-implicit (SI) version of the CBS scheme for both natural and forced convection. The original SI version of the CBS algorithm, introduced in the early days of the scheme development, has been already applied to the solution of mass and energy transport phenomena in porous media [1]. More recently, the AC version of the CBS scheme was proposed, obtaining a matrix-inversion free algorithm [2]. Nevertheless, the application of the AC version of the CBS scheme to the simulation of flows inside porous media is still in a developing stage. The interest in the AC CBS scheme has increased since it offers the possibility of an easy and efficient parallelization procedure.

The fields of interest (velocity, pressure and temperature) have been predicted by solving the generalized model for saturated porous media. In fact, while the SI version of the CBS scheme needs great computational requirements, because of the simultaneous solution of algebraic equations, the AC CBS scheme does not show this kind of problems. Both the versions of the CBS algorithm have been studied by comparing the obtained numerical results with analytical or numerical solutions available in literature [3, 4], showing an excellent correspondence (Figures 1 and 2). In figure 1, the non-dimensional velocity profile, obtained with the AC CBS scheme, in the case of forced convection, in a section of a porous channel with a Darcy number equal to 5.0×10^{-2}, is compared to the analytical solution of [3]. The top and bottom walls of the channel have a non-dimensional temperature respectively equal to one and zero. Table 1 shows the CPU time to reach the convergence (velocity norm residuals equal to 10^{-6}), in the case of forced convection, for different Darcy numbers. It can be noticed that the AC CBS scheme performs better when the Darcy number increases, while the SI CBS scheme shows the opposite behaviour. Figure 2 shows the temperature contours, obtained with the present scheme, in a square porous cavity, in the case of natural convection, for Rayleigh, Prandtl and Darcy numbers respectively

equals to 7.0×10^4, 0.71 and 1.0×10^{-3}. The left, right and bottom walls have a non-dimensional temperature respectively equal to zero, zero and one, while the top wall is adiabatic. The results obtained with the AC CBS scheme compare excellently with the numerical solution of [4]. Table 2 shows the CPU time to reach the convergence, for different Darcy and Rayleigh numbers. It can be noticed that the AC CBS algorithm performs firmly better than the SI CBS algorithm at any Darcy or Rayleigh number.

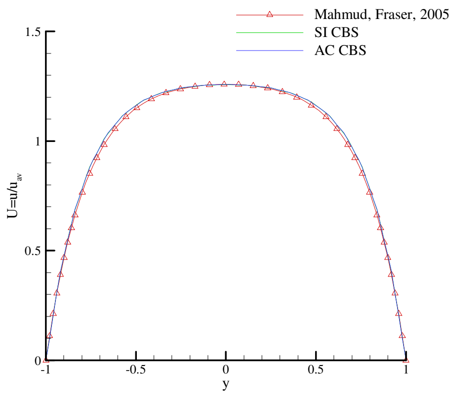

Figure 1. Non-dimensional velocity for forced convection in a section of a porous channel.

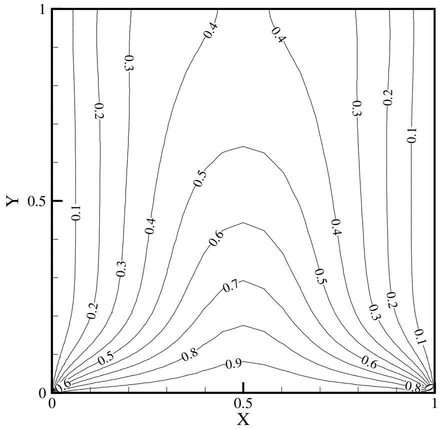

Figure 2. Temperature contours for natural convection in a square porous cavity.

	Forced convection CPU time [s] on 8Gb workstation				
		Da=0.01	Da=0.05	Da=0.1	Da=1
6191 nodes	AC CBS	4266	1316	864	188
	SI CBS	571	1150	1331	1742

Table 1. CPU time for forced convection in a porous channel at different Da.

	Natural convection CPU time [s] on 8Gb workstation				
		$Ra=1.0\times10^6$		$Ra=7.0\times10^4$	
		$Da=1.0\times10^{-3}$	$Da=1.0\times10^{-4}$	$Da=1.0\times10^{-3}$	$Da=1.0\times10^{-4}$
1521 nodes	AC CBS	44	163	52	145
	SI CBS	1230	1028	1330	1499

Table 2. CPU time for natural convection in a porous cavity at different Ra and Da.

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