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Mathematical model of the Bloch NMR flow equations for the analysis of fluid flow in restricted geometries using the Boubaker polynomials expansion scheme

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ABSTRACT

In this study, the Bloch NMR flow equations are modelled into diffusion equation with constant transport coefficient in terms of the NMR transverse magnetization. Mathematical conditions are established for the diffusion coefficients to be constant or spatially varied with direction. When these conditions are met, the diffusion coefficients can then be easily evaluated in terms of Boubaker polynomials for the study of flow in restricted geometries.

1. Introduction

The mathematical models presented by Bear adapted the well known Darcy laws in the mathematical formulation of flow systems (fluid dynamics). This included the Navier Stokes equation [1] and the Ficks law of diffusion [2]. These laws are well suited to porous media because an evaluation of the fluid permeating the pore gives an elaborate information about the material. The discovery of the phenomenon of nuclear magnetic resonance in the 1940s [3] opened a new means of understanding substances at nuclear level. In his work, Felix Bloch developed a set of coupled differential equations meant to described the nuclear motion of the substances. Torrey [4] modified the equations in order to describe the diffusion phenomena observed in all flow systems, an equation now known as the Bloch–Torrey equation. It was later observed in theory and experiment [1–9] that the diffusion coefficient measured in the Ficks equation and the Bloch–Torrey equation carries information on the structure of the pore, the chemical composition of the pore and geometrical restrictions. Awojoyogbe [10–15] developed a general differential equation from the Bloch equation which is very invaluable in analyzing fluids and their containing media.

In this study, we shall develop a mathematical formulation which shall use the equation developed by Awojoyogbe to accommodate fundamental NMR parameters of fluid flow in porous media. We shall also relate the diffusion process in such media to the Boubaker polynomial (a new expansion scheme).

Such a formulation would then make it very easy to evaluate various porous media and the desirable feature in any experimental setup.

The Bloch NMR flow equations are a set of coupled differential equations that describe the behavior of the macroscopic magnetization. The equations can account for the effects of precession, relaxation, field inhomogeneity, and RF pulses. If one considers the magnetization as a function of space as well as time, we can include the effects of gradients and diffusion [3–7]. The NMR transverse magnetizations, the diffusion coefficient obtained in terms of NMR flow parameters from the solution of the Bloch NMR flow equations as presented in this study can play more fundamental role in the analysis of flow in restricted geometries such as in biology (nutrient transport, membrane function, blood flow), catalysis, foodstuff, materials (concrete, cement, polymer networks, self-organizing materials, and geology) fluid movement in

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