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DYNAMICS OF PULSATILE FLOWS THROUGH MICROTUBES FROM NONLOCALITY

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Highlights:

1-A new notion of complexified nonlocal material derivative operator is introduced

2-Complexifed fluid equations of motion are derived

3-For long laminar tubes, the axial velocity profile has a parabolic shape in agreement with the standard result

4-For small length scales, the velocity profile depends on Bessel functions of order zero indicating the presence of a pulsatile flow in microtubes.

Abstract
In this paper we introduce a new notion of complexified nonlocal-in-time-space material derivative operator and we discuss its implications in fluid mechanics. After deriving the complexified fluid equations, we investigate the problem of laminar flow of a particle fluid in a microtube. We demonstrate the occurrence of pulsatile flows through microtubes in agreement with recent findings.

Keywords: Complexified nonlocal-in-time-space material derivative operator; complexified fluid equations; laminar flow; pulsatile flows in microtubes

Mathematics Subject Classification (2000): 37N10; 35Q30

1. Introduction

Nowadays there is a large interest to deal with nonlocal-in-time (NLT) dynamical systems since nonlocality in general may correlate classical mechanics to quantum mechanics. Nonlocality has been thoroughly proven experimentally and therefore it is considered as a fundamental property of non-differentiable complex systems. In continuum classical mechanics, nonlocality appears in heterogeneous materials characterized by anisotropic non-locality, in elastic materials with couple-stress, in strain-gradient linear and micropolar elasticity and in elastic material surfaces (see [**31**] and references therein). Currently there are many mathematical concepts dealing with non-local formulations. The first article in this area was released in 1948 and dates back to Feynman. It is based on the notion of nonlocal-in-time backward-forward coordinates (NLTBFC) where the position differences are shifted with respect to each other [**12**]. This idea was used in 1966 by Nelson in his seminal paper [**23**] which aims to derive the Schrödinger equation from classical mechanics and mainly from a primary Brownian stochastic process in configuration space. More specifically, it was observed that the combination of the backward and forward Wiener processes transform the Newton’s equation of classical mechanics into the Schrödinger equation of quantum mechanics. Nelson's approach motivated Nottale to construct the scale relativity which combines quantum mechanics with relativity theory by introducing a complex derivative operator which leads to put up a nonlocal physical state of the coordinate system [**25**]. NLTBFC was in addition used in different frameworks, e.g. in extended Newtonian mechanics characterized by a nonlocal-in-time kinetic energy [**33**], in nonconservative dynamical systems [**19**], in complexified Lagrangians dynamics [**9,10**], in nonlocal fractional dynamics [**11**] among others. In applied mathematics, NLT is used in boundary value problems mainly in parabolic and hyperbolic equations [**14-17**]. The main aim of the present manuscript is to discuss the implications of NLTBFC in fluid mechanics. In a fluid system, internal interactions occur usually at all scales and the consequential force fields could be non-differentiable. Regardless of the details of specific formulation, non-differentiability has in reality a number of mathematical and physical consequences e.g. scale dependence, similarities, higher algebra and jets in an ideal fluid; fractal and non-deterministic trajectories [**23**]. It is notable that the fractal nature of molecular trajectories in fluids was discussed in [**28**] and experimental evidences were presented in [**1,21,30,31**]. Fractals and multifractals in fluid turbulences were discussed in [**31**] and a number of interesting research papers confirming the importance of fractal and differentiability in fluid mechanics are found in [**4,23,35**] and references therein.