Dynamics of Continuous, Discrete and Impulsive Systems
Series **A:** *Mathematical Analysis* **23 (2016)** 125-141
 http://www.watam.org

EXISTENCE AND A PRIORI BOUNDS FOR RADIAL STAGNATION FLOW ON A STRETCHING CYLINDER WITH WALL TRANSPIRATION

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Dedicated to the memory of our teacher Professor J. Bryce McLeod.

Abstract. In this paper we investigate a boundary value problem resulting from a similarity transformation of the Navier-Stokes equations governing radial stagnation flow toward a permeable stretching infinite cylinder with superimposed suction or blowing on the cylinder surface. A steady, laminar, viscous, and incompressible fluid impinges normally onto the cylindrical surface and spreads out axially away from a stagnation circle. The boundary value problem governing the flow is given by

$$\eta f''' + f'' + R(ff'' + 1 - f'^2) = 0, \quad f(1) = \gamma, \quad f'(1) = \lambda, \quad f'(\infty) = 1,$$

where R is the Reynolds number, γ represents wall suction ($\gamma > 0$) or blowing ($\gamma < 0$), and $\lambda > 0$ represents the stretching rate of the cylinder. Here we prove existence of solutions with monotonic derivatives for all $\lambda \geq 0$ and for all $\gamma \in \mathbb{R}$. We also prove that if $0 < \lambda < 1$ and $\gamma \leq -1/R$, then the boundary value problem has a unique solution. If $\lambda > 1$, we show that any further solution cannot have a monotonically decreasing derivative. Finally, an a priori bound on the skin friction coefficient is obtained for all $\lambda \geq 0$.

Keywords. Boundary Value Problem; Topological Shooting; Existence and Uniqueness of Solutions; Navier-Stokes Equation; Similarity Transformation.

AMS (MOS) subject classification: 34B15, 34B40, 34B60.

1. Introduction

The problem of radial stagnation flow directed normally toward the surface of a circular cylinder was first investigated by Wang [13]. Later in a series of papers [14]- [15], Wang considered the steady axisymmetric stagnation flow toward an impermeable or a permeable infinite cylinder. Several extensions of the radial stagnation flow problem have been considered that take into account several physical phenomena such as steady heat transfer [3], unsteady viscous flow [5], steady axial translation of the cylinder [4], and rotation of the cylinder with suction or injection of a fluid through the bounding surface [1]. Wang [14] also studied such flow far a stretching cylinder. Further