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Numerical Analysis of Terrain Variabilities and Their Impact on the Traction Performance of Agricultural Tire

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Abstract

This study uses numerical analysis to examine how terrain variability affects agricultural tire traction performance, utilizing ANSYS simulations and the Wong and Preston-Thomas tire model. Tractor tire performance was evaluated across ten different clay soils with varying mechanical properties. The ANSYS simulations modeled tire-soil interactions, and the Wong and Preston-Thomas model predicted traction performance based on stress data. Results showed notable variations in thrust, drawbar pull, and motion resistance, with certain soils delivering better traction. The study offers insights for optimizing tire design to improve vehicle productivity on diverse terrains.

Keywords: Wong and Preston-Thomas tire model, numerical analysis, traction performance, ANSYS simulation, clay soil parameters, tire-soil interaction.

1. Introduction

Agricultural vehicle performance is not only pivotal for efficient farm operations but also crucial for ensuring productivity and sustainability in agriculture. Among the numerous factors influencing agricultural machinery performance, tire design and terrain characteristics play vital roles. Understanding the complex interactions between tires and diverse terrains is essential for optimizing traction, minimizing energy consumption, and enhancing overall agricultural productivity. This research explores the intricate dynamics of tire performance across varied terrain conditions, employing advanced numerical techniques through ANSYS and the improved tire model by Wong and Preston-Thomas. The study provides an in-depth analysis of these interactions, highlighting key parameters that influence agricultural vehicle traction. Over the past few decades, significant progress has been made in numerical modeling, particularly in understanding the complexities of vehicle-terrain interactions. Early foundational work by Yong and Fattah (1976) and Yong et al. (1978) introduced finite element models to simulate tire-terrain interactions. However, these initial models were constrained by their reliance on input values, such as contact displacements or stresses, limiting their applicability in more complex scenarios (Shoop, 2001).

As computational power grew, more refined models emerged. Pi (1988) introduced elastic tire models on viscoelastic soils, and simplified methods, such as pre-defined contact stress distributions, became common to address computational challenges (Shoop, 2001). Researchers like Liu and Wong (1996) and Foster et al. (1995) expanded the scope of simulations, evolving from two-dimensional to more complex three-dimensional models. Institutions like the Automotive Research Institute (IKK) in Hamburg, Germany, contributed significantly by developing realistic models of pneumatic tires on deformable soils. Aubel (1993, 1994) and Fervers (1994) offered valuable insights into the influence of lug design on tire performance. Collaborative efforts by organizations such as the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Goodyear, and Caterpillar propelled the development of three-dimensional models of deformable tires on deformable terrain. Researchers like Tordesillas at the

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