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Synthesis and analysis of the steering system of an adjustable tread-width four-wheel tractor

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Abstract

In this paper the problem of synthesizing the Ackermann linkage and the steering control mechanism of an adjustable tread-width tractor is presented. Several conflicting requirements were simultaneously considered as follows: ensuring minimum wheel-slip and symmetric steering control for left and right turns, ensuring minimum cross-coupling between steering and axle oscillation, maintaining favorable pressure angles in the joints, and avoiding interference between the moving parts of the mechanism and between these and the body of the vehicle. This difficult multi-criteria optimization problem was solved in a simplified manner by sizing the Ackermann linkage first, followed by an optimum synthesis of the steering control mechanism, assuming it has the drag link removed. The removal of the drag link induced the extra degree of freedom which allowed the steering arm and the pitman arm to be exactly coordinated over the whole working range of the mechanism. An objective function based on the variation of the distance between the centers of the drag-link joints in several essential configurations of the steering control mechanism, was defined and further minimized in the presence of interference avoidance and pressure angle constrains.

Keywords: Adjustable tread-width vehicle; Ackermann linkage; Steering control mechanism; Constrained optimization problem; Search algorithm

1. Introduction

With very few exceptions, agricultural tractors are equipped with steering axles that are pin-jointed to the chassis without any springing (other than the pneumatic tires) [1]. For subcompact and compact tractors [2], steering is commonly ensured by an Ackermann linkage, controlled by the driver from the steering wheel via the steering-box, pitman arm, drag link, and steering arm assembly (Fig. 1).

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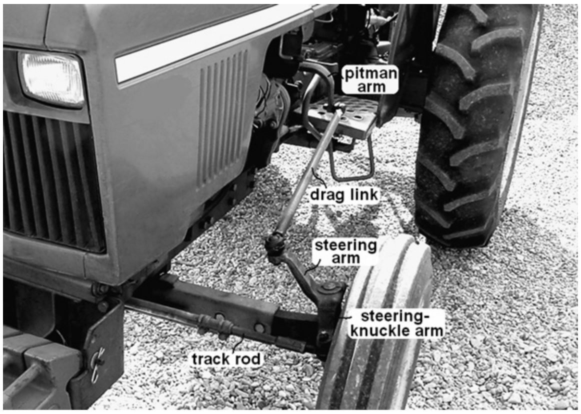

Fig. 1. The steering system of an adjustable tread width, rear wheel drive compact tractor.

The Ackermann linkage has been investigated by a number of authors in the past [3–8]. It is a symmetric, four-bar spatial function generator symbolized RSSR (S stands from spherical joint and R from rotational or turning joint), and has the role of pivoting the steered wheels at certain variable ratio imposed by the condition of correct turning i.e. the axes of all four-wheel meeting at a common center [3,4,6–9].

The steering control linkage has been also investigated [1,8,10,11], although simplifying assumptions were usually made, like the kingpin and the pitman arm having nonintersecting, perpendicular axis (i.e. the caster and kingpin inclination angles are assumed zero). As schematized in Fig. 2, the steering control linkage is an RRSSR mechanism with two-degree-of-freedom (without considering the trivial rotation of the drag link about its own axis). These DOFs are the rotation of the pitman arm (change of angle φ_1 measured from the reference position φ_{01}) which is the steering control motion, and the rotation of the axle relative to the chassis (change of angle ψ measured from the OX axis). If this latter degree-of-freedom is ignored, the mechanism can be considered a spatial four-bar linkage (RSSR), which is analyzed in theoretical kinematic

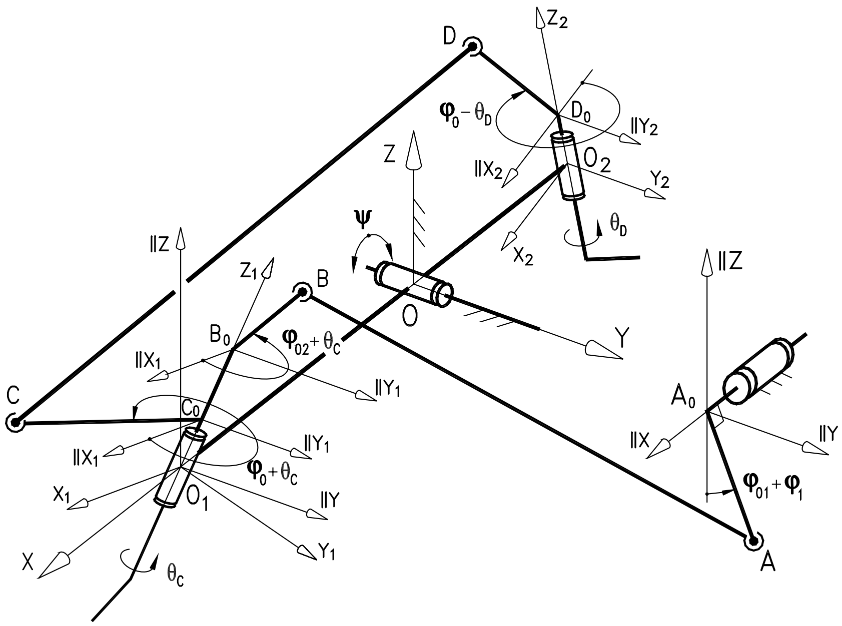

Fig. 2. Schematic of the Ackermann linkage controlled via spatial four-bar mechanism; $\|X$, $\|Y$ and $\|Z$ signifies axes that are parallel to OX, OY and OZ respectively.