Chapter 12

Simulation of a Hydropneumatic Suspension for Agricultural Working Vehicles

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ABSTRACT

The chapter shows the study and simulation of a hydropneumatic suspension to be adopted for a telescopic handler vehicle. The hydropneumatic suspension system with independent wheels and with quadrilateral architecture has been studied to improve comfort and productivity of the existing vehicle, which has a suspended rigid axle on the front and a rigid axle on the rear, limiting the comfort and the grip. After the choice of the architecture and the kind of suspension, the chapter shows the design of the suspension kinematics. The optimization of the characteristic angles of the suspension has been performed using Adams/Car and Adams/Insight. The kinematic model optimized is subsequently reproduced in Adams/View to simulate the dynamics of the complete vehicle. Simulation results are used to evaluate vehicle performance in terms of comfort and stability according to the methods proposed by the standards.

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INTRODUCTION

In the last years, working vehicles manufacturer are investing money and efforts to make their machines compliant with the current quality standards, especially when dealing with safety and comfort (Zampieri et al., 2013; Kittusamy & Buchholz, 2004; Kuijt-Evers et al., 2003) of the operator during working operations. Several studies in the literature show that long working sessions (lifting, moving, pulling, etc.) can affect the operator comfort inside the cab due to the exposure to prolonged vibrations (Akinnuli et al., 2018; Caffaro et al., 2016; Zampieri et al., 2013). According to the European Agency for Safety and Health at Work (European Agency for Safety and Health at Work, 2008) todays mobile machinery operators can be exposed to prolonged vibrations with accelerations in the range from 0.2 up to 2 m/s². The frequency content of the vibration can affect the human body in different ways: low frequency vibrations, below 10 Hz usually lead to human motion sickness while frequencies up to 100 Hz are associated to a general discomfort for the operator (Guignard, 1971). In the June of 1989, the European Directive 89/391/EEC (European Council Directive, 1989) introduced for the first time the need for special attention on safety and health of workers, especially against mechanical vibrations levels to which they can be exposed during their daily activities. Then, several other directives stated the Whole Body Vibrations (WBV) levels to which worker can be exposed without risks (European Parliament and European Council, 2002). Generally speaking, vibration acceleration should not exceed 3.2 m/s² for short operations (30 minutes) and 0.8 m/s² long operations (> 1 hour).

On a Working Vehicle, vibrations can derive from different sources: a bad filtered Diesel engine, tools attached and propelled by the vehicle and the road asperities. One of the key elements which affect comfort and safety of a vehicle is the type of suspension adopted to introduce a degree of freedom between the body of the vehicle and the wheels directly in contact with the road surface. It is not unusual to find working vehicles with no real suspension mechanism (Nicolini et al, 2018; Mocera & Nicolini, 2017; Peachey et al., 1989; Lines et al., 1989). The ground asperities can be mitigated by the stiffness and damping provided by the deformation of the tyres (Siefkes, 1989; Rasmussen & Cortese, 1968) but are practically entirely transmitted to the main body if the machine is equipped with tracks (Zhang et al., 2018; Cai et al. 2012). The lack of a suspension mechanism provides robustness and cost effectiveness for the simplicity of the solution, but at the cost of a lower comfort for the operator and limited dynamic performance of the vehicle. To provide a minimum level of filtering from vehicle vibrations, the most common solution adopted is the suspension of the cab by mean of rubber elements placed at the interface connection with the chassis (Zehsaz et al., 2011; Hansson, 1995; Hilton & Moran, 1975). Considering the most common commercial solution, this approach can well filter vibrations in the high frequency range but does not provide good comfort levels when it comes to low frequencies. A possible solution to improve comfort consists in the adoption of active or semi-active suspensions for the cabin (Deprez et al., 2005) which however does not improve the overall dynamic behaviour of the vehicle. In this work, a semi-active suspension system between the tyres and the chassis will be investigated considering a telescopic handler as case study. The suspension architecture will be discussed to understand the benefits and the overall impact of the solution at vehicle level in terms of performance.

Generally speaking, vehicle suspension system can be grouped in four relevant classes:

- Passive suspension (Grott, 2010);
- Adaptive suspension (Cebon, 2000);