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Development of a simplified model for the vibration analysis of lawn mowers

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Abstract

The vibrational behavior of vehicles is a crucial issue for the comfort, especially for the professional vehicles. This paper presents a simplified modelling approach for studying the vibrational behavior of a lawn tractor. The vibrational response of a real vehicle is analyzed by an extensive experimental modal analysis and Finite Element model (FE) simulating the modal behavior of the whole tractor. The FEM was then validated by the comparison with the experimental results and then used for identifying the components and connections effectively driving the modal response. Based on these results, a simplified Multi-Body (MB) model, able to reproduce the vibrational response of the studied lawn mower, was then setup, showing good correspondences with experimental results. General guidelines for defining effective vehicles Multi-Body modal models were also derived.

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Keywords: Experimental modal analysis; Finite Element modal model; Multi-Body modal model; lawn mower.

1. Introduction

The vibration behavior of vehicles is important for comfort analysis, especially if the vehicle is intended for long-term human operation, such as professional lawn tractors. Unfortunately, experimental analyses are time consuming, expensive and usually provide a partial description of the vehicle behavior. Moreover, the correction of vibration

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phenomena on a prototype is expensive and has a severe impact on the layout. For these reasons, it is useful to have computational tools able to predict the machine behavior. However, the development of detailed models of the vehicle is not affordable in this industrial field and the setup of simplified models should be preferred.

The presented research activity originated in the framework of a collaboration between University of Pisa and Global Garden Products Italy S.p.A. (GGP, Castelfranco Veneto, TV, Italy), with the aim of developing a simplified model for determining the vibration behavior of a lawn mower. Two numerical models of a real lawn mower prototype were developed. The first model exploited the Finite Element (FE) method, considering all the tractor's parts as deformable bodies. This more sophisticated model provided a full description of the vehicle modal response in a wider frequency range and was indeed used to tune the simpler MB model. The second one was a simplified semi-flexible MultiBody (MB) modal model: the main structural parts were modelled as flexible bodies, the tires were modelled as vertical linear springs and all the other parts were modelled as rigid added masses. The main advantage of this simplified model consists in relatively short computational time, while the main drawback is represented by a limited capability of the model to describe the structure's behavior corresponding to high frequency modes.

The FE model was firstly validated by comparison with the experimental modal analysis of the lawn mower; then, the main masses, inertia and compliances to be included in the MB model were identified with a step-by-step procedure: a comparison between the modal responses furnished by the two numerical models was performed to set the parameters until a good agreement was found. The activity allowed to derive some guidelines for developing simplified and accurate semi-flexible multibody models, without the need to repeat the FE modelling.

2. Material and methods

2.1. Lawn mower description

The vehicles of the present study are professional lawn mowers as shown in Fig. 1. More precisely, the studied tractor is a MTR 122 Proto 1, whose main characteristics are reported in Table 1.

Table 1. Lawn mower main dimensions.

Quantity	Value	Unit
Overall length	1710	mm
Overall width	1255	mm
Overall height	1150	mm
Wheelbase	1250	mm
Total weight	200	kg

The vehicle is powered by a single cylinder 4-stroke air cooled engine, which exert a gross torque of 41 Nm (at 3600 rpm). The mower is also equipped with a cutting deck composed of two counter-rotating blades having a diameter of 1220 mm. The parts of the vehicle can be schematically divided in two groups: structural components and additional parts. The main structural part is the base frame, which is composed of two rectangular tube rails, supporting the seating and the steering frames, and a cross plate supporting the engine. The rails are connected by a U-shape beam at the front end (which supports the front axle) and by an L-shape beam at the rear end. All the connections are obtained through welded joint. The seating frame is composed by beams of various sections (L-shape, and rectangular) two C-shape plates and a folded plate supporting the driver's seat. The connections are obtained though continuous or intermittent welded joints and bolted joints. The steering frame is composed by several components: L-shape and rectangular beams, several folded plates supporting the dashboard frame, two multi-holed plates supporting the fuel tank and four cylindrical spacers. The connections are obtained through intermittent welded joints and bolted joints. Finally, the components supporting the box system are a main folded plate, two brackets and four threaded bars, which are connected through bolted joints.

The main structural parts are assembled to host the additional parts, which may be characterized by their inertia properties, and are mainly represented by: the engine (Briggs & Stratton INTEK 5-210 AVS, dry weight of 29.5 kg,