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Energy efficiency analyses of a vehicle in modal and transient driving cycles including longitudinal and vertical dynamics

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ABSTRACT

The growing concerns about the environmental issues caused by vehicles and a strive for better fuel economy, urge the legislators to introduce conservative regulations on vehicle testing and homologation procedures. To have accurate evaluations, driving cycles that can sufficiently describe the vehicles' conditions experienced during driving is a prerequisite. In current driving cycles there are still some issues which are disregarded. The aim of the presented work is to study the contribution of chassis and vehicle dynamics settings on tyre rolling loss in comparison with the original assumptions made in the NEDC, FTP and HWFET driving cycles. A half-car model including a semi-physical explicit tyre model to simulate the rolling loss is proposed. For the chosen vehicle and tyre characteristics, depending on the specific chassis settings and considered driving cycle, considerable difference up to 7% was observed between the energy consumption of the proposed- and conventional approach. The current work aims to provide the legislators with a better insight into the real effects of chassis and vehicle dynamics during the certification process to further improve the test related procedures required for homologation such as generation of road load curves. I.e., the aim is not to provide a new homologation process, since there are also other effects such as road roughness and tyre temperature that need to be considered. The results are also of interest for the vehicle manufacturers for further considerations during test preparation as well as in the development phase in order to reduce the environmental impacts.

1. Introduction

Nowadays, when launching new vehicles, most countries have type approval emission tests that the vehicles need to pass. Considering that the vehicle emissions are rather variable and therefore have different environmental impacts, it is important to perform the tests under standardised laboratory conditions to ensure a reproducible and reliable test procedure. A driving cycle is therefore commonly used as a standard test defined by legislators, which allows the accomplishment of emission tests in a reproducible manner. This includes a record of the vehicle speed and gear selection in the time domain.

Different perspectives of regulatory organisations lead to introduction of various driving cycles which could either be used generally (Dembski et al., 2002) or regionally in specific city or country (André et al., 1995; Hung et al., 2007; Wang et al., 2008; Kamble et al., 2009) in order to measure the emission performance of vehicles. Simultaneously, many efforts

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and research have been made to either reveal the existing discrepancies in the current homologation process (Pelkmans and Debal, 2006; Kühlwein, 2016) or optimise the driving cycles in order to improve the test procedures towards a more real-world emission performance (Amirjamshidi and Roorda, 2015; Rapone et al., 1995; Bata et al., 1994; Kishan et al., 1993; UNECE). Even though the results of these efforts have improved the test procedures, there are still some simplifications in the conventional test procedures and modifications by vehicle manufacturers during tests that might be of importance for the estimation of fuel consumption in type approval process (Kühlwein, 2016).

Most driving cycles used for homologation are normally performed using a stationary vehicle tied down on a chassis dynamometer where the load on the wheels are adjusted to simulate driving resistances on the vehicle, such as rolling resistance and aerodynamic drag (Dembski et al., 2002; Kühlwein, 2016). These characteristics are conventionally considered as coefficients, which are often considered to be constant during the whole test. However, based on the type of vehicle, its powertrain, weight and dimensions as well as other chassis components like suspension and tyres, those coefficients can be subjected to changes, thus influencing the fuel consumption and emission performance of the vehicle in real-world driving.

Among all resistive forces in a passenger car, the rolling resistance is one of the characteristics that is highly dependent on the load change, speed and wheel alignment settings. Rubber deformation results in rolling loss and some of the different ways that deformations in the tyre can occur, and thereby contribute to the tyre energy dissipation, are illustrated in Fig. 1 (Davari et al., 2015; Davari, 2015). The current certification process under estimate the vehicle emissions due to their inadequate representation of chassis components and vehicle dynamics compared with the performance of a vehicle in real-world driving wherein for instance the chassis or suspension are sometimes adjusted/adapted by the manufacturers (Kühlwein, 2016).

Without understanding the mechanism of rolling loss and realise its contribution to the driving resistances and accuracy of certification process, suggestions on the improvement of current certification procedures cannot be made realistically. In this work, consequences of the assumption of no wheel alignments and no load transfer, made in current procedures, are investigated with the focus on rolling loss estimation. I.e., the contributions to rolling loss from chassis and suspension kinematics by considering longitudinal and vertical dynamics of the vehicle are estimated and compared. Here, the main European and US driving cycles are used as case studies to evaluate the vehicle energy consumption. Essentially, this paper is aimed to specifically investigate the contribution of chassis and related vehicle dynamics issues on the result of homologation process which are missed until now. Therefore, this work will not suggest a new driving cycle, rather provides a broader insight into the contribution of the chassis and vehicle dynamics on the certification results, which are somehow eliminated todays, thereby suggesting further consideration of those parameters during homologation by either modifying the test procedures or test benches.

2. Background

2.1. Driving cycles

A driving cycle is a standardised driving pattern, which is used to gain a quantitative understanding of fuel consumption and emissions for a vehicle during either development phase or homologation process, or they might also be used for engine

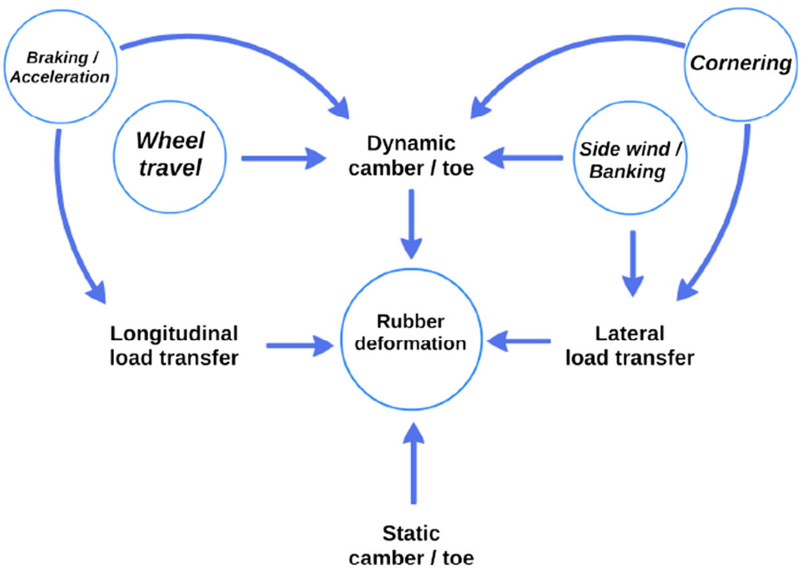

Fig. 1. The deformation mechanisms induced on a tyre (Davari, 2015).