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An analysis of the influence of suspension design parameters on passenger car ride comfort

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ABSTRACT: *In order to analyze influences of design parameters of suspension system on ride comfort of a passenger car, The design parameters of vehicle suspension system (VSS) are analyzed for their influence on the vehicle's ride comfort. The time domain acceleration responses of vertical vehicle body (a_{bz}), pitching vehicle body angle (a_{bphi}) and rolling vehicle body angle (a_{bteta}) are selected objective functions according to the ISO 2631:1997(E) based on a full dynamic model of a passenger car with 7 degrees of freedom. The study results have shown that the design parameters of VSS have a direct impact on vehicle ride comfort.*

KEYWORDS: *Passenger car, Dynamic model, Design parameters, Ride comfort*

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I. INTRODUCTION

A three-dimensional vibration model of bus with 10 DOF (degree of freedom) was recommended based on Dragan Sekulić model to analyze the suspension parameters directly influenced ride comfort. The suspension parameters which include the stiffness and damping parameters were analyzed based on the weighted r.m.s. (root-mean-square) acceleration responses of the space of a driver, passenger in the middle part of the bus and passenger in the rear overhang according to ISO 2631-1:1997 [1]. A quarter bus model of bus was recommended to evaluate an active bus suspension system with an in-wheel electric motor and to show the effect of this motor on the performance of the bus's suspension system [2]. A full model of a bus using air suspension system with air spring element, which was modeled based on the Gensys model was recommended to optimize the parameters of the air spring element [3]. A state-of-the-art quarter-car model was recommended to eliminate the influence of feedback controller performance and to integrate both actuator limitations and necessary constraints on dynamic wheel-load variation and suspension travel [4].

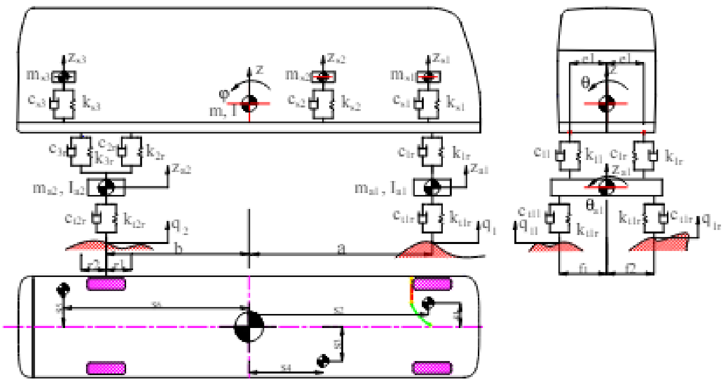

Fig.1. Full dynamic model of the bus IK-301 [1]

The effects of different vehicle speeds on ride comfort on bump road was recommended the frequency and time domains by analyzing the suspension dynamic disturbance by taking the vertical acceleration of the foot floor and seat rail, the wheel dynamic loads, and the suspension dynamic deflections of the suspension as the objects of analysis [5]. A quarter electric vehicle vertical dynamic model under the combination of two excitation sources such as electromagnetic excitation in motor and road surface roughness excitation was recommended to improve the Electric vehicle's ride comfort and road friendliness [6].A 3-DOF quarter-vehicle dynamic model of an electric vehicle under two input excitation sources such as road surface roughness excitation was recommended to evaluate the effects of design parameter of in-wheel motor suspension system (IMSs) on electric vehicle ride comfort [7]. A dynamic model of quarter vehicle with the combination of n-wheel motor (IWM) and road surface roughness excitations was recommended to to analyze the impact on the vehicle ride comfort caused by IWM suspension system [8]. A quarter-vehicle model of the in-wheel motor (IWM) configuration with the motor of an electric vehicle with three degrees of freedom was proposed under two combined excitation sources of road surface and electric motor to investigate the effects on the design parameters of an electric vehicle suspension system on the value of the root-mean-square (r.m.s.) acceleration of the vertical vehicle body according to the international standard ISO 2631-1 (1997) [11]. A quarter-vehicle dynamic model with an air suspension system was proposed based on the reference to consider and evaluate the effects of the design initial parameters of air suspension system on the value of dynamic load coefficient (DLC) [12]. The aim of this paper is to analyze the influences of design parameters of suspension system on ride comfort of a passenger car according to the ISO 2631:1997(E) [9] based on the modeling and simulation results of the research team.

II. EVALUATION OF THE RIDE QUALITY

Currently there are many methods to evaluate the vehicle ride comfort such as frequency-domain method, time-domain method, etc. This study is based on ISO 2631-1 (1997), vibration evaluation based on the basic evaluation method including measurements of the weighted root-mean-square (rms) acceleration is defined by:

$$a_w = \left[\frac{1}{T}\int_0^T a_w{}^2(t)dt\right]^{1/2} \quad (1)$$

where, $a_w(t)$ is the weighted acceleration (translational and rotational) as a function of time, m/s^2; T is the duration of the measurements.

In this way, for indications of likely reactions to various magnitudes of overall vibration in the public transport a synthetic index-called the weighted r.m.s acceleration, aw can be calculated from formula Eq.(1) and the r.m.s value of the vertical acceleration in vehicle would be compared with the values in Tab. 1.

Table 1 Comfort levels related to a_w threshold values

a_w/(m.s^2)	Comfort level
< 0.315	Not uncomfortable
0.315÷0.63	A little uncomfortable
0.5 ÷ 1.0	Fairly uncomfortable
0.8 ÷ 1.6	Uncomfortable
1.25 ÷ 2.5	Very uncomfortable
> 2	Extremely uncomfortable

III. RESULTS AND DISCUSSION

In order to analyze the influences of design parameters of suspension system on ride comfort of a passenger car, Eq (1) are simulated by the MATLAB/Simulink with design parameters of a passenger car in reference [12]. In this study, stiffness of VSS is selected as suspension system design parameters. The stiffness values of driver's SSS, K_{ij}=[0.5 1 1.5] K_{ij0} in which K_{ij0} is value of the original stiffness values of VSS are selected to analyze its influence on vehicle ride comfort. The time domain acceleration responses of vertical vehicle body (a_{bz}), pitching vehicle body angle (a_{bphi}) and rolling vehicle body angle (a_{bteta}) when the vehicle moves on very good surface condition (ISO class B) at v=72 km/h are shown in Fig.2, Fig.3 and Fig.4.

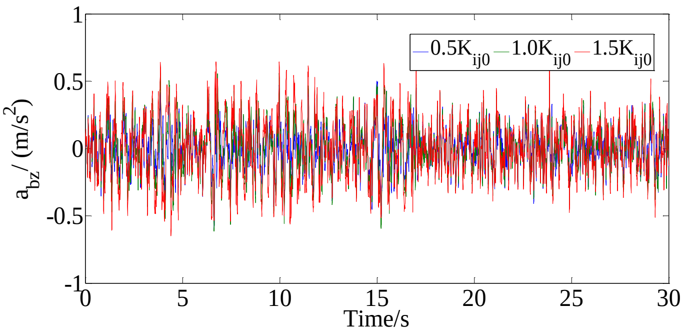

Fig.2 Time domain acceleration response of vertical vehicle body (a_{bz}) with variable suspension stiffness

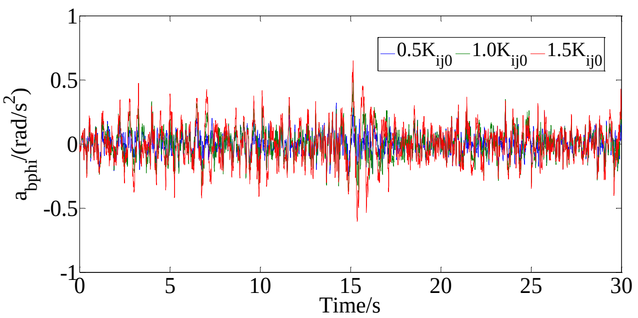

Fig.3 Time domain acceleration response of pitching vehicle body angle (a_{bphi}) with variable suspension stiffness

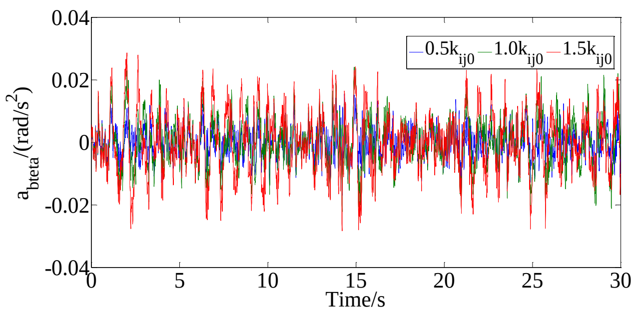

Fig.4 Time domain acceleration response of rolling vehicle body angle (a_{bteta}) with variable suspension stiffness

From the obtained results of Fig.2, Fig.3 and Fig.4, we could be determined the values of a_{wbz}, a_{wbphi} and a_{wbteta} according to Eq.(1) such as a_{wbz}=0.1470 m/s^2, a_{wbphi}=0.0810rad/s^2 and a_{wbteta}=0.0049 rad/s^2 with K_{ij}=0.5K_{ij0}; a_{wbz}=0.1784 m/s^2, a_{wbphi}=0.1084rad/s^2 and a_{wbteta}=0.0073 rad/s^2 with K_{ij}=1.0K_{ij0}; and a_{wbz}=0.2119 m/s^2, a_{wbphi}=0.1466 rad/s^2 and a_{wbteta}=0.0094with K_{ij}=1.5K_{ij0}. From the obtained results of Fig.2, the K_{ij} value decrease from 1.0xK_{ij} to 0.5 K_{ij0}, the a_{wbz} value decrease leading to improved vehicle ride comfort and the K_{ij} value increase from 1.0K_{ij0} to 1.5 K_{ij0}, the a_{wbz} value increase leading to reduced vehicle ride comfort. From the obtained results of Fig.3, the K_{ij} value decrease from 1.0K_{ij0} to 0.5 K_{ij0}, the a_{wbphi} value decrease that leads to to improved vehicle body shaking and the k_s value increase from 1.0K_{ij} to 1.5 K_{ij}, the a_{wbphi} value increase that leads to reduced vehicle body shaking. From the obtained results of Fig.4, the K_{ij} value decrease from 1.0K_{ij0} to 0.5 K_{ij0}, the a_{wbphi} value decrease that leads to to improved vehicle body rolling and the k_s value increase from 1.0K_{ij} to 1.5 K_{ij}, the a_{wbphi} value increase that leads to reduced vehicle body rolling. The a_{wbz}, a_{wbphi} and a_{wbteta} values all satisfy vehicle ride comfort according to ISO 2631-1 (1997).

IV. CONCLUSION

This study is to analyze effects of design parameters of driver seat suspension system on ride comfort of a double-drum vibratory roller according to the ISO 2631:1997(E) based on the modeling and simulation results of the research team. The conclusions could be drawn: (1) K_{ij} value decrease from 1.0xK_{ij} to 0.5 K_{ij0}, the a_{wbz} value decrease leading to improved vehicle ride comfort and the K_{ij} value increase from 1.0K_{ij0} to 1.5 K_{ij0}, the a_{wbz} value increase leading to reduced vehicle ride comfort; (2) K_{ij} value decrease from 1.0K_{ij0} to 0.5 K_{ij0}, the a_{wbphi} value decrease that leads to to improved vehicle body shaking and the k_s value increase from 1.0K_{ij} to 1.5 K_{ij}, the a_{wbphi} value increase that leads to reduced vehicle body shaking; (3) K_{ij} value decrease from 1.0K_{ij0} to 0.5 K_{ij0}, the a_{wbphi} value decrease that leads to to improved vehicle body rolling and the k_s value increase from 1.0K_{ij} to 1.5 K_{ij}, the a_{wbphi} value increase that leads to reduced vehicle body rolling.

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