Dynamic response of a geometrically nonlinear quarter car model with a MacPherson suspension travelling on a harmonic road profile

Pankaj Wahi and Vaibhav Dhar Dwivedi

*Department of Mechanical Engineering, Indian Institute of Technology Kanpur, Kanpur, India

Abstract. We perform a detailed study of the geometrically nonlinear quarter car model with a MacPherson suspension system. This study fills the gap in the literature on the influence of the geometric nonlinearity of the MacPherson suspension system on the dynamic response of the car. A kineto-dynamic quarter car model accounting for the kinematics of the MacPherson suspension under dynamic conditions is considered. We have found interesting features like transition from softening to hardening nonlinearity with increase in the suspension stiffness for a given harmonic base amplitude.

Introduction

MacPherson strut shown in Fig.1(a), is a popular passive suspension for passenger cars due to its low cost combined with acceptable performance, easy assembly, and compactness. Most studies [1, 2] on suspension performance consider a simplified reduced-order model of quarter car wherein the strut deformation is aligned with the vibrational direction of the sprung mass resulting in a linear system. Even though this model gives reasonable estimates for the performance; it does not consider the geometric nonlinearity arising due to interconnection between the various members of the suspension assembly. In this paper, we have focused explicitely on the various phenomenon associated with this geometric nonlinearity which has been ignored in most previous studies.

A kineto-dynamic quarter car model accounting for the kinematics of the MacPherson suspension to dynamic responses is considered. Based on existing literature, we have included the wheel hop frequency by considering a linear tyre stiffness along with linear stiffness and damping of the shock absorber in the formulation of a comprehensive quarter car model of MacPherson suspension as shown in Fig.1(b). We derive a two degrees of freedom mathematical model, with respect to ground reference coordinate, using the Lagrangian approach. This model is validated against a similar model assembled in the multibody dynamics simulation software MSC Adams. We review the dynamic features of this linkage suspension in time as well as frequency domain.

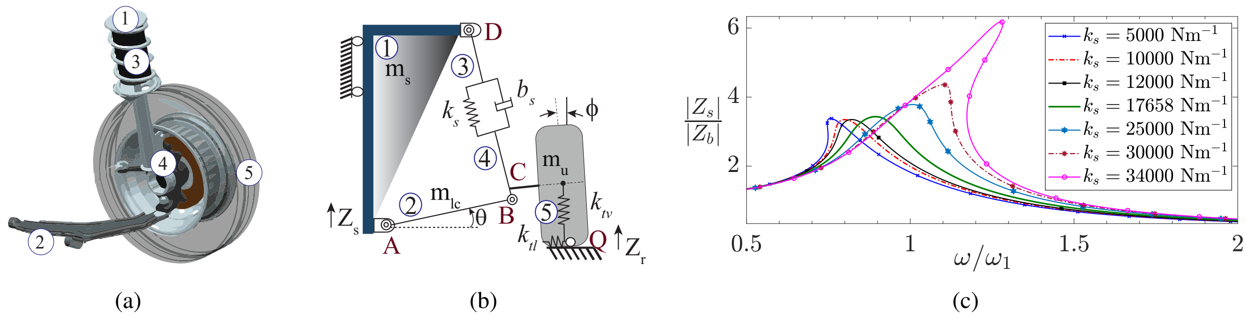

Figure 1: MacPherson suspension assembly (a), Quarter car model of MacPherson suspension assembly (b), and Normalized amplitude response for different suspension stiffness in our quarter car model under harmonic base amplitude of $Z_b = 0.06\ m$ (c).

Results and discussion

A detailed discussion on the influence of the geometric nonlinearity on the dynamic response is covered in this work which will be presented at the conference. As a sample, we show that the response to harmonic base excitation changes from softening to hardening with an increase in the suspension stiffness, as shown in Fig.1(c). We have ascertained that the geometric nonlinearity associated with the strut deformation is hardening in nature, while that associated with the vertical tyre deformation is largely softening. The geometric nonlinearity due to the lateral tyre deformation is softening for small amplitude response which transitions to hardening even for moderate responses. A combined effect of all of these behavior involves a softening to hardening transition in the response, with the transition amplitude depending on the relative stiffness of the various components.

References

[1] Fallah, M.S., Bhat, R., and Xie, W.F. (2009) New Model and Simulation of Macpherson Suspension System for Ride Control Applications, *Veh. Syst. Dyn.*, **47(2)**: 195-220 .

[2] Abebe, B.A., Santhosh, J., Ahmed, A.A., Murugan, P., and Ashok, N. (2020) Non-linear Mathematical Modelling for Quarter Car Suspension Model, *Veh. Syst. Dyn.*, **11**: 596-544.