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Dynamic and exciting analysis with modal characteristics for valve train using a flexible model

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ABSTRACT

The dynamic and exciting characteristics of a valve train system are predicted and investigated using a flexible dynamic model. In this model the elastic vibration mechanism of each flexible component is described in a floating reference frame. The mechanical impacts at the valve unseating and seating events are affected by the contact stiffness and damping of contact components. The contact force model for the cam–tappet interface was developed based on the elasto-hydrodynamic lubrication theory of finite line conjunction. The dynamic and exciting characteristics of the valve train system are influenced by its drive, natural properties and working conditions, so these factors are investigated in details. It is concluded that the dynamic responses at the low frequency range are mainly related to the cam function, namely the sectional characteristics of the cam profile; the valve train system can be easily induced to resonance between the second mode of transmission chain and the corresponding harmonic; as the rotating speed is increased, the variation of contact force can be described as: the peak values at the positive cam pseudo acceleration phase become bigger and the valley values at negative cam pseudo acceleration phase become smaller.

1. Introduction

The valve train system is an important vibration source of an internal combustion engine. Its contributions to structure vibration directly rest with the contact forces between any two adjacent components. These contact forces include the force between cam and tappet, pushrod and rocker arm, rocker arm and valve, and spring and cylinder head as well as valve and its seat. Fig. 1 shows a schematic drawing of the exciting sources due to the motion of the valve train system.

The characteristics of contact forces are determined by the dynamics of the valve train system which are influenced by its drive, natural properties and working conditions. The valve train system should work according to the cam function defined by the cam profile. As a result, the cam function is the only drive of the valve train system. The natural properties of the valve train system include the stiffness, size and mass distribution of its components, initial valve clearance, friction and so on [1,2]. The dynamics of the valve train system are also influenced by its working conditions; it is because the lubricating condition between the cam and tappet and the inertia forces of the components are all related to the rotating speed of the camshaft. Therefore, as for the low vibration design of an internal combustion engine, it is necessary to predict the dynamic and exciting characteristics of the valve train system. Of course a prerequisite is a prediction tool, namely a dynamic model in which all the dynamic factors should be taken into consideration correctly.

2. Cam profile of valve train

Fig. 2 shows a kind of multiple cycloid cam profile, with a constant acceleration–constant velocity ramp. The derivatives of follower motion are calculated with respect to the cam angle and can be called pseudo quantities in Fig. 2(a). For example, $dh_C/d\theta_C$

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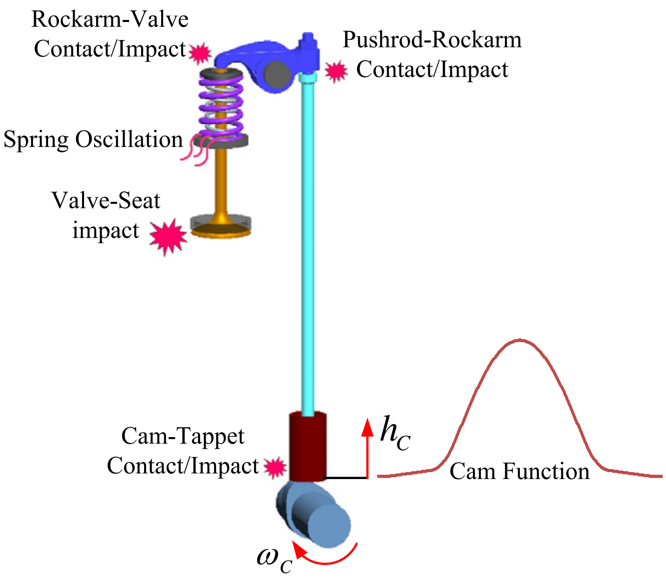

Fig. 1. Exciting sources in the valve train system.

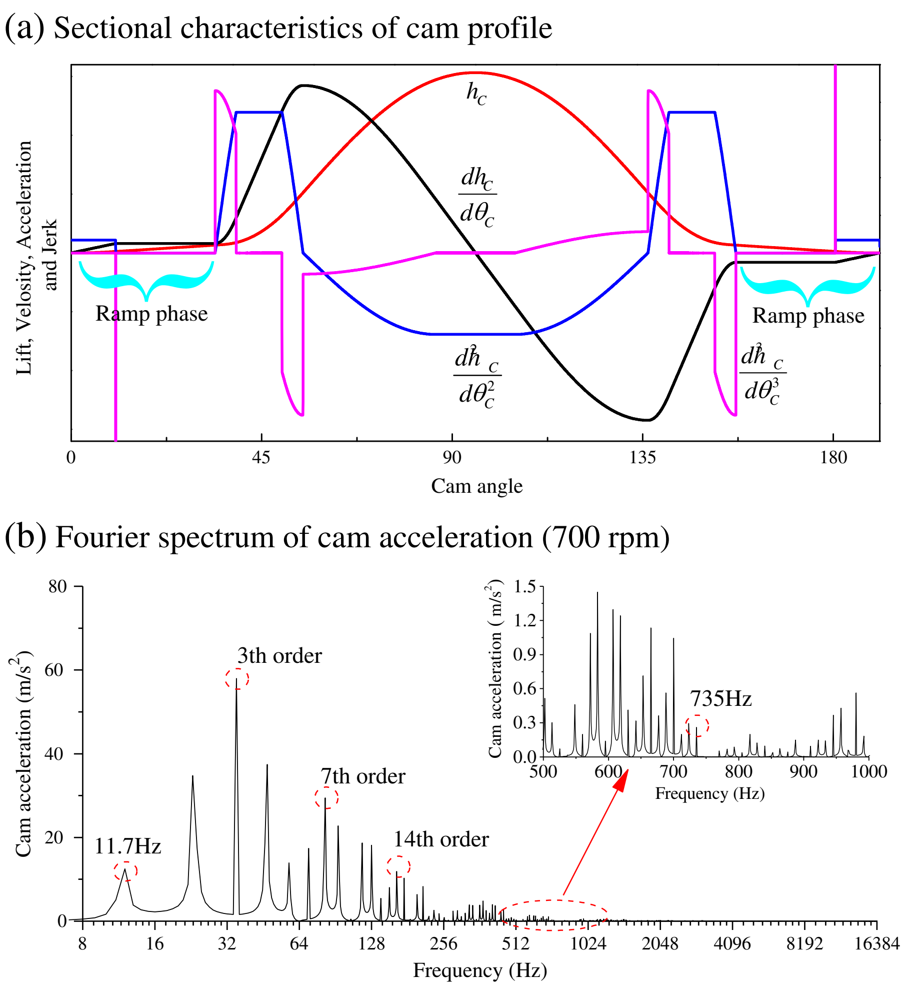

Fig. 2. A kind of multiple cycloid cam profile.