Optimizing Automotive Valve Trains to Minimize Valve Bounce and Onset of Valve Float

H. K. Yau[1] **and R. W. Longman**[2]

Abstract: A common method for increasing the power output of an engine is to increase the engine's speed. However two problems that arise are that the increase of speed also increases the occurrence of valve float or jump, the phenomenon where the valve is lifted off of the cam lobe's surface and also valve bounce, the situation where the valve returns to the seat but does not stay seated. Neither are desirable as the reseating of the valve may lead to failure of one or more components. The cause of valve bounce and float are the same, namely the variation in spring load does not provide enough force to keep the valve in contact with the seat and cam lobe respectively. Valve jump will always occur given a high enough cam speed, however due to the varying load exerted by the spring resulting from spring surge, the speed at separation is lower than that which is predicted by a linear spring model. Therefore when designing the valve train and evaluating its dynamics characteristics, spring surge and combating its effects must be taken into account. A commonly used method to reduce the effects of spring surge is to use springs with varying pitch. Typically a valve spring would have two distinct sections, open and close. The close-coiled section provides damping by releasing energy as the coils come in contact with each other. This type of spring may be modeled by a lumped multi-mass spring with each mass element representing a full turn of an active coil. The jump discontinuities that result from the collisions may be treated within the multiple shooting framework by creating multiple shooting intervals at the time of the collisions and restarting the integration at start of these intervals. Both valve bounce and float problems are addressed by optimizing the spring's varying pitch and the cam profile such that the spring's load fluctuation is minimized when excited by a cam for a range of speeds, given the constraints placed on the spring's prescribed rest length and geometric constraints imposed on he cam profile. The multiple optimization criteria for this constrained optimization are the reduction in the magnitude of valve bounce, a delay in the onset and minimization of the magnitude of valve float, and maximizing the area under the lift curve. Additional competing design goals, such as minimizing contact stress, may be added to the framework without difficulty. It should be noted that a range of speeds is needed as the cam profile optimized for one speed generally performs poorly for others, which complicates the formulation of the cost function.

[1,2] Department of Mechanical Engineering
Columbia University, MS 4703. 500 W. 120th St., 220 Mudd Bldg.
New York, USA
hy2215@columbia.edu, rwl4@columbia.edu