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Dynamic Simulation of Valve Train System for Prediction of Valve Jump

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***Abstract*— This paper is an attempt to study the optimization of valve train mechanism. Creo is used for the dynamic simulation of valve train model with the different values of valve spring stiffness. With regard to the automotive valve train that has high stiffness in nature, it is generally believed that the valve spring surge is the sole and primary cause that induces valve jump. The model incorporates the inertial elements, the assembly constraint functions and the sources of compliance in the valve train. The sources of compliance include the valve spring characteristics, including the spring surge effect under dynamic conditions. This paper introduces a general simulation and design tool which features general multi-body dynamic analysis capabilities. In the study described in this paper, an analysis of the valve jump generating mechanism and prediction of the valve jump occurrence engine speed are conducted by calculating surge-induced valve spring load fluctuation. The surge induced in the valve spring when it reaches to critical speed is neglected by changing the spring stiffness.**

Index Terms— **Spring Surge, Valve Jump, Valve Spring, Valve Train.**

I. INTRODUCTION

Facing the challenge of characteristics improvement, like power output, fuel economy and emissions reduction, the high level of dependability of the valve train is required in order to strengthen the capability of the overall engine system. However, one of the problems with high-speed engine operation is a phenomenon called "valve jump", in which intake and exhaust valves unexpectedly lift up and lose contact with the cam surface. Valve jump causes such problems as valve-to-piston interference and breakage of parts due to the shock when valves are reseated.[3]

Furthermore, in response to the existing defects derived from original design of valve train, some major components, especially the cam and valve spring need to be optimized accurately based on the optimizing theory as well as their performances after the simulation. In the last couple of decades, several kinds of valve train mechanism systems have been researched and implemented, ranging from mechanically-driven valve trains to cam less systems that are actuated electrically, hydraulically and/or pneumatically. Whatever the method of variable valve control, the design and optimization of such systems remain difficult, time consuming and expensive activities. The amount of improvement in the engine performance that can be achieved is clearly limited by the actual capabilities of each specific type of valve train and its actuation systems and often requires multiple iteration and juggling of different design factors before an optimal set of operating parameters is found. The design process of valve train mechanism can be greatly accelerated through the use of sophisticated numerical simulation tools.

Presents work aims at study the effect of spring stiffness at different rpm on valve jump and dynamic simulation of valve springs to predict the surge in valve spring.

II. VALVE TRAIN MECHANISM

Fig. 1shows a schematic of a typical pushrod valve train system. The valve spring, which is the most flexible component, plays an important role in the dynamic characteristics of valve train system. It may be excited by the harmonics of the cam profile and the cam shaft rotational speed. The contact between cam and tappet contributes most to the energy loss in valve train system. The effects of camshaft torsional and bending vibrations cannot be neglected at high speed, especially in the multi-cylinder engine. In order to build an effective, but simple model for the dynamic simulation of a valve train system, the above factors need to be considered. Four types of springs with different stiffness are use as valve springs to provide the effect of damping the resonance generated in them [6].

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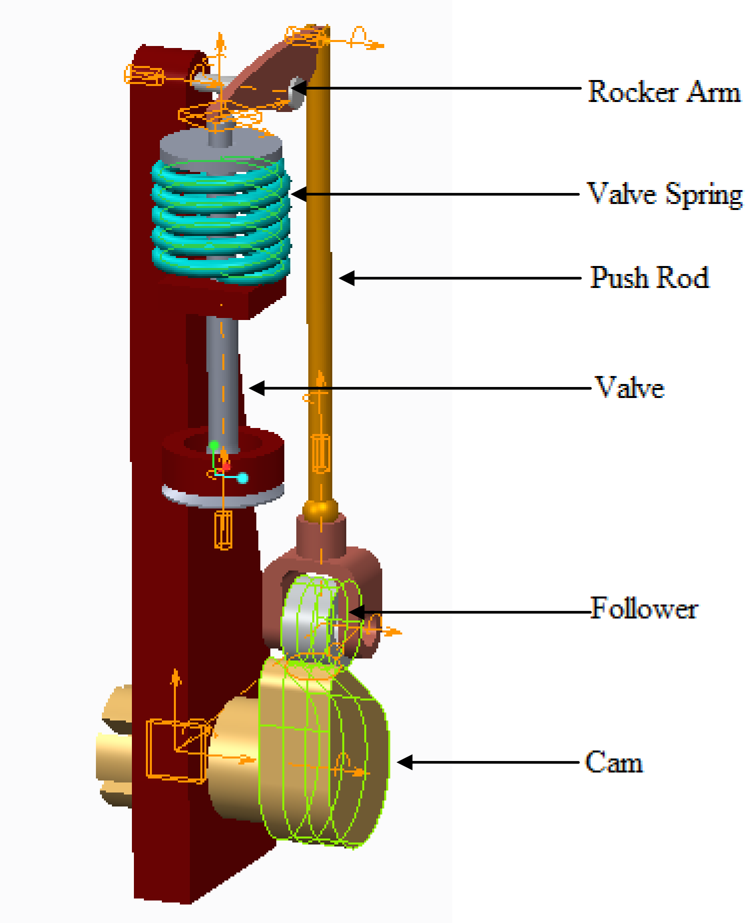

Fig. 1 Schematic of Valve train mechanism

III. VALVE JUMP PHENOMENON

In a cam follower system, the contact between the cam surface and follower is maintained by means of retaining spring. Beyond the particular speed of cam rotation, the follower may lose contact with the cam, because when the inertial force increases as the engine speed increases, the pressing force decreases in the region that has a negative inertial force. When the pressing force further decreases to zero, the set of valve train components loses contact with cam lobe surface. This phenomenon is called as 'jump phenomenon.'
However because a resonance phenomenon called surge occurs in the valve spring and the valve spring load fluctuate during the high speed operation, jump occurs at the critical speed. For this reason the prediction should be based on by increasing the stiffness of the retaining spring derived from simulation or other appropriate method [1].

IV. DYNAMIC SIMULATION OF VALVE TRAIN

CAD tool 'Creo' is use for the dynamic simulation of the valve train. This software is capable of including the stiffness of valve spring and other valve train components as parameters. Here assuming that the valve tappet, retainer and cotter are sufficiently stiff to prevent the generation of vibration that might affect valve jump, In simulation valve spring consider as an elastic body and all other components as rigid bodies.

V. VALVE SPRING MODELS

Four types of springs with different stiffness are use as valve a spring which provides the effect of damping the resonance generated in them when the spring get compress. Four types of spring are use as the simulation models, each having different spring stiffness as shown in Table 1

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I. ***Valve Spring Specification for analysis***

Parameters	**Spring A**	**Spring B**	**Spring C**	**Spring D**
Set Load, N	300	300	300	300
Number of turns	9	9	9	9
Free length , mm	50	50	50	50
Pitch, mm	6	6	6	6
Stiffness, N/mm	30	33	36	38

The four springs are same in static load characteristics and installed dimensions but different in spring stiffness and dynamic characteristics of natural frequency. Due to these differences the four springs are assume to difference in resonance conditions and thus cause valve jump at different engine speeds.

VI. RESULTS AND DISCUSSION

First the behavior of designed spring having stiffness 30 N/mm in installed state is simulate to confirm how the software reproduced the spring dynamic characteristics. Fig 2 shows results of velocity profile at different speed of the engine. In the test with the spring 1 installed, a sign of valve jump is detected at a speeds beginning of 1500 rpm and jumps are evident as speed is increases. Fig 2 shows the surge induced in valve spring and Fig 3 shows the valve lifts at 700rpm, 1000 rpm, 1500 rpm, 2500 rpm. It is observed from this comparison as speed is increased more jump is observed and lower speed this jump got reduced.

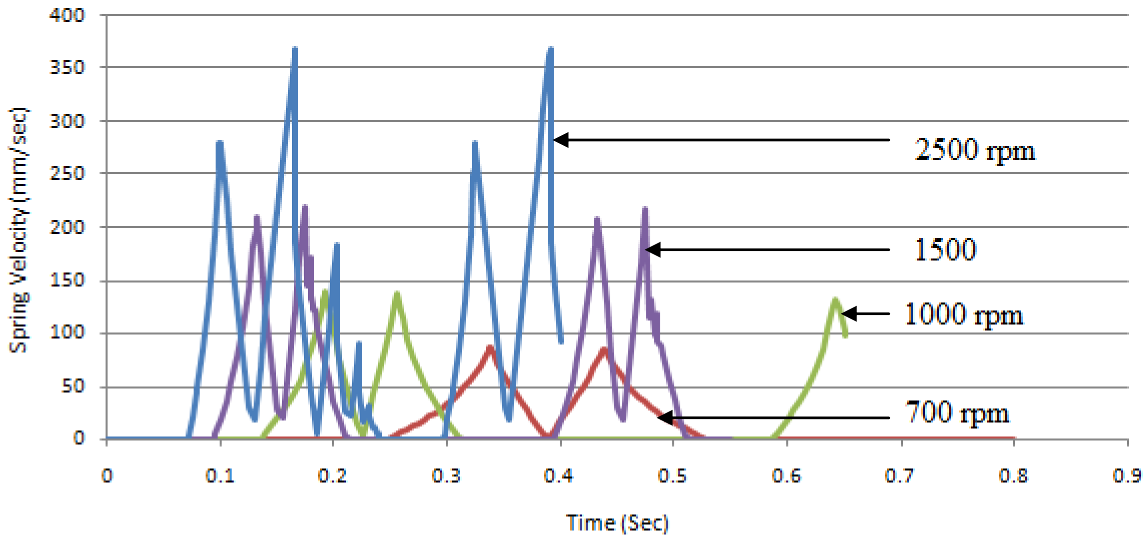

Fig.2 Dynamic behavior of spring at different rpm

This jump is to be predicted by changing the stiffness of the spring and the results are simulated as above. Assuming the all valve train components as a rigid body excluding the spring, their mass is applied to the top of the spring and the valve lift is given in accordance with the cam lob profile.

In the test conducted with spring B,C,D a sign of valve jump appeared for the spring B and C at speed 2500 rpm.The Fig 4 and Fig.5 shows the spring lift of spring A,B, C, D. The simulation results formulate as spring stiffness is increases there is decrease in spring surge as shown in Fig 4 and Fig.5.

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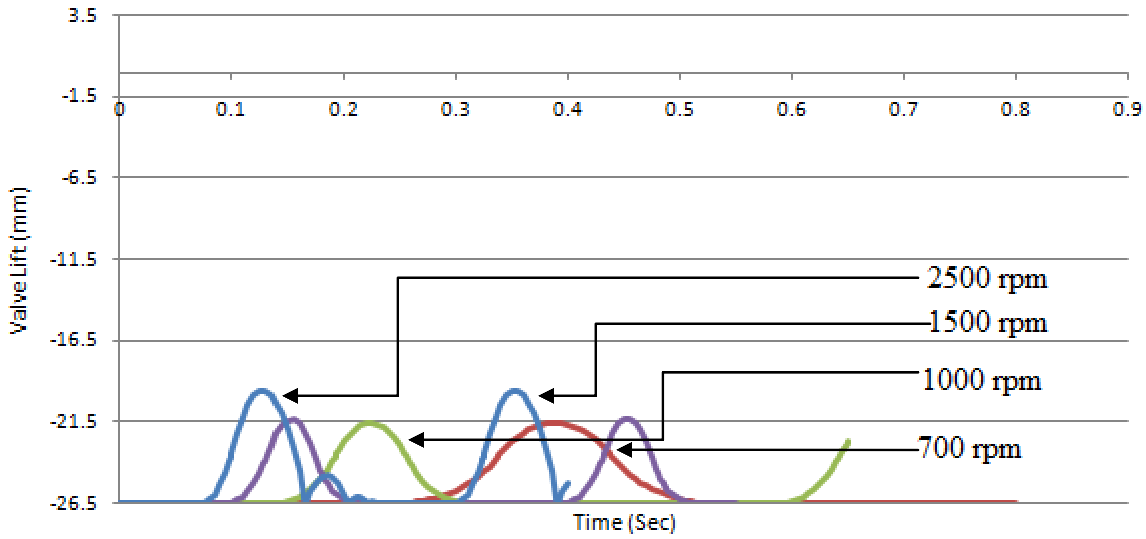

Fig.3 Valve lifts characteristics at different speed

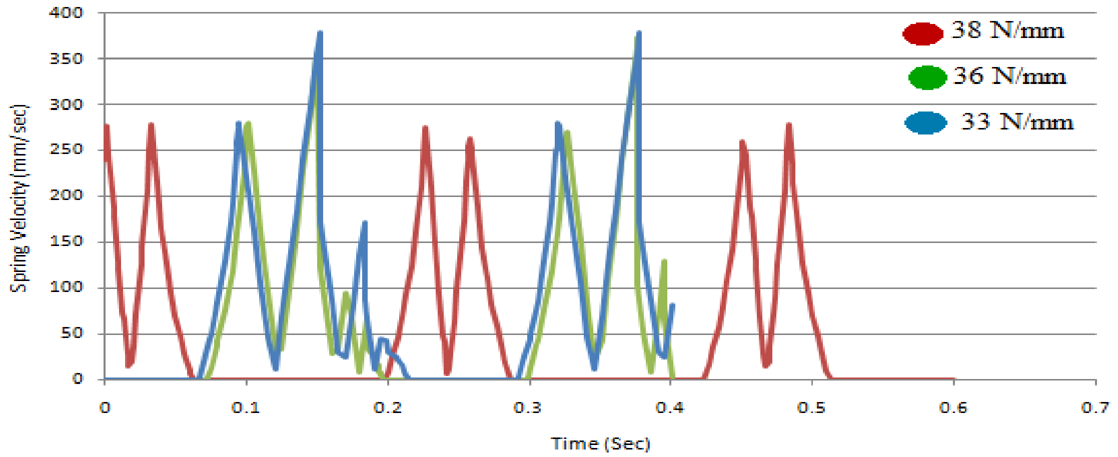

Fig.4. Spring characteristics at different stiffness at 2500 rpm

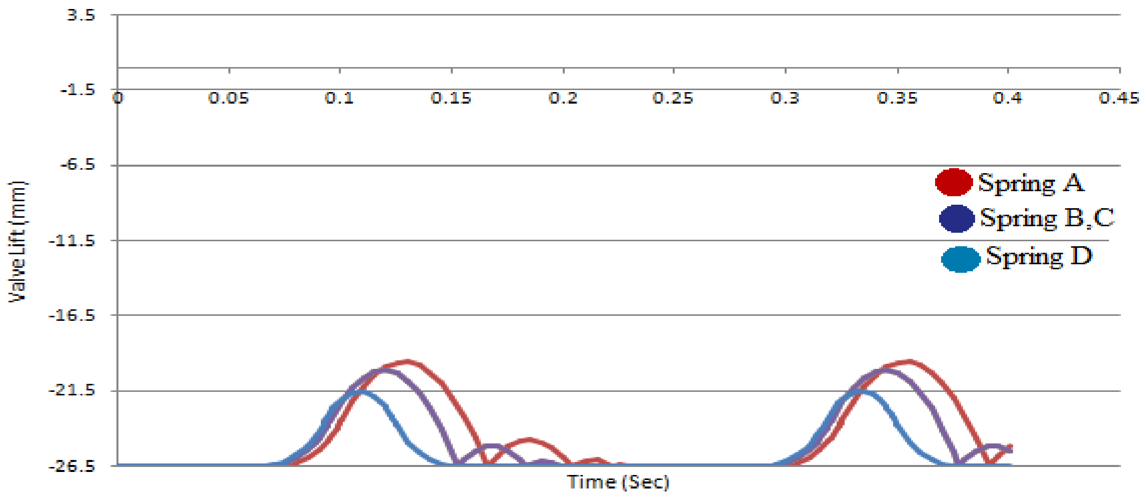

Fig.5 Valve lifts characteristics at different spring's stiffness

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VII. CONCLUSION

Dynamic simulation of Valve train mechanism is done by commercially available CAD software Creo. Creo provided an insight effect of variation of valve spring stiffness in valve train mechanism on dynamic characteristics of valve spring. In the present study four valve springs with the different stiffness is study. The valve train model is generated with software Creo. Keeping the other parameter of valve spring constants excluding stiffness following conclusion can be easily drawn,

During the high speed operation spring surge induce in valve spring and jump will occur. As the speed is increases spring changes its dynamic characteristics such as natural frequency. Spring surge is predicted by changing the spring stiffness up to 38 N/mm. While changing the stiffness of valve spring valve jump remains same for Spring A,B,C and is eliminate by the spring D. By doing the dynamic analysis we can obtain the dynamic characteristics of valve spring in valve train mechanism.

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