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FLEXIBLE MULTIBODY MODELING OF VALVE SPRING IN THE VALVE TRAIN OF DIESEL ENGINE

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ABSTRACT

The characteristics of valve train are responsible for the dynamic performance of engine. In order to obtain a normal operation and high efficiency of engine, it is important to secure an appropriate timing of opening/closing of valve mechanism. Valve spring is one of the most important elements which determine the dynamic characteristics of valve train. This means that the dynamic characteristics of the spring must be predicted at the initial stage of design, so that valve opening/closing timing can be optimized.

One of the most popular method to obtain a computer model of spring is to make use of TSDA (Translational Spring Damper Actuator) element which is provided in most of CAE software. It consists of a spring constant and a damping coefficient, and is simple to use. If a more accurate dynamic characteristics of valve spring are required, it is customary to model valve spring with beam elements. These method can produce a fairly reasonable results, but it is not sufficient to investigate critical situation when nonlinear phenomena occur, such as contact of spring wires and surging.

Recently with development of high performance PC and software, it becomes possible that the flexible multibody analysis method can be applied to the analysis of spring through the finite element model.

This research proposed a procedure to develop a flexible model of the valve spring. We constructed the flexible mutibody model of valve train for 1500 PS diesel engine. Our model is composed of cam shaft, tappet, pushrod, rocker arm, elephant foot, valve, and valve spring. These elements are connected with joints and contact elements, and the cam is rotated through drive joint. The FE model of valve spring, which is constructed through modal synthesis method, consists of 23,652 tetragonal elements and 6,493 nodal points. Modal analysis was conducted with MSC/NASTRAN, and results up to 45th mode were used to calculate the stress. The flexible dynamic analysis was accomplished with Craig-Bampton method so as to consider the local load and frequency of operating region. We implemented this model with LMS Virtual. Lab software. This model was used to estimate the stress and strain in spring under the load condition and contact situation.

The pressure at the intake and exhaust manifold have direct effect for the behavior of valve. In order to simulate valve train accurately, manifold pressure was applied in the intake/exhaust model with the Combustion module of Virtual Lab.

Dynamic simulations were conducted for two valve train models, one with TSDA spring element and the other with flexible multi body spring model. TSDA element was applied between the valve cotter and the hard point which is generated at the center of seat of valve spring, and generates the spring force proportional to spring deformation. The dynamic characteristics, such as seating velocity and cam contact force, are compared for these two models.

We compared the velocity and acceleration of valve, and reaction force of spring for each case. Flexible body model produced a similar valve lift curve with the TSDA model, but vibrational fluctuations in the reaction force of spring were found as incresing the engine speed, which were not found in TSDA model. We also investigated the jumping of tappet and contact loss through comparing the contact force between cam and tappet.

It is shown that the flexible multi-body spring model can be used to investigate the displacement, stress, and contact stress of spring in terms of rotation of cam. To calculate the contact stress between spring wires, we created dummy elements of same radius with spring wire, and placed along the wires at 90º intervals. Simulation showed that contact occurred between elements at 1/2 turn and 3/2 turn. Contact forces of dummy elements could be used to estimate the maximum contact force of spring, and contact interval of spring wire were predicted by examining the contact force.

This research is expected to be useful to investigate the dynamic characteristics of valve train, and thus to predict the engine performance. It can be used also to obtain the data for design of valve train and fatigue analysis of the spring.

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