Effect of CM Location on Vibration of Diesel Engine Isolation System

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***Abstract*—An diesel engine with four elastic supports was modeled to deeply study the vibration response characteristics of diesel engine, and the each support with three-dimensional isolators was modeled by ADAMS. During analysis, the rotating speed of diesel engine is constant, and the mass center of whole engine body (CM) is changed, the responses were studied. The results show that at the constant rotating speed, with the change of CM location, its motion torque has the stable trends and magnitude, with a change ratio below 0.47%, but the displacement of engine body center changed with a 5.46% ratio, and the four vertical springs have the different vibration velocity curves, with a ratio high to 32.53% in analysis case 2 than others'.**

Keywords—diesel engine; elastic supports; center of mass; vibration response

I. INTRODUCTION

The diesel engine is wide-used in shipping, due to its vital role in dynamic power, a lot of research has been done on the vibration response of diesel engine with elastic support.[1-8]. Due to the complexity of diesel engine vibration isolation system, there are also many hot points, including the optimization of isolator location, reduction of vibration shock and so on[9-11]. At present, many numerical technique, including ANSYS, ADAMS and COMSOL, can be used to calculate the engineering problem in design process, In shipping area, the structure is almost plate-welding, the ship plates are easily excited by external loads, and the vibration load of diesel engine is also intense, so the vibration and noise problem caused by diesel engine are severe. In previous studies, the nonlinear isolator and piston slap are modeled and analyzed by our team[12-13]. With the corresponding regular about ship vibration is issued, to deeply study the vibration isolating characteristics of diesel engine, a single layer four elastic-support system, with one spring modeled isolator on each direction at each supporting point, is modeled by muti-body dynamic technique, and the vibration response are compared and analyzed in ADAMS.

II. MODELLING OF DIESEL ENGINE WITH FOUR ELASTIC SUPPORT

TABLE I. THE MASS OF EACH PART

NO	part	Mass(kg)	Number
1	base	10	4
2	Piston pin	3.65	4
3	piston	9.75	4
4	Engine body	2190.51	1
5	Connecting rod	16.4	4
6	Cylinder liner	14.34	4
7	crankshaft	329.47	1
8	flywheel	263.46	1

The diesel engine is composed of many components, including the piston, connecting rod, engine body, crankshaft and so on. In this paper, the main parts are figured in solidworks, and exported as IGES files, to be imported in ADAMS. The dynamic motion model are constructed by each motion pair, such as the cylinder motion pair of piston and cylinder liner, the revolution pair of connecting rod and crankshaft, where some unimportant parts are ignored. In ADAMS, the model parts can be settled with mass and location of mass center[2]. so that, some CM location cases are computed.

According to math theory, the primary unbalanced load are inertia of engine moving parts. The inertia of parts are insured based on the exact mass shown in table.1. As the revolution of crankshaft, the dynamic parameters and vibration response can be figured out synchronously.

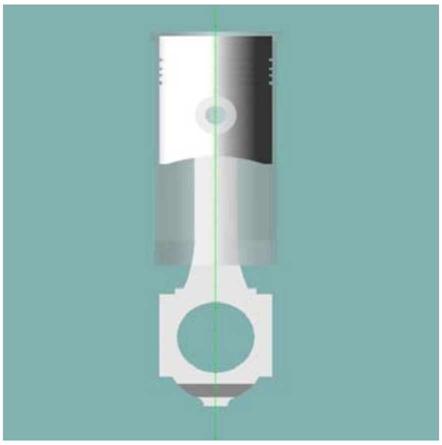


FIGURE I. ALIGNMENT OF ONE CYLINDER IN ADAMS

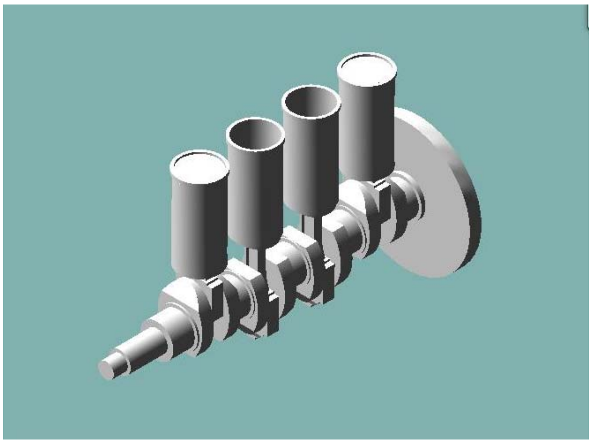


FIGURE II. MAIN MOVING PARTS

To maintain the stable revolution of system[3], the speed is set as 1000rpm in the crankshaft and main bearing revolution. According to dynamic formula of diesel engine power, there is a definition as:

$$M_e = \frac{9550P_e}{n} \tag{1}$$

In E.q. (1), M_e is output torque $N \cdot m$; P_e is power kW ; n is revolution speed r/min .

III. MODELING OF ISOLATION SYSTEM

The engine parts are modeled as rigid body in ADAMS, with their outlines. The spring is used to model each isolators. In linear analysis, the vertical direction spring has $k=1\times 10^6$N/m, c=0, other two direction springs have the same parameters $k=1\times 10^{10}$N/m and c=0.

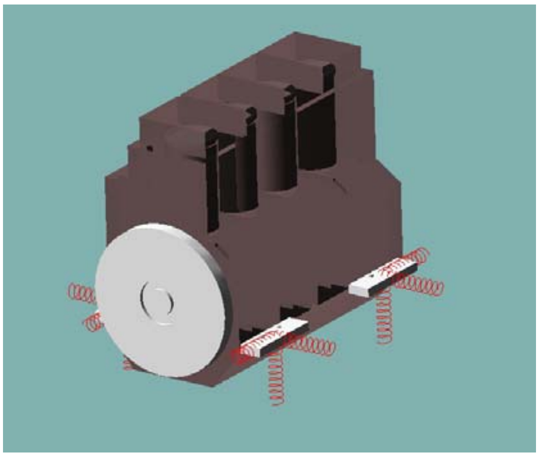


FIGURE III. THE ENGINE VIBRATION SYSTEM IN ADAMS

As the focus of study is the effect of engine body mass center on the whole vibration system, and the change of CM is in table 2.

TABLE II. THE CENTER OF ENGINE BODY MASS

case	location(Y direction)
1	0.222m
2	0.223m
3	0.224m
4	0.221m

Fig.3 shows the diesel engine with four point elastic supports, in which the engine body, flywheel and supported springs can be clearly presented. During the analysis, the four vertical spring are the analysis key parts, shown in fig.4.

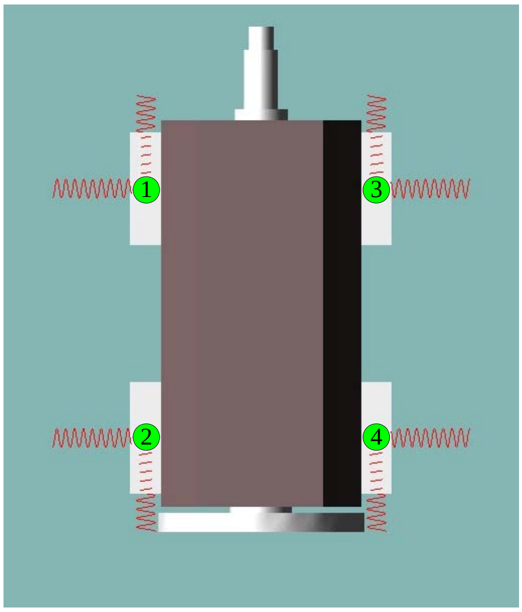


FIGURE IV. THE FOUR VERTICAL ISOLATORS

IV. MULTIBODY DYNAMIC THEORY OF VIBRATION SYSTEM

For vibration system, the dynamic modal can be expressed as

$$\begin{cases} A\ddot{q} + \Phi_q^T \lambda = B \\ \Phi(q,t) = 0 \end{cases} \tag{2}$$

Where, Φ is the constraint equation of coordinate matrix q , Φ_q is the Jacobian matrix and λ is the lagrange multiplier.

In Cartesian coordinate, the multibody system has the differential-algebraic equations as,

$$M(q,t)\ddot{q} + \Phi_q^T(q,t)\lambda - Q(q,\dot{q},t) = 0 \tag{3}$$

$$\Phi(q,t) = 0 \tag{4}$$

where, q , $\dot{q}$, $\ddot{q} \in R^n$ are the position, velocity and acceleration vectors of the system, t is the time step, M is the inertia matrix of mechanical system, Q is the excited load vector.

With the following initial conditions,

$$\begin{cases} q(0) = q_0 \\ \dot{q}(0) = \dot{q}_0 \end{cases} \quad (5)$$

V. Analysis of Vibration Response

During 0~2s, vibration system is calculated with 1000 steps. With good convergence, the response of each spring and test points can also be exported to do more post processing analysis.

A. Engine Block and Spring Response

In ADAMS, only the center of engine body mass is varied as shown in table.2. some periodic time response curves are plotted. As shown in Fig.5, with different CM of engine body mass, the vertical displacement of engine body are changed obviously, the average magnitude is respectively 0.788mm, 0.745mm, 0.787mm, and 0.746mm for case 1, case 2, case 3 and case 4. The case 2 has the lowest vibration displacement response, with a decrease of 5.46% than the case 1.

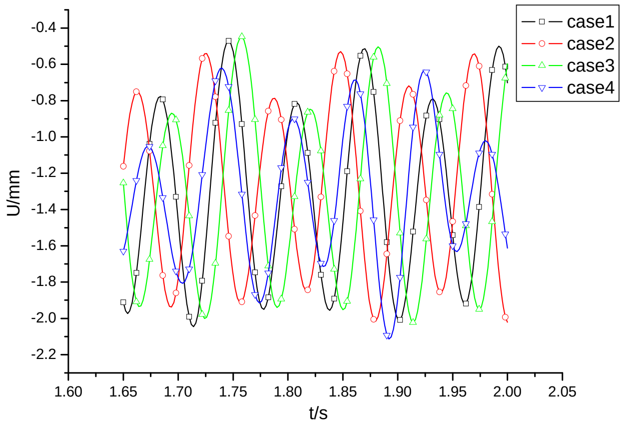
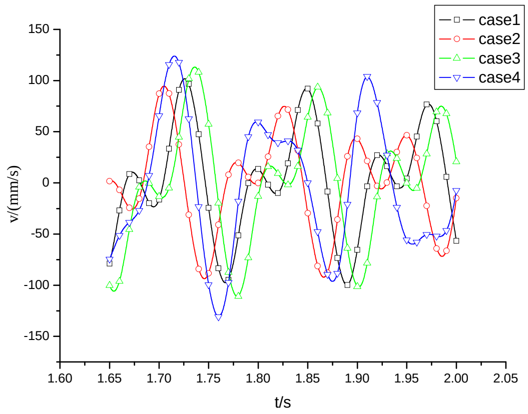
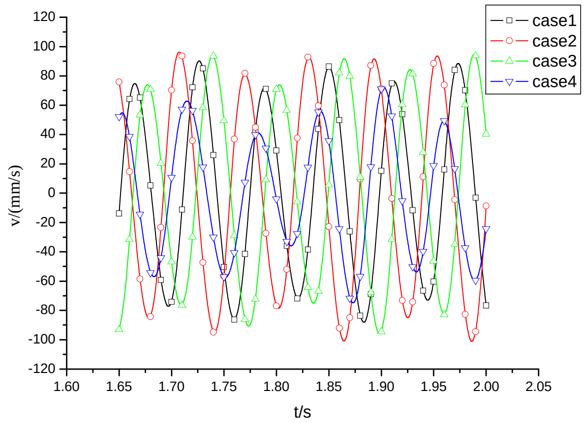


FIGURE V. THE VERTICAL DISPLACEMENT OF ENGINE BLOCK CM

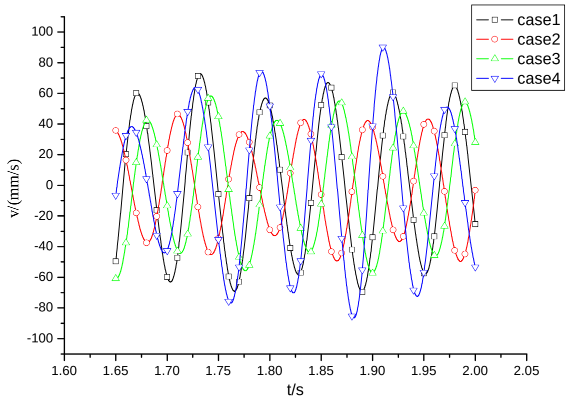
The velocity of four vertical direction springs are shown in Fig.6(a,b,c,d). In ADAMS, all the velocity responses have the periodic curves, but during each case, there are different vibration trend for each spring. The concrete data are shown in table.3, in case 2, the springs have the least magnitude, the decrease is high to 32.53%.



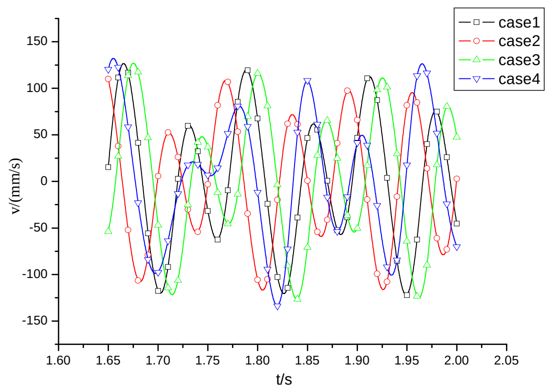
(a) spring1



(b) spring2



(c) spring3



(d)spring

FIGURE VI. THE VELOCITY OF VERTICAL SPRINGS

TABLE III. THE VELOCITY AMPLITUDE OF SPRINGS(MM/S)

springN	Case1	Case2	Case3	Case4
1	101.03	91.36	112.44	127.59
2	89.66	99.20	95.57	74.04
3	71.41	48.18	59.75	88.64
4	124.57	113.42	126.93	133.05

B. *Engine Motion Torque*

The trends of cures are similar to trigonometric function, shown in fig.7, with a periodicity. For the four cases, the torque is 206.71Nm, 207.27Nm, 207.68Nm, 207.06Nm respectively, the change ratio is below 0.47%.

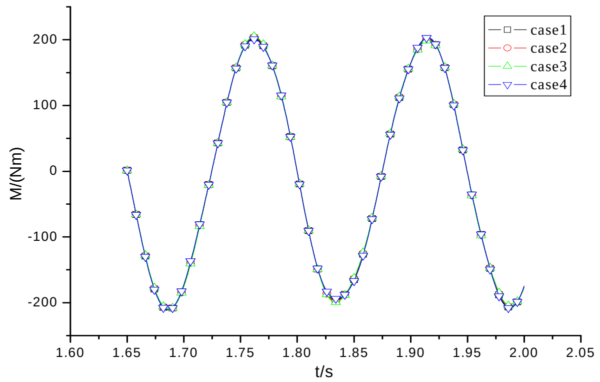


FIGURE VII. THE MOTION TORQUE CURVES

VI. CONCLUSIONS

Focusing on the vibration problem of diesel engine, a dynamic model with four elastic supports is modeled. It is clearly shown that the CM location is important for the diesel engine vibration isolation system. The magnitude of engine vibration is lower than others, when the CM is 0.223m. As the four vertical isolators are modeled by spring, there is a huge change between each vibration velocity, with a minor velocity in case 2. During the change of CM, due to the same revolution, the rotating motion torque is almost the same. So, under the same working case, the CM of main part of engine can pay a large role in the vibration analysis.

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