Research on the Impact of Engine Support Position on Dynamic Response

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Abstract. The common arrangement form of engine support position includes three-point mounting or four-point mounting. In this paper, the form of symmetric three-point mounting was adopted, and 5 groups of numerical values were respectively used. An engine moved to the third supporting point through the support positions of the first and second cushion support point and to the support positions of the first and second cushion support point through the third support point at the same time, while the dynamic response rules of the engine assembly on three mounting points were researched, and the change rules of the resonance frequency and resonance peak of three groups of numerical values on the three mounting points were found out, so as to work out the reasonable matching measures for the engine mounting.

Impact of the front Support Position of Rubber Cushion Mounting on Dynamic Response

Dynamic response after changing the front support position of the rubber cushion mounting. assuming that the three elastic shafts of the rubber cushion are p, q and r respectively, and the position of the third strong point remains unchanged, the engine assembly is moved from the first and second support point to the third support point at the same time, and its displacement relative to the original place each time is shown in table 1.

Table1 Displacement of comparison among the first, second and third original place

	First support point (mm)	Second support point (mm)	Third support point (mm)
Group 1	0	0	0
Group 2	124.5	124.5	0
Group 3	186.75	186.75	0
Group 4	249	249	0
Group 5	311.25	311.25	0

Under the case that the stiffness and support angle of the rubber cushion mounting of the engine assembly are unchanged, the support positions of the first and second mounting are changed to get the corresponding 6-order mode as shown in table 2. As can be seen from table 2, as the engine assembly approaches from the first and second support point to the third support point, the mode of the power assembly moving along Y axis and rotating around Y axis and X axis is in a downward trend. The mode of the power assembly moving along Z axis and X axis and rotating around Z axis is fluctuating.

Table2 Mode shapes at different mounting place about engine assembly

	Mode (Hz)					
	Y	Z	X	R_Z	R_Y	R_X
Group 1	2.66	6.38	6.88	10.5	12.1	13.4
Group 2	2.64	6.47	6.74	10.7	11.7	12.7
Group 3	2.62	6.50	6.62	10.8	11.3	12.1
Group 4	2.60	6.30	6.68	10.8	11.0	11.6
Group 5	2.57	6.03	6.77	10.5	10.8	11.5

Because the dynamic response on the first and second support point is the same, the dynamic response of each group of data on the first and third support point is given below, as shown in figure 1~ figure 10.

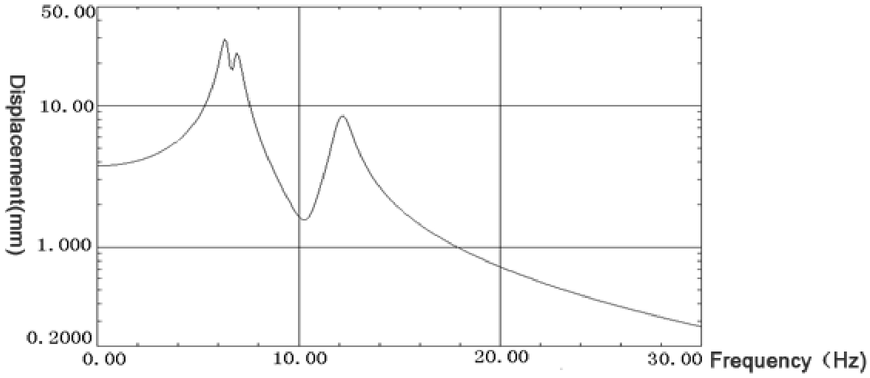

Fig.1 Displacement response at point 1 in group 1

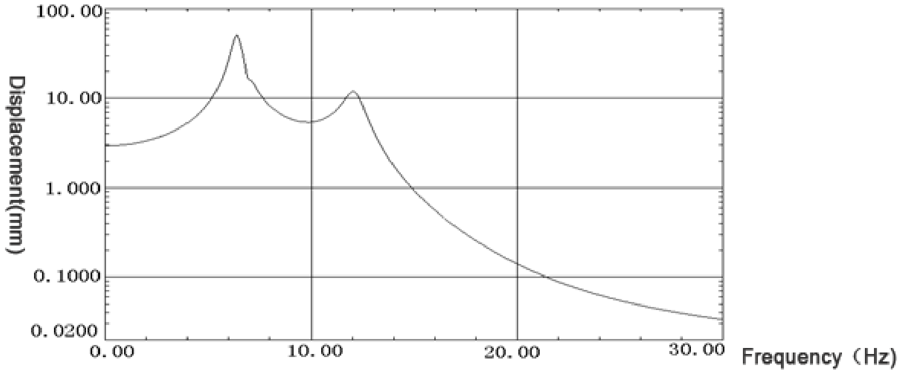

Fig.2 Displacement response at point 3 in group 1

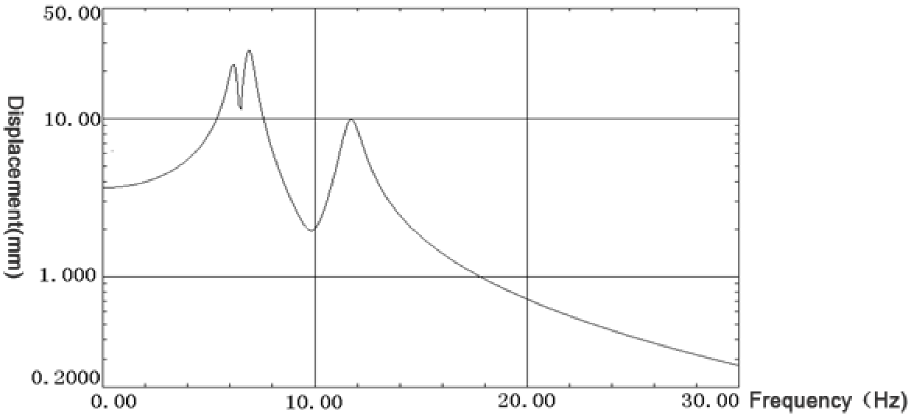

Fig.3 Displacement response at point 1 in group 2

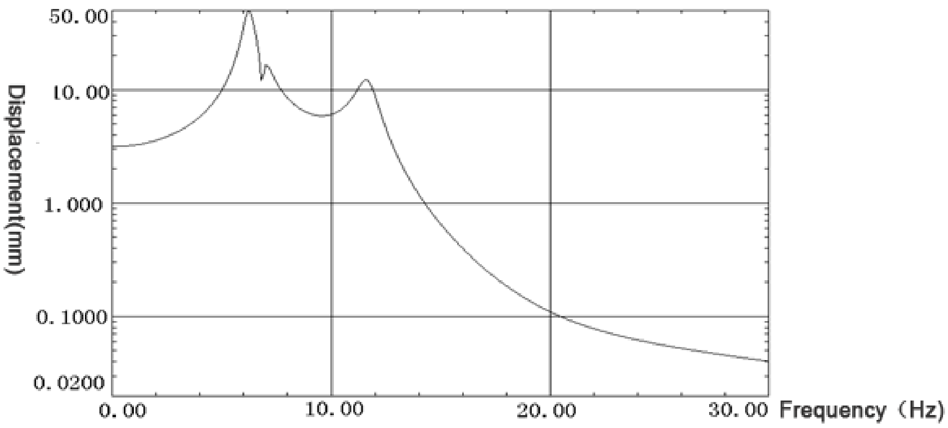

Fig.4 Displacement response at point 3 in group 2

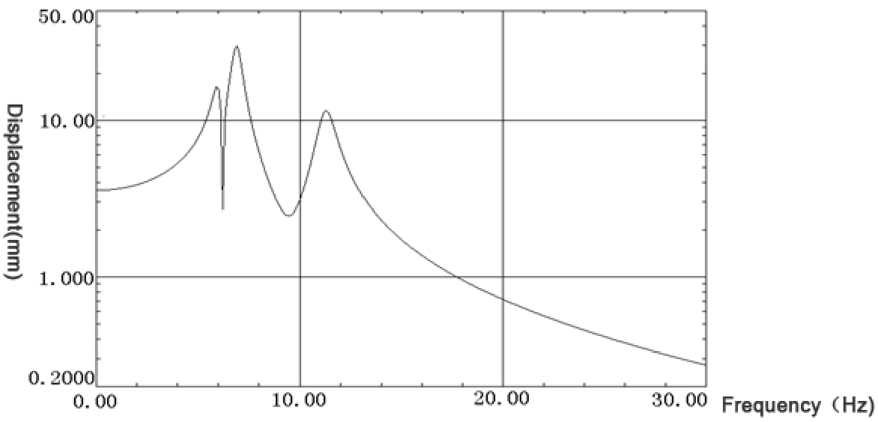

Fig.5 Displacement response at point 1 in group 3

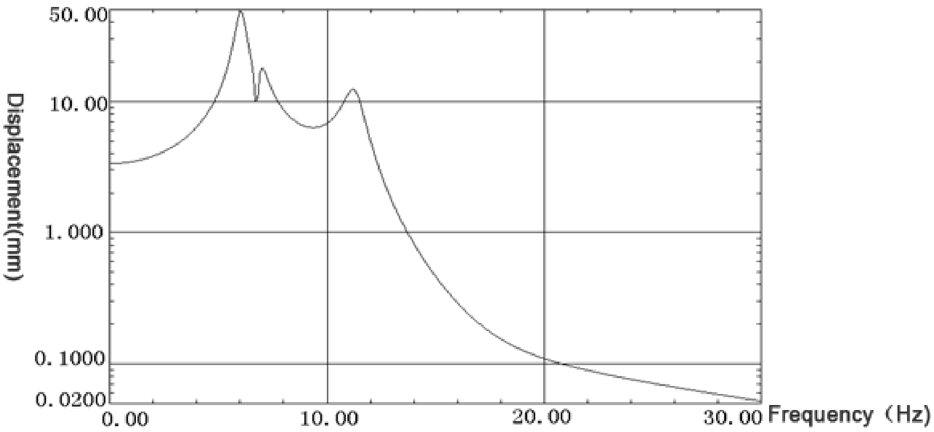

Fig.6 Displacement response at point 3 in group 3

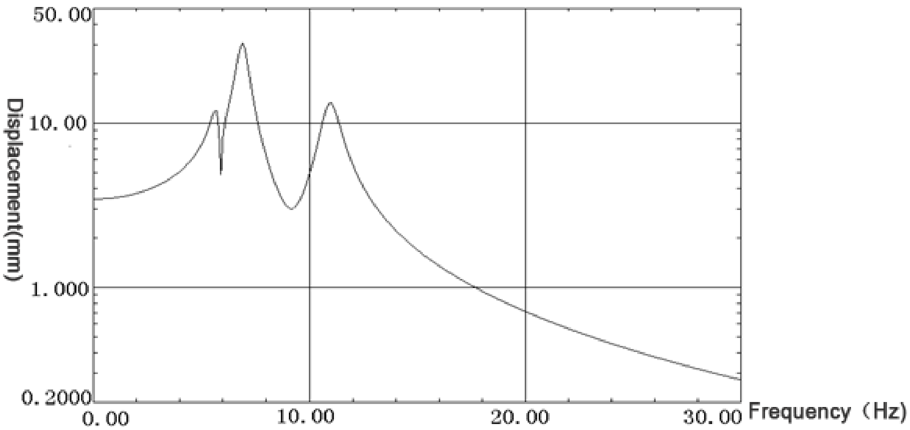

Fig.7 Displacement response at point 1 in group 4

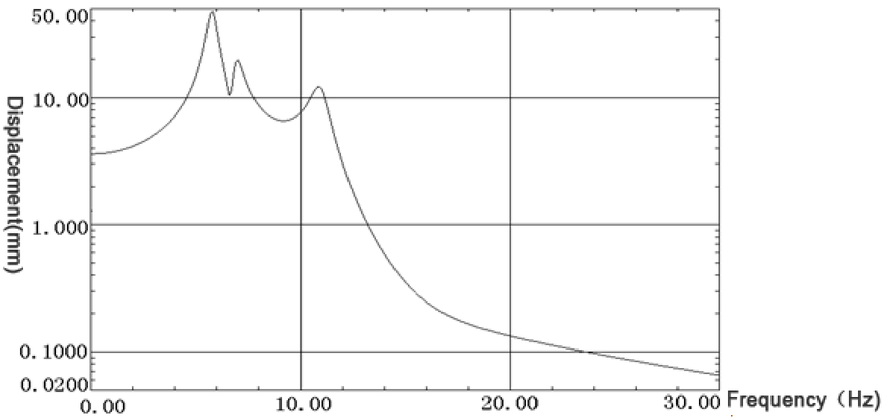

Fig.8 Displacement response at point 3 in group 4

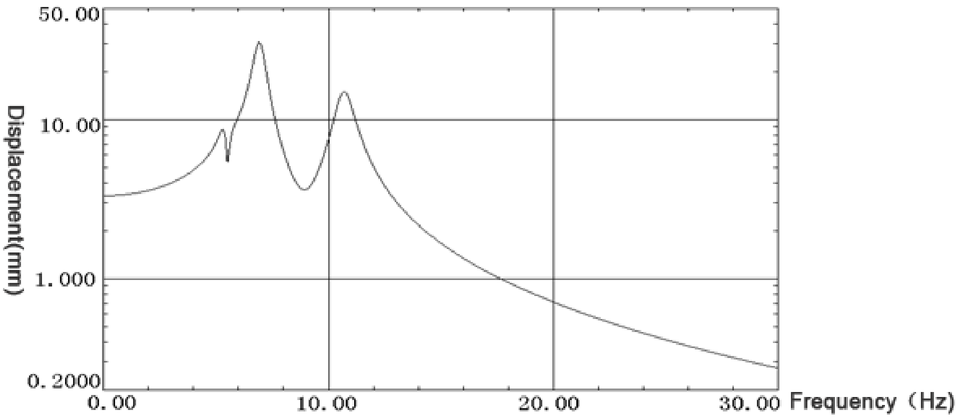

Fig.9 Displacement response at point 1 in group 5

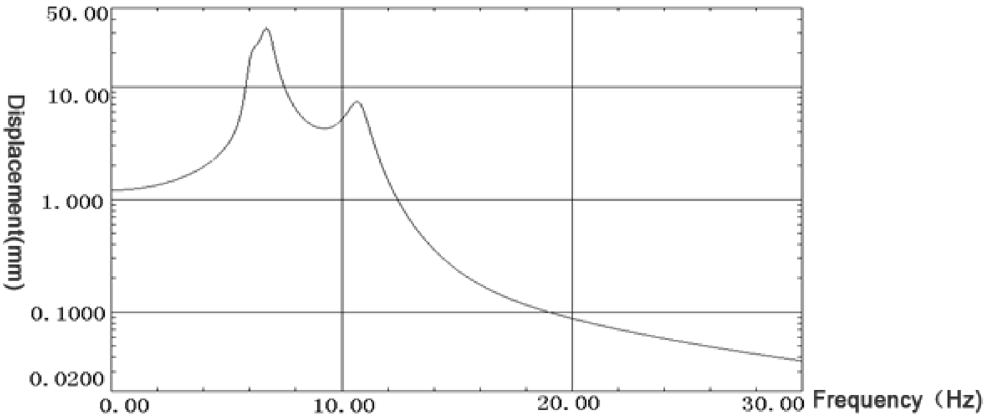

Fig.10 Displacement response at point 3 in group 5

Result analysis on dynamic response. Figure 1, figure 3, figure 5, figure 7 and figure 9 show the displacement peak and corresponding frequency value of the first support point, and the results are shown in table 3. It can be seen from table 3 that as the power assembly approaches to the third support point from the first and second support point, the resonance peak of the first support point and the corresponding resonant frequency value have both changed. The first resonant frequency value is very close to the modal frequency value of it moving along Z axis (see table 2), and there is synchronous fluctuation, indicating that the vibration is mainly manifested as the power assembly moves along Z axis. The second resonance frequency value is close to the modal frequency of it moving along X axis, and there is synchronous fluctuation; at this time, the vibration is mainly manifested as the power assembly moves along X axis; of which, the third group of values are vacant, mainly because it is too close to the frequency of the first resonance peak, and it itself is covered up. The third resonant frequency value is close to the modal frequency value of it rotating around Y axis, indicating that the vibration at this time is mainly shown as the power assembly rotates around Y axis.

Table3 Dynamic response value peak at the first support

	Dynamic response					
	First frequency (Hz)	First peak (mm)	Second frequency (Hz)	Second peak (mm)	Third frequency (Hz)	Third peak (mm)
Group 1	6.30	29.2	6.90	23.5	12.2	8.50
Group 2	6.50	36.3	6.80	29.5	11.7	7.47
Group 3	6.50	47.3	——	——	11.4	6.28
Group 4	6.30	44.2	6.80	25.5	11.1	4.95
Group 5	6.00	44.8	6.90	21.5	11.0	3.67

Figure 2, figure 4, figure 6, figure 8 and figure 10 show the displacement peaks and corresponding frequency values of the third support point, and the results are shown in table 4. It can be seen from table 4 that as the power assembly approaches to the third support point from the first and second support point, the resonance peak of the third support point and the corresponding resonant frequency value have both changed. The first resonant frequency value is very close to the modal frequency value of it moving along Z axis (see table 2), and there is synchronous fluctuation, indicating that the vibration is mainly manifested as the power assembly moves along Z axis. The second resonance frequency is close to the modal frequency of it moving along X axis, and there is synchronous fluctuation, showing that the vibration is mainly manifested as the power assembly moves along X axis; of which the values of group 2 and group 3 are vacant, mainly because it is too close to the frequency of the first resonance peak, and it itself is covered up. The third resonant frequency value is close to the modal frequency value of it rotating around Y axis, indicating that the vibration at this time is mainly manifested as the power assembly rotates around Y axis.

Table4 Dynamic response value peak at the third support

	Dynamic response					
	First frequency (Hz)	First peak (mm)	Second frequency (Hz)	Second peak (mm)	Third frequency (Hz)	Third peak (mm)
Group 1	6.40	50.7	7.10	15.7	12.1	11.8
Group 2	6.50	45.8	——	——	11.7	11.4
Group 3	6.50	36.0	——	——	11.3	10.7
Group 4	6.20	12.3	6.70	31.5	10.9	9.44
Group 5	6.20	22.4	6.70	33.3	10.7	7.43

Impact of Rear Support Position of the Rubber Cushion Mounting on Dynamic Response

Keep the position of the first and second support point unchanged, and move it from the third support point to the first and second support point, and its displacement relative to the original place is shown in table 5.

Table5 Displacement of comparison between the third and original place

	First support point (mm)	Second support point (mm)	Third support point (mm)
Group 1	0	0	0
Group 2	0	0	85
Group 3	0	0	170
Group 4	0	0	255
Group 5	0	0	340

Dynamic response after changing the support position of the rubber cushion mounting. Under the case that the stiffness and support angle of the rubber cushion mounting of the engine assembly are unchanged, the support position of the third mounting is changed to get the corresponding 6-order mode as shown in table 6. As can be seen from table 6, as the engine assembly approaches to the first and second support point from the third support point, the mode of the mode of the power assembly moving along Y axis is on the rise. The mode of the power assembly moving along Z axis and rotating around Z axis, Y axis and X axis is in a downward trend. And the mode of it moving along X axis is fluctuating.

These rules enable us to comprehensively consider the impact of mounting stiffness and support angle and other factors, and select the most reasonable position parameter to reduce vibration and noise.

Table 6 Mode shapes at different mounting place about engine assembly

	Mode (Hz)					
	Y	Z	X	R_Z	R_Y	R_X
Group 1	2.66	6.38	6.88	10.5	12.1	13.4
Group 2	2.67	6.24	6.87	10.0	11.7	13.2
Group 3	2.68	6.03	6.89	9.44	11.3	13.1
Group 4	2.70	5.77	6.91	8.79	11.0	13.1
Group 5	2.71	5.46	6.94	8.13	10.7	13.1

Because the dynamic response on the first and second support point is the same, the dynamic response of each group of data on the first and third support points is given below, as shown in figure 11~ figure 20.

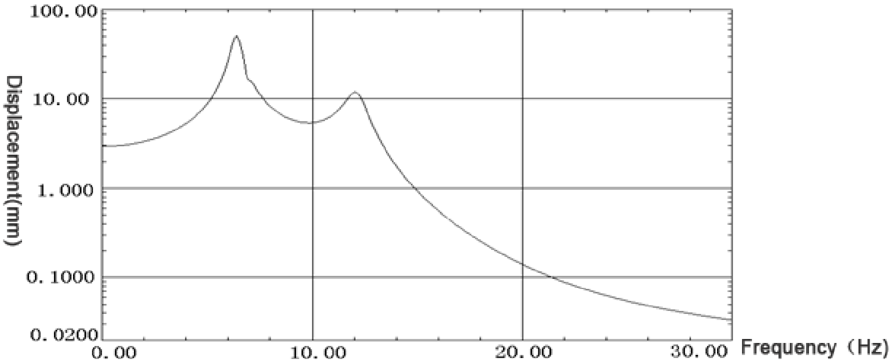

Fig.11 Displacement response at point 1 in group 1

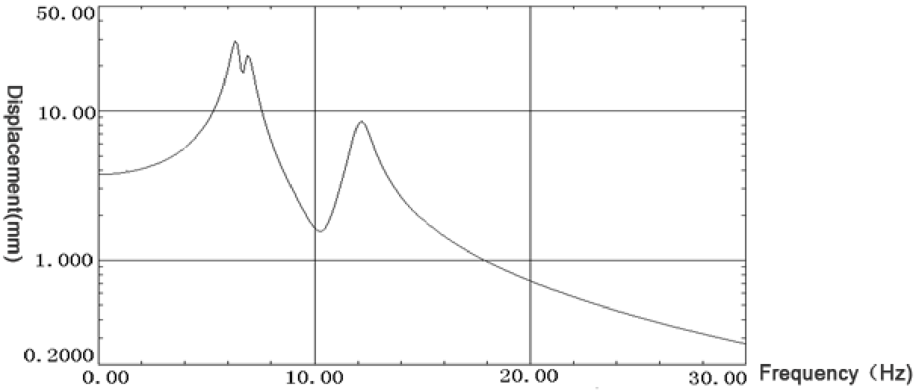

Fig.12 Displacement response at point 3 in group 1

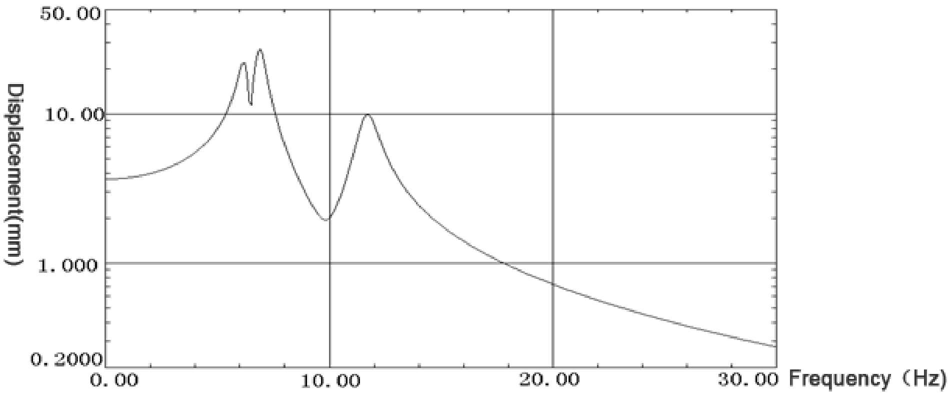

Fig.13 Displacement response at point 1 in group 2

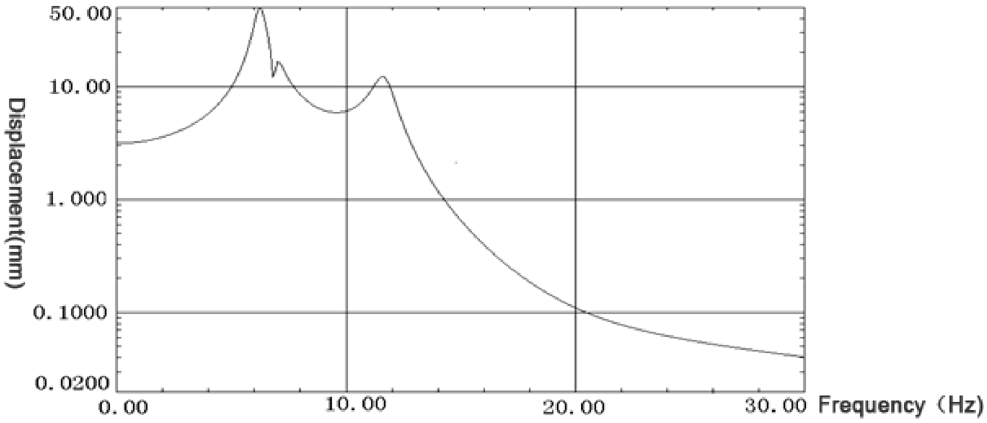

Fig.14 Displacement response at point 3 in group 2

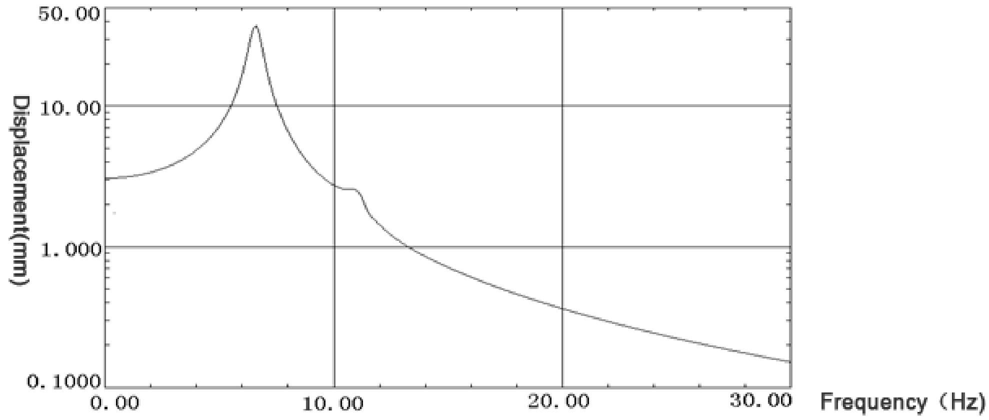

Fig.15 Displacement response at point 1 in group 3

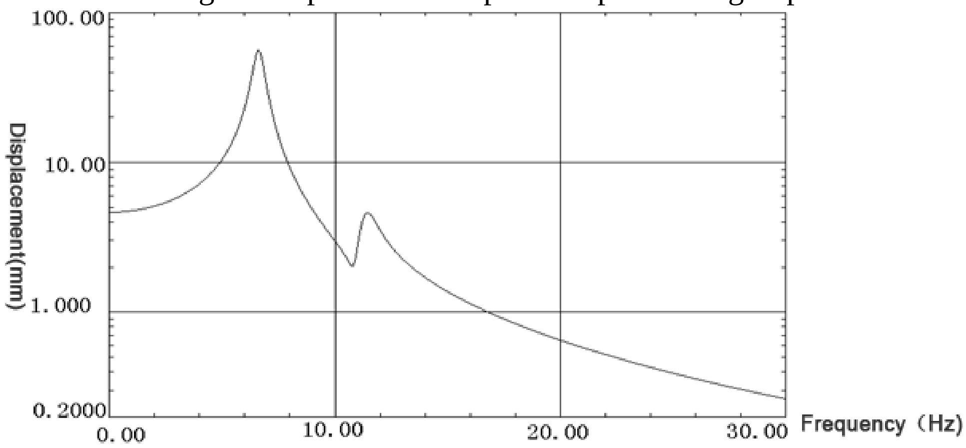

Fig.16 Displacement response at point 3 in group 3

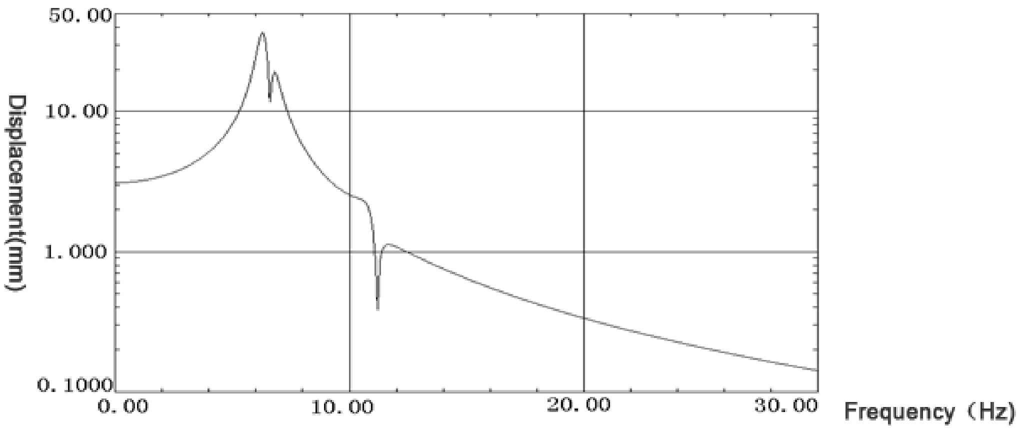

Fig.17 Displacement response at point 1 in group 4

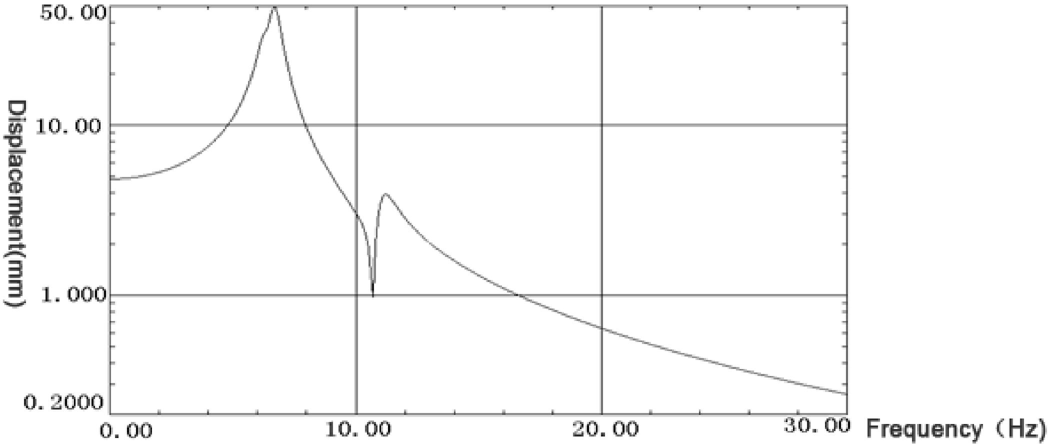

Fig.18 Displacement response at point 3 in group 4

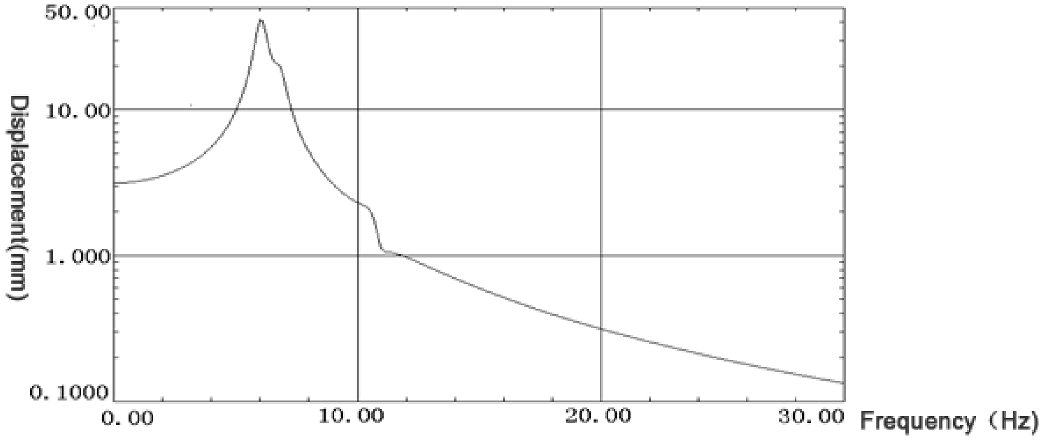

Fig.19 Displacement response at point 1 in group 5

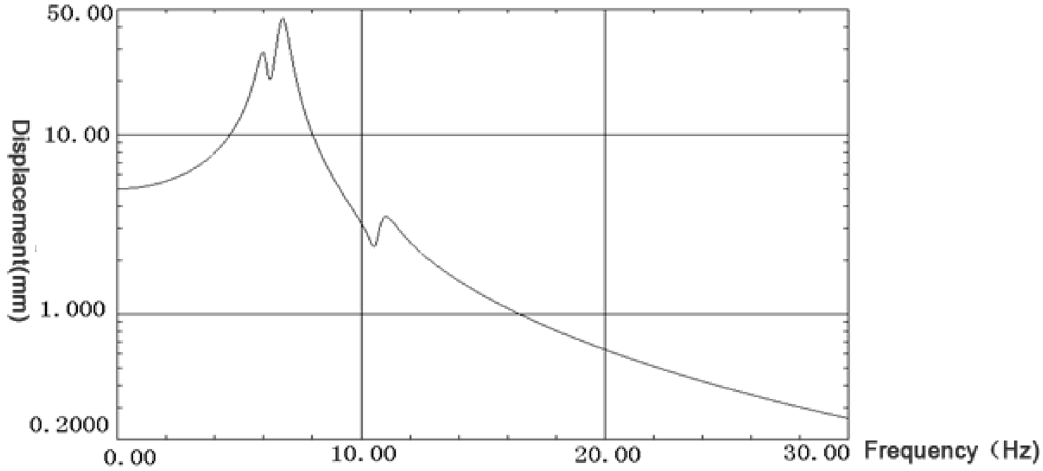

Fig.20 Displacement response at point 3 in group 5

Result analysis on dynamic response. Figure 11, figure 13, figure 15, figure 17 and figure 19 show the displacement peak and corresponding frequency value of the first support point, and the results are shown in table 7 below. It can be seen from table 7 that as the engine assembly approaches from the third support point to the first and second support point, the resonance peak of the first support point and the corresponding resonant frequency value have both changed. The first resonant frequency value is very close to the modal frequency value of it moving along Z axis (see table 6), and there is synchronous fluctuation, indicating that the vibration herein is mainly manifested as the engine assembly moves along Z axis. The second resonant frequency value is close to the modal frequency value of it moving along X axis, and the synchronous fluctuation occurs; at this time, the vibration is mainly manifested as the engine assembly moves along X axis. The third resonant frequency value is close to the modal frequency value of it rotating around Y axis, and the vibration is mainly manifested as the engine assembly rotates around Y axis.

Table7 Dynamic response value peak at the first support

	Dynamic response					
	First frequency (Hz)	First peak (mm)	Second frequency (Hz)	Second peak (mm)	Third frequency (Hz)	Third peak (mm)
Group 1	6.30	29.2	6.90	23.5	12.2	8.50
Group 2	6.20	22.0	6.90	27.2	11.7	9.92
Group 3	5.90	16.4	6.90	29.7	11.3	11.6
Group 4	5.70	11.8	6.90	30.8	11.0	13.3
Group 5	5.30	8.72	6.90	30.9	10.7	15.1

Figure 12, figure 14, figure 16, figure 18 and figure 20 show the displacement peak and corresponding frequency value of the third support point, and the results are shown in table 8 below. It can be seen from table 8 that as the engine assembly approaches from the third support point to the first and second support point, the resonance peak of the third support point and the corresponding resonant frequency value have both changed. The first resonant frequency value is very close to the modal frequency value of it moving along Z axis (see table 6), and there is synchronous fluctuation. The vibration is mainly manifested as the engine assembly moves along Z axis. The second resonant frequency value is close to the modal frequency value of it moving along Z axis, and the synchronous fluctuation occurs; at this time, the vibration is mainly manifested as the engine assembly moves along X axis. The third resonant frequency value is close to the modal frequency value of it rotating around Y axis, and the vibration is mainly manifested as the engine assembly rotates around Y axis.

Table8 Dynamic response value peak at the third support

	Dynamic response					
	First frequency (Hz)	First peak (mm)	Second frequency (Hz)	Second peak (mm)	Third frequency (Hz)	Third peak (mm)
Group 1	6.40	50.7	7.10	15.7	12.1	11.8
Group 2	6.20	49.7	7.00	16.4	11.6	12.7
Group 3	6.00	48.6	7.00	18.0	11.2	12.4
Group 4	5.80	47.6	7.00	19.8	10.9	12.2
Group 5	5.50	47.2	7.00	21.2	10.6	11.8

Conclusion

As the first and second support point approach to the third support point, the mode of the engine assembly moving and rotating along and around Y axis, and rotating around X axis is involved in a downward trend, namely the trend of the engine assembly laterally moving, pitching and reversing is weakening. The mode of the engine assembly moving along Z axis and along X axis and rotating around Z axis is fluctuating, however, indicating that the trend of the engine assembly vibrating from top to bottom, moving front and back and turning around horizontally is enhanced. As the engine assembly approaches from the third support point to the first and second support point, the mode of the engine assembly moving along Y axis is on the rise. The mode of the engine assembly moving and rotating along and around Z axis, rotating around Y axis and rotating around Z axis is involved in a downward trend, while the mode of the engine assembly moving along Y axis is fluctuating, indicating that the trend of the engine assembly laterally moving is strengthening, but the trend of it vibrating from top to bottom, turning around horizontally, pitching and side turning is weakening, and the back and forth movement is of fluctuating. These rules enable us to comprehensively consider the impact of mounting rigidity and support angle and other factors, and select the most reasonable position parameter to achieve the purpose of reducing vibration and noise.

While the engine assembly approaches from the first and second support point to the third support point, the resonance peaks and corresponding resonant frequency values of the first and third support points vary. The first resonant frequency value is very close to the modal frequency value of the engine assembly moving along Z axis, and there is synchronous fluctuation; at this time, the vibration is manifested as the engine assembly moves up and down; the second resonance frequency value is close to the modal frequency value of it moving along X axis, and there is synchronous fluctuation, while the vibration is mainly manifested as the engine assembly moves back and forth; of which the values of group 2 and group 3 are vacant, mainly because it is too close to the frequency of the first resonance peak, and thus it itself is covered up; the third resonance frequency value is close to the modal frequency value of it rotating around Y axis, showing that the vibration at this time is mainly manifested as the pitching motion of the engine assembly. The rules are identical to the stiffness response rule under our previous study.

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