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Research on the design of fixture for motor vibration test

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Abstract. The vibration reliability of the new energy automobile motor plays a very important role in driving safety, so it is very important to test the vibration durability of the motor. In the vibration test process, the fixture is very important, simulated road spectrum signal vibration can be transmitted without distortion to the motor through the fixture, fixture design directly affect the result of vibration endurance test. On the basis of new energy electric vehicle motor concrete structure, Two fixture design and fixture installation schemes for lateral cantilever type and base bearing type are put forward in this article, the selection of material, weighting process, middle alignment process and manufacturing process are summarized.The modal analysis and frequency response calculation of the fixture are carried out in this design, combine with influence caused by fixture height and structure profile on response frequency, the response frequency of each order of the fixture is calculated, then ultimately achieve the purpose of guiding the design.

The main performance of fixture for vibration durability test is passing the vibration energy from shaking table to the test piece, with little or no distortion in this passing process. Firstly the fixture need to clamp the test piece, and need to avoid resonant frequency in test frequency range in the passing process. The main influence factors of test result are system frequency、 centre of gravity、 quality and so on. The method of road spectrum excitation is used for Simulating vibration durability test of new energy automobile's motor on the test-bed, so researchers can investigate vibrate durability performance of motor system in a short time. The nature of the test is the simulation of vibrate reliability of new energy motor system in laboratory. Road spectrum excited vibration table is used to test motor vibrate durability in kinds of working-cases in real-time. The purpose of that is to simulate real working condition of motor , and to evaluate system vibrate reliability performance, to get its

Reliability quality.

According to the arrangement of the new energy vehicle's motor in the whole carload, currently the mainly two installations like fixtures are horizontal cantilever and base bearing type, are shown as below:

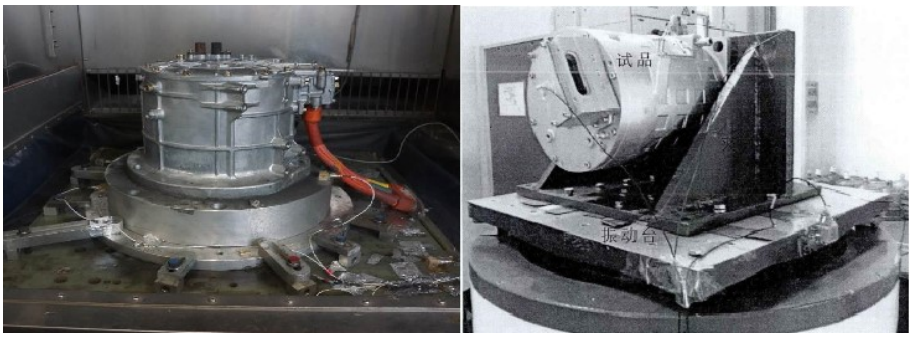

Figure 1. Horizontal cantilever and base bearing type fixtures.

Base bearing type fixture design scheme, it can be installed through adjusting the bolts location, (the bolts are on the vertical plate of the assembly), to meet requirements for different fixing bolt holes positions on the base for matching different test pieces; By adjusting location of waist-shape holes on the base of the assembly, the fixture can assemble with different screw holes which have different spacing on the vibration table , and finally meet genetic requirement of many types of motors. The fixture has the structure that its board and vertical plate are made as one body, also has many reinforce posts, it effective enhancement of the overall stiffness. For the whole structure, it has high vibrating basic frequency and big resistance, so it can avoid resonance in test. This kind of fixture can be installed easily, lots of preparing time before test can be saved . Horizontal cantilever type fixture design scheme, by adjusting the type-trough bolts' location which are on lower part of beam and upper part of the whole frame , finally meet genetic installation requirement of many types of test piece.Section steel and titled strutting pile are used in horizontal cantilever type fixture which can effectively increase the stiffness of the fixture.

The designing process includes the selection of material, weighting process, middle alignment process and manufacturing process . Material with big rigidity and big resistance should be chosen to manufacture fixtures for vibrate durability test. Fixtures made of big rigidity material has little influence to vibration and has wide frequency response, so it has more reliable performance for passing road spectrum vibration signal. Fixture's weight should be as light as possible,cause according to the formula $f_n = \left(\frac{k}{m}\right)^{\frac{1}{2}}$, only increase rigidity k, reduce mass m, the natural frequency of the whole fixture will increase. Otherwise , strength of fixture need to be considered, small strength can cause damage. When testing , the best condition is ,the center of gravity of test piece and fixture coincide in the central line of the vibration test-bed, which can avoid vibration of test-bed , the vibration will lead to vibrating waveform distortion. So fixture need to has symmetric and underslung structure, symmetric and closed shape such as cube、rectangular box、semisphere、cone and so on. Change of dynamic gravity center need to be considered also, especially elastic load even liquid load. Avoid jumpy change on cross section, that will reduce fixture's rigidity and fixture's natural

frequency.

Main manufacture methods of fixture are global processing、screw joins、casting、welding、bonding and so on. Among all methods, global processing should be preferred firstly. Screw joins should be designed meticulously, decrease roughness of interactive surfaces , bolt pretension force should be bigger at least 10% than the calculated vibration pull-off force. For big fixtures which are used for high frequency , bolt space should be less than 80mm。Especially pay attention to shear stress of bolt or screw in manufacture. When use bolts made by aluminum alloy or Al-Mg alloy for connection ,coarse thread should be chosen .For the fixture which are frequently disassembled ,stainless steel screwed bushing or wire thread should be used. Epoxy resin can be used on bolts connecting part,it can improve connecting strength. When use horizontal smoothing board, When using horizontal slide, should pay special attention to the shearing force. The parts between the in fixture should be tightly connected to each other, and the holes should be filled with full expansion pin or filled with epoxy resin. The phenomenon of "hair bundles" also lead to waveform distortion. For varying complex surfaces、 thickness and cross sections, casting method is usually applied. The damping of the cast alloy is relatively large, so it is beneficial to reduce the resonance condition. After casting and grinding, the damping of the fixture will be reduced and it is disadvantageous to shock absorption. Welding jig is more convenient and low cost, but the quality of welding must be guaranteed, otherwise the welding position can be easily broken in vibration. Compared with the bolt connection fixture, the welding fixture has no "burr", which saves time than the casting method. For a small fixture ,bonding method is faster than welding method and save cost, is more commonly used with epoxy resin as the bonding material, when using screw connection, welding, epoxy resin adhesive connecting to make the same fixture, welding can get slightly higher resonance frequency , and the epoxy resin method get slightly lower resonance , welding and epoxy resin method get higher resonant frequency than the screw connection. In combination with the specific conditions, the fixture is test is connected by welding and bolt.

The modal analysis and spectrum calculation should be carried out to optimize the design of the fixture for the completion of the initial design for the more complex working conditions. The design optimization process of the base bearing fixture for the motor of the new energy vehicle is introduced below. As shown in the following figure, the resonant image of the six order response frequency after the optimized design.

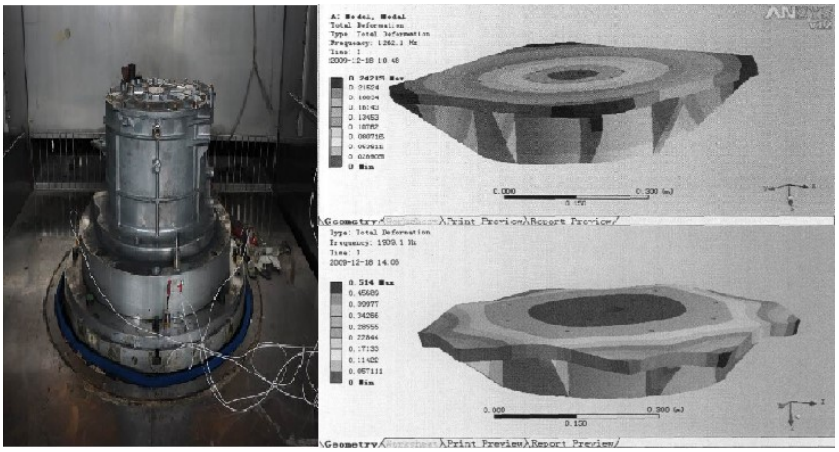

Figure 2. The resonant image of the six order response frequency after the optimized design.

Generally, when designing fixture, the strength and fatigue characteristics of materials are seldom considered. The high stiffness required by the fixture's high-frequency characteristics makes the fixture basically can not damaged by insufficient strength. The weight of fixture is often the most important parameter in fixture design. Therefore, aluminum magnesium alloy is chosen as fixture material and response spectrum need not be used in calculation. In the process of fixture design, combined with the structure and using requirements of the vibration test table, fixture mainly has symmetry design . Because the contact surface between the shaking table and the fixture is square, when designing the fixture surface for fixing test sample, the size should be designed as big as possible, so that the fixture can meet the requirements of the general test. So the designed fixture's outer diameter is 900mm, connected with the vibration test by bolts. At the same time, in order to reduce the weight, the weight reduction groove is used in the bottom area. The expanded clamp top surface is 1100 x 1100mm square, and 8 equidistance reinforcement are used to increase the stiffness of structure and increase the response frequency. In the process of design, the distribution direction of the connecting bolt of the fixed fixture is in the same angle as the direction of the reinforcing bar, so that the response frequency of the fixture can be improved. In Ansys modal analysis, for the convenient division of the grid, the connection part between model and test sample can be simplified, so that the calculation process can be simplified, but the effect to calculating result is not big.

In the design process, the first completed structure is a square with a diameter of 900mm at the bottom and a 1100×1100mm top square. The chamfering part of the fixture is about 120mm and the height is 300mm. After modal analysis, the first order response frequency is low, and it is necessary to be optimized. Therefore, the height of the fixture is changed to 200mm, and the other sizes remain unchanged. After analyzing the frequency response, we can see that, on the basis of meeting the using requirements, reducing the height of fixture has a very significant effect on improving its response frequency. However, the computer simulation analysis has limitations. Therefore, the measured frequency response data of the actual fixture in vibration endurance test is always slightly lower than the simulated value. At the same time, when using Ansys software to divide meshes, because of the limitation of computer hardware, In any case, the mesh can not be subdivided into the extent to which the test specimen can be completely reproduced, so the computation result always tend

to be bigger. So the real frequency of the real test specimen can not always meet the requirements of the high frequency test, so it is necessary to optimize the design again.

After lowering the overall height of the fixture, we can change the top surface to round shape with diameter of 1100mm, and the other data remain unchanged. The fixture at this time has double circular structure with a height of 200mm , a bottom diameter of 900mm, and a top surface diameter of 1100mm. The modal analysis is carried out again to the improved structure and the response frequency is calculated. The results show the response frequency of the optimized structure is greatly improved. Furthermore, after the grid division of the improved structure is further refined to 0.015, the response frequency of each order is reduced a little. More real data can be obtained. Through simulation analysis, we can think that the response frequency of the designed fixture tend to be stable. The first order frequency is 980Hz and six order frequency is 1474Hz ,this simulation results can meet the needs of the vibration endurance test of the new energy electric vehicle motor.

After the manufacture of the fixture for test is completed, scan the natural frequency of the fixture , then get the result that first natural frequency is 996Hz, which is slightly different from the modal analysis. When the fixture is in the simulation, cause the limited simulating capacity of Ansys software for the actual test pieces , the result always has deviation; And errors in machining process, such as surface roughness and parallelism, bolt hole position accuracy, also affect the results of the test; Otherwise human factors such as bolt fastening degree may also lead to deviation in results.

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