Research of the Vibration and Noise Controlling About the Automobile Exhaust Pipe

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Abstract. When a car engine working in the condition of idle speed or running on the slope pavement or bumpy conditions, the vibration noise will emerge from the automobile exhaust Pipe, to reduce and eliminate such vibration and noise, data analysis and testing for Vibration source of exhaust pipe and tube sizes were made. We found the vibration and noise is caused by too large amplitude of vibration when the car engine working in condition of idle speed or the car body bumping. By changing the exhaust pipe size and other technical measures to reduce or eliminate vibration noise of the exhaust pipe.

Preface

Vehicle noise has been the focus of environmental protection control, on noise control theory has been widely researched. The exhaust noise is the main noise sources of automobile, almost 36% percent of motor vehicle noise, current sound absorption, sound insulation, noise control, vibration isolation, damp buff technology to solve noise problem, but car exhaust noise related to the design, manufacture, fabrication and assembly, and other factors influence, Exhaust system design will not only influence the engine pumping losses and emissions, but also the automotive noise levels and riding comfort. A car engine idle, or bumps on the slope road driving conditions, some automobile exhaust pipe vibration produce the abnormal sound, customer complaints about this. This article subjects from the car's exhaust pipe, through test analysis and find out the cause of noise, its redesign, effectively control the vibration noise.

Exhaust Pipe Vibration Drive Source

For the vehicle exhaust pipe, the vibration and noise are two main sources of vibration excitation: one from the pavement, another from operating engine system. Pavement excitation in the low frequency range, by suspension system filtered energy transmission engine in the following 2.5Hz, excitation frequency of the engine and engine speed range of work-related, relatively frequency was higher, frequency range was wider. At present, in order to improve the efficiency of the engine, reduce fuel consumption, engine is designed to improve fuel combustion pressure, exciting forces has also greatly increased, corresponding vibrations are also more intense.

Excited Frequency Caused by Mixture Combustion in the Cylinder

Combustion excited frequency due to mixture combustion in the engine cylinder, crankshaft output pulse torque, because torque change periodically, resulting in engine reaction torque fluctuations. This wave makes the engine to generate cyclic torsion vibration; the vibration frequency is actually the engine's firing frequency, as follows:

\[ f_1 = \frac{Z_n}{60.\tau} \]  

(1)
Excited Frequency Caused by Unbalanced Rotating Mass and Reciprocating Motion Mass

From unbalanced rotating mass and reciprocating motion mass caused by the vibration frequency of the excitation force and moment of inertia

\[ f_2 = \frac{Qn}{60} \]  \hspace{1cm} (2)

In formula, Q is the scale factor (one-level of unbalanced force or torque Q=1), two-level of unbalanced force or torque Q=2.

The excitation frequency of unbalanced inertia force is independent and the number of engine cylinders, and inertial forces of unbalance and the number of engine and structural features have a close relationship.

Exhaust Pipe Vibration Noise Source Identification

Noise control engineering, sound absorption, sound insulation, noise control, vibration isolation, vibration and other traditional measures of noise reduction has been used for years, and is still in development, but measures to control sources of noise is a fundamental, so have people's attention in recent years. But to control the noise source is a very complicated thing, because the car is a complex machine, and there are many noise sources. To control the various sound sources at the same time, it is neither possible nor necessary. Only from cars a variety of sources to find out the main noise sources, and find specific ways, from design and manufacturing to reduce noise in order to work.

So-called noise source recognition, is on car exists of various source for analysis, understand its produced vibration and noise of mechanism, determine vibration source, and source of parts, analysis source of characteristics (including source of category, and sound level of size, and frequency characteristics, and voice changes and spread of law), then by noise of size arranged out order, to determine out main noise source. Noise source identification methods, there are: separate running method, selective sound insulation, frequency analysis method, near-field measurement method, correlation analysis, coherence analysis, etc.

Control of automotive exhaust noise is usually divided into two aspects, one aspect is taken measures for noise source itself, or optimization design of engine exhaust system; the second is the use of noise-vibration reduction measures, including the use of silencers and control of mechanical vibrations coming from other parts. Taking into account the models used in the engine in other vehicles do not appear on this type of situation, so consider using separate running method for noise source identification, separate running method is also called elimination method, is under the same operating conditions, remove and put on some parts, respectively, in the same noise value measured at two observation points, and then press the energy value is calculated by the subtraction of noise, that is, for the noise emitted by parts. The noise of the abnormal noise is mainly determined by the exhaust pipe vibration.

The Data of Vibration and Noise of Exhaust Pipe Acquisition and Analysis

Data Acquisition

To look for causes of noise of exhaust pipe vibration, for installation of parts and locations, the exhaust tail pipe and car assembly plant operation collection for data acquisition:

1. Measuring automotive insulation panels and stringers between the exhaust pipe and the frame size;
2. Measurement suppliers exhaust tail pipe full size;
3. Auxiliary stations of the survey vehicle assembly plant equipment can meet the requirements of exhaust tail pipe mounting dimensions, staff operations specification, whether the process is reasonable.
Through data acquisition, finding suppliers exhaust tail pipe sizes there are large variations along the Z axis. So focus on the analysis of exhaust tail pipe z-direction size.

**Data Analysis**

Found from the collected data, insulation panels and frame longitudinal beam sizes and car assembly plant practices meet the requirement. From the situation, the original design size to ensure exhaust tail pipe longitudinal beam of the frame there is a static gap and insulation panels, but the vehicle when driving on rough or sloping surfaces, not avoiding severe vibration caused by tailpipe longitudinal beam of the frame and the likelihood of collision with insulating plate. This may be a cause of vibration noise.

In order to better analyze, place the following sampling methods: Hourly sampling exhaust pipe suppliers production line two, three coordinates (x, y, z) to measure dimensions in the z-direction, and total samples 30 pieces, as a basis for measurement system analysis and process analysis. Exhaust tail pipe size on the critical points in the z-direction as listed in table 1:

| number | Z dimension | number | Z dimension | number | Z dimension |
|--------|-------------|--------|-------------|--------|-------------|
| 1      | -322.67     | 11     | -323.16     | 21     | -327.84     |
| 2      | -323.36     | 12     | -321.77     | 22     | -326.46     |
| 3      | -327.81     | 13     | -329.83     | 23     | -324.45     |
| 4      | -328.44     | 14     | -320.51     | 24     | -323.60     |
| 5      | -321.50     | 15     | -325.31     | 25     | -324.31     |
| 6      | -326.10     | 16     | -322.32     | 26     | -319.89     |
| 7      | -327.58     | 17     | -323.83     | 27     | -321.90     |
| 8      | -321.65     | 18     | -323.37     | 28     | -323.64     |
| 9      | -320.90     | 19     | -326.09     | 29     | -324.93     |
| 10     | -325.94     | 20     | -327.14     | 30     | -323.39     |

Measurement system analysis, measuring system is available; its production of process capability analysis is shown in Figure 1. Figure 1 shows that CPK values is only 0.21, large amounts of data beyond the size limits of the value distribution, where supplier production capacity is low, products need to be improved.

**Table 1. Key point of exhaust tail pipe z dimension (before improved).**

| number | Z dimension | number | Z dimension | number | Z dimension |
|--------|-------------|--------|-------------|--------|-------------|
| 1      | -322.67     | 11     | -323.16     | 21     | -327.84     |
| 2      | -323.36     | 12     | -321.77     | 22     | -326.46     |
| 3      | -327.81     | 13     | -329.83     | 23     | -324.45     |
| 4      | -328.44     | 14     | -320.51     | 24     | -323.60     |
| 5      | -321.50     | 15     | -325.31     | 25     | -324.31     |
| 6      | -326.10     | 16     | -322.32     | 26     | -319.89     |
| 7      | -327.58     | 17     | -323.83     | 27     | -321.90     |
| 8      | -321.65     | 18     | -323.37     | 28     | -323.64     |
| 9      | -320.90     | 19     | -326.09     | 29     | -324.93     |
| 10     | -325.94     | 20     | -327.14     | 30     | -323.39     |

**Figure 1. Improve product process analysis before.**
Exhaust Pipe Vibration and Noise Control Measures

Improvement and Optimization Processing

In order to solve the exhaust pipe vibration noise problems, suppliers from the following areas raise the level of processing, strengthening quality management:
(1) Readjust, repair clamps and welding mold;
(2) Adjusting Assembly gauge and redesigned positioning devices;
(3) Strengthen the site management increase the frequency of sampling and SPC control chart control quality.

Design Key Points Z Dimension

Re adjusts exhaust pipe dimensions; key point of exhaust tail pipe z-direction size reduces the 10mm. After adjustment, in accordance with the sampling method in the vendor line of the previous analysis sampling a 30 unit, measurement results are listed in table 2:

| number | Z dimension | number | Z dimension | number | Z dimension |
|--------|-------------|--------|-------------|--------|-------------|
| 1      | -323.67     | 11     | -325.16     | 21     | -323.84     |
| 2      | -324.36     | 12     | -323.77     | 22     | -323.46     |
| 3      | -323.81     | 13     | -323.83     | 23     | -324.45     |
| 4      | -324.44     | 14     | -324.51     | 24     | -323.60     |
| 5      | -324.50     | 15     | -324.31     | 25     | -324.31     |
| 6      | -324.10     | 16     | -324.32     | 26     | -323.89     |
| 7      | -323.58     | 17     | -323.83     | 27     | -323.90     |
| 8      | -323.65     | 18     | -323.37     | 28     | -323.64     |
| 9      | -324.90     | 19     | -325.09     | 29     | -323.93     |
| 10     | -323.94     | 20     | -324.14     | 30     | -324.39     |

Production of process capability analysis is shown in Figure 2.

Process capability analysis described by Figure 2, CPK value reached 1.23, and data distribution within the upper and lower limits to meet stability requirements.
Small Batch Trial Installation Verification

Lower the key point in the z-direction dimension 10mm, little changes on the tail pipe overall length, does not affect the installation dimensions. Small batch input on vehicle assembly line test Assembly, vehicle fitting result as listed in table 3:

Table 3. Exhaust tail pipe point z dimension improved test analysis.

| order number | With longitudinal clearances(mm) | With transverse beams clearances (mm) | With heat shield clearance (mm) | 15-20km Different sections of the road test |
|--------------|----------------------------------|--------------------------------------|--------------------------------|--------------------------------------------|
| 1            | 42                               | 31                                   | 34                             | Found no abnormal sound of the exhaust pipe |
| 2            | 47                               | 33                                   | 32                             | Found no abnormal sound of the exhaust pipe |
| 3            | 43                               | 32                                   | 32                             | Found no abnormal sound of the exhaust pipe |
| 4            | 39                               | 34                                   | 30                             | Found no abnormal sound of the exhaust pipe |
| 5            | 42                               | 34                                   | 31                             | Found no abnormal sound of the exhaust pipe |
| 6            | 41                               | 36                                   | 33                             | Found no abnormal sound of the exhaust pipe |
| 7            | 41                               | 35                                   | 32                             | Found no abnormal sound of the exhaust pipe |
| 8            | 45                               | 37                                   | 35                             | Found no abnormal sound of the exhaust pipe |
| 9            | 44                               | 38                                   | 32                             | Found no abnormal sound of the exhaust pipe |
| 10           | 41                               | 34                                   | 33                             | Found no abnormal sound of the exhaust pipe |

Conclusions

Through the testing and analysis of an automobile exhaust pipe, that causes vibration noise of the exhaust pipe is due to production quality stability, key points between exhaust tail pipe products caused large errors on z-direction size. New design improvements on the car's exhaust pipe, exhaust tail pipe key z dimension reduces 10mm, while strengthening the outer parts of quality management, design adjustments, materials and diameters were not changed, no effect on the noise performance of no other vehicle noises. These results indicate that improved measures are effective, eliminating the exhaust pipe vibration noise. These results indicate that improved measures are effective, eliminating the exhaust pipe vibration noise.

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