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Research Article

Vibration Analysis of Air Condition Unit on Subway

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Abstract: Subway system has many merits including large passenger carrying ability, high speed, strong controllability and reliability of driving. Nevertheless, subways also have brought many disadvantages for human. In many subway systems, noisy environments are clearly observed and passengers are exposed to higher noise levels than permissible limit. This study presents a study of noise and vibration of subway air condition system, so as to grasp the vibration distribution laws of the air condition system. By the tested of noise and vibration, the researcher find the sound distribution rule of air condition is very important Based on the consequence of the testing, the acceleration of air condition has little to do with the subway speed and more to do with the vibration of fan; When the train driving on the viaduct bridge, the acceleration of air condition is biggish in 125 Hz and In 50-1000 Hz the vibration of air condition is obviously. When the train running underground line, as a result of the resonance of body, air condition's vibration is biggish in 630 Hz and the vibration is obviously in 125-1250 Hz. With the increase of the speed, the influence of the ground's second radiation on body vibration is enhanced. The superfine gross wool which is used to air condition can achieve good results for noise reduction. This research has higher reference for the vibration and noise reduction of the subway air condition system.

Keywords: Air condition unit, spectrum analysis, subway, vibration

INTRODUCTION

Subway system has many merits including large passenger carrying ability, high speed, strong controllability and reliability of driving. The subway fosters the effective use of the area of the city road, relive the traffic congestion and reduce the air pollution. With the rapid evolution of urban rail train industry, more cities begin building the subway (Li *et al*., 2010; Sun and Peng, 2008; Wen, 2005).

In the subway devices, air condition system is vital. Because the air condition ensure the comfortable temperature, humidity and sufficient fresh air. By the action of fan, new wind, which is inhaled from the suction outlet, mixed with return air of compartment, what's more the wind is filtered, cooling and even distribute in the air flue according to the length of the train, at the last the wind blow to the compartment by the grille installed on the roof of the train is able to enhance the train comforts (Hong *et al*., 2011; Loh *et al*., 2011).

However, the air condition system can enhance the train comforts while it's noise and vibration problem pop out. As the boosting of the environment and the higher requirement of the train comforts, the noise and vibration of subway have been cause for concern. The noise interferes with people's normal life and work. It can be mainly reflected in the following aspects: affecting the rest; interfering with the study; even causing the cardiovascular system, nervous system and digestion system disease. Besides that, the noise could cause the psychological effect such as mental troubles, unable to concentrate and long-term causing insomnia, tinnitus, tired, weakness, memory loss and so on. The vibration caused human organ vibration or resonance so that lead to disease which has influences on the health of people even the life of the people (Chen *et al*., 2009; Song and Chen, 2009; Wang *et al*., 2007). What's more the vibration and noise lead to the early fatigue damage of some parts of the subway which reduce longevity of the subway and constraint the improvement of the subway to a certain extent (Song *et al*., 2008; Xia *et al*., 1999). When the subway running in the tunnel, the noise hardly spread, it can be spread only through multiples attenuation of the tunnel wall. As the result of the situation, the requirement of the subway noise is stricter than the train running on the ground. Especially the noise and vibration of the subway air condition (Chai *et al*., 2008; Wang *et al*., 2006; Yuan, 2003).

In order to reduce the noise and vibration level of the subway cars, the subway air condition system distribution laws should be studied. The vibration and

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Fig. 1: SQLab II data acquisition recorder

Fig. 2: HPS IV play back system

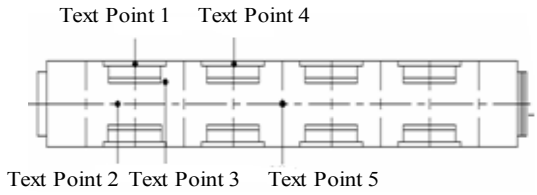

Fig. 3: Collocation of different points of the vibration test
Test point 1: ACC01 (the window of the end of the train, Y-axis); Test point 2: ACC02 (the ground of the above bogie, Z-axis); Test point 3: ACC03 (the top filed of the air condition unit, Z-axis); Test point 4: ACC04 (the window of the middle of the train, Y-axis); Test point 5: ACC05 (the ground of the middle of the train, Z-axis)

noise tests of air condition system are completed using the HEAD acoustics multi-channel noise test and analysis system. The characteristics of the vibration and noise are obtained through the study. The conclusions provide the bases for noise research and control of the subway air condition system.

TESTING EQUIPMENT AND LAYOUT OF TEST POINTS

Testing equipment: The testing equipment is test and analysis system of vibration and noise. The system include SQLab II multichannel-front end for Data recording and Data storage, HMS III binaural signal, HPS IV play back system, acoustics and vibration sensor etc. SQLab II multichannel-front end for Data recording and Data storage, HMS III play back system is shown in Fig. 1 and 2.

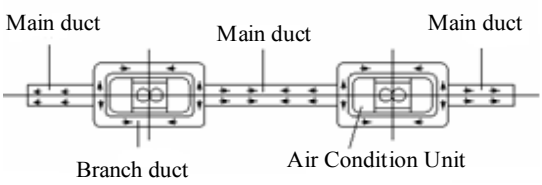

Fig. 4: Structure diagram of air condition units

Fig. 5: Vibrate test point collocation at air condition units

Layout of test points: The collocation of different points of vibration test in the subway is shown in Fig. 3.

As the vibration and noise of the air condition caused by the vibration of the train body and sound of the air flow, the analysis of vibration of the air condition is completely under different speed at viaduct and tunnel respectively. The air condition system installed at middle of the train supply the air to the both ends of the carriage. The air ducts of the unit are fixed to each side of the unit or to interlayer of the top of the carriage which is in the bottom of the unit. The return air inlet is arranged at end of the carriage. The concrete distribution is shown in Fig. 4.

In this test, firstly the vibrate test point collocation is at air condition vents. The test point must be close to the grid and can't fall off. The location of the points is shown in Fig. 5.

Test operating condition: The routes of the subway are ground, underground and viaduct. The routes of this test are viaduct and tunnel. When the train pulls into the station, its speed is 40 km/h. The speed of the train is 30 km/h when turnout appeared. Some sections are bend.

TEST RESULTS AND ANALYSIS

The analysis of the air condition vibration when subway running at the viaduct: The air condition vibration frequency spectrum when subway is

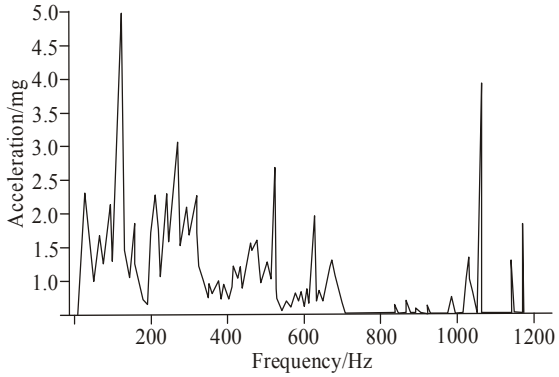

Fig. 6: The spectrum graph of vibration

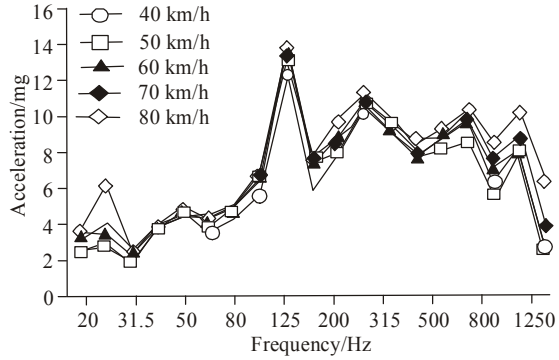

Fig. 7: The spectrum graph of vibration at air condition unit

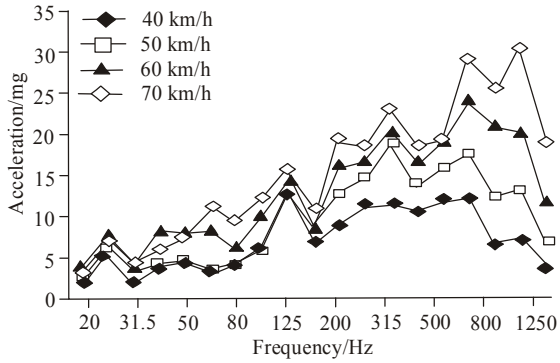

Fig. 8: The spectrum graph of vibration at air condition units

stationary is analyzed. The spectrum graph of vibration is shown in Fig. 6.

The Fig. 6 shows that the vibration of the air condition is biggish in 125 and 1000 Hz. Judging by the graph the natural frequencies of the air condition are 125 and 1000 Hz. In the 125 Hz, the SPL of the air condition is biggest. In part, the noise of the air condition is caused by its vibration.

The frequency spectrum analyses of air condition vibration in different speed are done. To get the acceleration of the air condition under different speeds, the accelerations of the air condition under 40, 50, 60 70 and 80 km/h are tested respectively. The spectrum graph is shown in Fig. 7.

The Fig. 7 shows that the frequency range around 25, 125 and 1000 Hz, respectively the acceleration of the air condition is biggish.

The analysis vibration of the air condition when the subway driving in tunnel: The acceleration of air condition has little to do with driving speed and is mainly caused by vibration of fan Fig. 8.

The accelerations of the air condition under 40, 50, 60 and 70 km/h, are tested respectively and the spectrum graph is presented in Fig. 8.

The Fig. 8 shows that when the subway running in tunnel, with the increase of the speed the vibration of the air condition is more obviously and the influence of the secondary radiation enhance.

With the increase of the speed, the vibration of the body is biggish in the frequency range around 630 Hz.

MEASURES OF REDUCING NOISE APPLIED IN SUBWAY

The sound-absorbing material used to reduce the noise and vibration: The noise of the air condition is caused by the noise of the fan and aerodynamic noise chiefly. The noise is obviously in 250-2000 Hz. As the aerodynamic noise caused during the air flowing, it is mainly component of rotation noise and worm flow noise. The aerodynamic noise of the ventilation air-condition radiate from inlet and outlet of the fan and spread inside and outside through duct. The smaller width of the air supply seam of mainly duct and static duct is better based on the fully consideration of resistance and noise of the duct. Meanwhile the mainly duct and static pressure tank are sticked the sound-absorbing material to reduce the noise caused by air flowing from compartment.

The result of the test and analysis shows that the natural frequency of air condition is approximately 125 Hz. The subway running underground, because of the resonance, the vibration of the air condition is biggest in 630 Hz. Its vibration is obviously in 125-1250 Hz. From what has been mentioned above, the porous absorbent is firstly considered to reduce the noise and vibration of the air condition (Shen, 2001; Zhou *et al*., 2004).

Generally speaking, the porous absorbent material whose mainly structural characteristics is from surface to inside evenly distributing interconnected tiny hole is mainly absorbent the mid and high frequency acoustic energy. When the sound wave incident on the surface of the porous absorbent material, the air inside the tiny hole begin to vibrate which cause the relative motion between air and material. Because of the viscidity resistance caused by viscosity of the air, the kinetic energy of the vibratory air is converted to heat. The

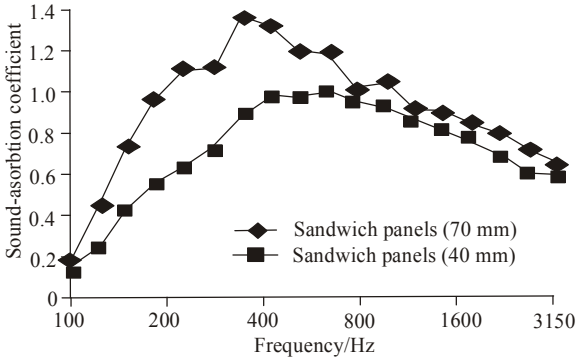

Fig. 9: Sound-absorption of sandwich panels

acoustic energy which is also converted to hear is attenuated. When the air subjected to adiabatic compression, the acoustic energy is attenuated for the heat exchange between air and edge of the hole that lead the acoustic energy covert to heat. From the absorbing principles, the porous absorbent material should satisfy the following conditions: firstly, there are a great deal of tiny holes inside the material meanwhile the holes should be evenly distributed and the size of the hole should be as small as possible; secondly, the holes open outwards in other words the holes extend to surface from inside which make the sound wave easily access to the inside of the material from the surface; the holes inside the material should be mutually connected not closed. The types of the porous absorbent material are fibers, granular material, foam material, metal material and curtain. The factors of effect on the sound absorbing property are flow resistance, porosity, structure factors, thickness, unit weight, air layer behind the material, top layer or brush layer, temperature, humidity and so on Ghotbi *et al*. (2012).

Superfine glass wool whose merits include that low weight, high absorption coefficient insulation, anti-freezing, heat-resisting, insect-resistant and soft act has been widely used in noise control industry and heat insulation engineering (Park *et al*., 2012). In general, absorbent of the superfine glass wool is high. However, when it becomes damp, its sound-absorption decreases. To overcome the drawbacks, the superfine glass wool could be treated by silicone oil so that it will be water resistant (Zhou *et al*., 2004). The dust of the superfine glass wool which cause the adverse reactions of skin, eyes, mouth, nose, etc., inevitable spill in the air so that the its environmental issues should be paid attention. To solve its environmental issue, the superfine glass wool is processed sandwich Panels. Sound-absorption of the sandwich panels is measured in reverberation and the result is shown in Fig. 9.

The Fig. 9 shows that the sound-absorption coefficient of sandwich is high in the high frequency. In the low and mid frequency the sound-absorption is improved. In 200 Hz, the coefficient is up to 0.58, better than superfine glass wool. In 200-500 Hz the absorption coefficient increased more than 0.2. In 500-2000 Hz the absorption coefficient are over 0.76. In 500-1000 Hz the absorption coefficient are over 0.93. From the above all the sandwich has much high performance in acoustic absorption.

Research the damping of the noise and vibration by changing the structure of the air condition unit: In general, when the train running the noise of the wheel, external device could be decreased by the body structure and doors and window sealed. The noise of the ventilator and the air flow in duct must use low noise and multi-bladed centrifugal fan and silenced duct to solve. The condenser fans should choose the low revs, large flow rate, low noise axial-flow fan. What's more the sound insulation and vibration attenuation of the train body, the seal of window and door are should be enhanced. The damping of the vibration and noise in junction of the air condition and train body should be noticed.

CONCLUSION

- The acceleration of air condition has little to do with the subway speed and more to do with the vibration of fan.
- When the train driving on the viaduct bridge, the acceleration of air condition is biggish in 125 Hz and in 50-1000 Hz the vibration of air condition is obviously. When the train running underground line, as a result of the resonance of body, air condition's vibration is biggish in 630 Hz and the vibration is obviously in 125-1250 Hz.
- With the increase of the speed, the influence of the ground's second radiation on body vibration is enhanced.
- Changing structure of the air condition in important to the damping of the noise and vibration.
- The superfine gross wool which is used to air condition can achieve good results for noise reduction.

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