RESEARCH ON HVAC SYSTEM NOISE CONTROL BASED ON FEATURE ANALYSIS

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ABSTRACT: This paper presents the designing and testing of a customized medical implant for the maxillofacial area of a biocompatible alloy (Ti6Al7Nb). In order to create the plan for this implant, CT images were required, they were analyzed and processed to obtain a 3D model of STL type. This was transformed into a solid model so boolean operations could be done (3D). After obtaining the 3D solid model, a series of finite element analysis were made to identify areas with high tension rate which are necessary in the design of the new implant from the alloy. A series of finite element analysis were performed in different areas of the zygomatic bone which show cases of blows or accidents. Considering these tests, several types of implants have been designed. In developing, constructive variants was aimed to achieve a weight close to the zygomatic bone and to the maximum mechanical strength of the alloy. Following the tests with finite elements analysis, an optimal customized implant was redesigned.
KEY WORDS: customized implant, maxillofacial, titanium alloy, CREO Parametric, FEA.

1 INTRODUCTION

With the continuously development of science and technology and the improvement of the comfort requirements of life, air-conditioning system has been widely used in our daily lives and work, and the application of centralized air-conditioning system is also more popular in high-rise buildings. But after the accomplishment of many large-scale construction in the construction, there are alot of noise pollution problems during the debugging of air conditioning equipment. The impact of noise on people is mainly from two aspects. On the one hand, it impacts the building outdoor environment, on the other hand it impacts indoor staff (Phun V. K. et al.,2016). In this paper, the main research is the impact of the HVAC system equipment noise on indoor staff, especially in the residential buildings and office buildings. Because the noise will directly affect people's sleep and work efficiency in these buildings. However, the impact of air conditioning noise on people is not only determined by the size of equipment noise, it is also closely related to the environment in which the building is and the equipment running time. The ambient noise will be different in different places and different operating hours, the noise generated by the device will have different effects on people, and there will be differences in governance.

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2 THEORETICAL REVIEW

Air conditioning noise sources are various. Generally speaking, the noise source of the air-conditioning system can be divided into two aspects. The first is the indirect noise, which means that the equipment and the people are not in a living space, such as chillers, fans (including air-conditioning units), cooling towers and water pumps. The second is the direct noise, which is the air conditioning noise that direct contacts with the living space, including fan coil noise, the noise generated bu return air (Thorburn S.,2016). In the HVAC system, in addition to equipment, air conditioning pipe fittings will produce air flow noise because of the flow of gas. The main sources of HVAC equipment noise are: various types of fans, refrigeration units, pumps, fan coil, cooling towers and so on.

The frequency range that human ear can sense is 20Hz ~ 20kHz, the dynamic range that can perceive is 0 ~ 96Db. The impact of different noise on human is different. The human ear is most sensitive to 2k ~ 4kHz sound pressure level. The sensitivity of the human ear decreases with the decrease of the frequency when it is below 1kHz. So, the feeling of discomfort is not the same for the low-frequency and high-frequency noise of the same sound pressure level. The human ear is more aware of the intensity change of low-frequency sound compared with the high-frequency sound. In the actual environment, most of the low frequency sound pressure level is not high, and some of its acoustic energy may be concentrated in the hearing threshold, and covered by high frequency sound

(Lametti D. R. et al.,2014). However, once the high-frequency masking effect is reduced, low-frequency noise can easily be perceived.

In a relatively quiet environment, people can clearly hear a voice, and the hearing threshold of the human ear is very low to the voice. If there is another sound (called "masking sound"), it will affect the sound effect of the hearing heard by the human ear, then the hearing threshold will increase. The phenomenon that the auditory sensitivity of a human ear to one sound is reduced because of the presence of another sound is called the "masking effect." The number of decibels raised by the threshold is called the "masking quantity." The increased threshold is called the "masking threshold"(Rosenhouse,G., 2014). Therefore, a sound can be heard because it is beyond the hearing threshold, it also needs to exceed the ambient noise masking domain. Conversely, if a sound is not heard, a background noise is required to mask the sound.

3 METHODS

In this study, the noise of different types of air conditioning equipment is tested and analyzed, and the factors and conditions for noise control are summarized. We also summarized the noise characteristics of different air-conditioning system equipment, so that the process of noise control will be more targeted. And the masking situation of the equipment noise of the environmental noise will be considered when the equipment operates in different locations and hours. So, the governance methods and the degree will be more scientific according to the actual situation of noise management, which not only reduces the impact of equipment noise on people, and will not do unnecessary management which results in unnecessary waste. Specific monitoring methods are as follows:

During the test, the sound level meter bracket is placed at the test point, and the A-level of the noise and the linear sound level of the different center frequencies are respectively read. Linear sound pressure level does not weigh the frequency of the sound pressure level and can directly reflect the noise spectral characteristics. Some background noise is not the steady-state in the test process. For example, the vehicle type and time is uncertain when there is the road near the test point. Under the condition of the presence of uncertain factors, the SPL test value of each center frequency will have more than ten. If the noise is relatively stable in the test process, only 3-5 groups data are generally measured in order to save test time.

Noise tests were carried out in two different types places for different air-conditioning equipment in order to collect the noise of different air-conditioning systems. Two test points were a university office building and a fast hotel. University office buildings are located near highways, and the office is subject to vehicle noise. Air conditioning system uses air-cooled heat pump unit, and the fan coil is also added fresh air system. The express hotel rooms are near the street, and are surrounded by downtown, and use central air conditioning which takes the air-cooled module unit as the host. At the same time, it uses air-source heat pump for 24-hour hot water.

The sound pressure test of the air-conditioning equipment is that test A-level sound pressure and the octave frequency band sound pressure level of linear sound pressure level based on the principle of octave frequency band sound pressure level. The sound pressure level of the frequency division test is used to derive the frequency characteristics of the noise of different equipment. There is background noise during measuring the noise of the equipment, so it needs to apply to the noise superposition formula to get the real equipment noise (Li H., 2015):

$$L_p = 10\lg\left(\sum_{i=1}^{N} 10^{0.1L_{p,i}}\right) \tag{1}$$

L_p is the sound pressure level after superposition, dB.

$L_{p,i}$ is a single value of the noise level, or the noise value of the same frequency band of the superimposed noise, dB.

Because the background noise and the noise value of the equipment in the environment are mainly obtained in the test, and it needs to obtain the actual value of the equipment noise, so we use the variant of the formula (1):

$$L_{p1} = 10\lg\left(10^{0.1L_P} - 10^{0.1L_{P2}}\right) \tag{2}$$

L_{p1} is the actual value of the noise of the device after the calculation, dB.

L_p is the measured sound pressure in ambient background noise, dB.

L_{p2} is the test value of a single ambient noise, dB.

4 RESULTS

4.1. Noise test results of university buildings

There are some other office buildings around the building, and there are highways nearby, which are the major contributors to environmental noise. The air-conditioning system used in the office building is McQuay Air-cooled heat pump unit, the indoor fan coil system. An office was chosen as the test object. Figure 1 shows the relative position of the fan coil to the test point.

As shown in the figure, four tests were conducted for the test points which are 1.4 meters high in the office. The sound pressure levels of the A-level and the linear sound-level at different

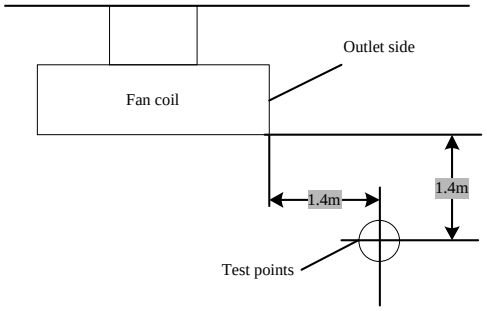

Figure 1. Schematic diagram of relative position of fan coil and test point

center frequencies are test when the unit and the fan coil are open, the fan coil unit intermittently stop, the unit is open and the fan coil is off, the unit and fan coil are both closed under the conditions that the fan of the fan coil is in the default wind. The test results are shown in Tables 1 and 2.

Table 1. Office noise test data

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A-level
Fan coil and unit are open	51.6	57.3	60.2	48.1	50.9	53.9	50.8	43.4	33.8	57.5
Fan coil is open and unit is closed	47.1	52.7	58.0	48.2	50.7	53.4	50.4	43.6	33.5	57.1
Fan coil is open, unit is closed	49.8	54.3	49.6	39.8	38.1	39.4	38.2	31.6	23.1	44.9
Fan coil and unit are closed	42.3	44.4	40.3	37.4	32.4	35.1	32.3	31.1	23.2	41.2

Table 2. Windshield test data in office

Center frequency（Hz）	31.5	63	125	250	500	1000	2000		4000	8000	A level
Default grade（dB）	47.0	57.2	58.0	48.2	50.7	53.4	50.4		43.6	33.5	56.8
First grade（dB）	44.1	52.9	58.3	47.6	50.5	53.3	50.1		42.9	33.5	56.2
Second grade（dB）	43.4	51.3	56.6	45.2	48.6	52.6	49.7		43.0	32.6	56.1
Third grade（dB）	42.7	50.2	55.1	43.9	48.7	52.6	49.4		42.5	32.1	55.3

Table 3. Noise after superposition of fan coil and unit in the office

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
Fan coil（dB）	45.8	53.0	58.8	47.6	50.6	53.6	50.4	43.2	33.2	56.9
Unit（dB）	48.8	53.8	48.9	35.7	36.5	37.2	36.7	21.5	21.0	58.1

Table 4. Values of noise after superposition from different windshields in the office

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
Default grade（dB）	45.0	51.9	57.9	47.8	50.6	53.3	50.3	43.6	33.0	56.7
High grade（dB）	38.9	52.1	58.2	47.0	50.4	53.2	50.0	42.6	33.0	56.0
Middle grade（dB）	36.1	50.2	56.5	44.2	48.5	52.5	49.6	42.7	32.0	55.9
Low grade（dB）	31.7	48.7	54.9	42.7	48.5	52.5	49.3	42.1	31.4	55.1

After superimposing the test data, the noise value of the air conditioning equipment without environment background noise is obtained, as shown in Table 3 and Table 4

The air conditioning unit of the office building was placed on the ground behind the office building, opposite to the monitoring office. The noise test was selected 1.5 meters in front of the unit and 1.2 meters high. The unit noise test data is shown in Table 5.

Table 5. Unit and pump noise

Center frequency（Hz）	63	125	250	500	1000	2000	4000	8000	A level
Unit and pump noise（dB）	76.2	70.0	70.4	71.6	71.7	67.8	66.1	58.1	76.2
Intermittent stop noise of unit（dB）	62.9	56.6	58.2	59.2	67.1	60.8	58.4	52.0	68.7
Unit noise after the superposition（dB）	76.0	69.8	70.0	71.3	69.6	66.8	65.2	56.7	75.3

4.2. Express hotel noise test results

This express hotel is located in a lively area near a university, totally five floors, of which 3 to 5 layers is the guest room area. The hotel uses central air conditioning which takes the air-cooled modular unit as the main engine, and uses the air-source heat pump for 24-hour hot water system. Air-cooled module units and air-source heat pump are placed on the roof of the 5th floor. The air source heat pump unit is one, and two air-cooled module unit. We mainly test the impact of unit and fan coil noise on personnel. Because all rooms are near the street, so the noise on the street is also an important factor affecting people.

In this hotel, we tested the noise of a fan coil on the fourth floor of a street, the roof unit and the noise generated by the unit on the fourth and fifth floor corridor. As the main function of the hotel, so we test the data at night. The test points are selected in the places where the impact on the people is large in the room, that is, the bed near the window, which is 1.5m away from the window, 1.2 meters high. The tested data are shown in Table 6 and Table 7.

Table 8 shows the results of the unit noise test conducted by the hotel.

Table 9 shows the results of the noise test on the 4th and 5th floors corridors transferred by unit.

Table 6. Fan coil noise test at night in hotel

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
First grade（dB）	59.6	57.2	46.6	44.7	42.8	41.6	37.8	30.7	23.0	47.6

Second grade（dB）	57.7	54.5	46.5	44.1	41.7	41.8	36.7	30.5	22.9	47.0
Third grade（dB）	53.0	54.6	42.5	35.6	31.5	31.9	31.2	29.8	23.0	39.4
Fan coil is closed（dB）	51.8	54.0	42.3	38.2	32.3	26.2	31.7	26.9	22.0	41.5

Table 7. The noise value of the fan coil after superposition calculation

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
First grade	58.7	58.9	44.4	43.5	42.3	41.4	35.7	28.2	15.3	46.2
Second grade	56.3	44.4	44.2	42.6	41.0	41.7	35.0	27.8	14.8	45.5

Table 8. Noise of the unit on the top floor

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
Night（dB）	79.3	78.5	68.2	65.2	64.2	68.8	72.3	63.5	54.6	76.2

Table 9. Noise on the 4th and 5th floors corridors transferred by unit

Center frequency（Hz）	31.5	63	125	250	500	1000	2000	4000	8000	A level
Fourth floor	61.0	60.4	50.2	42.5	36.4	38.9	42.7	33.4	23.3	47.0
Fifth floor	64.9	63.4	48.9	47.9	44.5	49.8	53.2	42.8	30.0	56.2

4.3. Noise spectral characteristics

The unit noise spectrum characteristics is shown in Figure 2.

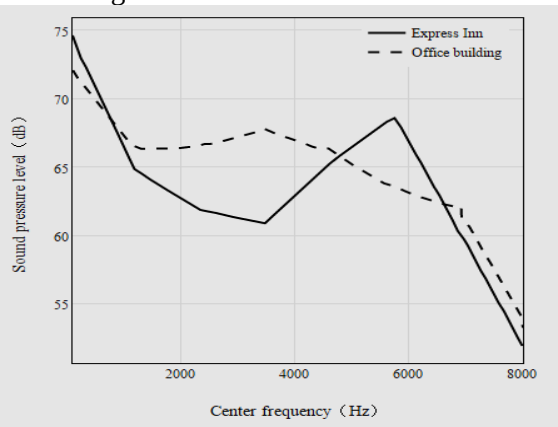

Figure 2. Air-conditioning unit noise spectral characteristics

Fan coil noise spectral characteristics is shown in Figure 3

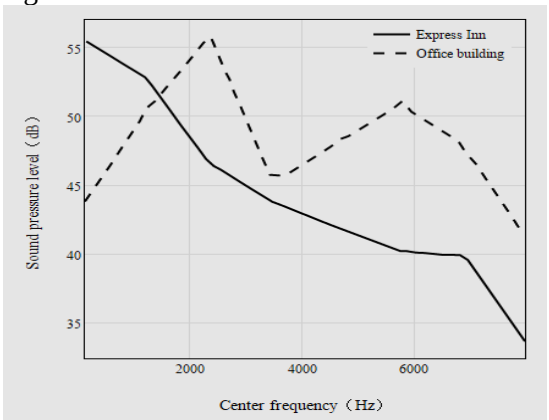

Figure 3. Spectrum characteristics of fan coil noise

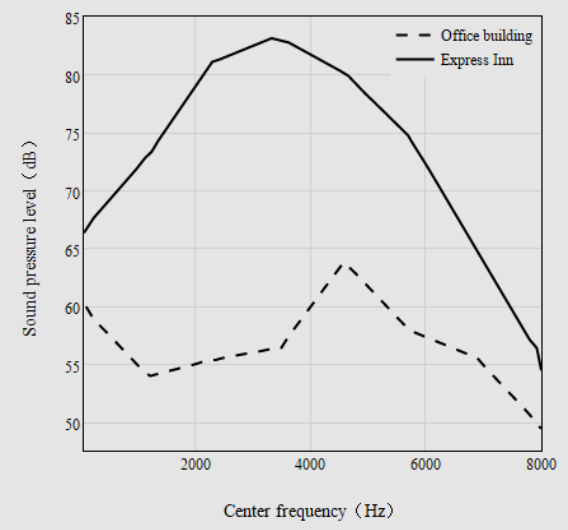

Figure 4. The noise spectrum of the pump

The noise spectrum of the pump is shown in Figure 4.

5 DISCUSSION

It can be seen from the above table and chart, under the same test conditions, when the unit is open, it has greater impact for low-frequency sound pressure value, and the main impact of unit on the office is the low-frequency noise. When the air conditioning is in different grade, the sound pressure value above 1000Hz basically has no difference. But when it is below 1000Hz, the windshield smaller, the smaller the noise, indicating that the fan mainly impacts the low frequency noise, which further illustrates that the noise of the office is mainly from the sound of water. So, it also explains why the hotel fan coil noise is mainly showing a low frequency, and the office has the low-frequency and high-frequency noise. In addition, the impact of the hotel unit noise on the 5th floor is significantly greater than that on the 4th floor, especially the high-frequency part. The difference of low-frequency part is little because the unit has produced a strong vibration, and this noise is transmitted to the whole hotel building with the vibration. The hotel fan coil noise source is mainly from the fan noise, and the fan noise generally shows low frequency characteristics. The fan coil in office appears in the high-frequency characteristics because there is a greater water sound in coil.

According the above analysis we can see that the noise in the office is mainly from the sound of the water, which is unconventional noise. So, we cannot directly use conventional air conditioning noise reduction method, and should consider that it is caused by too much bubble in coil, and we can discharge the air in the pipeline to achieve the purpose of noise reduction. The noise in the hotel comes from the conventional fan coil noise, so we can use silencers and other conventional means to realize noise reduction.

6 CONCLUSION

In this paper, we tested the noise of air conditioning system equipment in two different types of buildings, and analyzed the spectrum characteristics of each air conditioning equipment. Then we put forward the noise control suggestion for HVAC equipment according to the specific situation of the project.

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