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Structural Parameters Analysis of Sound Absorption Films in Industrial Gas Turbine Muffler

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Abstract. Aerodynamic noise is the main noise source produced by industrial gas turbines. It brings harm to production and life. Muffler is the key component to suppress aerodynamic noise. In this paper, the influence of the structure parameters such as the diversion angle, films number and porosity of the absorber for the noise reduction effect is studied, which provides the basis for the structure design and optimization of the muffler.

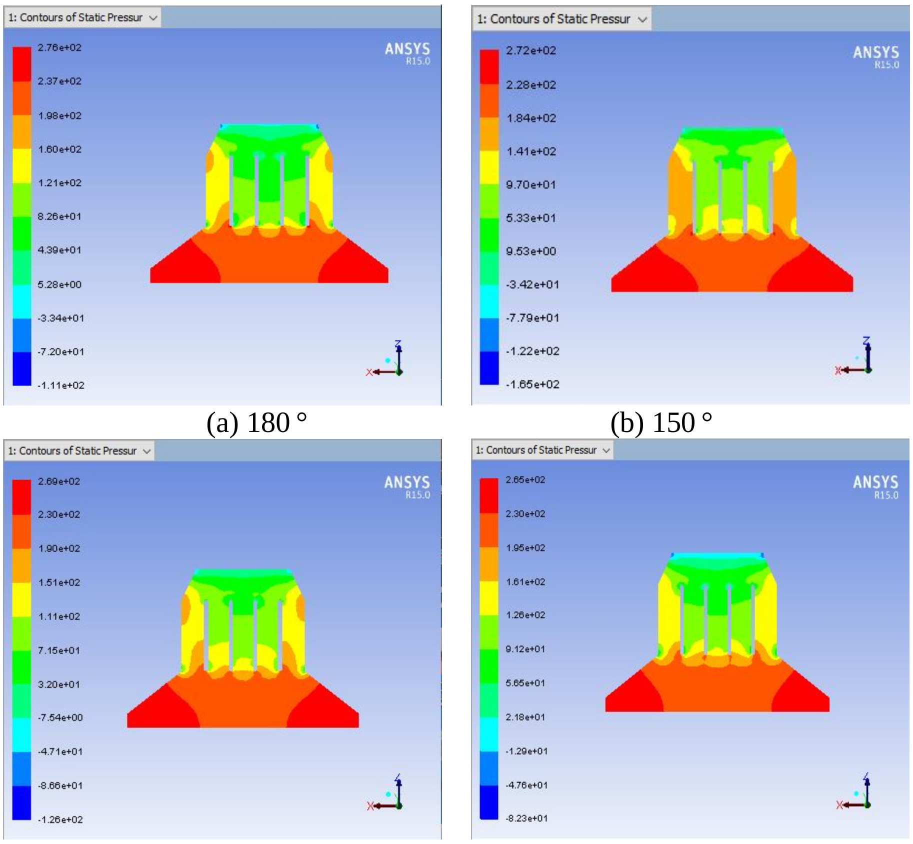
1. Introduction

Industrial gas turbine is an advanced and complex set of power machinery and equipment [1]. It is high-power and high-performance power machine that rely on high-temperature gas to drive turbo machinery continuously with air as the medium [2]. However, due to the air flow in the gas turbine pipeline, it produces eddy current, impact, or sudden change of pressure, resulting in air disturbance and a large number of noises [3]. Mufflers are used in air pipes of industrial gas turbine to absorb sound. As the most important part of the muffle, the sound absorption films determine the efficiency of noise reduction of the muffle. Therefore, it is of great significance to study the structural parameters of the sound absorption films.

2. Influence of Diversion Angle

The structure parameters analysis of the sound absorption films involves gas flow, acoustics, materials and other subjects, which is a complex problem. The design of mufflers is usually guided by one-dimensional plane wave theory. However, when the frequency is high, the results of one-dimensional plane waves are not accurate and are not applicable. Compared with it, the results of the three-dimensional numerical method are more accurate, the analysis efficiency is higher, and the cost is lower [4-5].

In order to understand the flow field and acoustic characteristics of sound absorption films in industrial gas turbine muffler, the intake pipe flow field of a gas turbine in an environmental protection equipment company was taken as the research object. The flow field and acoustic field of the intake pipe were simulated and analyzed by computational mechanics (CFD) and acoustic finite element method (Acoustics-FEM). Fig. 1 shows that the velocity of the flow field increases gradually with the inlet to outlet, especially in the inner space of the muffler. The overall velocity of the flow field decreases with the decrease of the diversion angle of the muffler. The high-speed flow area at the outlet increases gradually with the decrease of the diversion angle of the muffler. Therefore, the reduction of the diversion angle of the anechoic plate will lead to a small overall decrease of the flow velocity and increase the size of the high-speed air flow area at the outlet. The turbulence intensity at the inlet and outlet of the muffler is higher than that in other areas. Except that the turbulence intensity of the duct with 150 degree guide angle muffler is higher than that of the assembly site muffler, the turbulence intensity of the duct with other guide angles decreases with the decrease of the guide angle of the muffler. The intensity turbulence region increases with the decrease of the diversion angle of the muffler, so the decrease of the diversion angle will reduce the overall turbulence intensity of the flow field and increase the turbulence intensity of the muffler inlet and outlet.



(a) 180 ° (b) 150 °

(c) 120 ° (d) 90 °

Figure 1. Pressure distribution of sound absorbing films with different diversion angle

Table 1 shows that the pressure loss in the flow field of the anechoic tube fitted with the anechoic plate of each diversion angle is up to work. The variation rule is that the pressure loss increases gradually with the diversion angle of the sound absorbing films. The distortion parameters of the flow field in a duct with a 90 degree diversion angle anechoic plate are up to work. The variation rule is that the distortion parameters of the flow field will increase gradually with the diversion angle of the anechoic plate at first, but when the diversion angle of the anechoic plate is close to the plane angle, the distortion parameters of the flow field hardly change. Therefore, reducing the diversion angle of the sound absorbing films can reduce the flow resistance of the anechoic tube and improve the flow uniformity.

Table 1. Pressure loss of sound absorbing films with different diversion angle

Diversion angle (°)	**Loss(Pa)**	**Distortion**
180	253	2.61
150	249	2.61
120	247	2.52
90	242	2.43

3. Influence of Sound Absorbing Films Number

Except that the overall velocity of the flow with five pieces of sound absorbing films is less than that with four pieces of sound absorbing materials, the overall velocity of the flow field in the anechoic tube with other numbers of sound absorbing films increases with the increase of the number of sound absorbing films, especially near the center of the muffler. Therefore, increasing the number of sound absorbing films can increase the overall flow velocity in the pipe, especially in the area near the center of the muffler.

On the whole, the turbulence intensity at the inlet and outlet of the muffler is higher than that in other areas. Except that the overall turbulence intensity of the muffler with 7 pieces of sound absorbing films is higher than that of the muffler with 6 pieces of sound absorbing films, the overall turbulence intensity of the muffler with other pieces decreases with the increase number of the sound absorbing films. Therefore, increasing the number of sound absorbing films can reduce the overall turbulence intensity of the flow field. However, when the number of sound absorbing films increases to a certain amount, it will increase the overall turbulence intensity of the flow field.

Table 2. Pressure loss of sound absorbing films with different number of films

Number	Loss(Pa)	Distortion
4	253	2.61
5	265	2.50
6	280	2.60
7	290	2.58

Table 2 shows that the pressure loss of the anechoic tube assembled with different amount of sound absorbing films does not meet the requirements. The variation rule is that the pressure loss increases significantly with the increase of the number of sound absorbing films. The flow field distortion parameters of the pipes with 5 sound absorbing films can meet the requirements. Therefore, reducing the number of sound absorbing films to 5 pieces can effectively decrease the pressure loss of the flow field.

4. Influence of Sound Absorbing Films Porosity

When the sound wave propagates to the pores of the sound absorbing films, it will cause the small vibration of the fiber in the films. Because of the inhomogeneous distribution of the pores in the sound absorbing films and the friction and viscous resistance of the air, it will make the sound energy incident into the sound absorbing material into thermal energy and be absorbed. If the thickness of sound absorbing films is not enough, it will lead to incomplete absorption of sound energy. Although the noise reduction performance of muffler will increase with the thickness of sound absorbing films, when the thickness of the sound absorbing films increases to a certain value, the increase of noise reduction performance will gradually decrease. Considering the cost and the influence on the characteristics of pipeline flow field, if the thickness of sound absorbing films continues to increase, it will cause unnecessary waste and reduce the flow field characteristics of the pipeline.

	A	B	C
1	Frequency	Real	Imaginary
2	20	7.00E-13	9.89E-12
3	40	9.90E-13	1.98E-11
4	60	1.21E-12	2.97E-11
5	80	1.40E-12	3.96E-11
6	100	1.57E-12	4.94E-11
7	120	1.72E-12	5.93E-11
8	140	1.85E-12	6.92E-11
9	160	1.98E-12	7.91E-11
10	180	2.10E-12	8.90E-11
11	200	2.21E-12	9.89E-11
12	220	2.32E-12	1.09E-10
13	240	2.43E-12	1.19E-10
14	260	2.53E-12	1.29E-10
15	280	2.62E-12	1.38E-10
16	300	2.71E-12	1.48E-10
17	320	2.80E-12	1.58E-10
18	340	2.89E-12	1.68E-10
19	360	2.97E-12	1.78E-10
20	380	3.05E-12	1.88E-10
21	400	3.13E-12	1.98E-10
22	420	3.21E-12	2.08E-10
23	440	3.28E-12	2.18E-10
24	460	3.36E-12	2.27E-10
25	480	3.43E-12	2.37E-10
26	500	3.50E-12	2.47E-10
27	520	3.57E-12	2.57E-10
28	540	3.64E-12	2.67E-10
29	560	3.71E-12	2.77E-10
30	580	3.77E-12	2.87E-10
31	600	3.84E-12	2.97E-10
32	620	3.90E-12	3.07E-10
33	640	3.96E-12	3.16E-10
34	660	4.02E-12	3.26E-10
35	680	4.08E-12	3.36E-10
36	700	4.14E-12	3.46E-10
37	720	4.20E-12	3.56E-10
38	740	4.26E-12	3.66E-10
39	760	4.32E-12	3.76E-10
40	780	4.37E-12	3.86E-10
41	800	4.43E-12	3.96E-10
42	820	4.48E-12	4.05E-10
43	840	4.54E-12	4.15E-10
44	860	4.59E-12	4.25E-10
45	880	4.65E-12	4.35E-10
46	900	4.70E-12	4.45E-10
47	920	4.75E-12	4.55E-10
48	940	4.80E-12	4.65E-10
49	960	4.85E-12	4.75E-10
50	980	4.90E-12	4.85E-10
51	1000	4.95E-12	4.94E-10

Figure 2. Pressure distribution of sound absorbing films with different diversion angle

An acoustic finite element model of pipes was built up by ICEM. The simulation results are shown in Fig.2. It can be found that, as the porosity of the sound absorbing material increases, the transmission loss value of the pipeline increases gradually and moves to the low frequency area gradually. The noise attenuation of the pipeline assembled with various porosity in the range of 20-60Hz and 180-300Hz is less than 50dB, which does not meet the requirement. The effect of porosity of sound absorbing material on transmission loss of pipeline increases with the increase of frequency, especially in the range of 20-180Hz, the transmission loss curve of pipeline is almost unchanged. Therefore, the increase of porosity of the sound absorbing films can only slightly increase the muffler volume in the medium frequency range. The flow resistance of sound-absorbing materials has a great influence on the valley value and its adjacent range of the transmission loss curve of the pipeline, and the anechoic value increases with the increase of the flow resistance, while the flow resistance has a little influence on the peak value of the transmission loss and its adjacent frequency range.

5. Conclusion

The simulation results show that the diversion angle has little effect on the sound absorption, and only the anechoic Valley and its nearby frequency value decrease slightly with the decrease of the diversion angle. With the increase of the number of sound absorbing materials, the effect of noise reduction is significantly increased. On the other hand, the pressure loss and flow uniformity decrease with the increase of the number of sound absorbing materials and porosity.

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