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Analysis of Sound Field Transfer Loss in Inlet Pipeline of Industrial Gas Turbine

Jiangang Yi[1,*] and Siwei Ju[1]

[1] School of Electromechanical and Architectural Engineering, Jianghan University, Wuhan 430056, China
469883553@qq.com

Abstract. Taking an industrial gas turbine intake pipeline as the research object, the acoustic field of the intake pipeline is simulated and analyzed by using acoustic finite element method, and the internal acoustic field and transmission loss of the intake pipeline are calculated. Through simulation analysis, it is found that the transmission loss curve of gas turbine intake pipeline fluctuates greatly, and the frequency bandwidth of the peak muffler is narrow. The conclusions obtained provide a theoretical basis for optimizing the structure of industrial gas turbine intake pipeline.

1. Introduction

Industrial gas turbine (IGT) is a kind of internal combustion power machine, which uses continuous flowing gas as working fluid to drive the impeller to rotate at high speed and convert the energy of fuel into useful power. As one of the most important components of chemical gas turbine, intake pipeline, which makes air flow through the intake system of gas turbine, will form contraction, expansion and other flow, resulting in the change of air density and pressure in the pipeline. It can produce pressure wave. In the process of pressure wave propagation, air noise is formed. It not only seriously reduces the production efficiency, but also brings noise pollution. In order to solve this problem, this paper takes the sound field of the industrial gas turbine inlet pipeline as the research object, and analyses its transmission loss status, so as to provide conceptual support for energy saving and noise reduction.

2. Working Process

Figure 1 shows a schematic diagram of an industrial gas turbine. Air flows into the combustion chamber from the inlet of the intake pipeline through the contraction section and the compressor impeller of the gas turbine. The gas is discharged by the gas turbine after full combustion. The intake pipe is composed of two straight pipes and two tapered shrinkage pipes. The inlet diameter is 6.8m, the outlet diameter is diameter is 2.8m, the total length of the pipe is 4.42m, and the wall thickness of the pipe is 5mm.

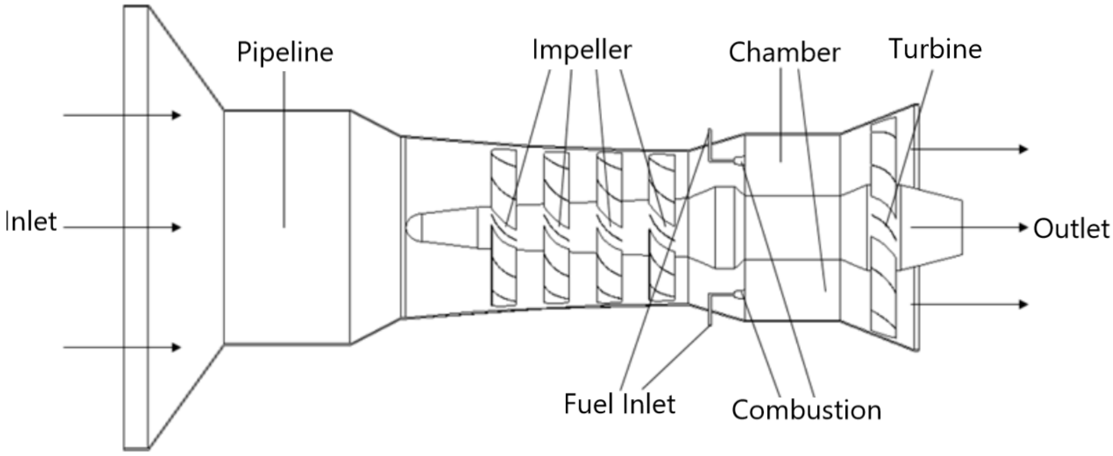

Figure 1. Industrial Gas Turbine

As shown in Figure 2, the length, width and height of the fluid microelement at the entrance of the block are dx, dy, dz. Respectively, the mass of micro-elements flowing into X direction is $\rho u_x dydz$, and the mass of micro-elements flowing out is $\rho(u_x + \frac{\partial u_x}{\partial x}dx)dxdy$. The the mass of micro-elements in X direction caused by medium flow changes to $-\rho\frac{\partial u_x}{\partial x}dxdydz$, and the mass of micro-elements in Y direction and Z direction is $-\rho\frac{\partial u_y}{\partial y}dxdydz$ and $-\rho\frac{\partial u_z}{\partial z}dxdydz$. The microelement obeys the law of conservation of mass, so the variable of mass is equal to the rate of change.

$$-\rho\left(\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} + \frac{\partial u_z}{\partial z}\right)dxdydz = \frac{\partial}{\partial t}(\rho dxdydz) \tag{1}$$

Assume $\nabla = \frac{\partial}{\partial x}i + \frac{\partial}{\partial y}j + \frac{\partial}{\partial z}k$, then the continuous equation of the sound wave obtained is as following.

$$\frac{\partial \rho}{\partial t} + \nabla \rho u = 0 \tag{2}$$

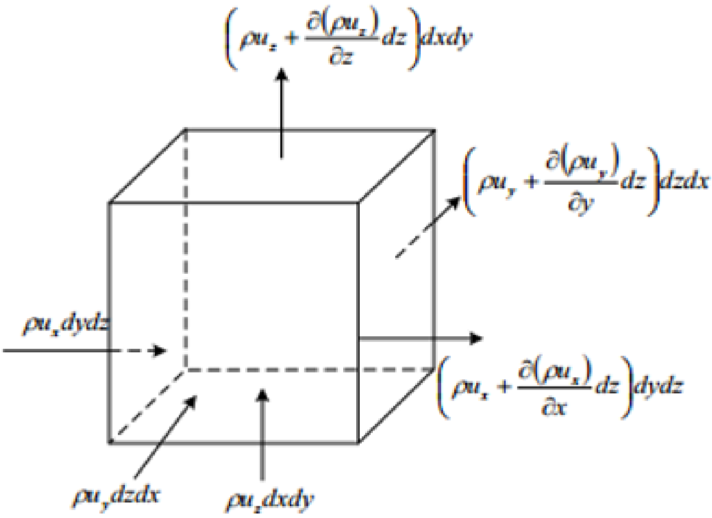

Figure 2. Fluid Microelement

3. Simulation and Calculation

There are three main evaluation indicators of acoustic performance: transfer loss, end noise reduction parameters and insertion loss. Among them, the calculation of insertion loss and other indicators needs to define the sound source and acoustic impedance characteristics. Generally, the parameters of sound source and acoustic impedance characteristics are obtained from physical experiments. However, the transmission loss is the acoustic characteristic of the research object itself, which does not need the definition of sound source and acoustic impedance characteristics. Due to the limitation of conditions, this paper uses the transmission loss to analyze and evaluate the acoustic performance of gas pipelines.

Figure 3 is schematic diagram of the theoretical model of transmission loss of sound field in the intake pipeline. The relationship between the incident sound pressure at x=0 and the inlet sound pressure is as following.

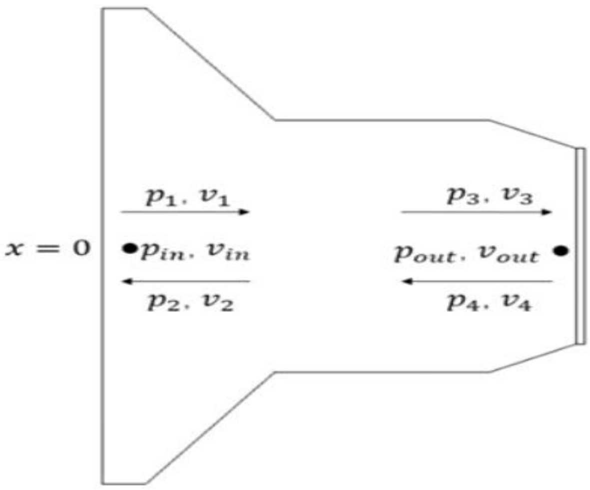

Figure 3. Landing Time Versus ξ

$$p_1 = \frac{1}{2}(p_{in} + \rho c) \tag{3}$$

When the area of the entrance section is A_{in} and the area of the exit section is A_{out}, the sound power of the entrance plane sound wave and the exit plane sound wave is as following:

$$W_{in} = \frac{p_1^2 A_{in}}{\rho c},\ W_{in} = \frac{p_3^2 A_{out}}{\rho c} \tag{4}$$

The formula for calculating the transmission loss defined is as following:

$$TL(db) = 10log\left(\frac{p_1^2}{p_3^2}\frac{A_{in}}{A_{out}}\right) \tag{5}$$

4. Simulation and Analysis

In the acoustic simulation calculation, the unstructured linear mesh generation method is used, as shown in Figure 4. The velocity of particle vibration at the entrance of airflow is known. Because the wall of intake pipeline is rigid and the incident sound wave is plane wave, it is impossible to transmit the internal sound wave to the outside world, so the sound wave will completely reflect at the wall of the pipeline, only from the outlet of the pipeline to the outside space. Considering the influence of the flow of sound transmitting medium on the acoustic performance, it is necessary to calculate the average flow velocity in the pipeline before calculating the acoustic transmission loss at the entrance and exit and the radiated noise at the exit. Flow boundary condition is used to calculate the average flow velocity, in which the inlet flow velocity of the intake pipe is given and the average distribution is given. Because the normal direction of the acoustical grid points to the outside of the grid, the inlet velocity is set to -3m/s and the flow velocity type is set to Flow Velocity. The results of the flow field inside the intake

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pipeline are obtained by calculation. The internal velocity vector distribution is shown in Fig. 5. The maximum particle velocity of the flow field is 27m/s. The center of the inlet and outlet face of intake pipeline is defined as the acoustic input point and the acoustic output point (Output Point). The acoustic pressure response data of the inlet and outlet points are obtained. Based on the transfer loss theory, the transfer loss at the inlet and outlet ends of intake pipeline is calculated by using the formulas mentioned above, as shown in Figure 6. From the figure, it can be seen that the transmission loss curves of 260-700Hz and 820-1000Hz fluctuate greatly, and there are many peaks with narrow bandwidth, among which the maximum value of transmission loss occurs at 980Hz, which is 31.434dB.

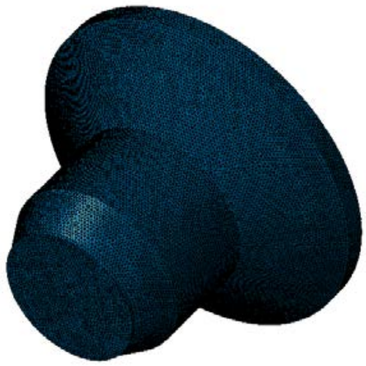

Figure 4. Sound Field Model of Intake Pipeline

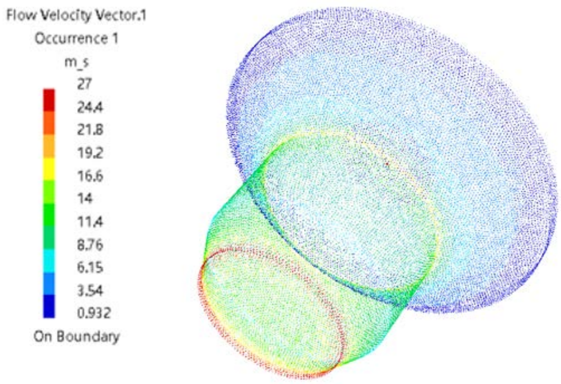

Figure 5. Velocity Vector Distribution of Sound Field in Intake Pipeline

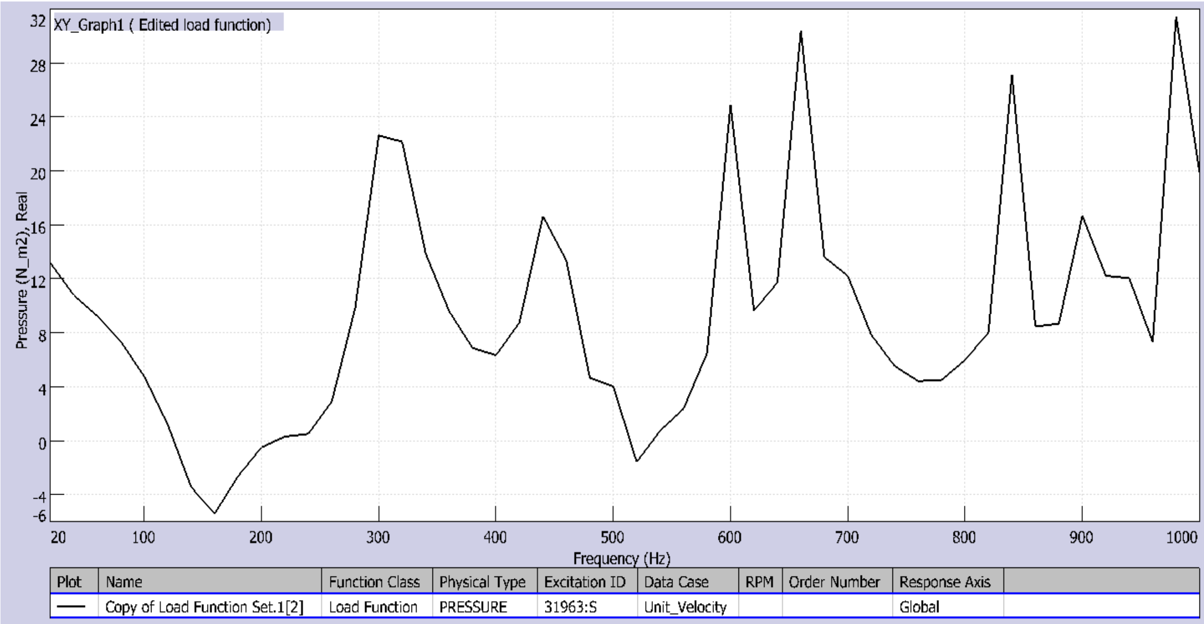

Figure 6. Acoustic Field Transmission Loss of Intake Pipeline

5. Conclusions

Gas turbine is the core equipment in industry, and the design of its intake pipeline is the key link of the overall design. By simulating the sound field of gas turbine intake pipeline, this paper analyses the sound field characteristics of intake pipeline and calculates the transmission loss of sound field. The calculation model is simulated and analyzed by using the finite element tool of sound field, and the transmission loss curve of sound field is established. The conclusion provides a reference and comparison basis for the optimization of pipeline structure. It is of great significance to understand the distribution of noise in intake pipeline and take pertinent noise reduction measures.

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