ANALYSIS OF AERODYNAMIC NOISE OF ELBOW PIPE AT WELL SITE

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ABSTRACT

Numerical simulation of an elbow pipe of ground pipeline at a well site is conducted by Fluent ,a CFD(Computational Fluid Dynamics) software, to study it's aerodynamic noise. Analysis of elbow pipe's fluid domain, sound domain and frequency spectrum is done to study the generating principle and spreading regulation of it's aerodynamic noise, in order to provide theoretical support of elbow pipe's design and reformation.

Key Words: Aerodynamic noise; flow field simulation; elbow pipe.

1 Introduction

Flow state of fluid will be changed when passing through elbow pipe, resulting in eddy diffusion at the same time. Meanwhile ,with the friction effect between fluid and wall of pipe, fluid dynamic noise is generated, it is also called aerodynamic noise[1].Considering the elbow pipe is an essential device at well site,CFD simulation of elbow pipe is conducted based on its original model at well site in this paper, to studdy the generating principle of it's aerodynamic noise.

2 Theoretical analysis of CFD

LES(Large Eddy Simulation) in Fluent is applied to do transient simulation of flow field. In order to promote convergence, the initial condition of LES is results of steady simulation based on standard k-ε equation. In the LES, turbulence is classified into vortex with different scales,filter function is established at first, vortex with bigger scale than filter function is solved by N-S equation directly[2],while the other vortex is filtered to ensure that extra stress is added into kinematic equation of vortex with bigger scale, dissipative effects exerted on big vortex by small one are realized in this way[3].This filter function is called SubGrid-Scale model(SGS).

Navier-Stokes equation is :

$$\frac{dv}{dt}=f-\frac{\nabla p}{\rho}+\mu\nabla^2 v+\frac{\mu}{3}\nabla(\nabla v) \quad (1)$$

ρ is density of fluid,f is volume power of mass flow rate per unit,v is velocity of fluid,t is flowing time,p is pressure of fluid, μ is dynamic coefficient of viscosity.

Control equation of SGS is:

$$\frac{\partial \bar{u}_i}{\partial t}+\frac{\partial \bar{u}_i \bar{u}_j}{\partial x_j}=-\frac{1}{\rho}\frac{\partial \bar{p}}{\partial x_i}+v\frac{\partial^2 \bar{u}_i}{\partial x_j \partial x_j}-\frac{\partial \bar{\tau}_{ij}}{\partial x_j} \quad (2)$$

$$\frac{\partial \bar{u}_i}{\partial x_i}=0 \quad (3)$$

$$\bar{\tau}_{ij}=\bar{u}_i \bar{u}_j-\overline{u_i u_j} \quad (4)$$

$\bar{\tau}_{ij}$ is sub-grid-scale stress,superscript "－" shows the variable filtered by filter function.

3 CFD simulation

3.1 Model for simulation

Real model and SPL(sound pressure level) distribution of a pipe at a well site is shown in Fig.1.

Fig.1 Model of pipe

In this paper,model for CFD simulation is only confined in elbow pipe. The internal diameter of the pipe ,D is 154.1m;,the length of straight pipe in the upstream is 5D, 770.5mm,;the length of straight pipe in the downstream is 10D,1541mm; bending radius of elbow pipe is R=1.5D,231.15mm,;angle of bending is 90°, “θ”is polar angle, and the polar angle of elbow pipe at inlet of mainstream is definedθ=0°, polar angle of elbow pipe at outlet is 90°. coordinate origin “O” is located at the center of bending radius. According to the field pipeline operation parameters, material of fluid domain is CH_4,of which the density $\rho = 0.72\,Kg/m^3$,kinematic viscosity $\mu = 1.087\times10^{-5}\,Pa\cdot s$ .velocity of inlet of elbow pipe is 10m/s,pressure of outlet is 8MPa,wall of pipe is defined as no slip wall. U_0 and U mean longitudinal distance of axis along the direction of elbow pipe,2D model of elbow pipe and mesh for simulation is shown in Fig.2 and Fig.3.

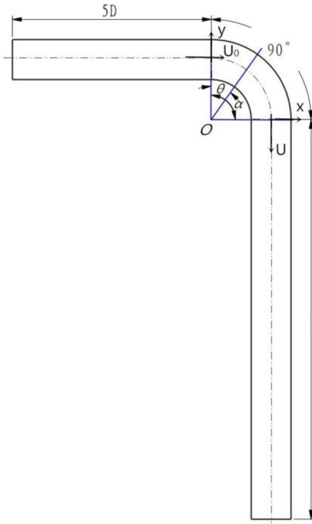


Fig.2 2D model of elbow pipe

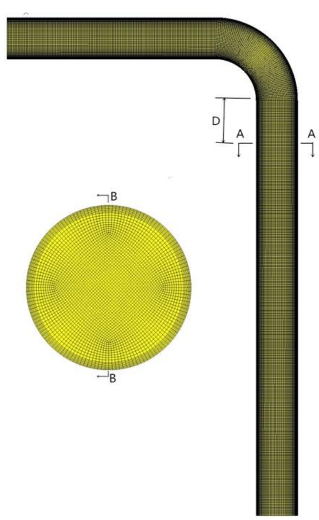


Fig.3 Mesh of elbow pipe

3.2 Result of fluid domain simulation

Section B-B is chosen as analyzing target,Fig.4 and Fig.5 show the pressure and velocity contour of section B-B.In the pressure contour it can be seen that: the pressure near outer wall is higher than that near inner wall at the bending part of elbow pipe. In the contour of velocity, compared with Fig.4,yet the velocity near inner wall is higher than that of outer wall at the same place. The velocity of fluid near inner wall tends to increase at the inlet of bending part. There is a separation point of velocity when polar angle is of high velocity decreases gradually.

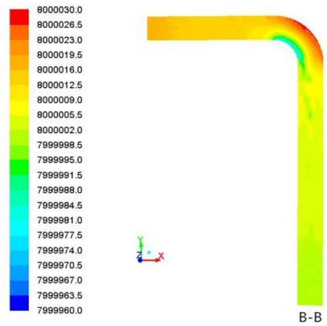


Fig.4 Contour of pressure at B-B

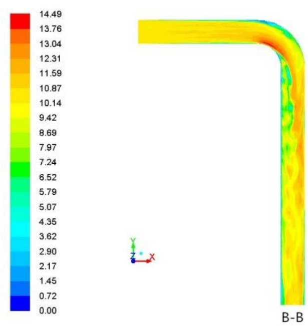


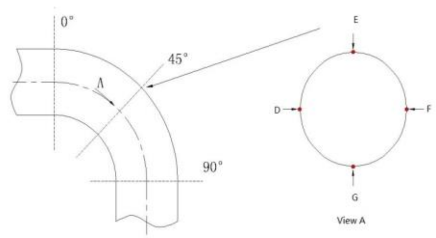
Fig.5 Contour of velocity at B-B

During the process from θ=0°to θ=30°,velocity of fluid near inner wall increases gradually, due to axis pressure of fluid lowers down at the same time. Meanwhile contrary to flowing conditions near inner wall, velocity of fluid near outer wall decreases along with increasement of pressure.In the 60°.Fluid with high velocity flows to outer wall,in the straight pipe in the downstream of elbow pipe, fluid with high velocity appears near the outer wall of straight pipe,and zone

process from θ=60°to θ=90°,fluid with high velocity flows to inner wall in bending part of elbow pipe. There is a secondary flow at cross section due to effect of centrifugal force, and fluid in center of elbow pipe diffuses outward[4],fluid near upper and lower wall spreads to inner wall so that there is a pair of small vortex near inner wall.S o it can be concluded that vortex of sections in elbow pipe tends to be more distinct with the increasement of bending angle, and the vortex generated in the elbow pipe moves from inner wall to outer wall[5].

4 Analysis of sound field

3 sections of pipe is chosen when θ=0°、θ=45°、θ=90°respectively, and 4 monitoring points at upper wall, outer wall, lower wall and inner wall are set at every section, in order to get information about frequency spectrum of every monitoring points, which are shown in Fig.6.

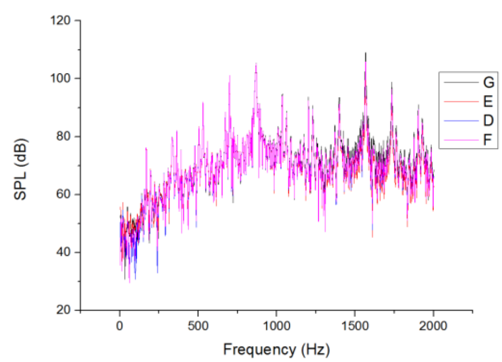


D-upper wall E-outer wall F-lower wall G-inner wall

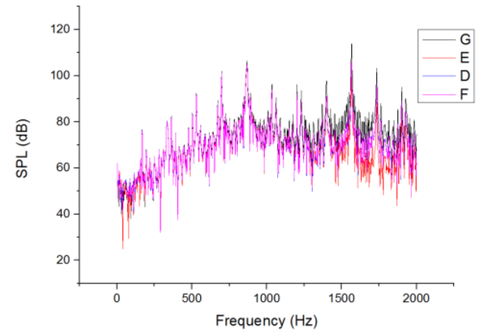
Fig.6 Monitoring points at wall of pipe

From Fig.7,on the 3 sections, the peak

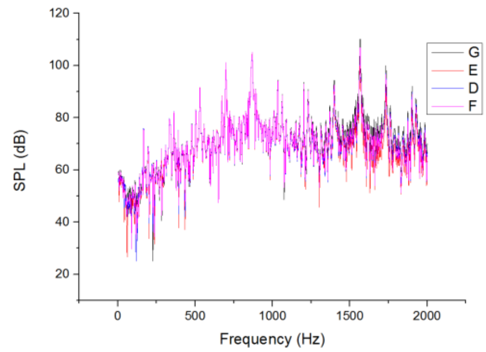
SPL of aerodynamic noise of elbow pipe is relatively high when frequency band stands around 700Hz、850Hz、1550Hz、1700Hz.On the section θ=45°, the highest value of SPL reaches 113.94dB when frequency is 1550Hz.In the range from 0Hz ~800Hz,SPL of 4 monitoring points at 3 sections raises with frequency's increasement[6],SPL of 4 points at every section rarely changes. Whereas, In the range from 800Hz~2000Hz,SPL of all points at 3 sections raises with frequency's increasement, and the valve of SPL fluctuates without instinct regulation.The most severe fluctuation appears at the section θ=45°.Fluctuation of SPL on every section of upper wall and lower wall is basically same, yet fluctuation on inner and outer wall is different: SPL of points at inner wall is clearly higher than that at outer wall[7].



(a) SPL of monitoring points at θ=0°



(b) SPL of monitoring points at θ=45°



(c) SPL of monitoring points at θ=90°

Fig.7 SPL of monitoring points at 3 sections

Table.1 Highest and average SPL of monitoring points

Section	Highest SPL（dB）				Average SPL（dB）			
	G	E	D	F	G	E	D	F
0°	110.23	105.11	106.46	106.45	70.92	68.60	69.62	69.57
45°	113.94	103.37	105.76	105.94	72.46	67.34	69.38	69.34
90°	110.28	103.20	106.49	106.96	70.79	68.27	69.38	69.49

Moving status of fluid in pipe changes when passing through bending pipeline due to the existence of secondary flow and eddy flow. disturbance near inner wall is more severe when compared with outer wall, disturbance near upper and lower wall tends to be symmetric[8],yet which is lower than that near inner wall, resulting in SPL near inner wall is higher that that near upper and lower wall. On the section θ=45°,the highest SPL near inner wall reaches 113.94dB,the lowest SPL near outer wall is 103.37dB.Speaking of the other place, upper and lower wall, the difference among SPL of monitoring points on 3 sections is small.4 points on every section show a same changing tendency:SPL near inner wall is highest,while lowest value of SPL appears near outer wall, and this tendency is same as result of fluid simulation discussed before.

5 Conclusion

According to analysis of CFD simulation' result of elbow pipe at a well site, of which the bending radius is 231.15mm,bending angle is 90°,it can be concluded that the main reason for causing aerodynamic noise of elbow pipe is secondary flow and eddy flow, which is also responsible for energy loss of fluid in the pipe. According to analysis of sound field, the most severe fluctuation apprears on section θ=45°,resulting in highest value of SPL,113.94dB,the noise pollution scattered from this noise source is much higher than what is confined by environmental protection law,so it is essential to take measures to control and lower down aerodynamic noise cause by elbow pipe at well site.

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