Bentham OPEN - Policies

All articles are freely available and immediately accessible online upon publication.

Readers can study, download and/or print OPEN access articles at no cost.

Bentham OPEN follows the single blind peer-review procedure for submissions of all manuscripts to its journals. Single blind is the most common type of peer-reviewing in which the identity of the reviewers is not disclosed to the authors of the submitted manuscript concerned. The anonymity of reviewers allows for objective assessment of the manuscript by reviewers and also free from any influence by the authors on the reviewers' comments.

All submitted articles are subject to an extensive peer review in consultation with members of the Journal Editorial Board and independent external referees; (usually three reviewers). All manuscripts are assessed rapidly and the decision based on all the peer reviewers' comments, taken by the Journal Editor-in-Chief, is then conveyed to the author(s).

All efforts are made to expedite the peer review process leading towards timely publication.

Authors publishing with Bentham OPEN retain the copyright to their work.

Authors have the flexibility to publish a wide range of articles in a Bentham OPEN journal e.g. short communications, full-length research and review articles, supplements, conference proceedings, and case studies.

Ethical Approval of Studies and Informed Consent: For human or animal experimental investigations, it is a prerequisite to provide a formal review and approval, or review and waiver, by an appropriate institutional review board or ethics committee and should be documented in your paper. For investigations undertaken on human subjects, the manner in which the informed consent was obtained from the study participants (i.e., oral or written) should be stated in the Methods section. Authors are encouraged to obtain patient consent when they use confidential case material. Consent is not necessary in the case of very brief case vignettes which do not contain identifying information or if the case material is disguised sufficiently to prevent identification of the patient. In obtaining consent, the author(s) should discuss the purpose(s) of publication, the possible risks and benefits to the patient and the patient's right to withhold or withdraw consent. In the case of a minor patient, consent should be obtained from the parent(s) or guardian(s) and assent should be obtained from the patient.
The Open Mechanical Engineering Journal

Volume 8, 2014

BENTHAM OPEN publishes over 230 plus peer-reviewed open access journals. These free-to-view online journals cover all major disciplines of science, technology, médecine and social science.
# Table of Contents

[DOI: 10.2174/1874155X01408010899]
**Study on Fluid-Structure Interaction for the Multistage High Speed Centrifugal Pumps Rotors**
*Tian Yabin, Wang Jing, Wang Liang*  
Pp 899-903

[DOI: 10.2174/1874155X01408010904]
**Turbulent Mass Transfer Optimization Control Technology in Coalmine**
*Shufang Wang, Zhiyong Yang, Yeming Zheng*  
Pp 904-909

[DOI: 10.2174/1874155X01408010910]
**Analysis of Local Vibration for High-Speed Railway Bridge Based on Finite Element Method**
*Wenjun Luo*  
Pp 910-915

[DOI: 10.2174/1874155X01408010916]
**Research of Fault Diagnosis of Belt Conveyor Based on Fuzzy Neural Network**
*Yuan Yuan, Wenjun Meng, Liyong Zhang, Xiaoxia Sun*  
Pp 916-921

[DOI: 10.2174/1874155X01408010922]
**Application of Resonance Demodulation in Rolling Bearing Fault Diagnosis Based on Electronic Resonant**
*Zhe Wu*  
Pp 922-929

[DOI: 10.2174/1874155X01408010930]
**Innovative Design Strategy Based on Customer Requirements**
*Chen Wang, Wu Zhao, Zhiyong Wang, Kai Zhang, Xiaolong Li, Xin Guo*  
Pp 930-935

[DOI: 10.2174/1874155X01408010938]
**The Application of Wave Energy Converter in Hybrid Energy System**
*Song Ding, Duanfeng Han, Yingfei Zan*  
Pp 936-940

[DOI: 10.2174/1874155X01408010941]
**Experimental Research and Analysis of Vortex Excited Vibration Suppression of Spiral Stripe Strake**
*Zhongguo Yang*  
Pp 941-947

[DOI: 10.2174/1874155X01408010948]
**Research on Test Method of Self-Propelled Agricultural Machine Based on Virtual Reality**
*Jinmei Wu, Han Peng, Chuangang Wang*  
Pp 948-953

[DOI: 10.2174/1874155X01408010954]
**Electric Vehicle Charging Load Model Based on Diffusion Theory**
*Han Peng, Jinmei Wu, Lu Wang*  
Pp 954-959
The Flow Noise Characteristics of a Control Valve
Xin Nie, Yangyang Zhu, Lei Li
Pp 960-966

Theoretical Research on Load Capacity of Double-Roller Enveloping End Face Engagement Worm Gear
Kai Wang, Jin Yao, Jueling Wang, Jinge Wang, Xingqiao Deng
Pp 967-973

Research on Backflow Region Length of Sudden-Enlarge Oil Tube Flows
Jiahong Wang, Wanzheng Ai
Pp 974-976
The Flow Noise Characteristics of a Control Valve

Xin Nie*, Yangyang Zhu and Lei Li

Mechanical Engineering Institute, Hangzhou Dianzi University, Hangzhou 310018, Zhejiang Province, China

Abstract: Using the enterprise’s valve as the research object, the research shows the characteristics of the flow field and noise of the valve. The theory of LES and Lighthill acoustic analogy is applied to study the flow noise characteristics of 100% opening and 70% opening of valve in the same flow. The result shows that the region of variation about pressure and velocity is concentrated in the valve sleeve window. The sound pressure spectrum characteristics of the same group of monitoring points are similar, when they are in low frequency. Acoustic pressure amplitude is relatively small, when monitoring points are in high frequency. When the valve opening decreases, because of the throttle effect of valve windows, the whole db SPL of valve becomes strong. The noise outside of valve has dipole characteristics.

Keywords: Acoustic analogy theory, enterprise’s valve, flow noise, LES, spectrum characteristic.

1. INTRODUCTION

Valve is widely used in industry. Noise has become a big risk when valve is in the work. Noise and vibration also affect the function of valve and can cause fatigue of adjacent piping and equipment, which will reduce the service life. Therefore, how to control the noise of valve becomes an important branch of valve research.

Depending on its causes, valve noise can be divided into vibration noise, cavitation noise, fluid channel noise and water hammer noise. Fluid channel noise accounts for a sizeable proportion of the noise in entire pipeline transmission system. When fluid pass the valve, the situation of liquidity changes a lot. Because of the throttling of valve, the fluid in the valve will cause the phenomenon of intense stirring and impact. Computing simulation of current research on the valve noise is less. Wei Huajun combine the basic principles of fluid mechanics and Lighthill quadruple source theory to study the valve noise of low-speed flow duct, and then get the distribution of valve noise sound source [1]. Liu Cuwei analyzes the noise characteristics of the valve in the gas transmission pipeline, which shows that the noise of valve has dipole characteristics [2]. Liu Shaoang uses Fluent to analyze the flow characteristics of gate valve, and puts forward to the optimization method of reducing flow noise [3]. The simulation of noise now mainly uses Acoustics module of FLUENT. But this module cannot solve the noise of external of valve, which is very important.

Based on LES and Lighthill [4] acoustic analogy theory, this analysis uses FLUENT and ACTRAN to study turbulence noise when fluid flow through the valve and radiated noise of pipeline downstream direction and outer wall of pipe.

2. THE MODEL OF VALVE

2.1. Valve Structure Model and Grid

The enterprise’s valve is one of control valve. The structure is shown in Fig. (1). The parameters of valve are shown in Table 1.

![Fig. (1). The structure of valve.](image)

It uses ICEM / CFD to generate computational grid of fluid and acoustic. Consider the complexity of the valve structure and workload of mesh generation, it use unstructured grids. The fluid computational grid is shown in Fig. (2) and the acoustic computational grid is shown in Fig. (3).

![Fig. (2). The CFD mesh of valve.](image)
Table 1. The parameters of valve.

<table>
<thead>
<tr>
<th>Nominal Pressure /Kpa</th>
<th>Nominal Diameter /mm</th>
<th>Rated Travel /mm</th>
<th>Material</th>
<th>Temperature /°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>60°</td>
<td>water</td>
<td>32.5</td>
</tr>
</tbody>
</table>

![Fig. (3). The acoustic mesh of valve.](image)

2.2. Basic Calculation Equations of Fluid Mechanics

It uses separate solver and explicit linear format, when valve is imported to FLUENT. The flowing medium of enterprise’s valve is water and there is no heat transfer process. Therefore, the valve can be treated as three-dimensional numerical calculations of incompressible fluid. The liquidity meets mass conservation law, the law of conservation of momentum and energy conservation law [5].

2.2.1. Continuity Equation

Continuity equation is the mass conservation equation; the mass conservation equation which is come out of the continuity equation can be expressed as: The mass of infinitesimal in per unit of time is equal to the net mass of the micro unit.

2.2.2. Momentum Conservation Equation

Momentum conservation law is the law that any flow system should meet. For an incompressible fluid, when it is introduced into Newton sheet stress formulas and N-S expressions, then it can get three velocity components of the momentum equation.

2.3. Turbulence Model

In this paper, the standard $K-\varepsilon$ model is used in steady calculation and LES is used in unsteady calculation. The standard $K-\varepsilon$ model is based on the transport equation of the turbulent kinetic energy $W_o$ and dissipation rate $r_o$.

The equation is expressed as:

$$\frac{\partial (\rho k)}{\partial t} + \frac{\partial (\rho u_j)}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\frac{\mu}{\sigma_k}\frac{\partial k}{\partial x_j}\right] + C_{1k}\left(G_k + C_{3k}G_\mu\right) - C_{2k}r^3_k + S_k$$

Large Eddy Simulation [6] is a spatial averaging of turbulent fluctuations (or turbulent vortex). The vortexes of large scale and small scale are separated by some kind of filter function. Large scale eddy uses direct simulation and small scale eddy is closed by model. The basic assumption is: 1. Momentum, energy, quality, and other scalar are mainly transported by large eddy; 2. The flow geometry and boundary conditions determine the characteristics of large eddy, and flow characteristics mainly behave in large vortex; 3. Small-scale vortexes are less affected by the geometry and boundary conditions and isotropic. In the process of large eddy simulation, large eddy can be directly solved and small scale vortex solved by simulation, so the demand of grid is lower than DNS. Large Eddy Simulation equation is expressed as:

$$\frac{\partial \rho}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\mu \frac{\partial u_i}{\partial x_j}\right]$$

$$\frac{\partial (\rho u_i)}{\partial t} + \frac{\partial (\rho u_i u_j)}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_s}\right) \frac{\partial u_i}{\partial x_j}\right]$$

It uses standard Smagorinsky model of large eddy simulation in this article. This model was proposed in 1963 by the Smagorinsky [7]. Smagorinsky model has been widely used since it proposed, because the concept of this method is simple and easy to implement [8].

2.4. FW-H Aeroacoustics Model

After Lighthill (Lighthill) proposed the famous proposed Lighthill acoustic theory wave equation in 1952, Ffowcs Williams and Hawking obtained FW-H equation based on Lighthill acoustic analogy theory and the generalized function method in 1969.

$$\frac{\partial\rho}{\partial t} - \nabla \cdot \rho' = \frac{\partial}{\partial t} \left( \rho u_j \frac{\partial f}{\partial x_j} \right)$$

$$\frac{\partial}{\partial x_j} \left( \rho' \frac{\partial f}{\partial x_j} \right) + \frac{\partial^2 T_0}{\partial x_j \partial x_j}$$

Right side of the FW-H equation is corresponding to three sound source terms [2]. The first term is monopole sound source, which is caused by the surface acceleration (fluid displacement distribution). The second term is dipole sound source, which is caused by solid surface acting the fluid surface. The third term is quadruple sound source, which is caused by the stress tensor of wake shear layer. For the valve studied in this paper, the strength of monopole source is related to the level speed of valve rigid surface. So it can be ignored. Since the strength of the quadruple and dipole sound source sound source is proportional to the
square of the Mach number [9]. The fluid flow rate in this study is small, so Mach number is very small. Therefore, quadruple sound source can also be ignored. Thus, the main consideration of this sound source is dipole sound source.

3. THE ANALYSIS OF FLOW FIELD

3.1. CFD Analysis of Flow Field

The CFD analysis choose ICEM / CFD to generate grid of valve, and then import the grid into FLUENT to do numerical calculations. The boundary conditions include that the dielectric material is water, temperature is 32.5°C, the density of the medium is 998 kg/m³ and the motion viscosity coefficient is $\nu = 1.0 \times 10^{-6}$ m²/s. The inlet boundary condition is mass flow inlet and the outlet boundary condition is pressure outlet. The wall condition of inner surface and the solid surface of valve are no slip. Steady calculation uses standard $K-e$ model. When the flow reaches to steady, large eddy simulation models is used to do unsteady calculation [10]. The time step of large eddy simulation is $1 \times 10^{-5}$ s.

This analysis of flow field mainly study the difference between opening degree of 100% and 70% opening of valve, when valve is in the same inlet conditions. Fig. (4) is the pressure distribution of 100% opening of valve at $Z = 60$. It can be seen from the figure that region of variation of pressure are mainly in the import and export position of the sleeve window. So this position is easy to be cavitation. The pressure distribution of valve is symmetrical. Fig. (5) is the pressure distribution of 70% opening of valve at $Z = 60$. Comparison of the two distribution of pressure, it can be seen that the smaller window of sleeve is substantially closed by spool and the fluid cannot pass through. So fluid primarily passes through three main windows of the sleeve. This is the reason that pressure change of 70% opening is mainly concentrated in the three main windows. However, pressure change of 100% opening has occurred in the main window and the surrounding.

Fig. (4). Pressure distribution of 100% opening in Z=60mm.

Fig. (5). Pressure distribution of 70% opening in Z=60mm.

Fig. (6). Velocity distribution of 100% opening in Y=0mm.

Fig. (7). Velocity distribution of 70% opening in Y=0mm.
3.2. Experimental Verification

According to the national standard GB / T 17213.9-2005 (industrial process control valves Part 2-3: Flow capacity - Test procedures) [11], this research builds the test bench which is shown in Fig. (8). It can measure basic parameters of the flow characteristics of the valve by the bench.

1. The unit of time the volume of water flowing through the valve. \( q \), m³/h

2. The average water flow rate based on the flow \( q \), and pipe diameter D, m/s

3. Pressure drop generated when the water flow valve, \( \Delta p \), pa

4. Flow coefficient, indicating water flows through the valve when differential pressure is 100kpa, for a given stroke of the flow through the value in m³ / h meter, medium density taken kg/m³

Flow coefficient calculation equation

\[
C_v = \frac{Q}{\sqrt{\frac{G_f}{\Delta p}}}
\]

(6)

\[
C_v = 1.168 \times K_v
\]

(7)

Based on test data, the flow coefficient respectively of 100% opening and 70% opening are 569.3 and 301. According to the analysis of the flow field, he flow coefficient of 100% opening and 70% opening are shown in Table 2.

Compare to the experimental data, taking into account of the error about simulation and experiment, when the error is less than 6%, the simulation results are correct [12]. This shows that the choice of CFD Simulation model has high accuracy.

**Table 2. Flow coefficient.**

<table>
<thead>
<tr>
<th>The Opening of Valve (%)</th>
<th>Static Pressure Difference (KPa)</th>
<th>Flow (Kg/s)</th>
<th>K_v (m³)</th>
<th>Average K_v (m³⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>30</td>
<td>82.86</td>
<td>544.611</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>107.20</td>
<td>545.773</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>135.6</td>
<td>545.779</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>30</td>
<td>44.84</td>
<td>294.719</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>56.83</td>
<td>289.331</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>73.04</td>
<td>293.980</td>
<td></td>
</tr>
</tbody>
</table>

4. THE ACOUSTIC ANALYSIS OF VALVE

When fluid passes through the valve, it can form vortex. Then vortex form pulsating pressure in the valve, what can cause strong dipole sound source characteristic. The data which is calculated by FLUENT can be an initial condition of ACTRAN analysis. According to GB / T 17213.16-2005 (Noise Prediction Method of hydraulic flow through control valves), the positions of noise of control valve are generally at 1m downstream of valve and 1m away from the wall. In order to better describe the spectral characteristics of inner piping and the external air, it sets two monitoring points. The first set of monitoring points: located at the downstream of the valve in X = -1.318m, as shown in Fig. (9). The second set of monitoring point: located out of valve in 1m, four monitoring points, the coordinates are (0,1,0), (0,-1,0), (0,0,1), (0,0,-1), as shown in Fig. (10).

For the first group of monitoring point, it choose point 1,3,5,7 to be a part and point 2,4,6,8 to be another part.

The sound pressure spectrum of 100% opening is shown in Figs. (11, 12).

It can be seen from Figs. (11, 12) that:
Fig. (9). Distribution of monitoring points in x=1.1318m.

Fig. (10). Monitoring points outside the valve at 1m.

(1) When the frequency is less than 2500HZ, the distribution of sound pressure at different frequencies is similar. With increasing frequency, the sound pressure distribution of different monitoring points shows huge difference and behaves as a fluctuation messy situation.

(2) Noise level of monitoring point within the valve substantially fluctuates between 20 to 140db. The band is wide and there is no obvious main frequency. Thus, the noise of valve is a broadband noise.

(3) The amplitude of sound pressure and the range of fluctuations are relatively large when monitoring points are at low frequency. But with increasing frequency, amplitude and fluctuations become smaller. It can be seen that the energy of noise at low frequency is higher than at high frequency.

Compare to sound pressure spectrum of 70% opening (Figs. 13, 14), it can be seen that the fluctuation range of 70% opening is between 40 to 160db, which is larger than 100% opening. The reason is that when the degree of opening of valve reduces, the turbulence intensity, speed and pressure fluctuations are correspondingly increasing, which leads to the increase of noise pressure amplitude. This point is same as the analysis of flow field.

Fig. (11). Sound pressure spectrum of 100% opening.

Fig. (12). Sound pressure spectrum of 100% opening.

Same as the above analysis, the pressure spectrum of second set of monitoring point is shown in Fig. (15).

According to the acoustic pressure spectrum, it can be obtained that, when the frequency is approximately at 257Hz, 692Hz, 1449Hz, 2152Hz, 3170Hz, 4127Hz, 4432Hz, the sound pressure is at the crest. Then the sound directivity characteristics of these frequencies are shown in Fig. (16). As can be seen from the figure, the sound directivity is regular and symmetrical, when noise is at low frequencies. With increasing frequency, the rule of sound directivity becomes worse. But generally, the distribution of sound directivity is symmetric, which indicates that the noise has
The Flow Noise Characteristics of a Control Valve

The sound directivity characteristics of 70% opening (Fig. 17) can be gotten by the same method. As can be seen, the dipole sound source characteristic of small opening of valve is better than the larger opening. The reason is that turbulence intensity of small opening is relatively large and the interaction between the solid surface and the fluid surface is more obvious.

Fig. (13). Sound pressure spectrum of 70% opening.

Fig. (14). Sound pressure spectrum of 70% opening.

Fig. (15). Sound pressure spectrum of the second monitoring points.

After the calculation of ACTRAN, the contour of sound pressure of 100% opening is shown in Fig. (18). As can be seen, the peak of sound pressure is in the outlet of window. The change of speed here is relatively large; the pressure drop is more obvious and the strength of vortex is more intense. Therefore, noise decibel of sound pressure here is relatively large. Fig. (19) is the contour of sound pressure of 70% opening. It shows that the peak of sound pressure is mainly concentrated in the lower half of the valve. However, the distribution is relatively uniform. The reason is same as the analysis of flow filed. When the window is reduced, fluid flow gets hinder and the change of flow rate at the outlet of window is also reduced.

CONCLUSION

It can be obtained from the analysis of flow field that the pressure distribution of valve is symmetrical and the different flow paths are generally similar. Change places of pressure and velocity are mainly in the import and export position of the sleeve window. These places are easy to be cavitation. The throttling
effect of the window makes the flow rate of the valve and the flow resistance increase, when the opening of valve is reduced.

(4) When the opening of valve reducing, turbulence intensity, velocity and pressure fluctuations are increasing, which makes the amplitude of the sound pressure increase correspondingly.

(5) When the speed of valve changes rapidly, the intensity of turbulent eddies is increased; then the noise decibel of sound pressure is correspondingly increased. And the peak of sound pressure is concentrated in the strongest areas of pressure drop.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

ACKNOWLEDGEMENTS

This work is supported by the National Natural Science Foundation of China(NO.11472095)

REFERENCES


