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Study on nozzle flow dispersion for noise reduction by using micro color Schlieren techuique

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Abstract
This article aims to reduce the nozzle noise by using micro color Schlieren techuique. In general, the high pressure flow running through the nozzle will yield the block flow due to the increasing resistance inside the nozzle tube. The yielded compressed diamond flow is the sound wave which courses extremely large noise. This work used filters on the nozzle to remove the block flow and reduce the noise. Experiments used the annular pore nozzle filters with hole diameters of 1mm、2mm、4mm arranging indifferent forms respectively. The results show that filter with 16holes of diameter 1mm in connection with air pressure of 7kilograms per square centimetre obtained the noise of 70.9dB, which is ca. 26.0% reducing rate.

1. Introduction

Schlieren techniques are basic and valuable tools for mechanical engineering sciences and physics disciplines which are often used to obtain the two dimensional refraction index gradient distribution within a transparent object [1]. During the past few decades, Schlieren technique has been widely implied visualization of fluid flow, such as gas field of wind tunnel, etc[2].

In 1859, Foucault et al. settled schlieren arrangement at the earliest. Foucault used a device to quality restriction of optical lens or mirror[3]. In 1864, Toepler et al. observed flow of compressible fluid and named Toepler Method. In 1892, Rheinberg et al. proposed color Mask, began a color schlieren research, thereafter North and Jeffree proposed different from mask, the different knife edge used a mask in different types. In 1980, Settles et al. proposed three RGB colors Mask [4]. In 2004, Ting et al. by using a digital color mask, the experiments were tested over

40different masks. With digital color mask, the three RGB colors are exactly defined in the computer which gives the best way for further quantitative evaluations[5- 7].

Studying the Schlieren history, there are more emphasis on the air-conditioning equipment 、 wind tunnel experiments of shock 、the sound pressure distribution and the flow field of nozzle 、cooling of electronic components for the general size imaging. In 2005, Huang et al. [3], through designing micro-hot water flow technology, observation of micro-thermal water flow in the water images, erecting experiment can observe the 200 um dimension hot water flow in fluid flow images under free boundary conditions.

Optical imaging is the study of multimedia music noise issue with useful technique. The sound waves are longitudinal waves or mechanical waves, fluctuations in the study, with the same light. Nature of sound waves and light waves are different from sound waves are passed through the media, transfer process. The medium density will produce density variations. Transfer medium density changes on the status of imaging, the noise will be the most direct of space research. Sound field imaging optical techniques used to observe, the most commonly used technology Schlieren [3,8-10] 、Moiré interferometry and Holographical interferometry etc. [11-15], research interests with ultrasonic imaging 、shock wave Imaging [3] and Faraday's wave imaging etc..Sound field imaging is a common problem. In addition, the sound field imaging through flame-like Ruben's Tube such as powder through Faraday's wave imaging.

Nozzles usually used in industry, in the high-pressure air nozzle conditions, will produce a high noise. This paper employed the micro color Schlieren technique to observe the nozzle flow with the ring filter to eliminate noise flow and lower the nozzle.

2. Basic Theory

Schlieren technique is often used to obtain two dimensional various refraction index gradient distribution within a transparent object. Base on the relationship between light intensity I and object density ρ which is shown in equation (1), Schlieren technique can not only visualize transparent flow, but also show object density distribution quantitatively[16,17].

$$I \propto \frac{d\rho}{dx} \tag{1}$$

The applied basic theory of schlieren is the smallest optical path length for light which is described by Fermat's principle in1657. Gladstone and Dale gave experimental data to illustrate Fermat's principle as follows (2),

$$\begin{aligned} n-1 &\propto \rho, \\ n-1 &= K\rho \end{aligned} \tag{2}$$

where K is called Gladstone-Dale constant and equation (2) Gladstone-Dale equation [1,3]. Actually, K is not exactly constant, but weakly dependent on the wavelength of the transmitted light. In most cases this dependency could be neglected.

$$p = \rho RT \tag{3}$$

where p stands for pressure、R is ideal gas constant and T is temperature, therefore, T is ambient temperature constant as follows (4) ,

$$\rho \propto p \tag{4}$$

According to Gladstone-Dale relations as follows (5) ,

$$n-1 \propto p \tag{5}$$

Color Schlieren using RGB color mask and will be mixed in test section, color Schlieren have clear hybrid light source, color grader and sensitivity is more than black and white schlieren.

When tube gas pressure gradient increase caused by the nozzle block flow, the gas increased resistance in the tube, squeezing phenomenon is more and more intense in the tube. Finally, gas clogging at the nozzle exit, gas continued forward to extrusion and Resulted in an on and off density block flow as follows (6)

$$\lambda = -\frac{2d}{\rho \cdot um^2} \cdot \frac{dp}{dx} \tag{6}$$

where λ stands for dimensionless coefficient of pipe friction、d is tube diameter 、ρ is gas density、um is tube gas average speed and dp/dx is gas pressure gradient. Noise is the main factor for the nozzle block flow, how to reduce the noise value is a major work of this study. In this study, the nozzle outlet set up a filter will gradually release the gas inside and reduce noise. Fig. 1 shows micro color schlieren photo of nozzle block (compressed diamond) flow.

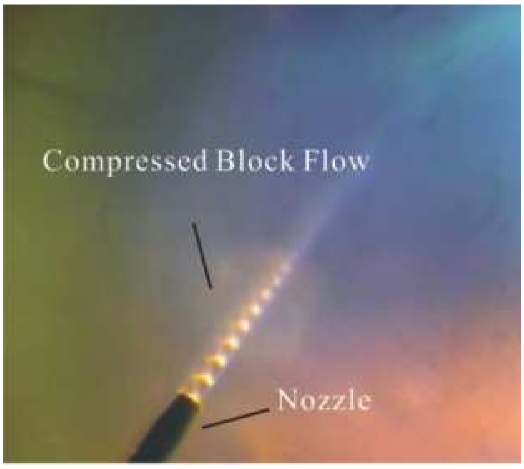

Fig1.*Micro color Schlieren photo of nozzle block flow.*

3. Experimental Setup

This work focuses on distributing nozzle flow and making annular nozzle filter to compare the commercial annular nozzle. The commercial annular nozzle with 16holes ϕ 1mmused to circular arrangement, Fig. 2 shows a commercial annular nozzle.

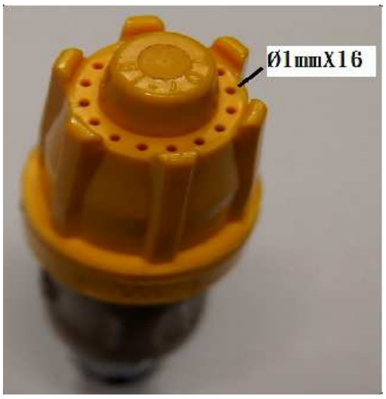

Fig2.*Photo shows a commercial low noise annular nozzle.*

In this study, a homemade annular nozzle is the same as commercial annular nozzle opening rate for arrangement. Experiments used the annular pore nozzle filters with hole of ϕ 1mm、ϕ 2mm、ϕ 4mm arranging indifferent forms respectively. Fig. 3 shows a homemade annular nozzle and fig. 4 shows a schematic diagram of homemade annular nozzle.

Fig 3.*Photo shows a homemade annular nozzle.*

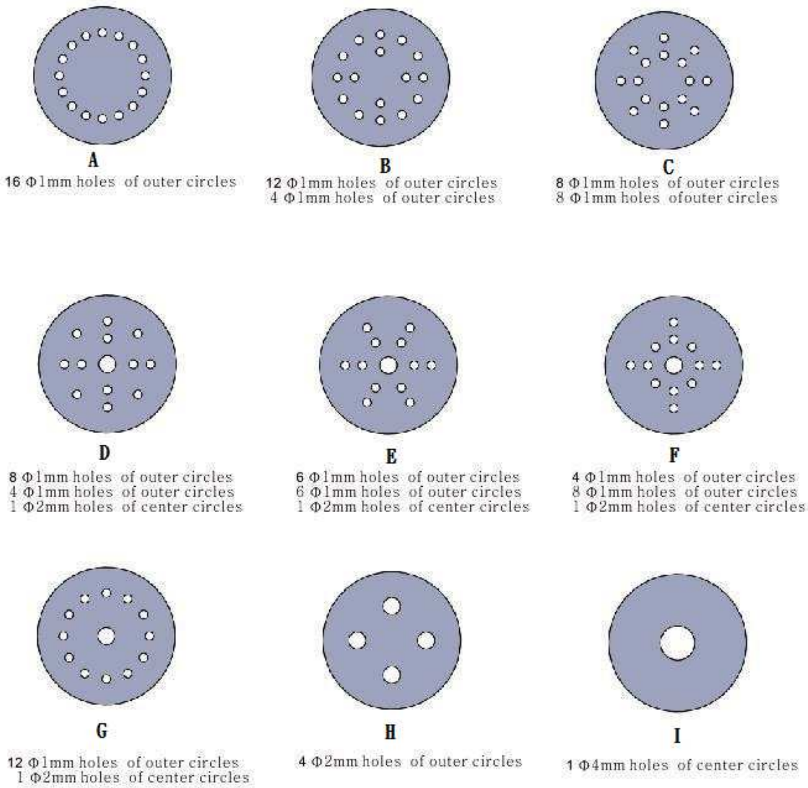

Fig4.*Schematic diagram of homemade annular nozzle.*

Noise measurement of the nozzle to establish a CNS standard, to test conditions in accordance with environmental C4127 and C3805[18], the free sound field of test environment and sound level meter selection a weighted. Fig. 5 shows nozzle photo of a noise measurement arrangement and fig. 6 shows arrangement of nozzle noise.

The typical schlieren technique uses white light source and its area of test section is limited by dimension of the applied parabolic mirrors for generating the parallel light. Fig. 7 shows Z-arrangement of the typical micro color schlieren setup. To compare with the results, a conventional Z-arrangement micro color schlieren using a white light 5 W LED lamp as light source was built for measuring in this work.

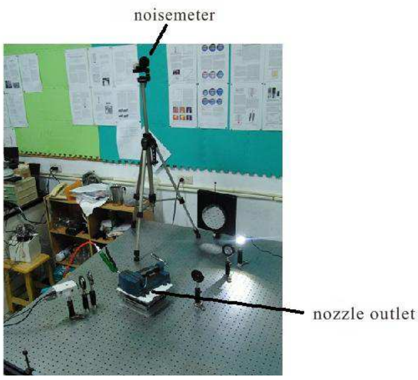

***Fig5.**Photo shows a Noise measurements of nozzle photo.*

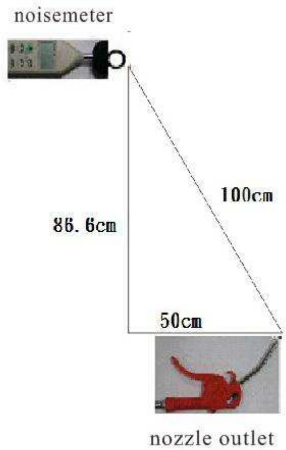

***Fig 6.**Photo shows a Schematic diagram of Nozzle Noise.*

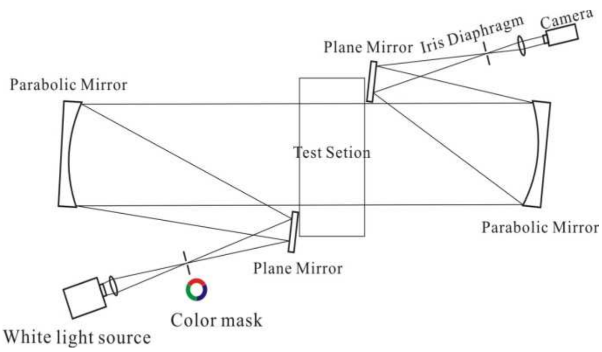

***Fig7.**Schematic setup of the typical schlieren technique.*

4. Results and Discussion

The micro color Schlieren technique applied for observation of micro-nozzle flow field. The compressed diamond nozzle flow images in test area of micro color Schlieren was enlarged and recorded. The commercial nozzle outlet is ϕ 4mm, we divided results and discussion into gas flow imaging and noise of Commercial nozzles and gas flow imaging and noise of annular nozzles.

As a basis of general commercial nozzle flow imaging and noise, fig. 8 is general commercial nozzle sprayed compressed diamond flow and accompanied 95.8dB.Fig. 8shows clearly diamond block flow at nozzle outlet and the color with green, blue, and yellow interact in block flow. This block flow is mainly making noise source. In this study, making a homemade annular nozzle is great for reduce noise.

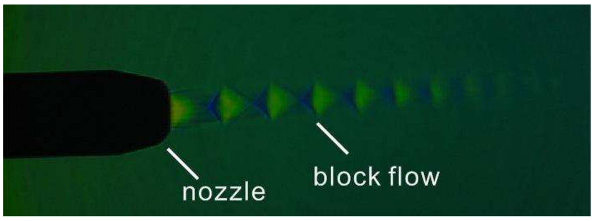

***Fig 8.**Schlieren photo of general commercial nozzle with 95.8dB.*

Fig. 9 shows the micro color Schlieren photo of commercial low noise annular nozzle with noise level of 79 dB. The photo indicates that the compressed diamond flow is totally different with fig. 8. The compressed diamond flow in fig. 9 is smaller than fig. 8, in other words, the sound energy in fig. 9 is smaller than fig.8. The dispersion method to reduce nozzle sound noise is reasonable and feasible in this study. It's reasonable explanation the physical meaning of nozzle noise which produces by compressed diamond flow by using micro color Schlieren technique.

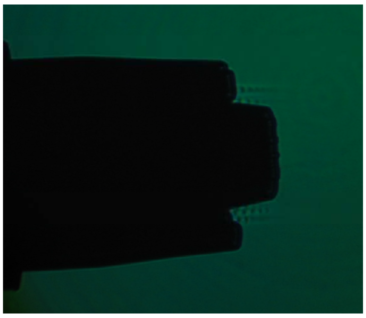

***Fig 9.**Micro color Schlieren photo of commercial low noise nozzle with 79dB.*

Fig.10 shows the micro color Schlieren photo of outer circles with 16 holes 1mm of an annular nozzle image and noise is 70.9dB (Form A). The design detail is similar with commercial low noise nozzle. The homemade nozzle is inexpensive than commercial low noise nozzle and the noise level is smaller than commercial low noise nozzle.

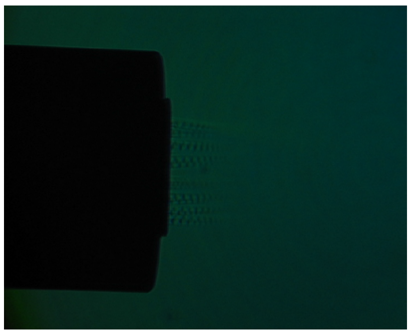

***Fig 10.**Micro color Schlieren photo of outer circles with 16 holes 1mm of an annular nozzle image and noise is 70.9dB (Form A).*

The block flow divided intoa lot of small by annular nozzle, using the decentralized method is great to reduce the noise, a homemade annular nozzle is the same as opening rate for experiment. Fig. 11shows inner and outer circles are each with 8 holes 1mm of an annular nozzle image and noise is 72.8dB. Fig. 12 shows inner and outer circles are each with 6 holes 1mm of an annular nozzle image and noise is 72.3dB. Micro color Schlieren can be clear a lot of airflow beam with air compression block and accompany a lot of micro block flow.

Fig 11.*Micro color Schlieren photo of inner and outer circles are each with 8 holes 1mm of an annular nozzle image and noise is 72.8dB(Form C).*

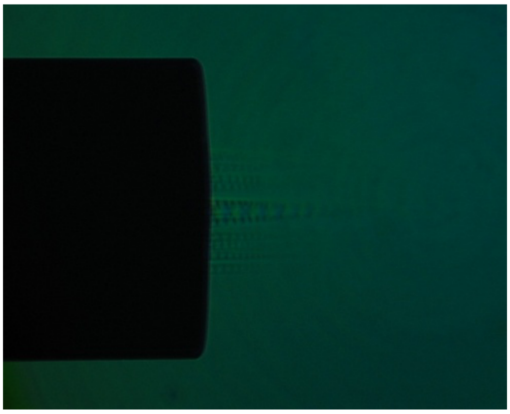

Fig 12.*Micro color Schlieren photo of inner and outer circles are each with 6 holes 1mm of an annular nozzle image and noise is 72.3dB(Form E).*

In the test, Fig. 11 is the optimization of annular nozzle reduces 24.9dB and noise reduction rate is about 26%. While the holes diameter increase to ϕ 2mm, the nozzle noise will be bigger than ϕ 1mm, the larger airflow beam diameter and low noise can choose the design of Fig. 12. The results can be used as a design basis for the following nozzles, by using interaction between holes and hole to deducing other test content on the influence of nozzle. Fig. 13 shows the 10 different kinds of reducing noise nozzle compare with the commercial nozzle noise rate.

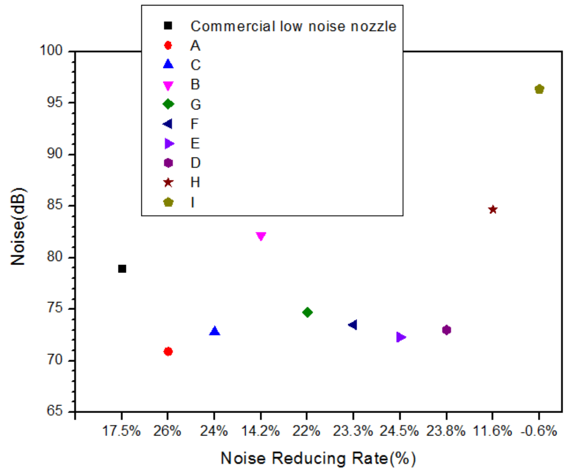

Fig 13. *The different kinds of reducing noise nozzle design with noise reducing rate.*

5. Conclusions

This study successfully sets up the micro color Schlieren to observe compressed diamond flow image of nozzle, the micro color Schlieren photos indicate that the compressed diamond flow through circular filter effectively dispersed into small air bundle, which effectively reduce the noise energy. The annular nozzle of 16holeswith ϕ 1mm can down the noise level from 95.8dB to 70.9dB and optimization of annular nozzle reduces 24.9dB and noise reduction rate is about 26%

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References

[1] E. Hecht, Optics, Addison Wesley 4th Edition, 2002.

[2] D. Kastell, M. Carl and G. Eitelberg," Phasestep holographic interferometry applied to hypervelocity, non-equilibrium cylinder flow," Experiments in Fluids, vol.22, 1996, pp. 57-66.

[3] M. Wolfgang, Flow Visualization, Inc. 2nd Edition. Orlando: Academic Press, 1987, pp. 115-218.

[4] G. S. Settles," Color schlieren optical - a review of techniques and application," International Symposium on Flow Visualization, Bochum, 1981, pp. 187-197.

[5] C.C. Ting, S. J. Wu, J. S. Huang, H. D. Lin and Y. B. Luo, The improvement of color schlieren technique by using an LCD projector, Presented at 2004 AASRC/CCAS Joint Conference, Taichung, Taiwan, 12 Dec., 2004.

[6] C. C. Chen, C. C. Ting, Investigation of the effect of color mask on the sensitivity for the color schlieren imaging, International journal of engineering and technology innovation, 2013, 3: (2), pp. 114-122.

[7] C. C. Ting, C. C. Chen, Detection of gas leakage using micro color Schlieren technique, Measurement, 2013, 46, pp. 2467-2472.

[8] G. S. Settles, Schlieren and Shadowgraph Techniques Heidelberg, New York: Springer, ISBN 3-540-66155-7, 2001.

[9] H. Kleine and K. Takayama,” Combined schlieren and interferometry visualization of blast waves, ”In: M. Samimy, K. S. Breuer, L. G. Leal and P. H. Steen, editors. A gallery of fluid motion. Cambridge: Cambridge University Press, 2004, pp. 115.

[10] H. Kleine and K. Takayama,” Combination of holographic interferometry with shadowgraph and schlieren visualization," In: T. H. Chang and K. S. Chang, editors. Proceedings of 6th Asian Symposium on Visualization, CD-version, paper 084, 2001.

[11] J. Robillard and H. J. Caulfield, Industrial Applications of Holography, Birkhauser, 1996.

[12] W. T. Cathey, it Optical Information Processing and Holography, Wiley, 1981.

[13] U. Schnars and W. Jueptner, Digital Holography: Digital Hologram Recording, Numerical Reconstruction, and Related Techniques, Springer, 2005.

[14] J. Ludman, H. J. Caulfield and J. Riccobono, it Holography for the New Millennium, Springer , 2002.

[15] G. S. Settles, B. T. Keane, B. W. Anderson and J. A. Gatto, "Shock waves in aviation security and safety," Shock Waves, vol. 12, 2003, pp. 267-275.

[16] H. Oertel, Optischestromungsmesstechnik, Braun, 1989.

[17] C. C. Ting, Stromungs und Warmeubergangsmessung fur das zweistufigeRaumtransportsystem ELAC, Verlag Mainz, Wissenschaftsverlag, Aachen, ISBN: 38-86130-189-X, 2003.

[18] The Republic of China national standard, CNS 3805 Range hoods.