Influences of Dis-tuned Tip Clrarance on the Discrete Aerodynamic Noise in Centrifugal Compressor

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Long Abstract

Introduction

With the emission restriction standard being more and more strict, turbocharging technology has been widely used in boosted engines for passenger and commercial vehicles and has the trend to be a standard technology to match the even more strict emission restrictions. However, due to the high rotating speed operation points and highly strong unsteady flow in compressor and turbine, the turbocharger acts as one of the major noise source in the engine system and introduces discrete noises and turbulence noises. With the purpose of decreasing the discrete aerodynamic noise in turbocharger compressor, numerical and experimental study on the influences of dis-tuned impeller tip clearances on the aerodynamic noise is carried out. The dis-tuned tip clearance configuration is realized by ensuring either a bigger tip clearance size for main blades while a smaller one for splitter blades, or a smaller tip clearance size for main blades while a bigger one for splitter blades. The influences of dis-tuned tip clearance on centrifugal compressor performances are first validated and results indicate that the dis-tuned tip clearance method used in current study has minor influences on compressor performances. Based on full unsteady flow CFD results, near field discrete aerodynamic noise analysis is performed on the tip clearance dis-tuned compressors, while far field aerodynamic noise is experimentally investigated. Both numerical and experimental results show that the dis-tuned tip clearance configurations have significant influences on compressor discrete aerodynamic noise, with maximum noise SPL decreased by 8 dB under the compressor operation points investigated in current research.

1. Methods

The J90 turbocharger compressor, characterized with impeller outlet diameter being 90mm, is investigated in current research. The compressor impeller has 7 main blades and 7 splitter blades. The tip clearance of the main blades and splitter blades is 0.5mm for the prototype impeller and dis-tuned tip clearance method is realized by increasing/decreasing the tip clearance of the main blades while decreasing/increasing that of the splitter blades. RANS-based steady state numerical calculations are performed on the prototype and dis-tuned compressors to investigate the influences of dis-tuned tip clearance on the compressor performances. Non-Linear Harmonic method is used to capture the pressure fluctuation in the flow field, and with the use of formulaton 1A raised for FW-H equation, the near-fileld discrete aerodynamic noise on the inlet surface of the compressor (as shown in figure 1) is thus predicted. The characteristics of the aerodynamic noise at compressor inlet under peak efficiency and near-choke operation points are compared among prototype and tip clearance dis-tuned compressors. Parts of the results are shown in figure 2.

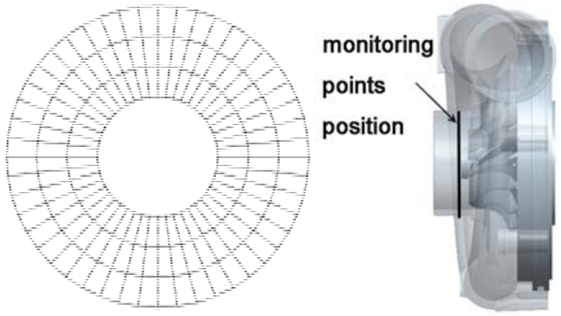


Fig.1 Illustration of the distribution and position of monitoring points

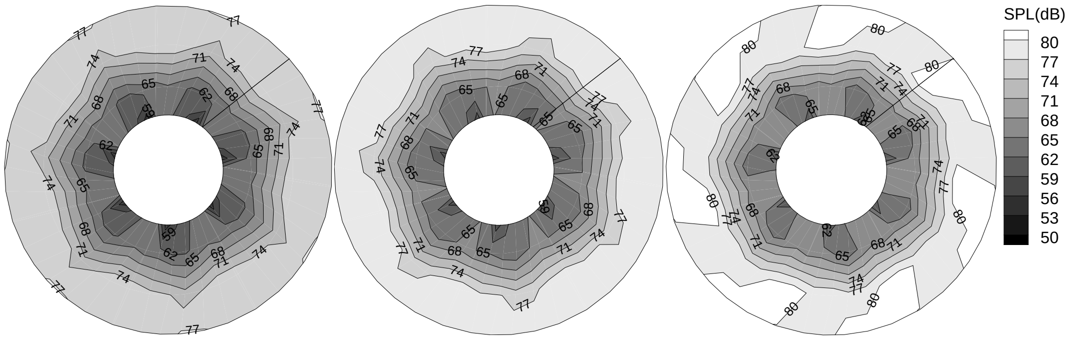
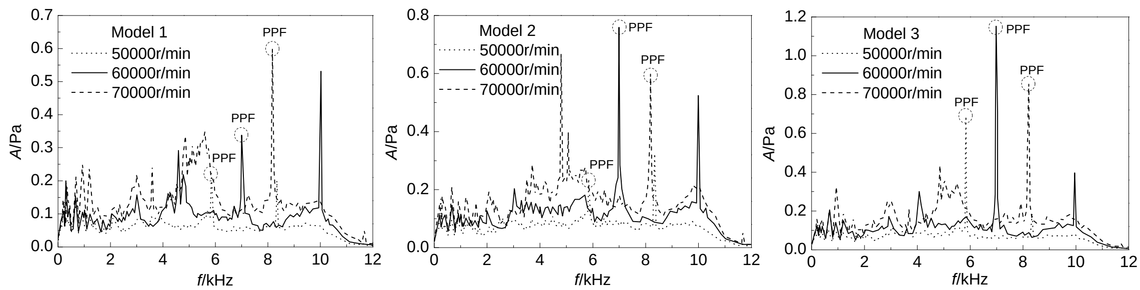


Fig.2 Discrete aerodynamic noise distribution at centrifugal compressor inlet
(Left: prototype Middle: model 2 Right: model 3)

Far field noise of the compressors is measured at the peak efficiency operation points under impeller rotating speed being 50000, 60000 and 70000 rpm. Meanwhile, the pressure fluctuation spectrum at upstream of compressor is also compared and the influences of dis-tuned tip clearance on compressor far field noise are also investigated.



(a) Model 1 (b) Model 2 (c) Model 3

Fig. 3 Noise sound pressure spectrum at upstream of compressor inlet

References

[1] Liu Yang, Zhang Wenzheng, Du Bingxin, et al. Numerical analysis of aerodynamic noise for turbocharger centrifugal compressor. Vehicle engine, 2:31-35, 2013.

[2] Wen Huangbing, Xu Wenjiang, Bao Suning, et al. Experimental research on noise characteristics and mechanism of marine diesel engine turbocharger. Chinese Internal Combustion Engine Engineering, 34(1):76-80, 2013.

[3] Raitor T, Neise W. Sound generation in centrifugal compressors. Journal of Sound and Vibration, 314(3): 738-756, 2008.

[4] Khelladi S, Kouidri S, Bakir F, et al. Predicting tonal noise from a high rotational speed centrifugal fan[J]. Journal of Sound and Vibration, 313(1): 113-133, 2008.

[5] Velarde-Suárez S, Ballesteros-Tajadura R, Pablo Hurtado-Cruz J, et al. Experimental determination of the tonal noise sources in a centrifugal fan. Journal of sound and vibration, 295(3): 781-796, 2006.