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REDUCTION OF NOISE IN SCREW COMPRESSORS

Elvedin Mujić
Ahmed Kovačević
Nikola Stošić
Ian K Smith
Centre for Positive Displacement and Compressor Technology
City University London
Northampton Square, London EC1V OHB
United Kingdom

ABSTRACT
It has recently been reported that noise generated in screw compressors can by reduced by modifying the shape of the high pressure port to minimize gas pulsations in the discharge chamber. This paper describes a simulation mode developed to predict the optimum form of this. The procedure used was to simulate the flow in three dimensions within the discharge chamber, using CFD, and to couple this with flow simulations in the working chamber and outlet reservoir, based on one dimensional models. The model takes into account the real shape of the discharge port. By its use it is possible to predict gas pulsations in the discharge chamber for different shapes of the discharge port and thereby optimise the port shape to reduce the compressor noise. Results derived from it show good agreement with experimental values.
Keywords: Screw compressor, noise, gas pulsations, discharge port

1. INTRODUCTION
In a screw compressor, the working chamber is connected to the suction and discharge chambers only periodically. This creates unsteady flow and variation of mass within both chambers, thus causing pressure pulsations within them during both the suction and discharge processes. These are the source of both vibration and noise. The amplitude of the gas pulsations in the compressor discharge chamber is much higher than that in the suction chamber. Therefore many authors consider the gas pulsations in a screw compressor discharge chamber to be the main source of noise.

Intensive research on gas pulsations in screw compressors started with Fujiwara and Sakurai [1]. They measured gas pulsation, vibration, and noise in a screw compressor. After that Koai and Soedel [3], developed an acoustic model in which they analysed flow pulsations in a twin screw compressor and related them to its performance. More recently, Sangfors [6] and Huagen et al [2] developed mathematical models for the prediction of gas pulsations in screw compressor suction and discharge chambers.
All these authors explored the influence of various screw compressor design and operating parameters on gas pulsations in the compressor suction and discharge chambers. Some authors, such as Koai and Soedel [3] recognized the influence of the compressor port area and recommended that the effect of the port shape on noise be further investigated. Mujić et al [5] reported that changing the shape of a screw compressor discharge port alters gas pulsations in the discharge chamber, with reduced pulsation amplitude leading to lower overall noise levels.

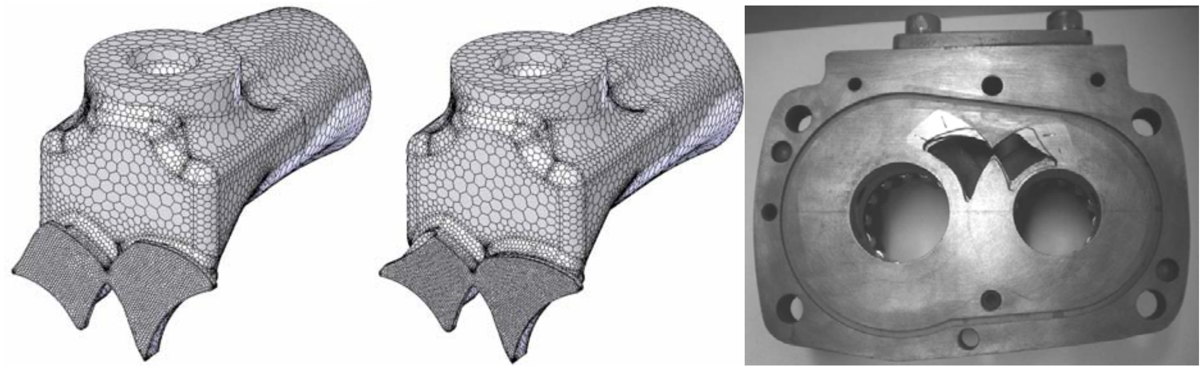
2. MATHEMATICAL MODEL FOR PREDICTION OF GAS PULSATIONS

An integrated model of the screw compressor discharge process has been applied to analyse gas pulsations in the discharge chamber. The integrated model consists of a 3-D CFD model of flow in the discharge chamber coupled to simulated flow in the working chamber and outlet reservoir, based on one dimensional flow models. The coupling method was applied interactively so that the one dimensional model of flow in the working chamber was used to determine the boundary conditions for the 3-D CFD model. The flow field within the discharge chamber, derived from the 3-D CFD model, then established the fluid flow both to the working chamber and the outlet reservoir and hence the gas conditions within them. The new gas conditions expressed in terms of pressure and temperature were then used as the boundary conditions for the next time step in the 3-D CFD model. This integrated model of the screw compressor discharge process is described in more detail by Kovačević et al [4]. This model accounts for a complex discharge chamber geometry and therefore is more accurate than the model of Mujić et al [5]. However, due to the complexity of the 3-D CFD model, it requires longer calculation time. StarCCM+, a commercial solver has been used for solving flow field quantities inside the discharge chamber. User subroutines, which enable the transfer of mass and energy between the 3-D CFD and the thermodynamic chamber model, have been specially developed for this purpose and are included in the solver.

3. NOISE REDUCTION BY ALTERING THE DISCHARGE PORT

For the purpose of this investigation an oil flooded air screw compressor was used because it operates over a larger pressure range and develops higher gas pulsations than an oil free compressor. In addition an oil injected screw compressor does not need synchronizing gears, which affect the overall compressor noise level, and it may be driven at moderate speeds. Therefore the noise generated by the test compressor was mainly caused by the gas pulsations.

Both numerical and experimental results were obtained for two different port shapes in the test compressor in order to evaluate their influence on the level of gas pulsations in the discharge port. Firstly, the pressure function in the compressor discharge chamber was calculated for the compressor with the original port by use of the integrated model. A numerical grid of the discharge chamber with original discharge port shape is shown in Figure 1.a. After experimental validation of the predicted results, a new discharge port shape was proposed as shown in Figure 1.b. These are both shown by brass inserts in the test compressor in Figure 1.c.



a) original port shape *b) modified port shape* *c)modification on real object*

Figure 1. Numerical grid of the discharge chamber and real object

The original discharge port was modified to reduce the gas pulsation amplitude by minimising the initial flow between the working and discharge chambers at the beginning of the discharge process, when the pressure difference between the chambers is the highest. The pressure function predicted with the integrated model for the modified port shows reduced gas pulsation amplitudes. Figure 2 shows predictions of the gas pulsations for two different compressor working conditions in the case of the original and modified ports. The opening curves that generate the port in the second case are defined by only three arcs. They are therefore simpler than the curves that define the old port which are based on rotor profiles.

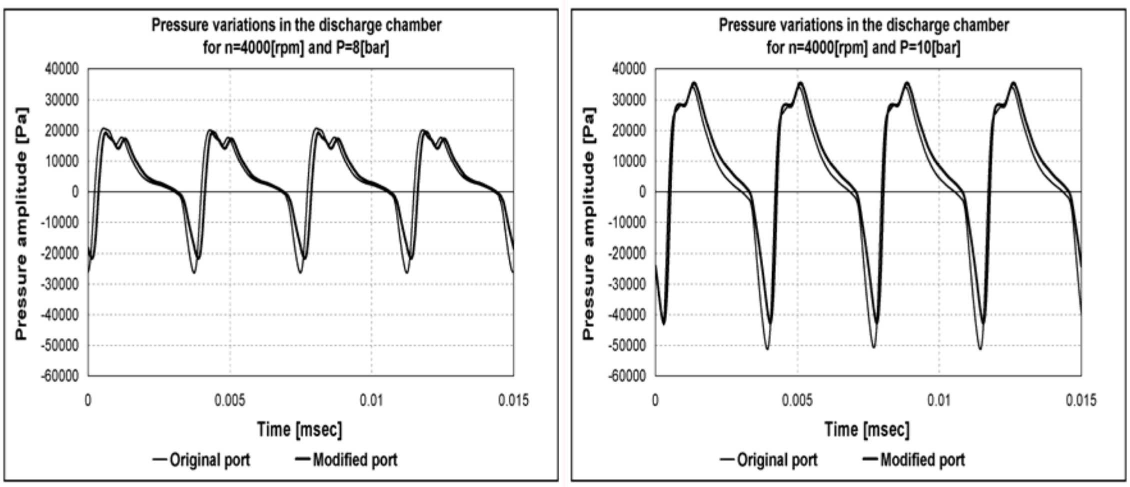


Figure 2. Comparison of predicted results for original and modified discharge ports

All other components in the experimental rig are unchanged. Therefore, the difference in gas pulsations presented in Figure 3 is consequence only of the different port shape.

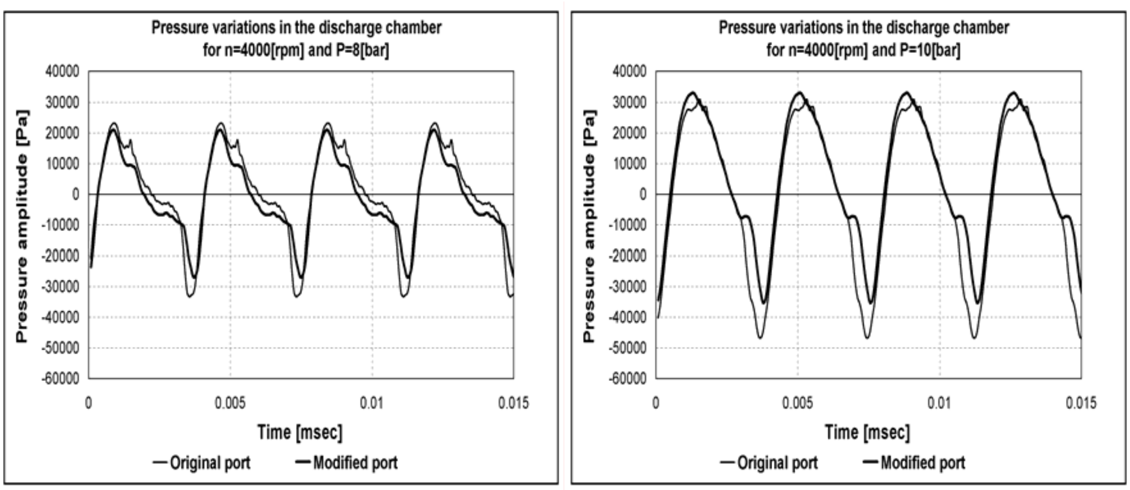


Figure 3. Comparison of experimental results for original and modified discharge ports

The achieved reduction in sound pressure level (SPL) inside of the discharge chamber for different compressor speeds and outlet pressures is presented in Figure 4. The SPL is obtained from the root mean square (RMS) amplitudes of the measured gas pulsations from the two port versions. The reduction in SPL across a range of compressor speeds for an outlet pressure of 8 [bar] is between 2 and 4 [dB]. For a constant compressor speed of 4000 [rpm] and different outlet pressures this reduction is from 1 to 4 [dB]. The SPL measured around the compressor also shows reduced generated noise.

The overall noise in the compressor environment is attenuated by about 3 [dB] at 4000 [rpm] over the whole pressure range, while there is a noticeable noise reduction across the compressor speed range, varying from 2 [dB] at the lowest speed up to 5 [dB] at the maximum speed for an outlet pressure of 8bar.

The modification of the port shape reduces the size of the port area. Therefore, the modified port requires more power input to the compressor for the same working conditions than the original port. This was anticipated because the flow area is smaller and losses increase as a result of the consequently higher fluid flow velocity through the port.

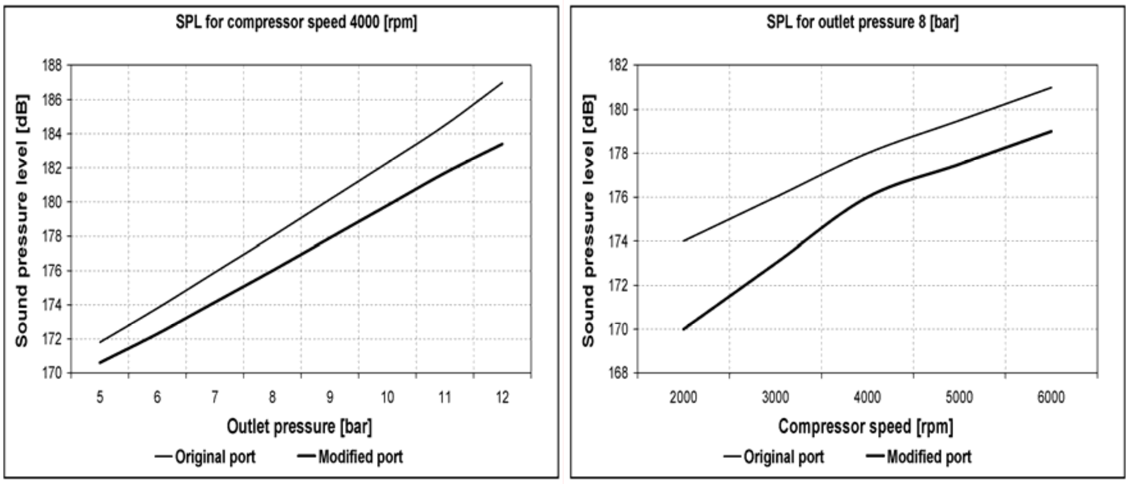


Figure 4. Comparison of measured SPL inside of the discharge chamber for original and modified discharge ports

4. CONCLUSIONS

Results from the integrated simulation model agreed well with the test results over a wide range of speeds and pressures for two different port shapes. It has been shown that gas pulsations in the screw compressor discharge port and, consequently, the noise generated can be reduced by changing the shape and the size of the discharge port to appropriate value.

The given example confirms that, by this means, it is possible to reduce level of gas pulsations in the discharge chamber by up to 5 [dB]. Unfortunately, this reduction is accompanied by a drop in compressor performance of up to 2%. Therefore, this method of reducing noise is most useful for compressor applications where lower noise levels take precedence over compressor power consumption.

5. REFERENCES

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