Muffler Design for a Refrigerator Compressor

Vamshidhar DONE, Bhaskar TAMMA, Kunal SONI, Subhrajit DEY, Shruti ANGADI
General Electric Global Research Center, Bangalore, India

B. Venkatesham, Vishal G P
Department of Mechanical Engineering, IIT Hyderabad, India
Introduction

- Pressure pulsations of compressors
- Role of mufflers to attenuate noise
- Systematic procedure to design mufflers
- Need for 3D modeling of acoustic and CFD simulation
- Validation of numerical simulation by impedance tube test
- Design improvements of extended inlet/outlet chamber mufflers
  - Improvement in sound transmission loss
  - Reduction in pressure drop across muffler
Analysis of Small Mufflers (Transmission Loss)

- Short chamber effects are significant when \( l/d \leq 1 \)
- Plane wave assumption invalid
- 1-D transfer matrix method not applicable
- Requires 3D analysis

Note: Transmission Loss is the reduction in sound power due to muffler

For small mufflers, 3D acoustic modeling provide accurate results
Validation of Numerical Simulation of Small Mufflers

- 3D acoustic analysis using commercial software
- Experiment using Impedance tube

(Schematic of two chamber expansion muffler)

Transmission loss curve of numerical simulations matches with experiments
Reactive Mufflers for Compressors

- Reactive mufflers work on impedance mismatch
- Impedance mismatch obtained by
  - Change of cross section
  - Adding baffles
  - Designing multiple chambers
  - Introducing extended inlet/outlet pipe
  - Creating multiple passes inside the muffler etc.

Majority of these geometrical changes introduce additional back pressure.

Design modifications are required to mitigate pressure loss in mufflers.
Method of Reducing Pressure Drop of EIEO Muffler

Use of perforated bridge with high porosity

- Low self-noise due to flow
- Low pressure drop
- Increased mechanical strength

EIEO Muffler with perforated bridge improves acoustic performance and reduces pressure drop

EIEO Muffler with perforated bridge improves acoustic performance and reduces pressure drop

Transmission Loss (dB)

Frequency (Hz)

0 10 20 30 40 50 60 70 80 90

0 10 20 30 40 50 60 70 80 90

Without Perforated Bridge in EIEO Muffler
With Perforated Bridge in EIEO Muffler

Simple EIEO Muffler

EIEO Muffler with Perforated Bridge

Pressure Contours

Low
High

Low
High

Use of perforated bridge with high porosity

- Low self-noise due to flow
- Low pressure drop
- Increased mechanical strength

EIEO Muffler with perforated bridge improves acoustic performance and reduces pressure drop
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Design of Side Inlet Side Outlet (SISO) Mufflers Equivalent to EIEO

- Lengths $l$, $l_a$ and $l_b$ to be matched
- Easy to manufacture

Methodology of Tuning Side Outlet Muffler

- Outlet pipe location close to pressure nodal locations reduced pressure pulsations
- Improves transmission loss

Tuning the outlet position of muffler increases the frequency bandwidth
Effect of Fluid Properties on Transmission Loss of Muffler

- Acoustic calculations with air can be used to analyze refrigerant
- Modal frequencies are proportional to speed of sound (C)
- Peak/trough frequencies need to be scaled

Refrigerant properties shift frequencies in the ratio of $C_{\text{refr}}/C_{\text{air}}$. 

![Graph showing transmission loss in dB vs frequency for refrigerant and air](image-url)
Conclusions

● For small mufflers, 3D acoustic modeling provide accurate results
● Acoustic numerical simulations are validated by experiments
● EIEO muffler with perforated bridge is proposed
● Acoustic and CFD simulations show improved performance of muffler with perforated bridge
● A SISO muffler is proposed equivalent to EIEO muffler
● Methodology of tuning side outlet muffler is presented
● Frequencies of transmission loss curve shift in the ratio of $C_{\text{refr}}/C_{\text{air}}$
Thank you