A Research On Design And Development Of Sound Jacket For Hermetically Sealed Compressor Using Visco-Elastic Material

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Abstract - **Recently, noise and vibration problems are gaining increasing importance in the electrical home appliances and the trend is to manufacture lighter and higher quality goods. It is complicated to find the generating source and propagating path of noise in the compressor. Fractional horse power reciprocating compressors are commonly found in HVAC systems such as household refrigerators and air-conditioners. The noise is a major issue in case of reciprocating compressor which leads to human perception. In order to address the noise perception, issue the concept of sound jacket is incorporated over the compressor shell. The viscoelastic material used for the developing sound jacket will help in attenuating the sound propagating from compressor and will lead to quiet operation.**

Index Terms— **Fractional horse power reciprocating compressor, HVAC systems, human perception, sound jacket, viscoelastic material.**

I. INTRODUCTION

A compressor is the most important and often the costliest component of any vapor compression refrigeration system (VCRS). Compressors are often noisy & effective solution is often required to suppress the noise emitted from them. Compressor noise is usually a nuisance because they are sitting on comparatively lightweight structures. Use of visco-elastic material may be thought of to address the issue.

Viscoelasticity may be defined as material response that exhibits characteristics of both a viscous fluid and an elastic solid. An elastic material such as a spring retracts to its original position when stretched and released, whereas a viscous fluid such as putty retains its extended shape when pulled. A viscoelastic material (VEM) combines these two properties-it returns to its original shape after being stressed. The degree to which a material behaves either viscously or elastically depends mainly on temperature and rate of loading (frequency). Many polymeric materials (plastics, rubbers, acrylics, silicones, vinyls, adhesives, urathanes, and epoxies, etc.) having long- chain molecules exhibit viscoelastic behavior. It is further found that visco-elastic materials have good vibration and noise damping properties.

The mechanism for reducing sound depends on from where the sound comes from. If it is generated within a room then sound is absorbed. If it is airborne, it is originating from outside then it is necessary to insulate the space. And if it is transmitted through the structure then the structure needs to be isolated from the source of vibration. The effective solution attenuating the compressor noise is by developing a sound proof jacket made up from visco-elastic materials.

II. OUTLINE OF PROJECT WORK

The project work is outlined in following three sections:

1. Theoretical analysis: -

- Studying the basic refrigeration cycle and Construction of Hermetic Reciprocating Compressor.
- Study of the physics of sound.
- Studying of working of reciprocating compressor.
- Studying the earlier NVH test results in order to compare difference between sound pressure and sound power.
- Discussing and finalizing various compressor model on which sound jacket is to be incorporated.
- Designing and developing sound jacket from the prototype compressor.

2. Experimental Analysis:

- To develop suitable setup to carry out the experimental analysis for compressor model for:
- Identification of noise source in hermetically sealed compressor by experimentation with square mesh structure.
- To determine the sound power and pressure by experimental analysis with and without sound jacket for various compressor models at NVH lab.
- To determine sound insertion loss values for the sound jackets used during NVH testing, as selecting the maximum sound attenuation jacket for performance and appliance testing.

- To carry out the performance testing for compressor model with and without sound jacket for determining compressor performance.
- To carry out the appliance testing of compressor with and without sound jacket.

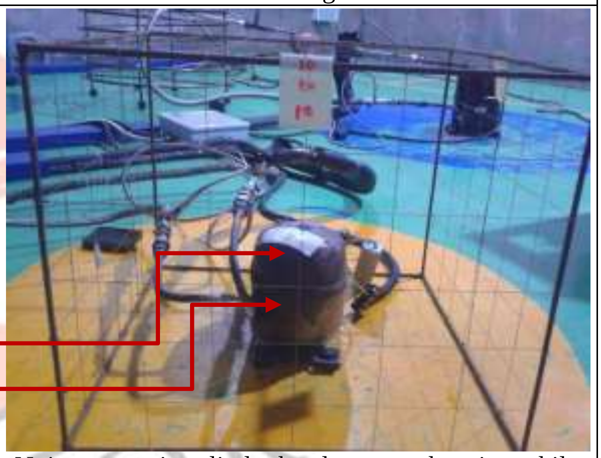
III. EXPERIMENTAL ANALYSIS\

1. Identification of noise source in hermetically sealed compressor by experimentation with square mesh structure:

Location	Frequency[Hz]	Sound Pressure [dBA]
1	160	45
2	160	45
3	400	49
4	160	45
5	160	45
6	400(1000)	50(42)
7	160	45
8	160	45
9	400	47

Noise Source is discharge muffler at the upper housing.

Location	Frequency[Hz]	Sound Pressure [dBA]
10	160	44
11	160	45
12	400	49
13	160	43
14	400 (6300)	48(46)
15	400(6300)	53(42)
16	400	43
17	400	48
18	400	51



Noise source is cylinder head at upper housing while suction muffler at lower housing

2. Overall sound power attenuation from experimental analysis with and without sound jacket for various compressor models at NVH lab.

Table 1 Overall Sound Power(dBA) attenuation by NVH testing

Compressor Model	Sound Jacket	Overall sound attenuation in sound power [dBA]
A	J1	2.8
	J2	0.5
	J3	1.8
	J4	1.5
B	J1	0.6
	J4	5.3
	J1	2.9

C	**J4**	**6.2**
D	**J4**	**6.2**
E	**J4**	**6.3**

3. Photographs of Sound Jackets used for testing:

Jacket J1

Jacket J2

Jacket J3

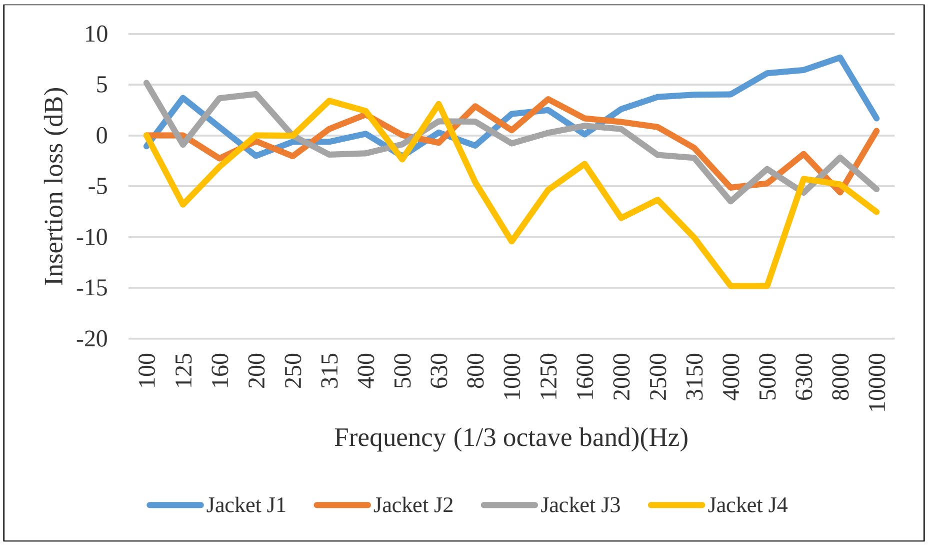
Jacket J4

4. Finalization of Jacket Based On Insertion Loss Values:

Table 2 Insertion Loss (dBA) values for different sound jacket

Frequency [Hz]	Jacket J1	Jacket J2	Jacket J3	Jacket J4
100	-1.07	0	5.18	0.01
125	3.69	0	-0.92	-6.8
160	0.84	-2.28	3.66	-3.09
200	-2.03	-0.57	4.06	0.02
250	-0.62	-2.06	-0.02	-0.03
315	-0.63	0.64	-1.88	3.4
400	0.15	2.06	-1.77	2.41
500	-2.04	0.03	-0.87	-2.37
630	0.28	-0.72	1.4	3.09
800	-0.99	2.87	1.35	-4.61
1000	2.13	0.5	-0.79	-10.44
1250	2.5	3.58	0.25	-5.37
1600	0.1	1.69	0.94	-2.79
2000	2.6	1.34	0.62	-8.14
2500	3.78	0.84	-1.92	-6.35
3150	4.01	-1.24	-2.19	-10.07
4000	4.04	-5.15	-6.51	-14.81
5000	6.14	-4.74	-3.32	-14.83
6300	6.43	-1.81	-5.64	-4.28
8000	7.67	-5.62	-2.18	-4.81
10000	1.67	0.45	-5.31	-7.55
Note-Negative value denotes the insertion loss (dBA) over the corresponding frequency(Hz) by various mentioned sound jackets.				

Graph 1 Trend for insertion loss Vs Frequency for different sound jackets



5. Performance testing of compressor with and without sound jacket:

Table 3 Performance testing for with and without sound jacket for compressor

Performance Data				
Sr. No.	**Parameters**	**Without jacket**	**With jacket(J4)**	**Variation (%)**
1	Mass flow (lbm/hr)	28.5	27.9	-2.1053
2	Cooling Capacity (BTU/hr)	1991.7	1949.4	-2.1238
3	EER	8.58	8.38	-2.331
4	Current(Amps)	1	1	0
5	Power(watts)	232	232.6	0.25862

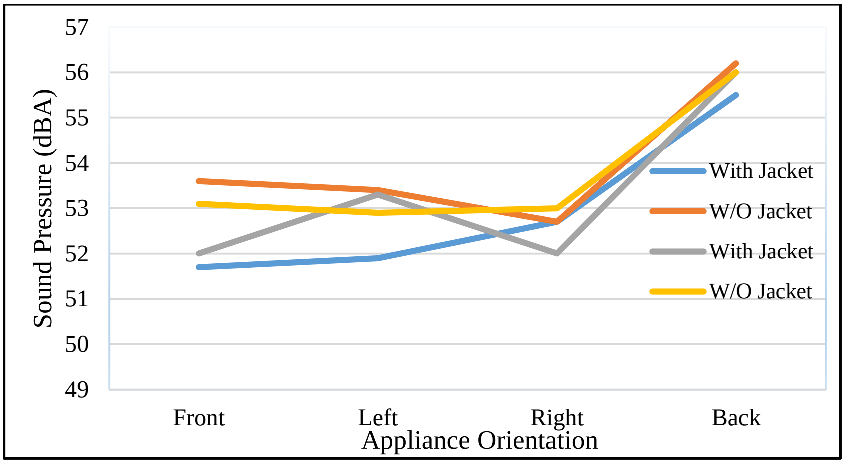
Thermal Performance				
Sr.No.	***Parameters***	***Without jacket (°F)***	***With jacket(J4) (°F)***	***Variation (°F)***
1	Top Shell	147.9	184.7	(36.80)
2	Bottom Shell	146.7	186.3	(39.60)
3	Middle at shell	169.5	181.1	(11.60)
4	Discharge Line	159.5	165.7	(6.20)
5	Winding Temp. (M/A/M+A)	189/178/177	202/198/197	(13/20/20)

6. Appliance testing of compressor with and without sound jacket:

7. Table 3 Sound Pressure (dBA) values by appliance testing

	Sound Pressure (dBA)			
	35°C Ambient		**43°C Ambient**	
Appliance Orientation	**With Jacket (J4)**	**Without Jacket**	**With Jacket (J4)**	**Without Jacket**
Front	51.7	53.6	52	53.1
Left	51.9	53.4	53.3	52.9
Right	52.7	52.7	52	53
Back	55.5	56.2	56	56

Graph 2 Trend for sound pressure Vs appliance orientation at Application Test lab



IV. CONCLUSIONS

From the experimental work carried on the design and development of sound jacket for hermetically sealed compressor using viscoelastic materials the following findings are discussed,

1. The NVH testing carried at semi-anechoic chamber, the testing conducted by four different sound jacket over wide range of compressor. The experimental test result concluded that the major sound power attenuation was observed in the frequency range of 1K to 10 K Hz frequency range in 1/3 octave band. The maximum overall sound power attenuation was observed in Jacket J4 ranging from 5.3-6.3 dBA. Hence the jacket J4 was finalized for further testing.
2. The insertion loss values of the sound jacket was basically calculated in order to justify the maximum sound attenuating capacity. From the stated insertion loss values, it can be concluded that the jacket J4 has maximum insertion loss of 15 dBA.
3. The performance testing was carried out by finalized sound jacket J4. The performance testing result concluded that the variation of the performance parameters values are within the specified limit of ± 5% as per IS5111 standard. The test also concluded there is only 4°C increase in shell temperature of compressor by sound jacketing which does not lowers the cooling capacity of compressor.
4. The appliance testing was conducted to address the issue of human sound perception issue. The sharp noise from the compressor was eliminated and sound pressure attenuation of 2dBA was achieved.

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