Experimental Study of Blower in HVAC to Reduce Noise Level

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Abstract— Centrifugal blower serves as the primary source of airflow & aero-acoustic noise. Present work focuses on the sources of noise in blower of HVAC. The main objective of the project is to design blower for improving their efficiency from an aeroacoustics point of view by modifying geometry in cut-off area. In this work different prototypes were made and then studied experimentally. The result shown that by making changes in geometry of cut-off area of blower, noise gets reduced.

Key words: Centrifugal Blower, Aero-Acoustics Noise, Cut-Off

I. INTRODUCTION

Passenger's acoustic comfort is of greater importance in the automobile development process. Car manufacturers and system suppliers are looking for more control of sound emission. The demand for the more control of noise is increasing day by day as levels of driver and passenger's satisfaction is continually growing. As a matter of fact, HVAC systems, are no longer evaluated only by the airflow performance, but today sound quality is an important criterion that should be considered.

HVAC is heating, ventilation and air conditioning component of vehicle to maintain climatic condition inside vehicle. Front HVAC is situated inside dashboard of vehicle and in some vehicle rear HVAC is also situated. Front HVAC has three louvers which works in bypass & recirculation mode. The rear HVAC works only in recirculation mode. Functions of HVAC is:

- It must cool or heat the air depending upon the surrounding temperature.
- It must circulate the air in vehicles.
- It must filter the air coming in the vehicle from outside containing dust particle.
- It must dehumidify the air.

An automotive air conditioning system is typically compact. The control and reduction of noise of automotive air conditioning systems is difficult. Due to complex flow field & packaging space limitation, HVAC produces high sound pressure levels & achieving noise improvement in HVAC is difficult. Doing modification in blower is also difficult as flow is highly turbulent in this region.

A centrifugal fan or blower is the air-moving component in all automotive heating and air conditioning systems. The flow of air can be changed. The working of blower is shown in fig 1. In operation, an electric motor rotates the fan or impeller. The rotation of the fan's blades imparts kinetic energy to the air in the form of a velocity change, which produces airflow and pressure difference. There are three types of centrifugal blower fan: i) Forward-curved ii) Backward-curved & iii) Straight-radial. Out of which forward-curved are widely used in industrial application. Mostly forward- curved fan is used as automotive centrifugal blower fan. The parts of centrifugal blower are schematically shown in fig 2.

Two important parts of any centrifugal fan are: Impeller & Scroll

- The impeller increase the kinetic energy of the air and,
- The scroll, or housing, directs the flow into, around, and out of the impeller and provide a smooth path to discharge of high energy air.

The inlet flow accelerates in two steps. First, when it turns radially to enter the impeller blades, and the second time is when the moving blades impose a tangential force. as a result of this process, there should be a reduction in static pressure. This pressure variation reaches its maximum immediately after the cutoff area and gradually reduces to a minimum on the discharge side of the cutoff.

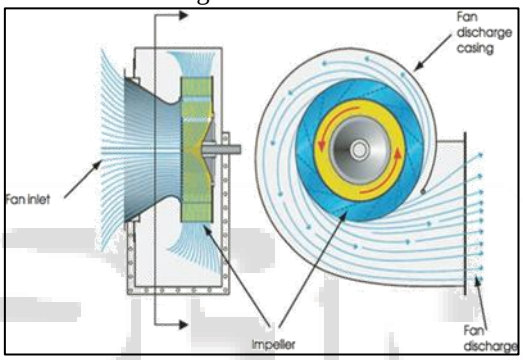

Fig. 1: showing working of blower system

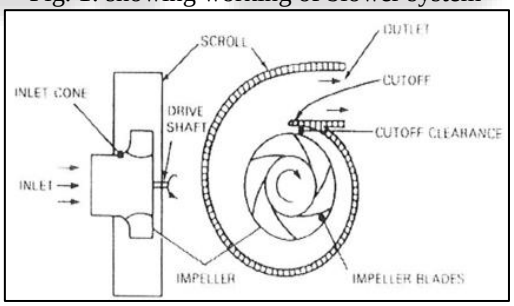

Fig. 2: Schematic of main parts of centrifugal fan

II. LITERATURE REVIEW

The fact is the control and reduction of noise of automotive air conditioning systems is difficult due to the packaging space limitation. Sources of noise are various components like flow ducts, evaporator core, blower, louvers but among them which is dominant source of noise needs a detailed investigation.

1) Kishokanna Paramasivam et.al., (2017) studied noise characteristics in high speed centrifugal fans. He suggested methods to predict tonal noise in centrifugal blower. He studied unsteady flow field in fan by Computational fluid dynamics using DES model. He predicted that due to jet-wake flow at impeller outflow causes pressure fluctuations at leading edge of diffusor vane which leads to tonal noise in centrifugal fans.

2) Kishokanna Paramasivam et.al.,(2015) To reduce tonal noise & non-traditional noise, he designed guide vanes to replace stationary diffuse vanes in centrifugal blower of vacuum cleaner using computational fluid dynamics(CFD) tools. He experimentally validated numerical modelling and concluded that tonal noise in centrifugal fan can be reduced by changing the leading edge inlet angle.
3) Franck Pérot, et.al., (2010) studied two cases of centrifugal blower by modifying shape of casing at inlet of blower. He used Explicit and compressible CFD/CAA simulations based on the Lattice Boltzmann Method to predict simultaneously the flow information in terms of pressure rise and aeroacoustics noise of two HVAC blowers.
4) Qi Datong et.al., (2009) carried an experimental study on centrifugal fan by modifying volute tongue, by modifying hub-volute clearance, coupling effect of volute tongue geometry and hub-volute clearance to reduce tonal noise. He studied effect of different modification on flow, noise & efficiency of centrifugal fan. He showed that coupling effect reduces tonal noise of fan.
5) M Younsi et.al, (2007) studied the unsteady flow in small squirrel cage fan using computational fluid dynamics (CFD) & validated experimentally. He studied the wall pressure fluctuations on volute surface. Using Ffowcs Williams–Hawkings equation he estimated tonal noise generated by the centrifugal fan. He correlated the wall pressure fluctuations and the far field noise signals.
6) Robert Sandboge studied a centrifugal blower with a flat hub is analyzed using Computational Fluid Dynamics. He predicted flow characteristics to provide input to noise analysis. He studied different approaches including steady state versus transient analysis, rotating blower frame versus moving mesh models, and analyzed different turbulence models.
7) Vahid Madani studied noise sources characteristics of automotive HVAC system. Author surveyed all sources of noise in HVAC e.g. from louver, impeller at different speed, blower, etc. He presented literature review of the flow-induced noise in automotive air conditioning systems and fans. He discussed performance and aerodynamic noise aspects of forward-curved fans. He presented results of all tests for the complete front and rear HV AC systems and their fans alone for both inlet and outlet sides.
8) Eui-Yong Kwon et.al. Studied forward-curved centrifugal fan in blower. He studied the flow behavior of two difeerent fan & made design improvement to find important flow features.
9) Asad. M. Sardar et.al. (2001) conducted experiment of flow visualization under water in similar conditions as those in air on actual HVAC fan module. He studied the flow pattern to improve aeroacoustic noise fan-scroll/diffuser interaction.
10) Neise (1975) studied causes of aerodynamic noise in centrifugal fan. His studied specifically focuses on impeller: impeller i) with forward curved blades ii) with backward curved blades iii) with radial curved blades.

A. Summary of Literature Review

Based on above literature review ii is concluded that blower is dominant source of noise & its causes are as follows:

1) Sources of Noise in Blower

- The noise sources are due to the distribution of surface stresses which consist of shear stresses and surface pressure.
- An unbounded flow that corresponds to the noise generation due to volume sources.
- Siren tone resulting from the interaction of rotating and stationary parts of a centrifugal fan
- Interaction of inlet flow with the flow around the blades of a fan generates sound due to fluctuating stress
- Location of cut off is dominant cause of noise
- Due to inlet turbulence and separated boundary layer.
- Interaction of the shedding vortices from the blade with the cut-off
- The mass-flow pressure characteristic
- Blade characteristic
- Flow separation on the blades
- From the high level of turbulence in the re-circulating flow at the blower inlet.
- The noise will be generated due to the pressure fluctuations applied to the blades.

B. Project Objectives

The objectives of this project work are as follows:

- To reduce the noise level in blower by 0.4 dB(A) at 422 m^3/hr
- To do geometrical modification in prototype of blower
- To study experimentally the different proposals of prototype to find noise level

III. METHODOLOGY

The experiment is carried out as per shown in following flowchart.

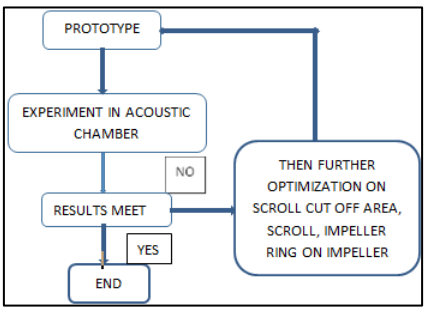

Fig. 3: Methodology

IV. EXPERIMENTAL SET-UP

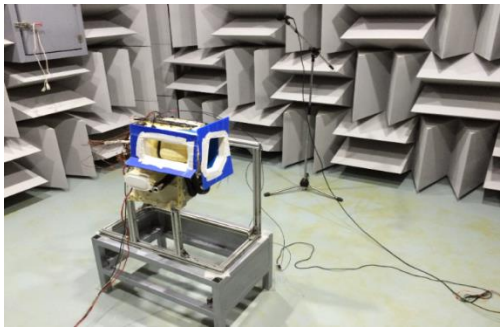

Fig. 4: Experimental Set-up

The experimental set-up is placed in semi-anechoic chamber where the background noise being measured is less than 10 dBA noise. One microphone is used which is located 1 m away in X direction & 0.5 m away in Z direction.

A. Conditions for Experiment

Experiment is carried out at 10.6 voltage for 0Pa pressure for the air flow of 422 m^3 /hr. The experimental conditions for blower is shown in table below.

Mode	Air inlet	Temp position	Pressure (Pa)	Voltage (V)	Air Flow ACMM	Air Flow (m3/hr)	RPM	Current (A)	Power (W)
Vent	REC	FC	0	10.6	7.03	422	2597	14.5	154

Table 1: Conditions for centrifugal blower to carry out experiment

B. Modification on Centrifugal Blower

Sr. No.	Proposal	Case	Model
1	Proposal 1	Case 1	Add Scroll Tongue
		Case 2	Add Scroll Tongue and impeller Ring
2	Proposal 2(case 3)		Add Scroll Tongue to Base Model
3	Proposal 3	Case 4	Reduce Gap Between Impeller & Flange
		Case 5	Reduce Gap Retest
4	Proposal 4 (Case 6)		Add Impeller Ring in Base Model

Table 2: Proposals finalized for Prototype to reduce noise

First modification is done by adding scroll tongue rib to base blower as per reference taken from as shown in fig 4. Initial value of sound pressure level is 59.41 dB (A) at 2689 RPM and after adding scroll tongue SPL is 59.44 dB(A) at 2690 RPM. Noise level increases after adding scroll tongue rib. Once impeller ring is added to case 1, the noise level is reduced to 59.25 dB (A).

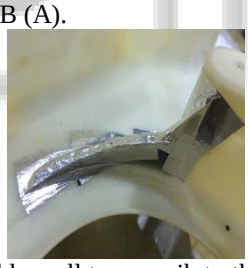

Fig. 5: Add scroll tongue rib to the top case

Fig. 6: Gap modification

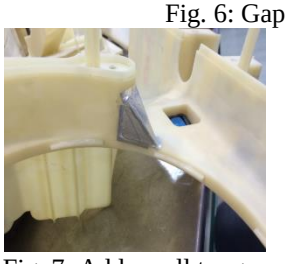

Fig. 7: Add scroll tongue

Fig. 8: Add impeller ring

The next modification is by adding small scroll tongue. The initial value is 59.46 dB(A) and after modification noise level increases to 59.80 dB(A).

Next modification is by modifying gap. Two iterations carried out on gap modification between impeller and flange. First one is reducing gap by 8 mm & second iteration is reducing by 6mm. The baseline value & noise level after modification is shown in table 3.

Proposal 3							
Case 1				Case 2			
Noise (dBA)	RPM	Noise (dBA)	RPM	Noise (dBA)	RPM	Noise (dBA)	RPM
58.5	2646	58.5	2663	59.46	2682	59.53	2691

Table 3: Readings of Sound Pressure Level (SPL) for Proposal 3

Further modification is done by addition of impeller ring to base model shown in fig 7. The noise level of base model & modified model is shown in table 4.

Mode	Air Inlet	Temp position	Initial Stautus		Add Impeller Ring		Improve (dBA)
			Noise (dBA)	RPM	Noise (dBA)	RPM	
Vent	REC	FC	59.61	2665	59.18	2648	-0.4

Table 4: Readings of Sound Pressure Level (SPL) for Proposal 4

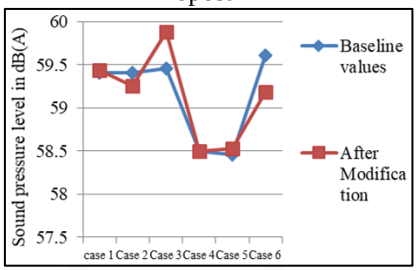

Fig. 9: Comparison between sound pressure levels of base model of blower & modified model of blower

V. RESULT AND DISCUSSION

1) Addition of scroll tongue rib as shown in fig 5 has increased the noise level by 0.4 dB (A).Once scroll tongue rib & impeller ring is added to base model noise level reduces by 0.02 dB(A). It confirms that noise level is reduced by adding impeller ring
2) Adding scroll tongue as shown in fig 6 increases noise leve.l
3) Optimization done by modifying gap has shown no improvement in noise level.
4) Adding impeller ring has given optimized reduction in noise level.It reduced noise by 0.04 dB (A). It has given additional improvement with fresh air in vent mode & foot mode as shown in table 5.

Mode	Air Inlet	Temp position	Initial Stautus		Add Impeller Ring		Improve (dBA)
			Noise (dBA)	RPM	Noise (dBA)	RPM	
Vent	Fresh	FC	57.71	2436	56.81	2406	-0.9
Foot	Fresh	FH	53.86	2404	51.34	2380	-2.5

Table 5: Result

VI. CONCLUSION

1) In the present paper, different modification on blower: i) add scroll tongue ii) add impeller ring iii) coupling effect of i) & ii) iii) gap modification are fabricated and experimentally tested.
2) The noise is reduced by adding impeller ring
3) By adding impeller ring re the noise level of blower is reduced by 0.4 dB (A) at 422 m^3 /h air flow & RPM 2648.

VII. FUTURE SCOPE

1) More study to dampening noise by changing the material at cut off area.
2) Dampening motor noise by using different motor cover material
3) FEM analysis to evaluate different cost-effective counter-measure proposals for noise reduction.

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