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A Comparative Study on Flow Resistivity for Different Polyurethane Foam Samples

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ABSTRACT

Polyurethane foams are used for noise control applications in Automotive and Genset Industries. These foams are good sound absorber and can be used in the vehicle interior and inside the genset enclosure. These foams are used as replacement to traditional combination of mineral wools / rock wool along with perforated panels which require labor and also health hazardous. Polyurethane foams are generally available in various densities and thickness. The paper presents effect of variation in density and thickness on flow resistivity and thereafter sound absorption of polyurethane foam. Due to their inhomogeneity and anisotropy, intrinsic material properties of PU-foams are found to vary with thickness and position. In this paper, flow resistivity of polyurethane foam samples of different densities and thickness is measured using standardized flow resistivity test rig. These flow resistivity values are compared with different density and thicknesses. The normal incidence sound absorption coefficient is also measured using two microphone impedance tube. The variation in sound absorption coefficient is found to be due to variation in flow resistivity values. A study is also carried out to correlate NRC values with density and flow resistivity of the samples which will aid noise control engineers in selecting proper polyurethane foam with a right airflow resistivity value for their particular applications.

1. INTRODUCTION

The acoustic performance of sound absorbing poroelastic materials is governed by its five intrinsic physical parameters like flow resistivity, porosity, tortuosity, viscous and thermal characteristic lengths. The most important parameter which determines sound-absorptive and sound-transmitting properties of acoustic materials is the flow resistivity. Measurement of specific airflow resistance is useful during product development and quality control during manufacture. It is defined as the ratio of the pressure difference across a sample to velocity of flow of air through that sample. Flow resistivity values range from 1000 to 300000 Ns/m4. The flow resistivity depends on the porosity of a material as well as its tortuosity, but for high porosity, low tortuosity fibrous materials, the flow resistivity is approximately inversely proportional to fiber radius squared at a constant bulk density i.e., a large number of small fiber diameters results in a higher flow resistance than does a small number of larger fibers. At microscopic level, the flow resistance results from the formation of a viscous boundary layer as fluid flows over each fiber, and the amount of shearing in that boundary layer increases as the fiber radius decreases[1]. There are two international standards available for measurement of airflow resistivity such as ASTM C-522[2] "Standard Test Method for Airflow Resistance of Acoustical Materials" and ISO 9053[3] "Determination of Airflow Resistance of Acoustical Materials". ASTM C-522 standard describes direct airflow method in which controlled unidirectional airflow is passing through test specimen and measuring the resulting pressure drop between two free faces of specimen. ISO 9053 specifies two methods to determine airflow resistance and flow resistivity - Method A is similar to ASTM C -522 and Method B is the alternating airflow method in which alternating airflow is induced slowly through the test specimen and measuring the alternating component of the pressure in a test volume enclosed by specimen [4].

2. MEASUREMENT OF AIRFLOW RESISTIVITY

Flow resistivity measurement was carried out as per ASTM C-522 standard. This test method is designed for the measurement of values of specific airflow resistance ranging from 100 to 10 000 rayls (Pa-s/m) with linear airflow velocities ranging from 0.5 to 50 mm/s and pressure differences across the specimen ranging from 0.1 to 250 Pa. The schematic diagram of the testing carried out and test rig are shown in Figs. 1 and 2. Specimen mounting assembly consists essentially of a mounting plate and a specimen holder. The mounting plate has two holes for tube connections to the pressure measuring device and to the airflow supply. The specimen holder, which is sealed to the mounting plate, is a transparent plastic tube made of acrylic at least 150 mm long with a diameter 100 mm. Vacuum pump, a suction generator is used to draw air at a uniform rate through the test specimen.

A flow meter is used to measure the volume velocity of airflow through the specimen. The steady state flow of air through the specimen was maintained by a pressure regulator and Differential Pressure Transducer is used to measure the static pressure difference between the free faces of the specimen with respect to atmosphere. Cylindrical specimen were die cut of diameter 100 1 mm to fit tightly into the specimen holder. The measurement is done at three different air flow velocities and average result was reported. An airflow velocity is well below 50 mm/s. The differential pressure and flow rate were recorded. A series of measurements repeated at least three times at airflow below the turbulent level is made and the flow resistivity is calculated using equation

Air flow resistance R is calculated as:

$$R = \Delta p / qv \qquad (2)$$

where, Δp = air pressure difference in pascals
qv = volumetric airflow rate in m^3/s

Specific air flow resistance is given as:

$$Rs = (\Delta p / qv)^* A = RA = \Delta p / v \qquad (3)$$

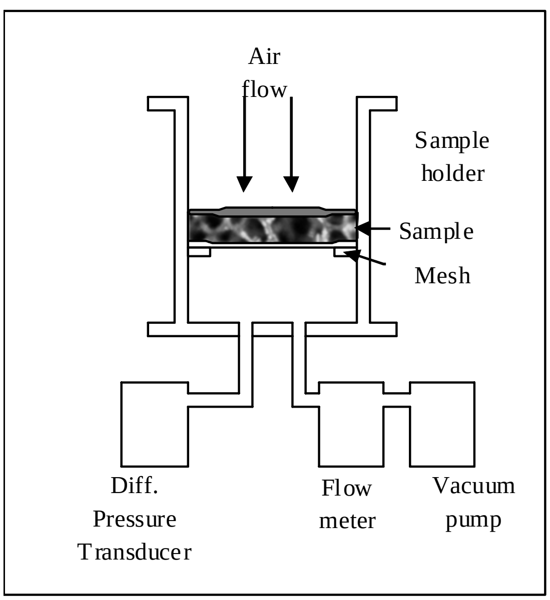

Fig. 1. Schematic diagram of flow resistivity testing

Fig. 2. Flow resistivity test rig

where, A = cross sectional area in m^2
v = linear airflow velocity in m/s

Air flow resistivity r is calculated as:

$$r = (\Delta p / qv)*(A/d) = Rs/d \tag{4}$$

where, d = thickness in meter

The validation of the tested results using flow resistivity test rig is carried out using standard samples such as melamine foam which is highly homogeneous. Table 1 shows the comparison of tested flow resistivity values for melamine foam samples in ARAI with other laboratories in the world. Flow resistivity tested in ARAI shows 5% deviation compared to other laboratories, which shows very good correlation of tested results.

Table 1. Flow resistivity values of melamine foam tested at different laboratories

Laboratory	ARAI,	ENDIF,	SHEBROOKE ,	PURDUE	UNIVERSITY
Air flow	INDIA	ITALY	UNIVERSITY	UNIVERSITY	OF NAPLES
resistivity		CANADA			
(Ns/m^4)	11055	10518	10718	10900	11000

3. RESULTS AND DISCUSSION

In this study, two polyurethane foam samples of different density 22 and 36 kg/m3 having thickness 15, 25, 50, 75 and 100 mm were chosen. Three samples of each thickness named as S1, S2 and S3 were tested. All these samples are die cut in 100 mm diameter as shown in Fig. 3.

For each sample S1, S2 and S3 flow resistivity measurements were repeated two times to check the repeatability. Maximum 2% variation is observed in flow resistivity values for all the tested samples. Table 2 shows the percentage deviation of flow resistivity for sample 1 and sample 2 is 5-35%. Figures 4 and 5 shows the flow resistivity values for different thicknesses 15, 25, 50, 75 and 100 mm of sample 1 and sample 2 respectively. It has been observed the variation in flow resistivity w.r.t. thickness for sample 2 is higher as compared to sample 1. This variation might be due to anisotropic and inhomogeneous nature of PU foam.

Normal incidence sound absorption coefficient (NISAC) was measured for all the samples using two microphone impedance tube as per ISO 10534 -2. Figures 7 and 8 shows the comparison of sound absorption coefficient of sample 1 and sample 2 for 25 mm and 50 mm thickness foam. Sample 2 shows higher sound absorption values as compared to sample 1 due to higher flow resistivity values. The sound absorption of acoustic materials is expressed in terms of single number rating called as NRC (Noise reduction coefficient). Figure 9 shows the effect of flow resistivity on NRC of sample 1 and sample 2 for all the thickness.

Fig. 3. Melamine and PU foam samples

Table 2. Flow resistivity values of sample 1 and sample 2 for different thicknesses

Flow Resistivity for Sample 1 of 22 kg/m^3 density						Flow Resistivity for Sample 2 of 36 kg/m^3 density					
Thickness, mm	15	25	50	75	100	Thickness, mm	15	25	50	75	100
S1	10216	9755	14258	10124	12881	S1	14943	11730	25419	22476	20331
S2	6325	6776	10648	9913	9879	S2	14241	15110	12893	31277	-
S3	10530	8033	6983	8162	-	S3	13089	13655	18437	22986	-
Average	9024	8188	10630	9400	11380	Average	14091	13498	18916	25580	20331

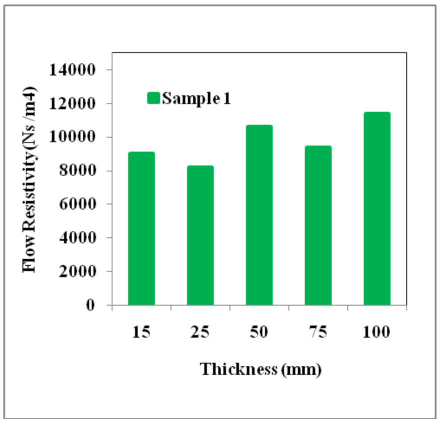

Fig. 4. FR of sample 1 for different thickness

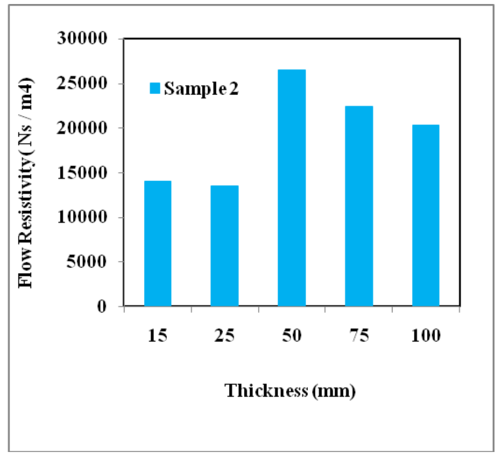

Fig. 5. FR of sample 2 for different thickness

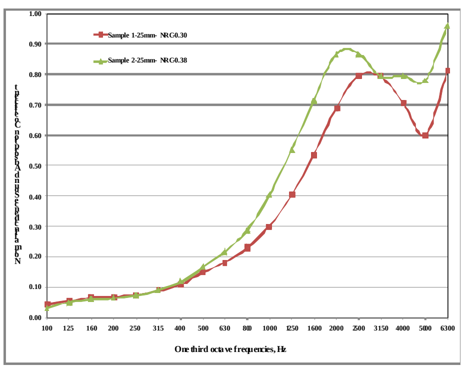

Fig. 6. NISAC for 25 mm thickness both samples

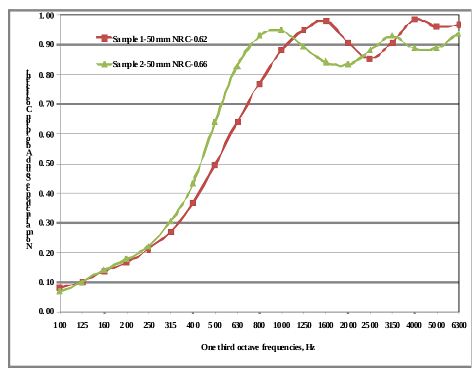

Fig. 7. NISAC for 50 mm thickness both samples

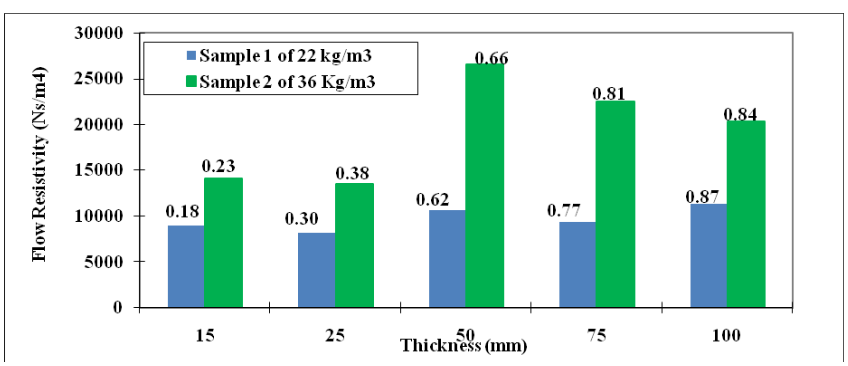

Fig. 8. Effect of flow resistivity on NRC of Sample 1 and Sample 2 for all thicknesses

4. CONCLUSION

This paper presents a detailed discussion on measurement of flow resistivity of PU foam samples. The flow resistivity of standard samples such as melamine foam has been validated with other laboratories worldwide, which shows the good accuracy of the tested results. It has been observed the flow resistivity increases with increasing the density of materials. Also sound absorption and NRC shows higher values with increasing the flow resistivity of materials. There is variation in flow resistivity for the same sample w.r.t. to thickness. This variation might be due to anisotropic and inhomogeneous nature of PU foam.

5. ACKNOWLEDGMENT

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6. REFERENCES

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