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Adjustable Acoustical Performance Based on Deformable Origamic Shapes: A Preliminary Experimental Investigation

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Abstract. This paper describes a preliminary investigation on the possible use of deformable origamic shapes as a technique to provide adjustable acoustical performance in multi-purpose hall. The term ‘deformable’ means that the origamic shape undergoes deformation which automatically resulted into the change of its geometrical configurations. The experimental investigation has been carried out on three types of origamic shapes with several geometrical configurations. The measurement tests were conducted in a reverberation room and in accordance to ISO 354:2003 *Measurement of Sound Absorption Coefficients in a Reverberation Room*. Findings from the preliminary investigation show good trends indicating that the origamic shapes have the capability of adjusting the sound absorption coefficients by varying their geometrical configurations. Following those results, future works with details investigation will be undertaken as to validate the preliminary results.

Introduction

Adjustable acoustical performance is necessary when an enclosure needs to serve more than one purpose. It may due to economics reason that an enclosure is designed to carry multi-acoustics requirements [1]. Such enclosure is called as multipurpose hall or multipurpose room. Examples of them are studio recording room, concert hall, seminar hall etc. To carry this objective, the enclosures were equipped with adjustable acoustics where the acoustics conditions can be adjusted according to the type of events to be held inside the enclosures. This is because different type of events (e.g music performances, speech) would require different acoustics conditions in order to achieve optimum conditions as well as producing good sound quality [2]

Generally there are two types of techniques namely variable absorption and variable volume [3]. The draperies technique is considered as the common technique in variable absorption since 1940 [1]. The technique employed drapes which can be introduced when the absorption properties need to be increased and can be retracted when the absorption need to be reduced. This technique also widely used in many acoustics halls which is very effective to vary the reverberation characteristics of the hall [4]. Besides that, variable absorption also can be achieved by introducing portable absorbent panels, hinged panels, louvered panels and also rotating elements/panels [1]. However careful adjustment need to be taken into serious account since too much absorption would affect the sound strength and might deaden the room or hall [4]

Another method is based on variable volume technique. This technique normally achieved by using moveable ceiling. For instance, Studio Acusticum in Sweeden has adopted moveable ceiling which can be adjusted up to 5 meter and resulted in the change of volume of about 30 % [5]. In addition, volume of the hall can be varied by coupling the main hall with multiple chambers [3]. However, application of diffusers inside the acoustics hall also contributes to a good acoustics. Diffuser has the ability to disperse the reflected sound and helps to conserve the reverberation time and sound energy as well as reducing echo problem on a large hall [6]. Usually, the diffuser is made from wooden structures and comes from various corrugated shapes [7].

Following those techniques, this paper proposes another technique which based on the deformable origamic shapes where it is believe that the origamic structures have the capability to provide adjustable acoustics by varying their geometrical configurations.

Measurement Method

The aim of the measurement is to investigate the possible use of deformable origamic shapes in adjusting the acoustic properties by varying their geometrical configurations. To carry out the investigation, three different types of deformable origamic shapes (*see* Figure 1 to 3) have been tested in a reverberation room. The specimens were folded from 1200 gsm chipboards and in order to form a large specimen, they were joined with white glues. The reverberation room has a volume of 54.65 m^3 and a Schroeder frequency of 500 Hz. The measurement procedures were according to ISO 354:2003 *Measurement of Sound Absorption Coefficient in a Reverberation Room* [8]. The measurements were taken for empty reverberation room and with the present of the specimen of different configurations as tabulated in Table 1 to 3. The excitation inside the reverberation room were done by using balloon bursts and the impulse responses were recorded by a Solo 01dB Sound Level Meter from two different microphone positions. The microphones were 1.5 m apart and the distance of the specimen to the microphone was 1 m. Each measurement was repeated four times and the reverberation times were then averaged for two microphones positions. The temperature and relative humidity of the measurement were maintained approximately at 26°C and 78% throughout the whole measurements.

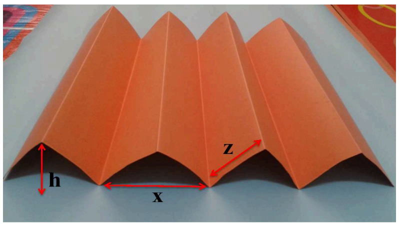

Fig. 1: Origamic Shape 1

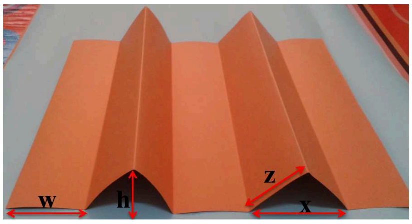

Fig. 2: Origamic Shape 2

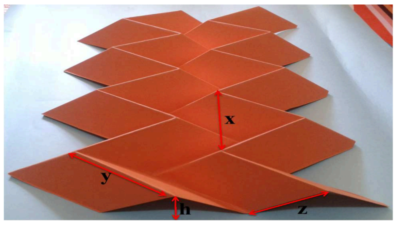

Fig. 3: Origamic Shape 3

In the preliminary investigations, the surface area covered by the specimen were approximately maintained the same throughout the variations of geometrical configurations. This is because when the origamic shape changes its configuration, the parameters of origamic geometry (i.e h and x) and surface area covered by the specimen would be varied according to the change of the origamic shapes. However, since it was already known that the surface area covered by the specimen do affects the reverberation time of the reverberation room [6], the surface area in this investigation must be kept constant while other geometry parameters (h and x) were varied. Therefore, to maintain the surface area covered by the specimen, fractions of the specimen were removed from one configuration to another in order to maintain constant surface of the three deformable origamic shapes. Noticed that the length of parameters w, y and z were the same throughout the change of geometrical configurations.

Table 1: Geometrical Configurations of Deformable Origamic Shape 1

Configuration	h (cm)	x (cm)	z (cm)	Surface Area (m^2)
Configuration 1	22	37	28	3.34
Configuration 2	18	42	28	3.34
Configuration 3	14	47	28	3.34
Configuration 4	10	52	28	3.34

Table 2: Geometrical Configurations of Deformable Origamic Shape 2

Configuration	h (cm)	x (cm)	w (cm)	z (cm)	Surface Area (m^2)
Configuration 1	20	9	20	20	3.34
Configuration 2	18	18	20	20	3.34
Configuration 3	16	24	20	20	3.34
Configuration 4	14	30	20	20	3.34
Configuration 5	12	33	20	20	3.34
Configuration 6	10	35	20	20	3.34

Table 3: Geometrical Configurations of Deformable Origamic Shape 3

Configuration	h (cm)	x (cm)	y (cm)	z (cm)	Surface Area (m^2)
Configuration 1	23	31	21.5	28	3.34
Configuration 2	21	33	21.5	28	3.34
Configuration 3	17	36	21.5	28	3.34
Configuration 4	15	38	21.5	28	3.34
Configuration 5	13	40	21.5	28	3.34

Results and Discussions

The results were presented in one-third octave bands frequencies and the calculation of sound absorption coefficients were calculated according to ISO 354:2003 [8]. Throughout the whole measurements, the main questioned was 'When the geometrical configurations of the deformable origamic shapes vary, are the results of sound absorption coefficients vary too?' For that questioned, this preliminary work try to provide some insight on the appropriateness and suitability of research objective which is to propose a technique on adjustable acoustics using deformable origamic shapes.

Figure 4 to Figure 6 show the results of sound absorption coefficients of several geometrical configurations of origamic shape 1, 2 and 3. Each origamic shape shows different number of configurations due to different type of geometry. Figure 4 shows the variation of sound absorption coefficients of origamic shape 1 when its geometry changes from configuration 1 to configuration 4. At the frequency of 2000 Hz and above, the variations of the results show good trends. Based on the trends, sound absorption coefficients decrease as the origamic shape 1 change its configuration from 1 to 4. The differences on the sound absorption coefficients from one configuration to another seem inconsistent throughout the measurements. Meanwhile, Figure 5 shows the change of sound absorption coefficients from configuration 1 to 6. This clearly shows that at the frequency of 2000 Hz and above, the sound absorption coefficients decrease as the origamic shape 2 change its geometrical configurations but at configuration 3, 4 and 5 the trends seem unchanged. Similarly, a same trend also observed at Figure 6 where the sound absorption coefficients slightly decrease as the geometrical configurations of origamic shape 3 varied from configuration 1 to 5. Although the results show small differences, the differences between configurations were still noticeable.

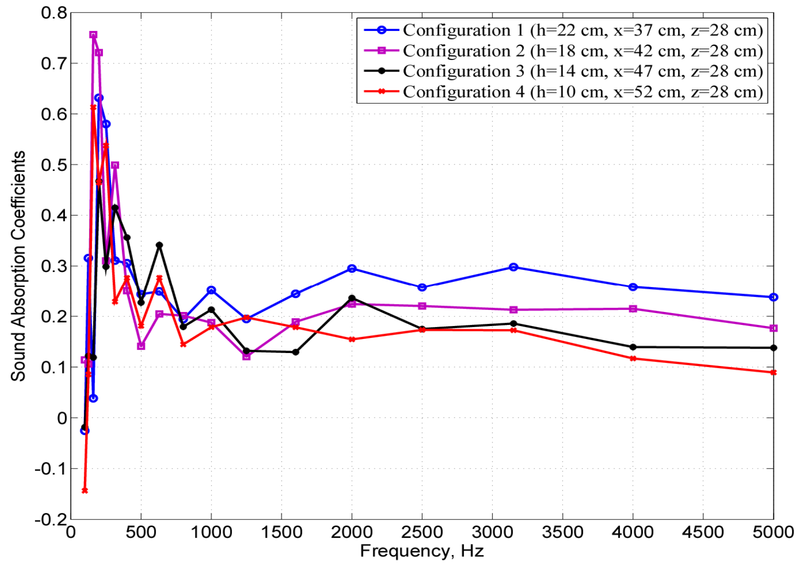

Figure 4: Variation of Sound Absorption Coefficients of Origamic Shape 1

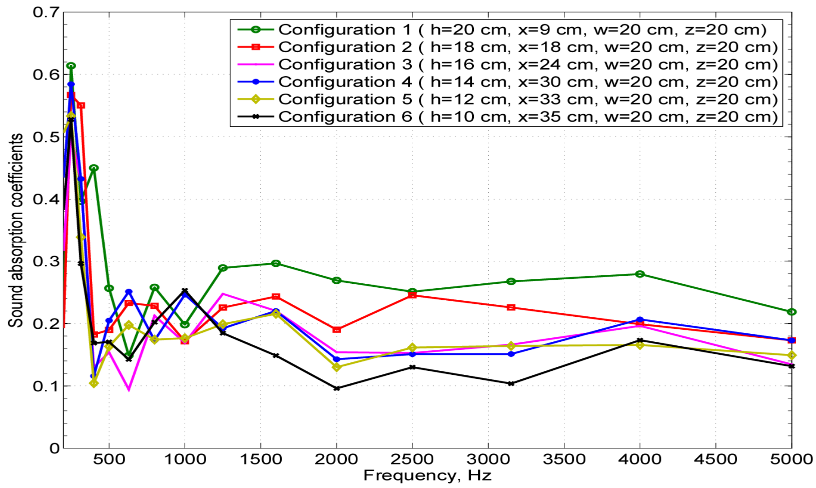

Figure 5: Variation of Sound Absorption Coefficients of Origamic Shape 2

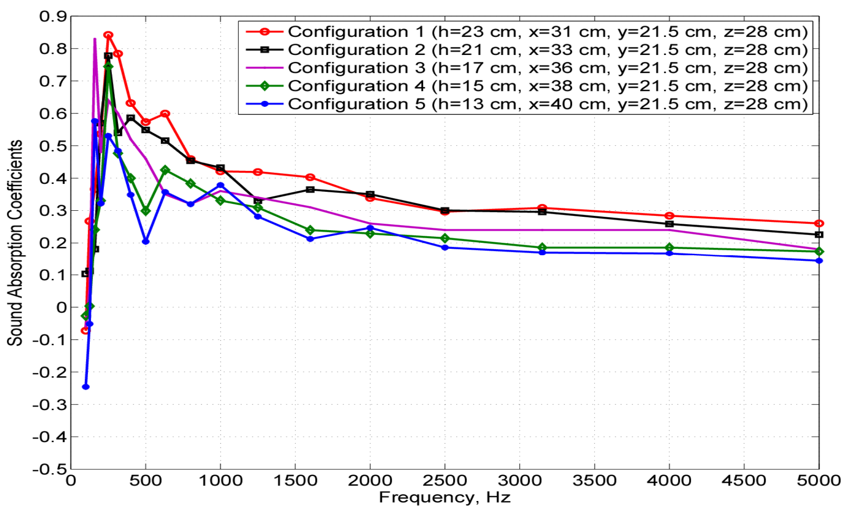

Figure 6: Variation of Sound Absorption Coefficients of Origamic Shape 3

However, the results of sound absorption coefficients at low and mid frequencies did not show any conclusive trends. This is because, at low frequencies the wavelengths are very long, thus the thickness of the material should be at least one-quarter of a wavelength in order to effectively absorb sound at those frequencies ranges [9]. Consequently, the results show good trends at high frequencies which are above 2000 Hz which probably due to the depth of the origamic shapes were sufficient to absorb sound at high frequencies. Besides that, the measured sound absorption coefficients are often more inaccurate at low than high frequencies due to modal effects [6]. In addition, since the specimen was quite large which was about 3.34 m^2 and joined with white glue, there are surface irregularities. The problem then affected the measurements process especially when taking the value of parameters h, x, w, y and z as well as maintaining the fixed surface area. The surface irregularity of the origamic shapes also might contribute to the edge effects which then will result in poor prediction of sound absorption coefficients [10].

Conclusion

Overall, despite the small changes obtained on the sound absorption coefficients from the three types of deformable origamic shapes, a similar trend was observed from all the results. Thus, the objective of the study has been achieved which provides significant knowledge on the behavior of the origamic shapes based on the variation of their geometrical configuration. However, results from the preliminary work will be validated in a one-fifth scale model of reverberation chamber since the reverberation room that has been used to carry out the measurements did not meet the ISO Standard. Therefore, further investigations in a one-fifth scale model of reverberation chamber will be carried out in order to verify the preliminary results as well as to improve the accuracy of the measurement methods.

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References

[1] F. A. Everest and K. C. Pohlmann, Adjustable Acoustics, in Master Handbook of Acoustics, fifth ed., McGraw-Hills, 2009, p. 151.
[2] F. Jacobsen, T. Poulsen, J. H. Rindel, A. C. Gade, and M. Ohlrich, Fundamentals of Acoustics and Noise Control, 1999.
[3] M. A. Poletti, Active Acoustic Systems for the Control of Room Acoustics, Proceedings of the International Symposium on Room Acoustics, *ISRA*, 2010, no. August, pp. 1–10.
[4] M. Aretz and R. Orlowski, Sound strength and reverberation time in small concert halls, J. Appl. Acoust., vol. 70, no. 8, pp. 1099–1110, Aug. 2009.
[5] R. Okvist, A. Ågren, and B. Tunemamlm, Studio Acusticum – A Concert Hall with Variable Volume, Proceedings of the Institute of Acoustics, 2008, vol. 30, pp. 158–162.
[6] T. J. Cox and P. D'Antonio, Acoustic, Absorbers and Diffusers, Second Edi. Taylor & Francis, 2009, pp. 84–85.
[7] J. Y. Jeon, S. C. Lee, and M. Vorländer, Development of scattering surfaces for concert halls, J. Appl. Acoust., vol. 65, no. 4, pp. 341–355, Apr. 2004.
[8] BS EN ISO 354:2003, Acoustics - Measurement of sound absorption in a reverberation room
[9] P. Newell, Sound, Decibels and Hearing, in Recording Studio Design, Third Edit., Elsevier Ltd., 2012, pp. 13–33.
[10] J. Kim, J. Lee, Y. Choi, and D. Jeong, The Effect of an Edge on the Measured Scattering Coefficients in a Reverberation Chamber based on ISO 17497-1, J. Build. Acoust., vol. 19, no. 1, pp. 13–23, 2012.