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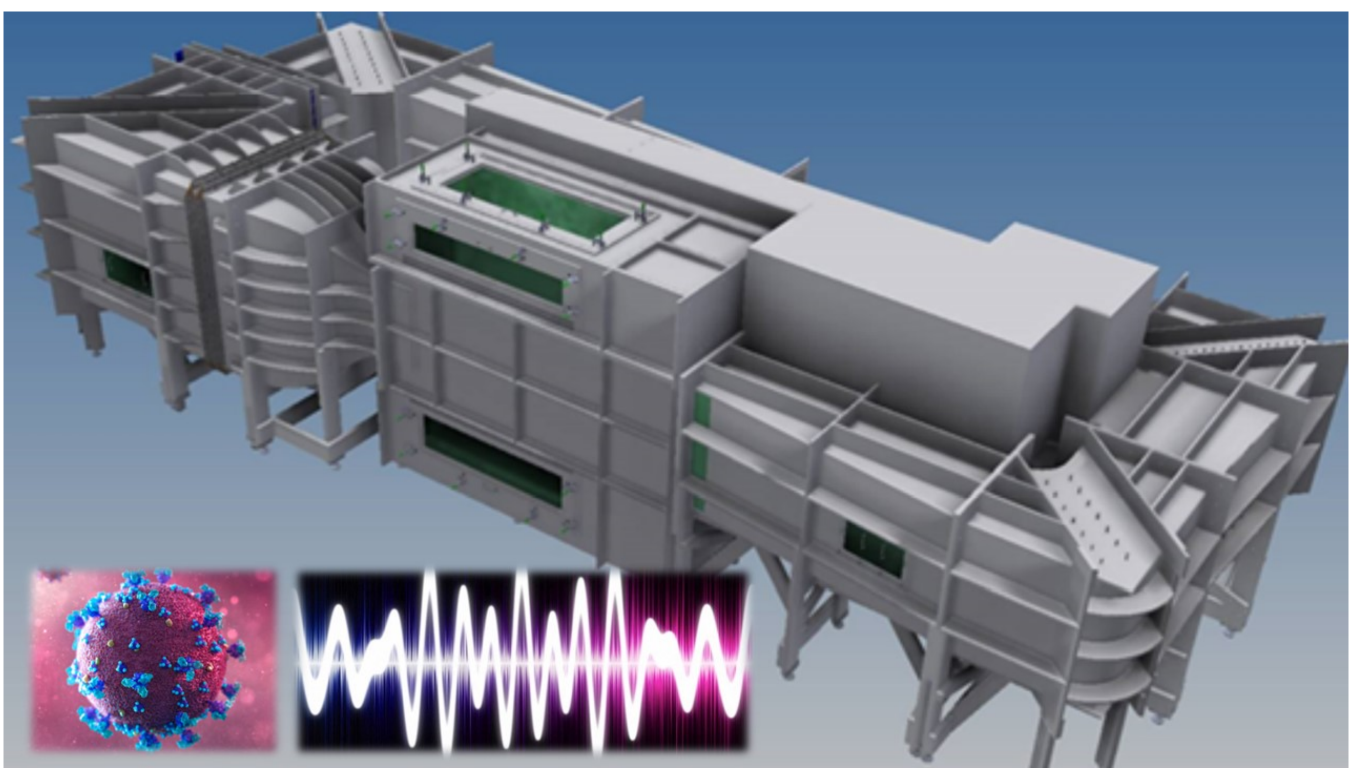

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Acoustique canadienne est publié quantre fois par an, en mars, juin, septembre et décembre. Cette revue trimestrielle est envoyée gratuitement aux membres individuels de l'Association canadienne d'acoustique (ACA) et aux abonnés institutionnels. L'**Acoustique canadienne** publie des articles arbitrés et des rubriques sur tous les aspects de l'acoustique et des vibrations. Ceci comprend la recherche, les recensions des travaux, les nouvelles, les offres d'emploi, les nouveaux produits, les activités, etc. Les articles concernant les résultats inédits ou les applications de l'acoustique ainsi que les articles de synthèse, les tutoriels et les exposées techniques, en français ou en anglais, sont les bienvenus. L'Association canadienne d'acoustique a sélectionné **Paypal** comme solution pratique pour le paiement en ligne de vos frais d'abonnement. Paypal prend en charge un large éventail de méthodes de paiement (Visa, Mastercard, Amex, compte bancaire, etc) et ne nécessite pas que vous ayez déjà un compte avec eux. Si vous désirez procéder à un paiement par chèque de votre abonnement, merci de remplir le formulaire d'inscription et de l'envoyer au secrétaire exécutif de l'association (voir adresse ci-dessus). - - Dr. Roberto Racca - Canadian Acoustical Association/Association Canadienne d'Acoustique c/o JASCO Applied Sciences 2305–4464 Markham Street Victoria, BC V8Z 7X8 - - secretary@caa-aca.ca

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Laissons ta voix et notre musique jouer de plus en plus fort

Cher lecteur, il semble plus qu'évident que nous sommes sur le point de résoudre l'une des pandémies mondiales les plus difficiles que nous aurions pu imaginer, même si le monde est encore plein de problèmes. Ainsi, alors que nous récupérons complètement, nous avons besoin de nouvelles énergies et passions pour que nos vies reviennent pleinement à la normale.

Pour cela, je voudrais aujourd'hui parler de l'état de notre revue. Acoustique Canadienne est notre lieu, le médium que nous utilisons depuis toujours pour communiquer entre nous et présenter des travaux, des recherches et des informations. Le plaisir de recevoir la copie papier de notre revue, ainsi que la possibilité d'avoir un libre accès à nos articles en, ligne est et un avantage considérable et représente l'un des éléments les plus précieux de notre société.

Pour cette raison, je voudrais vous inviter toutes et tous à considérer cette revue comme la vôtre en 2022. Une revue existe pour les auteurs qui y contribuent. Grâce à eux, nous pouvons apprécier la lecture de leurs projets et articles, et grâce à leur contribution, nous découvrons tous ce qui se passe au Canada dans le monde de l'acoustique. Cependant, je sais que de nombreux lecteurs sont restés silencieux ou n'ont pas trouvé le temps récemment de présenter leur travail.

Je voudrais inviter chacune et chacun d'entre vous à nous envoyer au moins un article en 2022, et à nous présenter vos projets de recherche. Ce serait une excellente façon de développer le sentiment de communauté que nous avons besoin de nourrir dans notre vaste pays. Après plus de deux ans d'isolement, nous avons besoin de nous connaître davantage, nous avons besoin de redécouvrir les chercheurs que font nos collègues et amis et nous avons besoin que la voix des jeunes acousticiens soit plus forte. Combien d'entre eux n'ont pas encore présenté à nos conférences AWC ou n'ont pas encore publié dans cette revue et peuvent être "inconnus" de leurs pairs. Nous sommes trop silencieux alors qu'il est temps que nos voix et notre musique recommencent à jouer.

Enfin, je voudrais rappeler que nous nous rencontrerons bientôt en personne et j'espère donc que vous pourrez soumettre vos articles pour qu'ils soient présentés à la Semaine de l'acoustique au Canada 2022, qui se tiendra du 27 au 30 septembre à St. John's, Terre-Neuve. En espérant vous revoir bientôt, je vous souhaite une agréable lecture.

Umberto Berardi
Rédacteur en chef

Let's your voice and our music playing harder and harder

Dear reader, it seems more evident that we are close to resolve one of the most challenging global pandemic we could have imagined, although the world is still full of troubles. So, while we full recover we need new energy and passion to take our lives back again.

For this, today, I would like to speak about the status of our journal. *Canadian Acoustics* is our place and the medium we have been always using to communicate each other, and present works, research, and information. The pleasure to receive the hard copy of our journal and the possibility to have our papers made available forever in an online open-access depository is extreme and represent one of the most valuable elements of our society.

For this reason, I would like to invite all of you to consider this journal as yours in 2022. A journal exists for the writers who contribute to it. Thanks to them we can enjoying reading their projects and papers, and thanks to their contribution we all discover what is happening in Canada within the world of acoustics. However, I know many readers have been silent or have not found the time recently to present their work to *Canadian Acoustics.*

I would like to invite each one of you to send to us at least one paper in 2022, and to present your research projects. This would be a great way to expand the sense of community that in our wide country, we need to nourish. After over two-years of self-isolation, we need to know more each other, we need to rediscover the research that colleagues and friends are doing, and we need the voice of young acousticians to be louder. How many young acousticians have not yet presented at our AWC conferences or have not yet published in this journal and may be "un-known" to peers. We are too much silent while it is time that our voice and music start again playing.

Finally, I would like to remind that we will soon be meeting in person and so I hope that you can submit your papers to be presented at the The Acoustics Week in Canada 2022, which will be held 27-30 September in St. John's, Newfoundland. Hoping to see each other soon, I wish you a pleasant reading of this issue.

Umberto Berardi
Editor in Chief.


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ON THE EFFECT OF TRAILING-EDGE BLUNTNESS ON AIRFOIL NOISE

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Résumé

Le but de cette étude est d'étudier expérimentalement l'effet du profil aerodynamique sur la génération de bruit tonal à différents angles d'attaque et à des nombres de Reynolds allant de faibles à modérés. Des mesures aéroacoustiques détaillées sont effectuées pour un profil aérodynamique, à trois angles d'attaque : 0°, 5° et 10°. Les nombres de Reynolds basés sur la corde du profil aérodynamique analysés sont 2.8×10^5, 3.7×10^5 et 5×10^5, correspondant à des vitesses de flux libre de 14, 18 et 24 m/s, respectivement. On voit que le bruit du profil aérodynamique avec un bord de fuite droit passe de bruit large bande à un bruit tonal intensif pour un angle d'attaque croissant ; tandis qu'il passe de bruit tonal à bruit large bande avec un nombre de Reynolds croissant. De plus, les résultats montrent que pour des valeurs plus élevées des nombres de Reynolds, le pic tonal dominant diminue en amplitude et se déplace vers des fréquences plus élevées. En général, on observe qu'à mesure que la netteté du bord de fuite augmente, les pics tonals dominants ont des amplitudes globales plus grandes.

Mots clés: bruit de profil aérodynamique, épaisseur du bord de fuite.

Abstract

The purpose of this study is to experimentally investigate the effect of trailing edge bluntness on the generation of airfoil tonal noise at different angles of attack and low to moderate Reynolds numbers. Detailed aeroacoustic measurements are made for an airfoil at three angles of attack: 0°, 5°, and 10°. Airfoil chord-based Reynolds numbers analyzed are 2.8×10^5, 3.7×10^5 and 5×10^5, corresponding to free stream velocities of 14, 18 and 24 m/s, respectively. The airfoil noise with a straight trailing edge is seen to change from a broadband hump to intensive tonal noise with increasing angle of attack, while it changes from tonal noise to a broadband hump with increasing Reynolds number. Moreover, results show that for higher values of Reynolds numbers the dominant tonal peak decreases in amplitude and shifts to higher frequencies. In general, it is observed that as the trailing edge bluntness increases, the dominant tonal peaks have larger overall amplitudes.

Keywords: airfoil noise, trailing edge bluntness.

1 Introduction

Airfoil trailing edge (TE) noise is believed to be a major noise source in many industrial applications, such as wind turbines, high lift devices on aircraft airframes, cooling fan blades, to name a few. The character and level of trailing edge self-noise are known to be highly sensitive to Reynolds number (free stream velocity), angle of attack (AoA), airfoil geometry and trailing edge bluntness [1]. TE noise has a characteristic narrowband structure consisting of a broadband hump superimposed with many tones, at low Reynolds numbers, with minor residue turbulence in the free stream [2, 3]. In contrast, for high Reynolds number flow, TE noise is typically broadband in nature. If the chord length of the airfoil is larger than the acoustic wavelength, the convective turbulent eddies in the boundary layer will scatter effectively into "broadband noise" at the TE. In the situation of Reynolds number of $2.8{\times}10^5 \leq Re_c \leq 5{\times}10^5$ the boundary layer on the airfoil surface is laminar, or in transition, but potentially unstable. Under a certain range of conditions, hydrodynamic instabilities such as the Tollmien–Schlichting (T–S) waves, grow in the boundary layer and eventually scatter into noise at the trailing edge. This mechanism of self-noise is referred to as instability tonal noise. Tam [4] proposed that the tonal noise was generated by a feedback loop between the oscillating wake and the airfoil trailing edge. After a moderate Reynolds number is reached, a nominal two-dimensional vortex shedding will be formed downstream of a blunt TE from which narrowband tonal noise will be emitted from the shear layer [5, 6]. It is worth mentioning that the use of blunt TE could also reduce the base pressure and subsequently increase the base drag. At moderate angle of attack, flow separates near the TE on the suction side of the airfoil to produce TE self-noise; at large angle of attack, large scale separation occurs causing the airfoil to radiate low frequency noise from the chord as a whole.

Previous studies on a NACA-0012 airfoil have shown that the prerequisite condition for a broadband hump and/or tones to occur is the existence of a separation region near the trailing edge on the pressure surface [7, 8]. It was concluded that the incoming T–S waves must be amplified by the separating shear layer before tonal noise can be radiated effectively. For most symmetrical airfoils, an adverse pressure gradient always prevails at the rear region of the airfoil, and its level depends on the airfoil's profile and angle of attack. These factors influence the separation region, which

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ultimately affects the intensity and frequency of the radiated instability tonal noise.

Through the use of different degrees of TE bluntness, this study aims to investigate whether flow separation can be reduced or prevented, hence providing a reduction in tonal noise. The ability to produce a turbulent wake by the trailing edge could potentially eliminate or reduce the tonal noise source. It is hoped that results from this study can be used to provide aid in the design of low noise airfoils suitable for low to moderate Reynolds number flows.

2 Experimental setup

2.1 Airfoil model and trailing edge design

The airfoil under investigation is a NACA-0012 airfoil with different level of TE bluntness, as shown in Figure 1. The airfoil model with the straight trailing edge (S0) is used as the reference configuration for all tests and so will be referred to as the baseline. The chord length of the S0 airfoil is 300 mm, and the width is 510 mm. Between the leading-edge x/c=0 and x/c=0.73, the original airfoil model profile is unmodified, where x is the streamwise direction. Further downstream, $0.73 \leq x/c \leq 1.0$, is a section that can be removed and replaced by either a straight (S0) or modified trailing edge profiles (S1 and S2). Once attached, the trailing edge section forms a continuous profile. Boundary layer tripping elements were applied using rough sandpaper near the leading edge on both sides of the airfoil at x/c = 0.15.

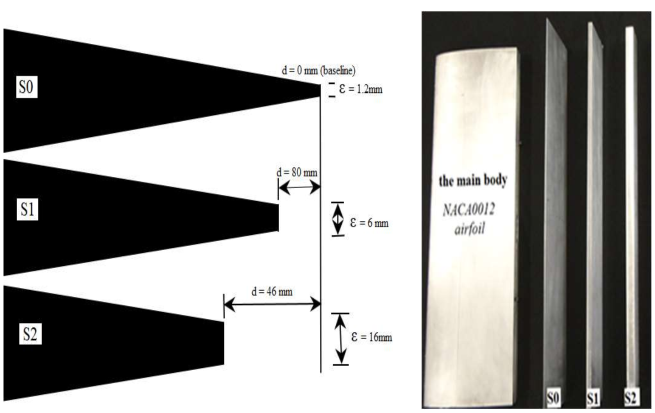

Figure 1: Airfoil model with three different degrees of TE bluntness

Trailing edge noise measurements for a NACA-0012 airfoil model are presented. Far-field noise spectra is obtained using a directional calibrated microphone. Treatments were applied to the trailing edge of the airfoil to modify its thickness and to model different blunt trailing edges. Three trailing edge configurations were examined with the level of thickness "ε" as shown in Table 1. The airfoil was placed at angles of attack ranging from 0° to 10°.

2.2 Wind tunnel facility

The experiment was conducted in a closed-loop type, low speed wind tunnel at the Carleton University. The wind tunnel contains an exit cross-section that is rectangular and has dimensions of 0.3 m (height) × 0.73 m (span). The airfoil was mounted vertically across the entire width of the test section, as shown in Figure 2. Taking into account the maximum velocity achievable by the current wind tunnel, a Reynolds number of 2.8×10^5 (freestream velocity, U_∞, of 14 m/s), 3.7×10^5 (U_∞=18 m/s) and 5×10^5 (U_∞ = 24 m/s) were chosen for this study. Further details can be found in [9,10].

Table 1: Airfoil trailing edge configurations.

Model	c [mm]	d [mm]	ε [mm]
S0	300	0	1.2
S1	220	80	6
S2	254	46	16

Figure 2: Wind tunnel at Carleton University.

2.3 Instruments and procedures

To measure the radiated self-noise from the airfoil, a single calibrated microphone (Bruel & Kjaer 4944-A, ¼ inch) at a polar angle of θ = 90°, is mounted at a distance of 1.4 m perpendicular to the airfoil trailing edge at mid-span, as shown in Figure 3.

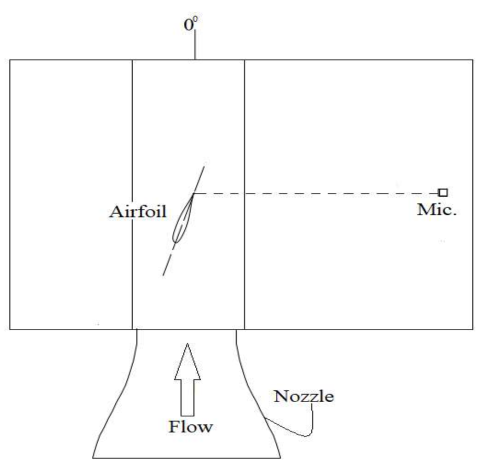

Figure 3: Schematic showing the position of the microphone in the test section.

Microphone signals were amplified by a B&K Nexus amplifier before digitally stored in a computer, through an A/D converter of 24-bit resolution. Acoustic data was sampled at 20 kHz and recorded for 30 seconds. The digitized data was passed through a time domain filter to remove low and high frequency contamination, caused by the microphone's low frequency roll off and high-frequency aliasing. The band-pass filter used is a Butterworth filter with the first and second stopband frequencies of 100 and fs/2 Hz, respectively, where fs is the sampling frequency. The attenuation is 60 dB for both the first and second stopband. The passband ripple was kept as the 1 dB default and the band match used was a stopband. The sound pressure level, SPL, is computed using the root mean square (RMS) of filtered pressure using the following equation:

$$SPL = 10\ log_{10}\left(p_{RMS}^2 \Big/ P_{ref}^2\right)$$

where P_{ref} is the standard reference pressure in air, 20 µPa. The background noise of the facility, i.e., an empty test section without the presence of the airfoil model, was measured prior and after the airfoil noise study [10]. The ranges of flow speed and of angle of attack in which the tonal trailing edge noise of an airfoil is observed is a key step in the characterization. The first acoustic data was registered by simply listening to the sound for determining the limiting conditions of the tonal trailing edge noise. The measurements were conducted at several velocities (14, 18 and 24 m/s). It was found that the clean airfoil exhibited several regimes of tonal noise generation. This fact motivated the current detailed investigation. The registered data was transposed into SPL versus frequency for different angles of attack and flow velocities, as discussed in detail in the following section.

3 Result

This section surveys and discusses the experimental results for the NACA-0012 airfoil. The detailed investigation of the noise emission and its dependence on the tripping, angle of attack, and TE bluntness is discussed. It is observed that the separation bubble is a necessary condition for the existence of high-intensity trailing-edge noise. Comparison with previous studies provides reasonable agreement and confirms that the measurements are reliable. Lowson et al. [11] examined NACA-0012 and NACA-23015 airfoils. They suggested the involvement of a separated flow in the noise model. In their model, it is proposed that the T-S waves were strongly amplified by the shear layer in the laminar separation. They also outlined a region of conditions (with respect to Re and angle of attack) where tonal noise is expected to occur for the NACA-0012 airfoil. Later in Probsting et al. [12], an overall figure was compiled showing this region and summarizing results of several studies examining different points in and outside of the region. This is shown in Figure 4. Many experimental observations tend to fall in between a bell-shaped envelope (Figure 4), as already reported by Desquesnes et al. [13], where tonal noise has often been observed (solid symbols). Data for the present study comprises relatively low to moderate Reynolds numbers ($Re_c = 2.8 \times 10^5 - 5 \times 10^5$) and the measurement points are indicated (in black squares). The reduction of tonal noise for lower Reynolds numbers at AoA = 4° is corroborated by the data by, Nash, Lowson and McAlpine [14] and the low-Reynolds-number limit of Desquesnes et al. [13]. When the Reynolds number is increased, separation and transition to turbulence tend to occur further upstream on both the suction and pressure sides, which is

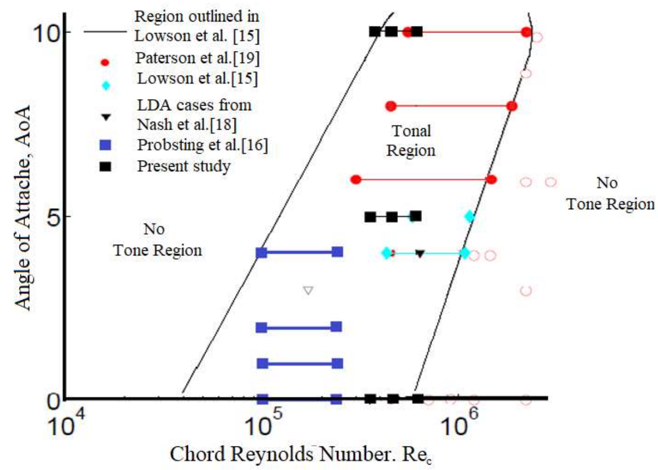

Figure 4: Region of Reynolds number and angle of attack where tonal noise can be found for a NACA-0012 Airfoil. Adapted from Probsting et al. [12].

considered the cause for the suppression of tonal noise. Instead, in this regime the acoustic emissions from the airfoil are of broadband nature (Paterson et al. [15]). At zero angle of attack this limit is reached at a Reynolds number of approximately 500,000 for the NACA-0012 at the lower limit, and transition will not occur upstream of the trailing edge. Instead, a laminar boundary layer and vortex shedding behind the trailing edge might result in weak or no tonal noise. Figure 5 shows the sound pressure level radiated by the straight airfoil for three different velocities (14, 18 and 24 m/s) corresponding to Reynolds numbers of 2.8×10^5, 3.7×10^5 and 5×10^5, respectively, at angle of attack of 0°. Results shown in Figure 5 are following discussed, in section 3.1.

3.1 Far field noise

The far-field spectra for the three velocities investigated illustrate the behavior of the NACA-0012 airfoil, as shown in Figure 5 for AoA 0^0. At 14 m/s a dominant tone at 351.6 Hz is clearly noticeable followed by two lower tones at 455.8 Hz and 555.9 Hz. At 18 m/s the hump is more visible with a marked dominant tone at 545.9 Hz. An interesting observation is the disappearance of the tones at 24 m/s. It is suspected that one or more of the components leading to tonal trailing edge noise such as instability waves, feedback loop or separation bubble is suppressed when velocity is increased to 24 m/s. It is observed that the frequency of the tone increases gradually with increasing velocities, and the tone intensity increases first to a maximum value and then decreases with the velocity. It is also found that the instability noise spectra changes from intensive tonal noise to broadband humps with increasing velocity.

Figure 6 shows the sound pressure level for the straight TE airfoil for various angles of attack, at a Reynolds number of $5x10^5$. It can be observed that there is no distinct tonal noise at 0°, while the spectrum exhibits 3 broadband humps at 5° between ~300 Hz and ~600 Hz. At AoA of 10° the instability noise exhibits an intensive tone at around 449.2 Hz followed by other tow lower tones at 527.3 Hz and 525 Hz.

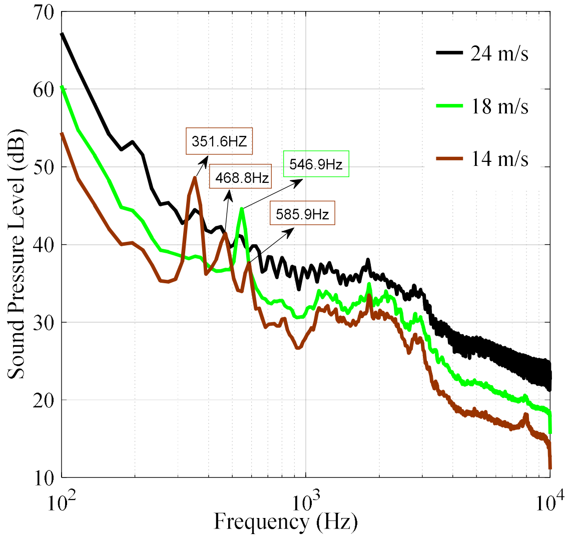

Figure 5: SPL radiated by the straight TE airfoil at 0° AoA, for various inflow velocities.

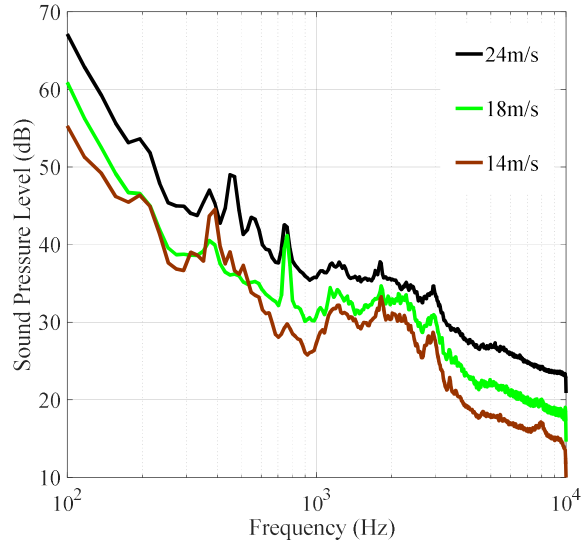

Figure 7(a): SPL measured at 5° AoA for U_∞ = 14,18 and 24 m/s, for the untripped airfoil.

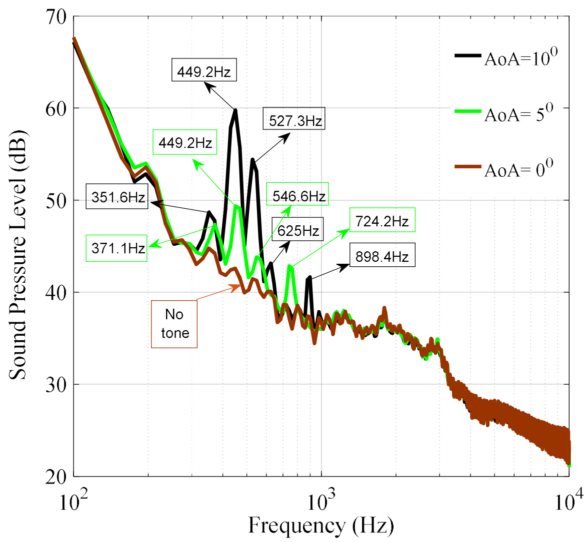

Figure 6: SPL radiated by the straight airfoil for various angles of attack, at a Reynolds number of 5×10^5 (U_∞ = 24 m/s).

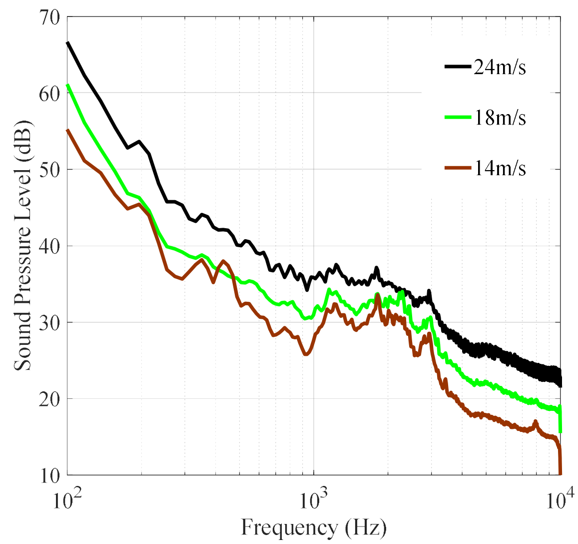

Figure 7(b): SPL measured at 5° AoA and U_∞= 14,18 and 24 m/s, for the tripped airfoil

In addition, high harmonic instability noise with much lower sound level is also found for angles of attack of (5°) at 724.2 Hz and for (10°) at 898.4 Hz. Overall, the instability noise changes from a broadband hump to intensive tonal noise with increasing angle of attack, but the main tone frequency does not change significantly with the angle of attack.

3.2 Influence tripping the flow

Figures 7(a) and 7(b) show the SPL for the straight trailing edge measure at 5° AoA, for the untripped and tripped flow cases, respectively. The spectrum for the untripped case is characterized by numerous tones for the deferent free stream velocities (Figure 7(a)). On the other hand, no tones are present for the tripped case (Figure 7(b)), in which broadband self noise is the dominant mechanism [16]. Boundary layers at both the suction and pressure surfaces are turbulent near the trailing surfaces. Without tripping, the boundary layer at the pressure surface is laminar (or separated) near the trailing edge.

3.3 Effect of TE bluntness

Measured spectra, including the effect of bluntness, are presented in Figure 8. The present analysis investigates the noise emitted by the three airfoils with different trailing edge bluntness tested at zero degree angle of attack (shown in Figure 1) – case in which the boundary layer flow is attached nearly all the way to the trailing edge of the airfoil. All the flow separation features tend to increase the complexity of the tone generation processes (present at higher AoA). In Figure 8 (a), for S0, one can observe a defined dominant tone. One can also notice that, for an increased flow velocity, the dominant tonal peak decreases in level and shifts to higher frequencies. On the other hand, Figure 8 (b) for S1 shows that as velocity of the flow is increased the dominant tonal peak increases in level and shifts to higher frequencies.

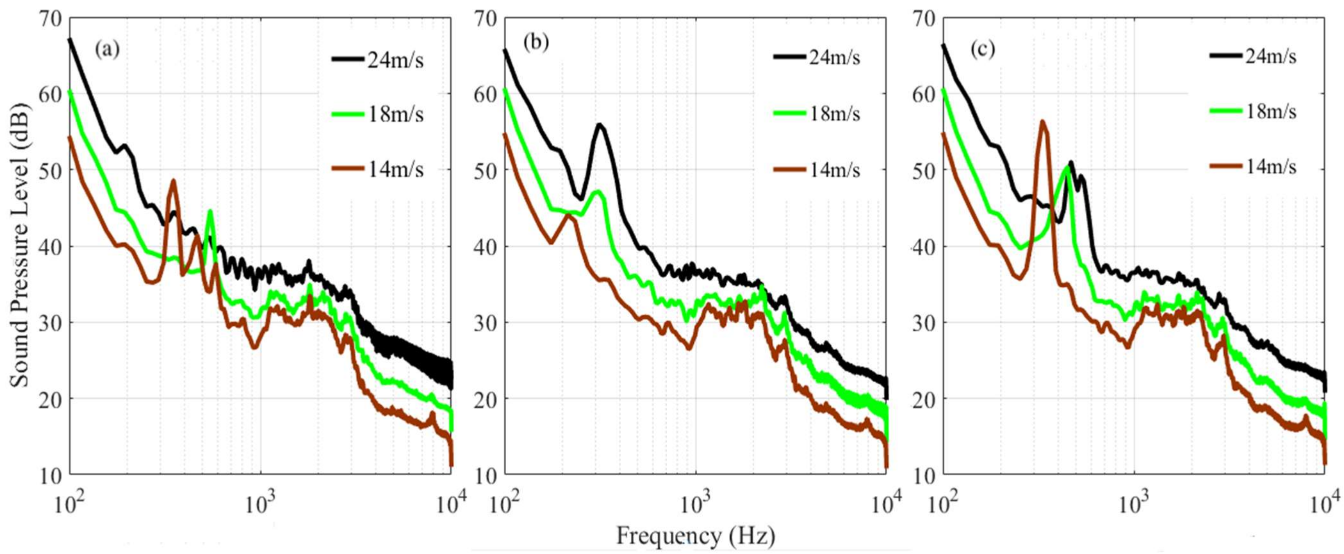

Figure 8: Effect of TE bluntness, for three TE configurations: (a) S0, (b) S1 and (c) S2. Results for 0° AoA , at14, 18 and 24 m/s.

For the S2 configuration, Figure 8 (c) shows three clearly defined tonal peaks for the lower Mach number case ($Re = 2.8 \times 10^5$). One can also observe, for S0, that an increased Mach number, results into dominant tonal peak amplitude decrease, which disappears at 24 m/s. In general, it is observed that as the trailing edge bluntness increases, the dominant tonal peaks have larger overall amplitudes for the TE configurations analyzed.

3.4 Effect of the angle of attack

The effects of angle of attack of the airfoil model with different TE bluntness are shown in Figures 9 to 11. In Figure 9, as the angle of attack is increased, it is observed that although the spectral peak shifts to higher frequencies and its level decreases, the higher frequency fall-off portion of the spectra is seemingly invariant. This appearance is due to increased higher frequency contribution from the pressure side due to its thinner boundary layer thickness (with small turbulence scales). Still, the levels and the dependence on angle of attack basically agree. The results obtained with increased bluntness at the TE are presented in Figures 9, 10, and 11 for ε = 1.2, 6, and 16 mm, respectively. It is observed that the lower frequency behavior with changes in angle-of-attack appears to be little affected by the bluntness differences. However, the noise spectral peaks, which become more prominent with decreased bluntness, are effectively affected by angle of attack. The larger the angle, the more reduced the spectral peaks. Tonal noise scales with free stream velocity and frequency. It also depends on how TE bluntness compares to the boundary layer thickness [17], as well as on TE geometric features that determine flow angulation in the separated region aft of the TE. As shown in Figure 11, for a small AoA of 5°, the larger thickness produces higher SPL at lower frequency. Decreasing the thickness, ε, results in an increase of the tonal frequency. Also, tonal noise levels diminish, and spectra broaden since ε decreases compared to the boundary layer thicknesses. For the larger AoA of 10° (as in Figures 9, 10 and 11), the boundary layer thicknesses in the pressure side of the airfoil decrease, which leads to decreased levels of the tonal noise.

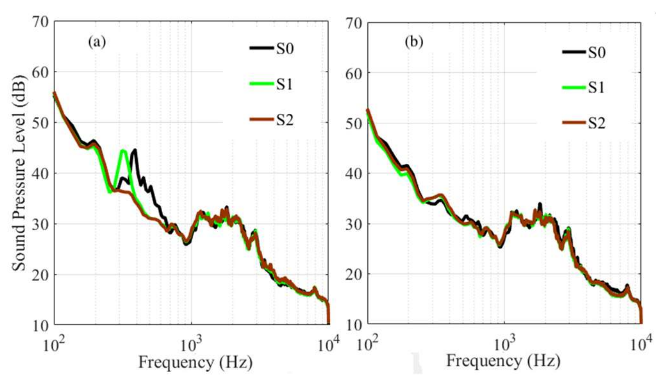

Figure 9: Effect of angle of attack for tests at U_∞==14 m/s, for: (a) AoA = 5°, (b) AoA = 10°.

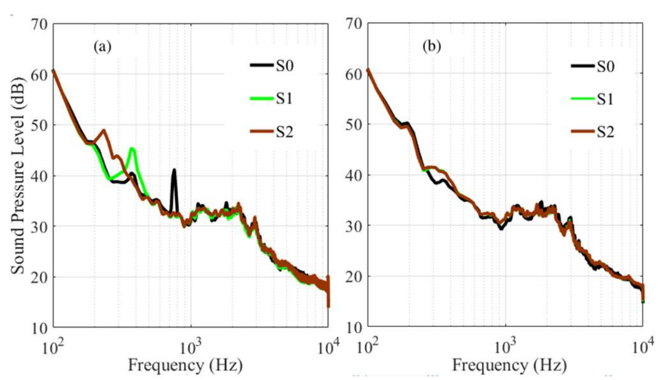

Figure 10: Effect of angle of attack for tests at U_∞=18m/s, for: (a) AoA = 5°, (b) AoA = 10°.

4 Conclusion

The present work provides a detailed analysis of airfoil tonal noise generation at low Reynolds numbers. The effects of

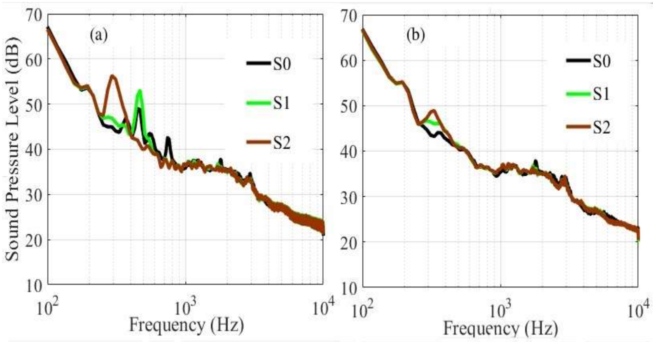

Figure 11: Effect of angle of attack for tests at U_∞=24 m/s, for: (a) AoA = 5°, (b) AoA = 10°.

trailing edge bluntness on noise generation and propagation over a NACA0012 airfoil with three different blunt trailing edge geometries are experimentally investigated for low to moderate Mach numbers. Far-field noise spectra is obtained using a single calibrated microphone. The effects of varying the free stream velocity and angle of attack on the far-field spectra are examined for TEs with different degrees of bluntness. The main findings of the present study include:

- For increased free stream velocity, the dominant tonal peak decreases in amplitude and shifts to higher frequencies.
- As the airfoil angle of attack is increased, the spectral peak shifts to higher frequencies and its amplitude decreases.
- In general, as the trailing edge bluntness increases, the dominant tonal peaks have larger amplitudes. For the same TE bluntenss, inceasing the flow velocity results into a shift of the dominant tonal peak to higher frequencies.

Acknowledgments

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Using a Passive Feedback Connection to Control Low-Frequency Pressure Fluctuations in a Wind Tunnel

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Résumé

Les souffleries à jet ouvert souffrent souvent de fluctuations de pression à basse fréquence et à forte amplitude, liées aux modes résonants du circuit. Généralement, ces fluctuations sont contrôlées à l'aide de générateurs de tourbillons de tuyères, de résonateurs de Helmholtz, de la conception des collecteurs, de l'annulation active du bruit et de diverses autres méthodes. L'objectif de cet article est d'évaluer une connexion de rétroaction passive (PFC) pour une utilisation dans une soufflerie aéro-acoustique. Le PFC peut réduire les fluctuations de pression à haute amplitude et basse fréquence dans le circuit de la soufflerie. En outre, le PFC peut également réduire les fluctuations non périodiques des vitesses du vent, c'est-à-dire les fluctuations de pression non associées aux modes résonants. Le PFC a obtenu ces résultats sans modifier de manière significative le gradient de pression statique axiale dans la soufflerie.

Mots clefs: Fluctuations de la pression en soufflerie, Connexion de rétroaction passive, Modèle de soufflerie

Abstract

Open jet wind tunnels often suffer from low-frequency, high-amplitude pressure fluctuations which are related to resonant modes within the circuit. Typically, these fluctuations are controlled using nozzle vortex generators, Helmholtz resonators, collector design, active noise cancellation, and various other methods. The goal of this paper is to evaluate a Passive Feedback Connection (PFC) for use in an aero-acoustic wind tunnel. The PFC can reduce the high-amplitude low-frequency pressure fluctuations in the wind tunnel circuit. In addition, the PFC can also reduce non-periodic fluctuations in wind speeds, i.e. pressure fluctuations not associated with resonant modes. The PFC achieved these results without significantly altering the axial static pressure gradient in the wind tunnel.

Keywords: Wind tunnel pressure fluctuations, Passive Feedback Connection, Model Wind Tunnel

1 Introduction

Wind tunnels are an important tool for the development of new vehicles. Automotive companies perform extensive aerodynamic, aero-acoustic and thermal testing on new vehicles to bring about improvements in efficiency, comfort, safety, and to show compliance with government regulations. With its combination of an open jet representing the unbounded free flow and solid floor representing the ground, the 3/4th open jet test section is the most common configuration in aero-acoustic wind tunnels, preferred for its open access to the test vehicle and its avoidance of near-field acoustic boundaries. When the air flow exits the nozzle, it interacts with the low-speed air in the plenum. As a result, a shear layer develops around the core of the jet between the nozzle and the collector. Small-scale vortex structures originate from the trailing edge of the nozzle, which are transported downstream towards the collector at approximately 65% of the velocity of the jet [1]. These vortical structures evolve as they move downstream, which changes their associated frequencies. If the frequencies of these vortices match the resonance frequencies of any of the modes of the wind tunnel, high amplitude pressure fluctuations can be created.

There are four possible resonant conditions which can exist inside an open-jet closed-circuit wind tunnel [1–3].

- The complete wind tunnel circuit can resonate with frequencies associated with organ pipe modes.
- The vortices generated from the edge of the nozzle can impinge on the collector, which can send a pressure disturbance upstream. This pressure disturbance can generate additional vortices, setting up an edge-tone feedback loop.
- The volume within the test section plenum can resonate.
- The combination of the nozzle and the test section plenum can act as a Helmholtz resonator, causing a resonance.

The low-frequency high-amplitude pressure fluctuations can degrade the quality of aerodynamic and acoustic measu-

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rements in the wind tunnel and therefore must be minimized. Typically, a wind tunnel will be designed with several features or devices to minimize the pressure fluctuations. This is achieved by altering the strength and frequencies of the vortical structures in the flow, or by changing the geometry of the wind tunnel to passively target the resonant modes.

Several methods of controlling the low-frequency pressure fluctuations have been investigated. Passive control of the pressure fluctuations can be achieved by installing angled-blade vortex generators on the lip of the nozzle. The vortex generators are effective in breaking up large coherent vortex structures. However, they generate smaller vortical structures which produce high frequency noise. They also induce a vena-contracta type flow at the exit of the nozzle which produces a negative axial pressure gradient. These two factors make the use of angled-blade vortex generators unsuitable for application in many aerodynamic and aero-acoustic wind tunnels. In contrast, Blumrich et.al. [4] have developed a different vortex generator design which largely avoids the pressure gradient and noise contributions.

Rennie [1] investigated the effect of jet length on the low-frequency pressure fluctuations. The length of the jet in a pilot wind tunnel was varied by inserting spacers between the test-section diffuser inlet and the collector flaps. It was found that at a given wind speed, the jet pulsations frequencies were found to scale with the jet length. As the jet length is increased, the thickness of the downstream shear layer increases, which increases the turbulent energy. The amplitudes of the pressure fluctuations can be significantly reduced by selecting the 'correct' jet length, which is usually small. In practice, this is difficult to implement since the length of the test section is designed to suit the size of the intended test objects, and it is desirable to have the longest possible test section length.

Rennie [1] also investigated a collector design for the minimization of pressure fluctuations by using simple, rectangular flaps with bell-mouthed leading edges. It was found that the amplitude of the pressure fluctuations was sensitive to the collector inlet area. A larger collector was found to reduce the coefficient of overall unsteady pressure fluctuations ($C_{p,rms}$). A similar observation was also reported by Kudo et al. [5] and Wiedemann et al. [6] who found that the aerodynamic noise decreased when the collector area was increased. Kudo et al. however noted that increasing the collector area increases the pressure loss in the wind tunnel circuit. Therefore, the noise reduction from increasing the collector area should be weighed against the increased power demands from the main fan. The change in the geometrical shape of the collector can also have an impact on the pressure fluctuations. Such geometrical changes include modifying the collector wall angle, collector flap angle, collector leading edge geometry, changing the gap between the collector flaps and the diffuser. Changing any of the above aspects of the collector design may also have an impact on the axial static pressure gradient, and care must be taken during the collector design process to balance all the requirements of a wind tunnel.

Helmholtz resonators have been used successfully to attenuate pressure fluctuations arising from the coupling of the shear layer vortex frequencies and resonant modes in the circuit or test section [2, 7–9]. A Helmholtz resonator is comprised of a cavity with a neck connected to it. When a Helmholtz resonator is excited, the volume of fluid within the neck oscillates while the pressure of the fluid within the cavity fluctuates at a certain frequency. The absorption of sound within the resonator occurs due to various mechanisms. There are viscous losses along the neck, as well as along the front wall of the resonator. There are also thermal losses at the wall of the resonator cavity. There may also be some non-linear losses due to circulation effects and turbulence, specially in the presence of very high sound intensities. [10, 11]

The sizing of resonators follow the theoretical and experimental background provided by Ingard [11], Selamet and Lee [12] and others [13–15]. The key parameter is the natural frequency of the resonator, which is given by $f = \frac{c}{2\pi}\sqrt{\frac{S}{(l+\delta)V}}$. Here, f is the tuning frequency of the resonator, c is the speed of sound, S is the area of the neck, l is the length of the neck, δ is an adjustment to the neck length which is equal to 0.85 x the neck diameter, and V is the cavity volume. The relatively narrow bandwidth of these devices means that several resonators tuned to different frequencies can be required.

A Helmholtz resonator can be connected to the wind tunnel airline at the plenum or elsewhere in the circuit. To deal with a resonant mode, the resonator should ideally be connected at the location of the anti-node where the velocity of the oscillation is largest; though this location is not straightforward to determine. A full-scale wind tunnel has numerous constraints on the resonator location and sizing due to architectural needs, other sub-systems, and geometrical constraints. As a result, the resonators considered for the full-scale wind tunnel have shapes and locations which are not typically represented in the literature. Therefore, model-scale testing is often used to characterise the effectiveness of the resonators before they are implemented in the full-scale tunnel.

Beland [7] also investigated the use of a pressure compensation channel to reduce the low-frequency pressure fluctuations. When a standing wave is established in the wind tunnel circuit (which causes pressure fluctuations), there are fixed locations of maxima and minima (or nodes and anti-nodes) in the sound pressure. By connecting these nodes and anti-nodes of pressure with a duct, the overall sound power associated with the standing wave can be decreased. With the decrease in the strength of the standing wave, the activation mechanism of vortex generation in the edgetone feedback is damped, which reduces the strength of the resonance in the wind tunnel. Beland [7] found that the standing wave had a node right before corner 1 (the corner immediately downstream of the test section), while the anti-node was present in the test section. By connecting these two locations with an external compensation channel, the overall $C_{p,rms}$ levels were decreased. It was noted that the compensation channel changed the static pressure distribution in the vicinity of the collector. To correct the pressure distribution, the collector angle had to be increased by 10°. The size and the form of the compensation channel opening close to corner 1 had a great influence on the performance of the device, while the opening in the test section chamber played a subordinate role. The compensation channel concept was ultimately not implemented in the full-scale tunnel at FKFS to avoid making expensive structural changes to the wind tunnel building.

Another similar technique was used by Wang et al. [9] in a model scale wind tunnel at Tongji University by using the principle of sound wave interference. One end of a pipe was connected to the test section. At some distance along the length of the pipe, an interlink was made with the wind tunnel airline, creating two pipe segments. As an incident sound pressure field hits the open end of the pipe in the test section, some of the energy is transmitted into the pipe, while some energy is reflected off the open end, as well as from the end of the pipe. The properties of the pressure field coming out of the interlink can be determined by fixing the length of the two segments. The incident pressure field can then be attenuated by using destructive interference from the interlink pressure field. It was found that the sound interference method decreased pressure fluctuations in certain frequency bands, while increasing them in other bands.

Wickern et al. [3] used a 1/20th scale pilot wind tunnel to investigate the use of an Active Resonance Control system (ARC). Real time measurements of the pressure fluctuations were made using a microphone located in the test section. The phase of the measured signal was shifted, and it is played back through a loudspeaker placed in the return leg of the wind tunnel such that the pressure fluctuations could be attenuated. When the ARC system was implemented in the full-scale Audi aero-acoustic wind tunnel, 23 dB, 20 dB, and 15 dB reductions in the sound pressure levels (SPL) of resonances at 2.4 Hz, 3.9 Hz, and 6.8 Hz were found. The benefit of the ARC system is that a single space efficient system can dampen pressure fluctuations at multiple frequencies.

Many other devices and techniques have been extensively studied by many researchers. The current paper, like the approaches taken in [7, 9], considers a geometry change whereby a passive feedback connection between the first cross-leg and the test section plenum within the circuit is used to alter these low-frequency pressure fluctuations. The duct sets up a passive feedback mechanism to attenuate the low-frequency high-amplitude pressure fluctuations.

2 Test setup

Aiolos has found that the optimization of a wind tunnel circuit to minimize low-frequency pressure fluctuations is best performed in conjunction with wind tunnel tests rather than relying only on analytical or finite element methods, particularly when design constraints limit the application of previously successful geometries. Scale model tests with a full-circuit Model Wind Tunnel (MWT) have been used to effectively identify and correct low-frequency pressure fluctuations present in a full-scale tunnel [16]. The magnitudes of the fluctuations generally match between full and model scale, while the frequencies scale linearly with the geometrical scale of the MWT. This approach was taken in the development of a new aero-acoustic wind tunnel for BMW, leading to a test program using a 1/10th scale MWT of the planned full-scale facility.

For the design of the BMW full-scale tunnel, only passive approaches were considered. This is because passive devices (resonators and PFC) are mechanically simple with no moving parts. Once they are tuned correctly, they can be expected to always function without failure. The downsides of using a passive approach are the large volume requirement for the resonators, especially for the control of low-frequency fluctuations, and the complications of tuning such large devices. In the case of the BMW wind tunnel the tuning was addressed with reduced scale model wind tunnel tests.

Since the interest for these tests was related to a full-scale automotive aero-acoustic wind tunnel, the values given in this paper are generally converted to their equivalent full-scale values. This scaling was applied using the 1:10 scale factor on frequency and length dimensions; the wind speeds were not scaled.

A 3D rendering of the MWT is shown in Figure 1. The MWT was a close geometrical representation of the planned full-scale circuit but without any acoustic treatment except in the fan region. The 3/4th open jet test section had a nozzle size of 0.4 m x 0.625 m. At the end of the test section, a collector with bell-mouth inlet leading edge was used to divert the flow into the diffuser. Four large resonators with variable geometry were included in the model scale tunnel. The volume of the resonators could be modified, as well as the geometry of the connection between the resonators and the wind tunnel circuit. The resonant frequencies of resonators 1, 2 and 4 were between 1.2 Hz to 1.8 Hz. These three resonators were counteracting the dominant second organ pipe mode within the full-scale circuit, which is approximately 1.6 Hz. Resonator 3 was tuned to counteract resonance around 3.2 Hz, which corresponded to the fourth organ pipe mode. The MWT included a connection path between the first cross-leg (located downstream of the first corner) to the rear wall of the test section plenum, termed the Passive Feedback Connection (PFC). The influence of the PFC on the pressure fluctuations in the tunnel is the subject of this paper.

2.1 Determination of $C_{p,rms}$

The low-frequency pressure fluctuations in the MWT were measured with a GRAS Type 40 AN microphone and GRAS Type 26 AK preamp located out-of-flow at a location equivalent to mid-length and the height of a car in the full-scale test section. This arrangement provided a ±1 dB response down to 1 Hz and ±2 dB down to 0.5 Hz (which are 0.1 Hz and 0.05 Hz equivalent full-scale). A foam wind screen was used to reduce the self-noise of the microphone. The pressure signal was recorded at a sampling rate of 800 samples/s for 300 seconds. The signal was converted to the frequency domain

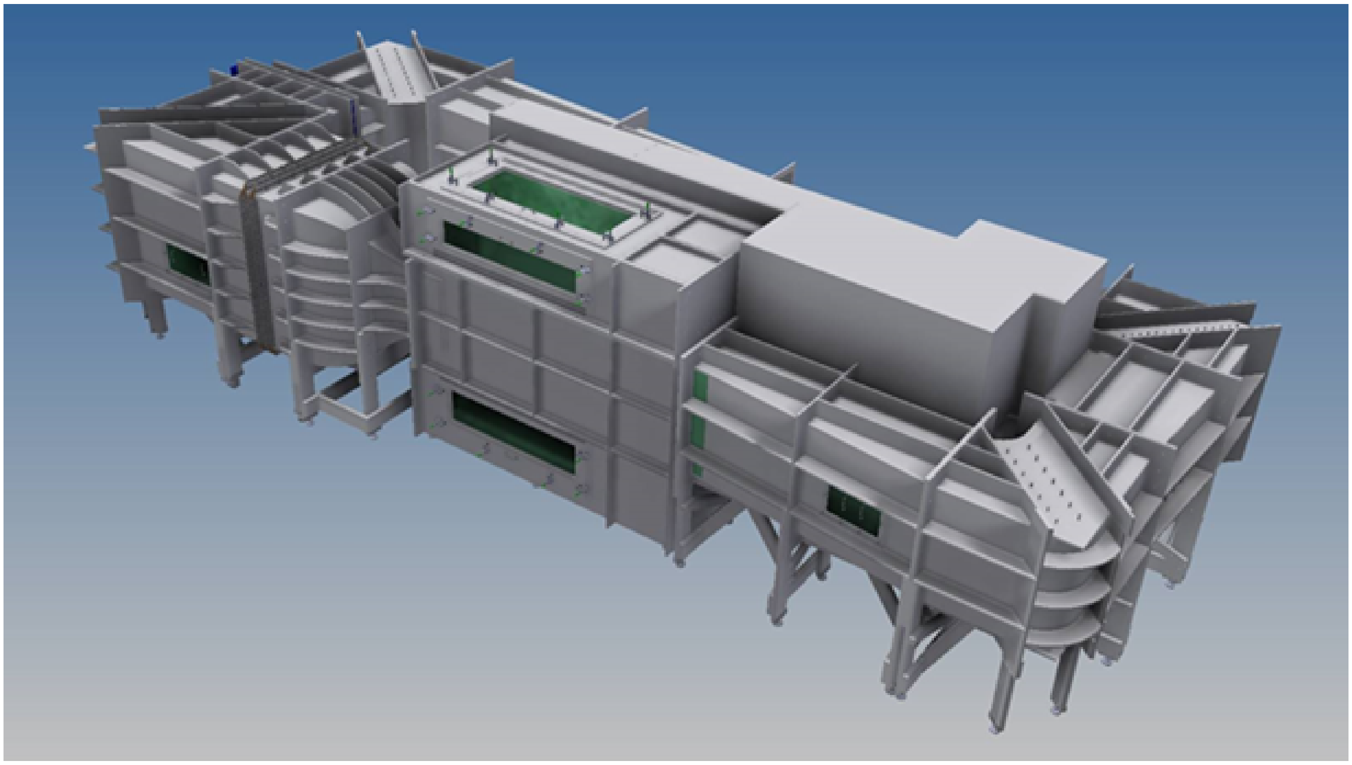

Figure 1: A 3D rendering of the model wind tunnel (MWT)

with 12801 intervals and a 312.5 Hz bandwidth by breaking the time-series into 7 non-overlapping segments, leading to a frequency interval of 0.024 Hz (0.0024 Hz equivalent full-scale) for each segment. A Hanning windowing function was applied to reduce the spectral leakage with the Hanning window correction applied to obtain the correct amplitude of the pressure power spectrum. The seven spectra were combined using rms averaging. Overall $C_{p,rms}$ values were determined by integrating the spectral $C_{p,rms}$ distribution over the full-scale frequency range of 1 Hz to 20 Hz, and were the primary measure of the low-frequency pressure fluctuations in the test section. The sound measurements reported in the paper are not weighted (i.e. flat response) over the full frequency range.

2.2 Wind speed measurements

The test section wind speed was inferred by measuring the pressure drop across the contraction. The pressure drop was measured using a Scanivalve differential pressure scanner (model DSA3217 16Px) connected to two pneumatically averaged static taps installed in the settling chamber downstream of the flow conditioning devices, and two pneumatically averaged static taps in the plenum. These contraction pressure drops were correlated to the actual wind speeds in the test section by first calibrating the wind tunnel with a bent-stem Pitot-static probe located at the equivalent vehicle center location. The pressure scanner sampled the pressure at 10 Hz, equivalent to 1 Hz full-scale. The time series results from these measurements were used to determine the *wind speed variability* and *unsteadiness* over the duration of a test.

2.3 Axial static pressure gradient measurements

The axial static pressure gradient was measured using a single bent-stem Pitot-static probe which was traversed at a low speed over the axial length of the test section. The axial pressure gradient was obtained by fitting an appropriate order polynomial to the pressure coefficient data and differentiating the curve fit equation to obtain the local gradient.

2.4 Passive Feedback Connection (PFC)

A sketch of the MWT circuit is given in Figure 2, which shows the layout of the four resonators in the circuit, along with the passive feedback connection. The Resonator 1 was closed for all the cases shown in this paper. The necks of Resonators 2, 3, and 4 were connected to the return cross leg, test section diffuser, and the rear wall of the plenum respectively. The passive feedback connection was created by attaching a duct between the return cross leg and Resonator 4.

3 Results

An extensive test program was undertaken to determine the geometries of Resonators 2, 3, and 4, as well as the geometry of the collector, in order to minimize the pressure fluctuations and axial static pressure gradient. The effectiveness of the PFC was investigated with these optimized geometries already configured. The PFC operated through the volume of the Resonator 4, and it was not possible to isolate the PFC from Resonator 4. The results from the five configurations listed in Table 1 illustrate the performance of the PFC. Progressing from case A to C1, the Resonator 4 and the PFC

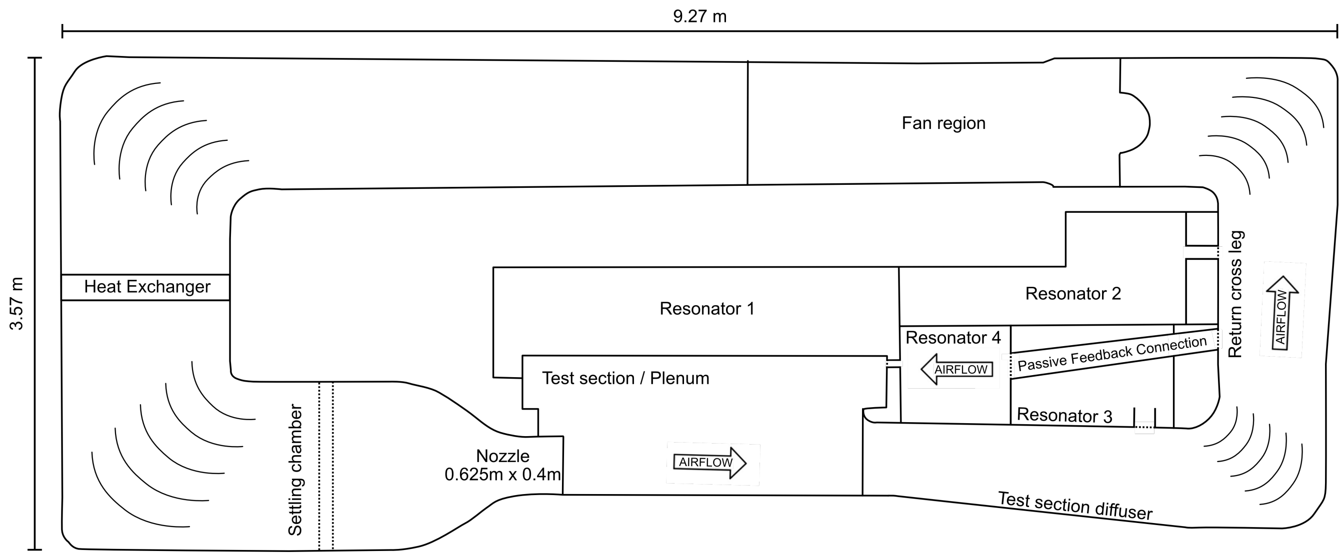

Figure 2: A sketch of the circuit showing the layout of the resonators and the passive feedback connection

Table 1: Resonator and PFC configurations

Name	Res. 1	Res. 2	Res. 3	Res. 4	PFC	PFC flow rate (Q_{pfc}/Q_{ts})
Case A	closed	open	open	closed	closed	0.0%
Case B	closed	open	open	open	closed	0.0%
Case C1	closed	open	open	open	open	3.0%
Case C2	closed	open	open	open	open	5.1%
Case C3	closed	open	open	open	open	6.5%

are systematically opened, while keeping the rest of operating conditions the same. Progressing from case C1 to C3, the flow rate through the PFC was systematically increased. The arrangement of the collector was kept the same for all five cases. The flow rate through the PFC duct (Q_{pfc}) was measured and related to the flowrate through the test section (Q_{ts}). The flow rate of air through the PFC could be varied by changing the inlet area of the PFC duct at the cross-leg.

The overall normalized out-of-flow unsteady static pressure measurements, $C_{p,rms}$, are shown in Figure 3. The baseline case (Case A, red circles in Figure 3) had the worst $C_{p,rms}$ amongst the configurations presented here at all wind speeds, peaking at 128 kph. The driver of this pressure fluctuation was a relatively small peak at 1.6 Hz, which is associated with the 2nd organ pipe resonance mode. It should be noted that the baseline case is not that of a wind tunnel with no resonators. The Resonators 2 and 3, as well as an optimized collector had already created conditions of low levels of pressure fluctuations for case A. By opening Resonator 4 (case B, blue square in Figure 3), the $C_{p,rms}$ values were further decreased. Further reduction could be achieved by opening the PFC up to a flow rate of Q_{pfc}/Q_{ts} = 3.0% (case C1, green diamonds in Figure 3). At higher flow rates, the gains made by using the PFC were diminished and the $C_{p,rms}$ values increased. The $C_{p,rms}$ for the highest flowrate case C3 however were always lower than case A (no Resonator 4) at all wind speeds. It is postulated that at higher flow rates, the flow through PFC began degrading the performance of Resonator 4, which led to an increase in the overall $C_{p,rms}$ for cases C2 and C3 compared to case C1. A resonator operates by oscillating a finite amount of a fluid inside the neck, with the large volume acting as a spring-mass-damper system. Since the PFC is connected to the Resonator 4, by increasing the flow rate inside the PFC (and thus the resonator), the effectiveness of the resonator is hindered. Consequently, the benefit of the PFC is outweighed by the loss in effectiveness of the resonator.

Beland [7] had noted that the effectiveness in the suppression of the pressure fluctuation was sensitive to the geometry of the inlet region for the compensation channel. The shape and the size of the outlet of the compensation channel into the test section plenum was inconsequential. A long, narrow opening in the plenum chamber wall, which was minimized to around 9% of the nozzle surface area was used by Beland [7]. In the current investigation, the outlet geometry of the PFC was found to also have an impact on the performance, but this is likely also due to its effect on the Resonator 4 performance.

The effectiveness of the PFC was further investigated by examining the wind speed time traces obtained though the pressure measurements. Figure 4 shows normalized wind speed traces for cases A to C1 at a nominal wind speed of 120 kph. The time shown on the x-axis has been corrected to full-scale tunnel values by multiplying it by the geometrical scaling factor. A 10 second (full-scale) rolling average of

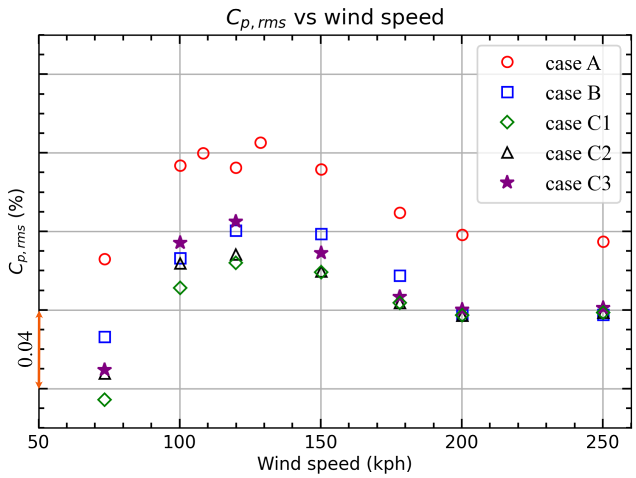

Figure 3: Overall $C_{p,rms}$ values versus the wind speed for the five cases (1 Hz $\leq$ f $\leq$ 20 Hz full-scale).

the wind speed ($\hat{ws}$) is applied to remove any short-term fluctuations. The rolling averaged wind speed ($\hat{ws}$) data is then normalized by the mean wind speeds ($\bar{ws}$), and the results are plotted as shown in Figure 4. That is, *wind speed variability* = $(\frac{\hat{ws}}{\bar{ws}} - 1)$. Unsteadiness in wind speed is evident for the cases without PFC by observing Figures 4 (a) and (b) where during intermittent spikes, the wind speeds reached *wind speed variability* = -0.7% and -0.8% respectively. With the PFC open (case C1), the intermittent large spikes were not observed, and the *wind speed variability* was very low.

Note that the MWT was operated with only a fan speed controller, which maintained a fixed fan rotational speed (i.e., a fixed volume flow rate of air). Small and slow drifts in the mean wind speed due to temperature drifts were accounted for with a straight-line fit to the measured data.

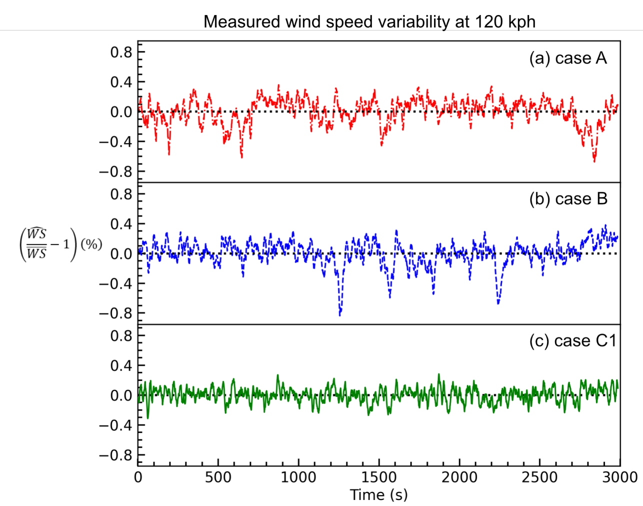

Figure 4: Wind speed variability demonstrated by normalized wind speed trace for cases A-C1 at nominal speed of 120 kph

An overall wind speed stability value can be deduced from the standard deviation of the wind speed time series. Results for different wind speeds are shown in Figure 5 which shows *overall wind speed unsteadiness* = $\frac{\sigma(\hat{ws})}{\bar{ws}}$. Use of the PFC is shown to improve the *overall wind speed unsteadiness* values by almost a factor of 2 across the wind speed range. The data suggests that increasing the flow rate through the PFC can marginally improve the *overall wind speed unsteadiness*.

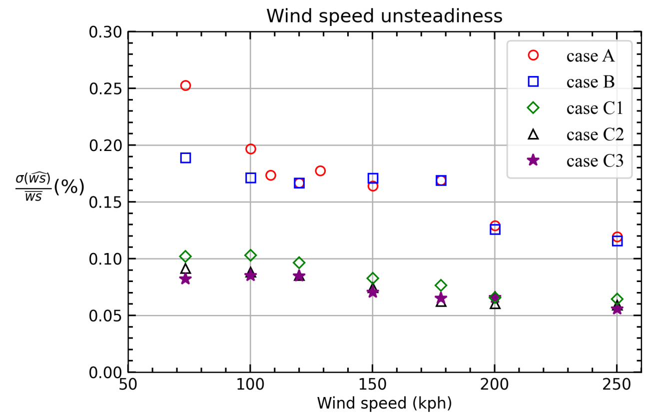

Figure 5: Overall wind speed unsteadiness for an averaging time of 10s (full scale)

This improvement in the wind speed unsteadiness is also evident by the improvements of the very low frequency pressure fluctuations (f < 1 Hz). Spectra for the five test conditions converted to dB(Z) with frequency intervals of 0.1 Hz (full-scale equivalent) are shown in Figure 6. The use of the PFC is shown to have its strongest influence for f < 1 Hz.

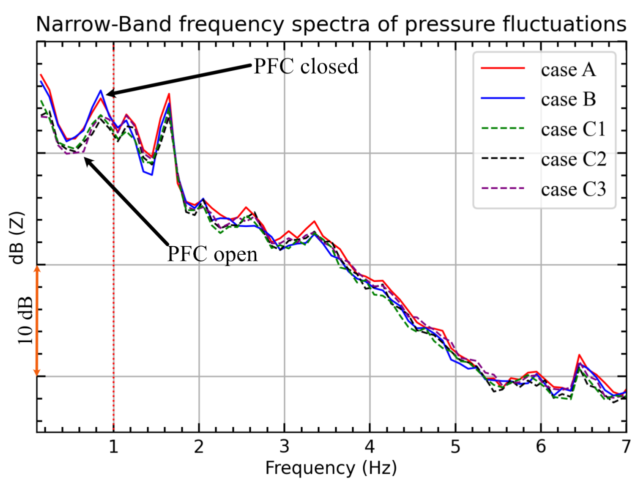

Figure 6: Narrow-band frequency spectra of pressure fluctuations at 120kph

A separate issue for wind tunnel test models is the variation of the axial static pressure due to the buoyancy force that can be induced on the test model by the pressure variation. It is desirable to have the smallest possible axial static pressure gradient in a wind tunnel test section. Figure 7 shows that the addition of a PFC (case C1) does not significantly alter the axial static pressure gradient in the MWT.

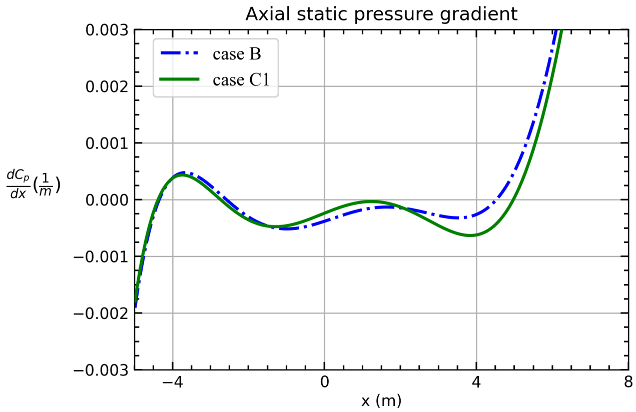

Figure 7: Axial static pressure gradients for cases B and C1

4 Conclusion

A 1/10th scale model wind tunnel was developed to aid in the design of a new aero-acoustic wind tunnel for BMW. The model wind tunnel was used to optimize the collector design, as well as to tune the Helmholtz resonators. In addition to the traditional means of controlling the pressure fluctuations, another novel approach, the Passive Feedback Connection (PFC) was also tested, which is the concern of the paper. The PFC connected the return leg of the wind tunnel with a resonator which was connected to the test section plenum. At low flow rates through the PFC, reductions in the amplitudes of the low-frequency pressure fluctuations were found. At higher flow rates, the performance of the overall system was slightly diminished, presumably due to the degradation of the effectiveness of the resonator. The PFC was also found to significantly improve the wind speed stability in the wind tunnel. Without the PFC, non-oscillatory spikes in wind speed variability were observed. With the PFC connected, these spikes were eliminated. The PFC achieved these improvements in pressure fluctuations without compromising the axial static pressure gradient.

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Characterization of Sound Properties of Talking Drums Made From Gmelina Arborea Wood

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Résumé

Le tambour parlant est utile à des fins musicales. Cependant, il produit un timbre sonore complexe, difficile à caractériser. Bien que la géométrie de la coquille de sablier en bois constituant le tambour parlant ait été identifiée comme un facteur influençant la composition du timbre sonore, il reste encore à enquêter sur d'autres facteurs suspectés. Cette étude a caractérisé les propriétés sonores des tambours parlants des housses en cuir, la force et la position de jeu, la tension sur la corde et l'impact de surface excité. Trois boulons du la base des arbres de Gmelina arborea a été utilisée pour produire les tambours parlants, par conséquent, les propriétés sonores ont été mesurées. Les valeurs obtenues ont été soumises à des statistiques descriptives, des graphiques et une ANOVA (α0,005). La fréquence fondamentale, l'amplitude et le temps d'amortissement acoustique (SDT) sans tension sur la corde étaient significativement les plus bas (90,06 ± 27,16, 41,03 ± 4,31 et 380,83 ± 103,58) pour la force de jeu légère et les plus élevés (97,00 ± 29,68, 60,26 ± 3,59 et 474,44 ± 59,48) pour une force lourde, respectivement. A tension maximale sur la corde, SDT de peau de chèvre était significativement plus élevée (478,50 ± 77,04) que la couverture en cuir d'utérus de vache (438,89 ± 97,65), tandis que l'amplitude et le SDT étaient significativement plus élevés (66,61 ± 2,95 et 508,52 ± 51,60) pour une force lourde que pour une force de jeu légère (46,16 ± 7,06 et 408,87 ± 92,46), respectivement. La tension sur la corde était le facteur le plus essentiel nécessaire pour caractériser la propriété sonore de qualité des tambours parlants.

Mots clefs : Musique, Culture du bois, Produit du bois, Propriétés sonores

Abstract

Talking drum is useful for musical purposes. However, it produces a complex sound timbre, difficult to characterize. Although the wooden hourglass-shell geometry making the talking drum was identified as a factor influencing the sound timbre make-up, there is still a need to investigate other suspected factors. This study characterized sound properties of talking drums from Leather covers, force and position of play, the tension on the rope, and excited surface impact. Three bolts from the base of *Gmelina arborea* trees were used to produce the talking drums, hence, sound properties were measured. Values obtained were subjected to descriptive statistics, graphs, and ANOVA ($\alpha_{0.005}$). Fundamental Frequency, Amplitude, and Sound Damping Time (SDT) at no tension on the rope were significantly lowest (90.06±27.16, 41.03±4.31, 380.83±103.58) for the light force of play and highest (97.00±29.68, 60.26±3.59, 474.44±59.48) for heavy force, respectively. At maximum tension on the rope, SDT of goat skin was significantly higher (478.50±77.04) than cow womb leather cover (438.89±97.65), while Amplitude and SDT were significantly higher (66.61±2.95, 508.52±51.60) for heavy force than the light force of play (46.16±7.06, 408.87±92.46), respectively. Tension on the rope was the most essential factor needed in characterizing the quality sound property of the talking drums.

Keywords: Music, Wood Culture, Wood Product, Sound Properties

1 Introduction

The talking drum (TD) is an hourglass-shaped percussion musical instrument whose two heads (skin surfaces) are vertically opposite to each other with leather string. It is a West African drum that has garnered relevance as a means of communication in Southwestern Nigeria, after human voice. Du-

Definition of some Terms:

Resonance Frequency (RF) – The sound frequency having the highest amplitude in a timbre

Fundamental Frequency (FF) – The first sound frequency in a timbre

Sound Damping Time (SDT) – The time required for a sound of material or musical instrument to return to silence after being excited

Excited Surface Impact – The measured response of the skin surface of the talking drum to strike

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rojaye et al. [1] confirm the talking drum to be perfectly fit for linguistic usage, owing to its excellent performance to mimic the human voice. Generally, the use of talking drums is cultural, communication, and music-oriented [1–3].

Furthermore, the major material used for producing talking drums is the wood making its shell. Interestingly, the potentiality of selected wood species for making talking drums have been discussed [4–7], and *Gmelina arborea* wood was confirmed suitably.

Scientifically, the measurement of sound from a musical instrument is characterized by a regular and uniform vibration of the wave propagated. Thus, Pitch, Timbre, Intensity, and Timing are the major properties of sound that distinguish a musical tone [1, 8]. This was also corroborated by Zatorre and Baum [9] who stated that musical sound is characterized by discrete pitches which sustain longer durations.

Pieces of literature have shown the existence of different musical (cultural) systems that define pitch movements, with specific scales and rules [10–13]. Akere [14] pointed out that the pitch of a talking drum can be regulated depending upon how a player strikes the head of the drum and changes its tension. Notwithstanding, this attribute makes the sound from talking drums complex and difficult to characterize. For instance, Figures 1a and 1b show a different sound frequency spectrum (Resonance Frequencies of 81 and 83 Hz) for two strikes made on a single talking drum.

Furthermore, Belcher and Blackman [2] noted the speculation that the sizes and shapes of the various drums, the tension of the drum skins, placement of the strikes, and so on, may hamper the perceived sound frequency. It is, therefore, appropriate to opine that many factors contribute to the properties of sound generated by talking drums. In addressing some of these challenges, Olaoye and Oluwadare [15] characterized the sound properties of talking drums based on the geometry of hourglass shells. However, there is still limited information on the influence of other suspected factors on sound properties of talking drums, thus, it will be difficult to attain optimal performance of talking drum at all times unless adequate characterization is done.

Therefore, there is a need to ascertain if, and how other suspected factors influence the sound properties of talking drums. Hence, this study characterized the sound properties of talking drums made from *G.arborea* wood, with a view of highlighting the influence of selected factors on its sound properties. The factors that were considered in this study were tension on the rope, leather cover, the force of play, position of play, and excited surface impact (ESI).

2 Material and method

Three fifteen years old trees of G. arborea were felled from Gambari Forest Reserve. From each tree, 3 bolts of 60 cm were collected from the base wood of the trees to make the hourglass shells. The bolts were conditioned under atmospheric temperature (30oC) and relative humidity (60%) for a month before carving. The selected acoustic properties of G.arborea wood were reported in Table 1, while Plate 1 shows all the major materials used in producing the talking drums.

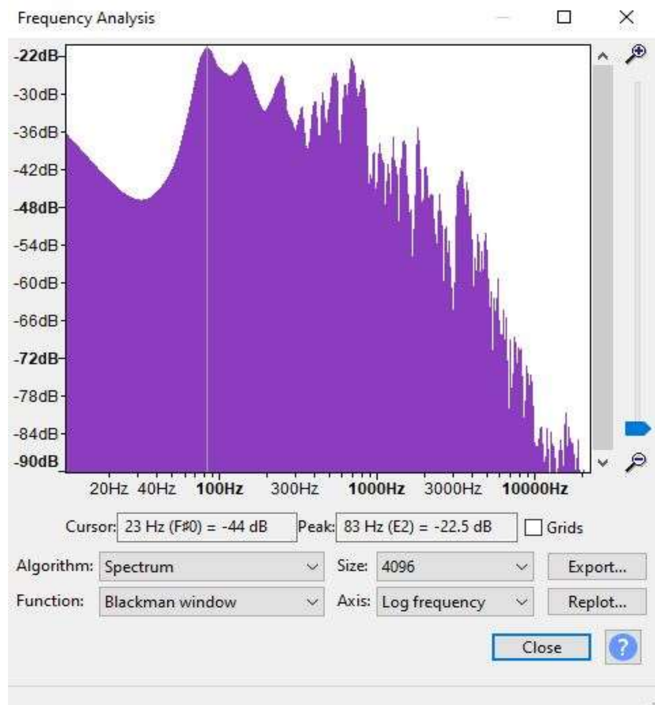

Figure 1a: Sound Frequency Sample (1) Obtained from a Talking Drum (A).

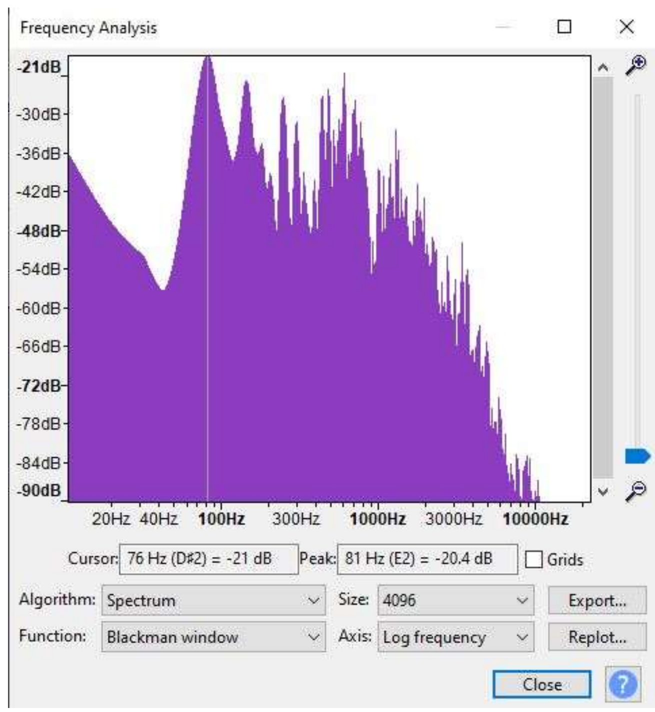

Figure 1b: Sound Frequency Sample (2) Obtained from a Talking Drum (A).

2.1 Steps in producing the talking drums

Step 1 – The three bolts were manually carved and shaped into a figure of an hourglass shell measuring 28 cm in length, 15 cm in diameter, and a thickness of 0.6 cm. Both ends of the shell were opened since the talking drum is a membranophone percussion instrument.

Table 1: Selected Acoustic Properties of *G.arborea* wood.

W.D (gcm^{-3})	E (GPa)	V (ms^{-1})	tan δ	Es (GPa)	Q	ACE (m^4/kg/s)
0.39	9.34	4848.58	0.0039	23.57	279.64	3435.66

W.D – Wood density; **E** – Dynamic elastic modulus; **V** – Velocity of sound; **tan δ** – Damping factor; **Es** – Specific elastic modulus; **Q** – Sound quality; **ACE** – Acoustic conversion efficiency. Source: [6].

Plate 1: Major components used in making the talking drum.

Plate 2: Experimental set-up for measuring the excited surface impact of a talking drum.

Step 2 – Goat skin and Cow womb (ole) used as leather covers for the opposite surfaces were prepared by soaking in ordinary water for 45 min and later rubbed and squeezed. Thereafter, the laying of the cover leathers on both ends of the shell was done. It was firmly held in place with leather string by sewing the tension rope and the membrane together. An adhesive was used to hold the tension rope against the shell frame to facilitate the turning of the drum using membrane pegs during production. Three talking drums (TD1, TD2, and TD3) of different cover leathers were produced.

Step 3 – The drums were sundried for two days after which the pegs were removed, and the tension ropes straightened.

2.2 Sound property test

The Fundamental Frequency (FF), Resonance Frequency (RF), Amplitude (A), and Sound Damping Time (SDT) were sound properties of the talking drums measured. The experiment was done in an enclosed silent room, as this was to prevent interference of external sounds during recording. A microphone was placed about 20 cm from the talking drums, and the service of a drummer was employed to generate single strikes on the talking drums' surfaces at no extension on the rope (NTR), and at the maximum tension on the rope (MTR), with respect to force of play (light and heavy) and position of play (up, center and down). The sound generated by these strikes was recorded and analyzed using Audacity. The experiment was repeated 108 times.

Additionally, to measure the Excited Surface Impact (ESI) on the leather covers, a piezoelectric crystal was mounted on the talking drums' surface to measure the impact of the drummer's strikes on them. The experiment was set up as shown in Plate 2.

Data obtained were subjected to Descriptive statistics, Pearson correlation, and Analysis of variance at α0.005. Meanwhile, eq. 1 was used to determine the frequency ratio.

$$Fundamental\ Frequency\ Ratio\ (FR) = \frac{Frequency\ at\ No\ Tension\ on\ Rope}{Frequency\ at\ Max.Tension\ on\ Rope} \quad (1)$$

3 Results

Tables 2 and 3 documents the means of sound properties of the talking drums to the factors considered for characterization, at NTR and MTR respectively. At NTR, FF, RF, A, and SDT were lowest (90.06 ± 27.16, 242.43 ± 201.53, 41.03 ± 4.31, and 380.83 ± 103.58) at the light force of play and highest (97.00 ± 29.68, 97.00 ± 29.68, 60.26 ± 3.59, and 474.44 ± 59.48) at the large force of play, respectively. Additionally, the amplitude was the only sound property having its value significantly higher at center/down (51.35 ± 10.65/51.46 ± 10.09) than up (49.13 ± 10.67). There were variations in sound properties characterized according to the factors investigated, for TD1, TD2, and TD3.

At MTR, the mean SDT at goat skin was significantly higher (478.50 ± 77.04) than cow womb leather cover (438.89 ± 97.65). Also, A and SDT were significantly higher (66.61 ± 2.95 and 508.52 ± 51.60) at a heavy force of play than a light force of play (46.16 ± 7.06 and 408.87 ± 92.46), respectively.

Meanwhile, Table 4 shows the analysis of variance of sound frequency measured between NTR and MTR. Also, it reported the sound frequency ratio (FR) for fundamental frequencies of the talking drums. SDT was the only sound property not significantly different, for TD2. The FR for TD1 was the highest (3.08) while TD2 had the lowest (1.34). Tables 5 and 6 describe the total count of RF obtained among the talking drums at NTR and MTR, respectively. The highest number of RF (28) was recorded at NTR for TD2, while the least was five (5), at MTR for TD1.

The spectrogram sample of a strike from TD3 was displayed in Figure 2. It describes the sound frequencies in the time domain. As such, the colors differentiate the degree of amplitude (white – red – blue represent high – medium – lower amplitude), while the width interprets the SDT. Figures 4 – 8 showed the histogram distribution of the RF at NTR and MTR for the talking drum. At NTR, TD1 and TD3 had only 33%, and 36% of their RF between 50Hz and 100Hz respectively. Meanwhile, TD2 had 14% of its RF between 100Hz

Table 2: The Mean Sound Properties of Talking Drums at NTR.

TD 1		Cover leather		Force of play		Position of play		
TD1		goat	Cow	light	heavy	up	center	down
	FF(Hz)	58.44^{a}	59.33^{a}	58.28^{a}	59.50^{b}	57.58^{a}	60.00^{b}	59.08^{ab}
	RF(Hz)	362.56^{a}	311.56^{a}	197.61^{a}	476.50^{b}	299.75^{a}	358.42^{a}	353.00^{a}
	A(dB)	48.72^{a}	47.61^{a}	37.27^{a}	59.06^{b}	45.97^{a}	48.55^{b}	49.97^{b}
	SDT(ms)	464.17^{a}	450.89^{a}	440.78^{a}	474.28^{b}	446.50^{a}	475.75^{a}	450.33^{a}
TD 2								
	FF(Hz)	127.67^{a}	126.06^{b}	123.78^{a}	129.94^{b}	126.50^{a}	125.92^{a}	128.17^{a}
	RF(Hz)	383.72^{a}	428.06^{a}	367.94^{a}	443.83^{b}	396.33^{a}	422.58^{a}	398.75^{a}
	A(dB)	51.89^{a}	51.89^{a}	39.89^{a}	63.89^{b}	50.75^{a}	52.83^{b}	52.08^{b}
	SDT(ms)	504.11^{a}	466.06^{b}	451.72^{a}	518.44^{b}	442.33^{a}	500.00^{b}	512.92^{b}
TD 3								
	FF(Hz)	93.89^{a}	95.78^{a}	88.11^{a}	101.56^{b}	97.83^{b}	89.08^{a}	97.58^{b}
	RF(Hz)	366.83^{a}	249.78^{b}	161.72^{a}	454.89^{b}	299.58^{a}	344.83^{a}	280.50^{a}
	A(dB)	52.50^{a}	51.28^{b}	45.94^{a}	57.83^{b}	50.67^{a}	52.67^{b}	52.33^{b}
	SDT(ms)	348.94^{a}	331.67^{a}	250.00^{a}	430.61^{b}	328.92^{a}	356.00^{a}	336.00^{a}
Mean								
	FF(Hz)	93.33 ± 29.04^{a}	93.72 ± 28.27^{a}	90.06 ± 27.16^{a}	97.00 ± 29.68^{a}	93.97 ± 29.30^{a}	91.67 ± 27.79^{a}	94.94 ± 29.18^{a}
	RF(Hz)	371.04 ± 208.35^{a}	329.80 ± 202.94^{a}	242.43 ± 201.53^{a}	458.41 ± 145.22^{b}	331.89 ± 220.41^{a}	375.28 ± 189.03^{a}	344.08 ± 209.92^{a}
	A(dB)	51.04 ± 9.60^{a}	50.26 ± 11.30^{a}	41.03 ± 4.31^{a}	60.26 ± 3.59^{b}	49.13 ± 10.67^{a}	51.35 ± 10.65^{b}	51.46 ± 10.09^{b}
	SDT(ms)	439.07 ± 97.93^{a}	416.20 ± 94.20^{a}	380.83 ± 103.58^{a}	474.44 ± 59.48^{b}	405.92 ± 84.66^{a}	443.92 ± 97.93^{a}	433.08 ± 104.01^{a}

Means of the same alphabet between columns are not significantly different

and 150Hz. Contrarily, TD1, TD2, and TD3 had 97%, 97%, and 100% of their RF between 150Hz and 200Hz respectively, at MTR.

On the other hand, the ESI bar chart in Figure 9 was used to convey the sensitivity of the leather covers to the impact of force, at NTR and MTR. The mean sensitivity of the cow womb was higher (0.24 ± 0.18v) at MTR. In furtherance, ESI significantly correlated with FF (0.499, at NTR), A (0.799, at MTR), and SDT (0.702, at MTR) for goat skin leather cover. For the cow womb, ESI significantly correlated with A (0.787, at NTR and 0.888, at MTR) and SDT (0.536, at MTR) (Table 7).

4 Discussion

The results of this study as presented in tables, figures and plates imply that the talking drums studied had different acoustic properties. This could be caused by variation in cover leather, force of play, position of play, and/or tension applied on the rope while playing the drums. As indicated by Table 4, a talking drum played when tension is applied to the rope had significantly increased acoustic properties. Notwithstanding, a musical instrument with a suitable sound frequency is determined by a high value of frequency ratio (FR), i.e. it must be able to produce low and high frequencies. Thus, TD1 with the highest FR is better suitable where a good sound frequency is desired.

The spectrogram presented showed the anatomy of the sounds generated. The occurrence of the dominance of red colors in ‘b and d’ implies that more frequencies are generated at MTR, while the positions circled showed evidence of white color (an indication that the highest sounded frequency ‘RF’ was found at that position). Also, a wider diameter representing SDT at ‘b and d’ showed that sound excited on the talking drum at MTR took a longer time to return to silence when compared with sound generated at NTR (a and c). As such, a higher value of SDT indicates a better and more desirable acoustic property of the talking drum.

Meanwhile, it should be noted that RF also contributes to the perceived pitch of the sound by a human. Therefore, there was a need to investigate its contribution to the sound frequency of the talking drums found in this study. It should be noted that too much variation of RF from FF is disadvanta-

Table 3: The Mean Sound Properties of Talking Drums at Maximum Tension on the Rope (MTR).

		Cover leather		Force of play		Position of play		
TD1		goat	Cow	light	heavy	up	center	down
	FF(Hz)	181.50[a]	181.17[a]	181.06[a]	181.61[a]	181.33[a]	181.25[a]	181.42[a]
	RF(Hz)	206.22[a]	181.17[a]	205.78[a]	181.61[a]	181.33[a]	218.33[a]	181.42[a]
	A(dB)	54.88[a]	54.50[a]	41.44[a]	67.94[b]	54.73[a]	54.10[a]	55.25[a]
	SDT(ms)	505.67[a]	467.72[b]	457.33[a]	516.06[b]	480.67[a]	500.83[a]	478.58[a]
TD 2								
	FF(Hz)	170.89[a]	168.5[a]	169.44[a]	169.94[b]	169.67[a]	169.58[a]	169.83[a]
	RF(Hz)	188.78[a]	168.50[a]	187.33[a]	169.94[a]	169.67[a]	196.42[a]	169.83[a]
	A(dB)	53.11[a]	56.56[b]	42.78[a]	66.89[b]	54.92[a]	54.33[a]	55.25[a]
	SDT(ms)	503.61[a]	507.17[a]	467.22[a]	543.56[b]	499.67[a]	506.58[a]	509.92[a]
TD 3								
	FF(Hz)	193.72[a]	194.67[b]	194.00[a]	194.39[a]	193.42[a]	195.42[b]	193.75[a]
	RF(Hz)	193.72[a]	194.67[b]	194.00[a]	194.39[a]	193.42[a]	195.42[b]	193.75[a]
	A(dB)	62.67[a]	56.61[b]	54.28[a]	65.00[b]	60.00[b]	58.17[a]	60.75[b]
	SDT(ms)	426.22[a]	341.78[b]	302.06[a]	465.94[b]	382.17[a]	387.83[a]	382.00[a]
Mean								
	FF(Hz)	182.04 ± 9.45[a]	181.44 ± 10.88[a]	181.50 ± 10.27[a]	181.98 ± 10.13[a]	181.47 ± 9.89[a]	182.08 ± 10.83[a]	181.67 ± 9.99[a]
	RF(Hz)	196.24 ± 73.65[a]	181.44 ± 10.88[a]	195.70 ± 73.87[a]	181.98 ± 10.13[a]	181.47 ± 9.89[a]	203.39 ± 89.66[a]	181.67 ± 9.99[a]
	A(dB)	56.89 ± 12.58[a]	55.89 ± 10.62[a]	46.16 ± 7.06[a]	66.61 ± 2.95[b]	56.55 ± 11.65[a]	55.53 ± 12.68[a]	57.08 ± 10.65[a]
	SDT(ms)	478.50 ± 77.04[a]	438.89 ± 97.65[b]	408.87 ± 92.46[a]	508.52 ± 51.60[b]	454.17 ± 92.22[a]	465.08 ± 87.76[a]	456.83 ± 91.46[a]

Table 4: ANOVA showing P-values for the Mean Sound Properties of Talking Drums, and Frequency Ratio (FR).

TD1		**NTR**	**MTR**	**P-value**	**FR**
	FF(Hz)	58.89 ± 2.29	181.33 ± 0.93	0.001*	3.08
	RF(Hz)	337.06 ± 249.06	193.69 ± 74.11	0.001*	
	A(dB)	48.16 ± 11.39	54.69 ± 13.77	0.001*	
	SDT(ms)	457.53 ± 43.57	486.69 ± 47.34	0.001*	
TD 2					
	FF(Hz)	126.86 ± 4.13	169.69 ± 1.35	0.001*	1.34
	RF(Hz)	405.89 ± 139.99	178.64 ± 53.91	0.001*	
	A(dB)	51.89 ± 12.36	54.83 ± 12.73	0.001*	
	SDT(ms)	485.08 ± 65.51	505.39 ± 64.99	0.092ns	
TD 3					
	FF(Hz)	94.83 ± 9.33	194.19 ± 1.85	0.001*	2.05
	RF(Hz)	308.31 ± 206.42	194.19 ± 1.85	0.001*	
	A(dB)	51.89 ± 6.37	59.64 ± 6.59	0.001*	
	SDT(ms)	340.31 ± 100.08	384.00 ± 96.95	0.001*	

Significantly different, ns – not significantly different

Table 5: Frequency analysis of Resonance Frequency obtained at no Tension on the rope.

	TD1			TD2			TD3		
	RF	Freq.	%	RF	Freq.	%	RF	Freq.	%
	57	6	16.70	122	1	2.80	87	1	2.80
	60	2	5.60	123	1	2.80	88	4	11.10
	61	5	13.90	124	1	2.80	89	1	2.80
	227	1	2.80	130	1	2.80	90	3	8.30
	228	1	2.80	132	1	2.80	91	3	8.30
	280	1	2.80	338	1	2.80	147	1	2.80
	281	2	5.60	339	2	5.60	149	1	2.80
	282	1	2.80	387	1	2.80	150	1	2.80
	383	1	2.80	388	1	2.80	223	1	2.80
	384	1	2.80	389	2	5.60	275	2	5.60
	459	1	2.80	390	2	5.60	389	1	2.80
	562	1	2.80	391	3	8.30	390	1	2.80
	566	1	2.80	405	1	2.80	391	3	8.30
	570	6	16.70	407	1	2.80	392	3	8.30
	587	1	2.80	409	2	5.60	393	2	5.60
	590	1	2.80	410	1	2.80	489	1	2.80
	684	1	2.80	413	1	2.80	573	1	2.80
	705	1	2.80	428	1	2.80	626	1	2.80
	722	1	2.80	430	1	2.80	627	1	2.80
	726	1	2.80	502	1	2.80	629	1	2.80
				504	2	5.60	634	1	2.80
				507	1	2.80	635	1	2.80
				574	1	2.80	682	1	2.80
				576	1	2.80			
				582	1	2.80			
				592	1	2.80			
				595	1	2.80			
				598	1	2.80			
				614	1	2.80			
Count	20			28			23		
Total		36	100		36	100		36	100
C.V. (%)	54.07			38.04			61.36		

C.V. – coefficient of variation

geous as it makes the sound pitch unstable, hence people will perceive the sound more different.

Tables 5 and 6, therefore, presented the analysis of the RF obtained per strike at NTR and MTR respectively. It can then be observed that sound pitch obtained at MTR will be better perceived as stable due to a minimal RF count. It was also evident from the histograms (figures 5-7) that many of the RF obtained at NTR were farther away from the first frequency (FF), an indication that the sound pitch of the talking drums played at NTR was unstable. On the other hand, at MTR a higher percentage of the RF was found closer to its FF thus, the pitches of sound at MTR are more stable and consistent.

Additional pieces of information about the sound properties of the talking drums found in this study were discussed below

4.1 Sound frequency

Plack et al. (Plack et al. 2005) described sound frequency as a sensation that refers to the pitch of a sound. Thus, sound frequency measures the degree of sound pitch of material or musical instrument. Similar to other musical instruments, the talking drum contains more than one natural frequency when struck. However, the two prominent frequencies reported for

Table 6: Frequency analysis of Resonance Frequency obtained at Maximum Tension on the rope.

	TD1			TD2			TD3		
	RF	Freq.	%	RF	Freq.	%	RF	Freq.	%
	181	28	77.80	168	10	27.80	191	1	2.80
	182	5	13.90	169	7	19.40	192	2	5.60
	183	1	2.80	170	5	13.90	193	9	25.00
	186	1	2.80	171	11	30.60	194	15	41.70
	626	1	2.80	172	2	5.60	195	5	13.90
				493	1	2.80	196	1	2.80
							199	2	5.60
							200	1	2.80
Count	5			6			8		
Total		36	100		36	100		36	100
C.V. (%)	72.94			58.92			1.64		

Table 7: Correlation analysis of ESI and Sound Properties of Talking Drum.

	FF	RF	A	SDT
ESI (at NTR, goat skin)	0.499*	-0.071	0.3	-0.118
ESI (at MTR, goat skin)	0.003	-0.304	0.799*	0.702*
ESI (at NTR, cow womb)	0.461	0.312	0.787*	0.389
ESI (at MTR, cow womb)	-0.059	-0.059	0.888*	0.536*

*Significant
FF – Fundamental Frequency RF – Resonance Frequency A – Amplitude SDT – Sound Damping Time

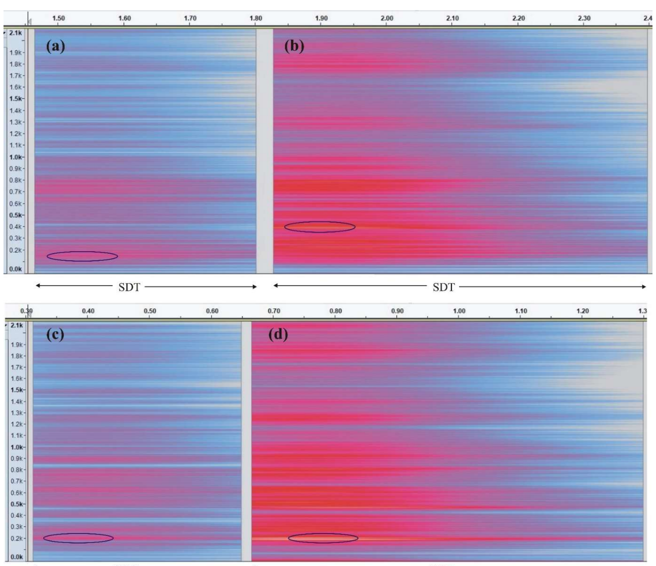

Figure 2: Spectrogram sample of sound obtained at (a) light force of play at NTR, (b) heavy force of play at NTR, (c) light force of play at MTR, and (d) heavy force of play at MTR.

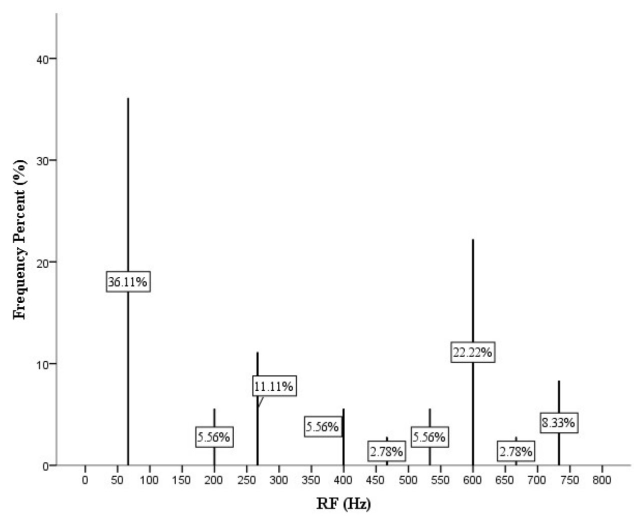

Figure 3: Histogram of Resonance Frequency of TD1 Obtained at NTR.

musical instruments are fundamental and resonance frequency [1, 3, 5, 15, 17]. The former measures the first frequency in a given sound, while the latter describes the peak frequency.

Since frequency defines the pitch of a sound, fundamental frequency measures the lowest pitch of a sound while resonance frequency describes the perceived loudness of the sound pitch. Howbeit, this peak frequency is not heard as a separate pitch but is grouped with other frequencies and heard

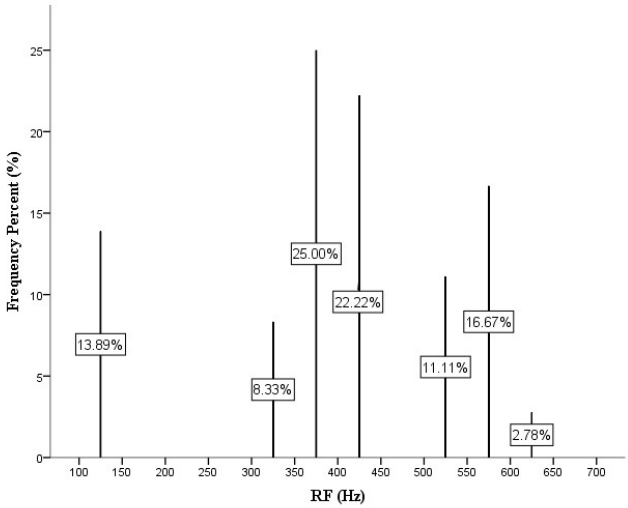

Figure 4: Histogram of Resonance Frequency of TD2 Obtained at NTR.

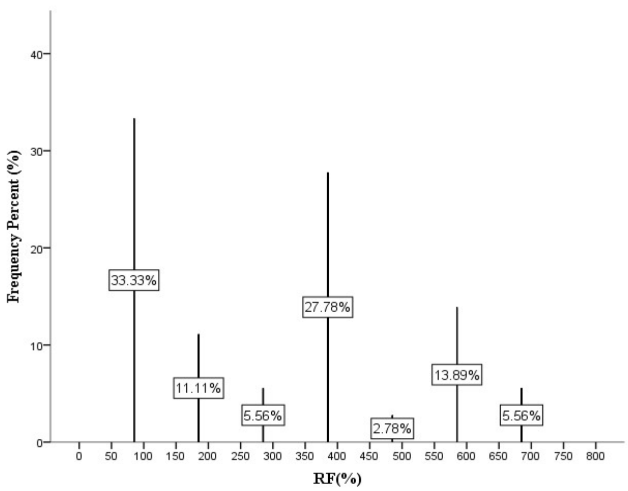

Figure 5: Histogram of Resonance Frequency of TD3 Obtained at NTR.

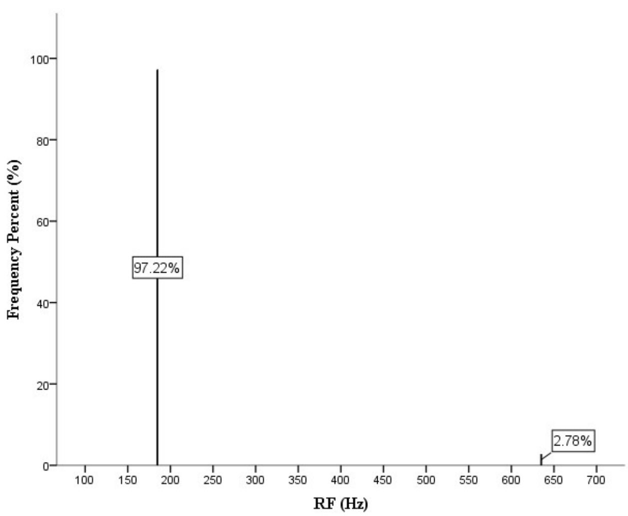

Figure 6: Histogram of Resonance Frequency of TD1 Obtained at MTR.

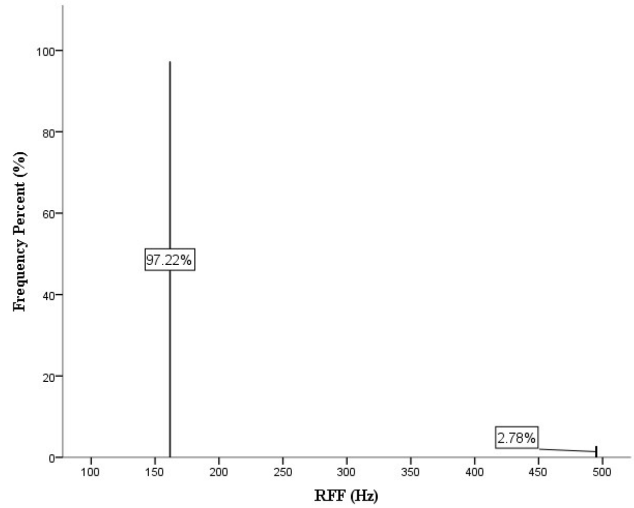

Figure 7: Histogram of Resonance Frequency of TD2 Obtained at MTR.

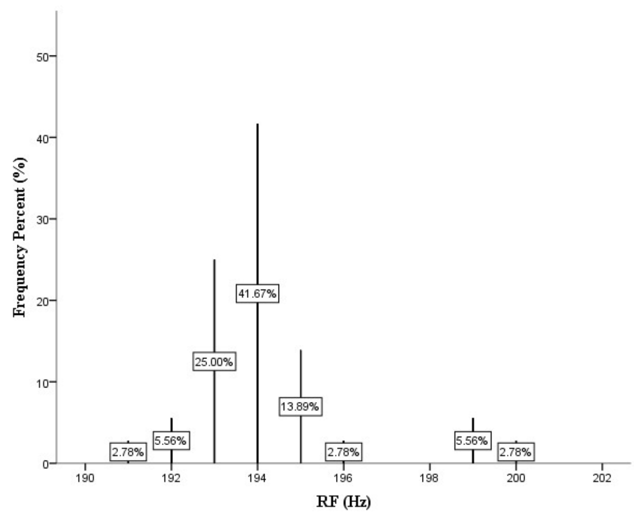

Figure 8: Histogram of Resonance Frequency of TD3 Obtained at MTR.

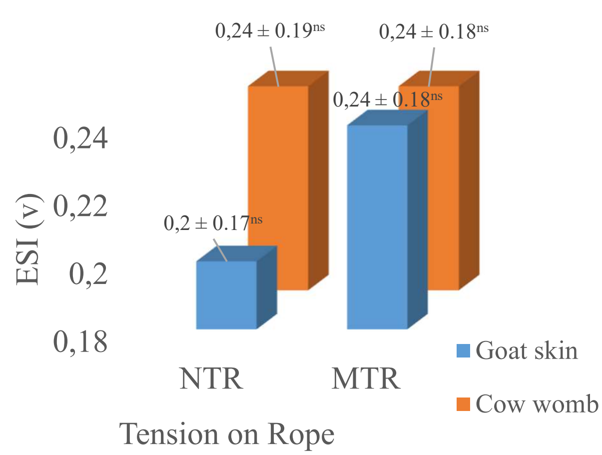

Figure 9: The Excited Surface Impact (ESI) on the Drums at NTR and MTR.

as a single coherent entity, that is, the auditory system automatically binds together frequency components that are integer multiples of a common fundamental frequency [18].

Therefore, the mean fundamental frequencies obtained in this study for talking drums characterized at NTR implies that TD1 and TD2 had the lowest and highest pitch of the sound, respectively, while at MTR, TD2, and TD3 had the lowest and highest pitch, respectively. A good index to characterize a talking drum as musically suitable is its ability to have a wider range of frequency, that is - it should be able to produce the lowest pitch at NTR and still have a high pitch at MTR. Following [19], the FR (≥ 2) of TD1 and TD3 imply that they completed an octave of a musical note. Thus, TD1 with the highest frequency range can be considered the most suitable.

Also, this study found that the fundamental frequency did not at all times sound the loudest, meaning there were occasions where the fundamental frequencies were not the resonance frequencies. In such an instance, the loudest frequency is expected to influence the perceived pitch of the sound. Hence, there was a need to determine the degree of variation and contribution of resonance frequencies to the general pitch of sound obtained at NTR and MTR.

At NTR, TD2 had the highest numbers (28) of obtainable RFs despite the lowest coefficient of variation. This thus explains that though multiple RF were obtained, they were still closer to the average value for its RF. However, the suitability of talking drum based on the frequency at NTR is best characterized by the minimum frequency value. Therefore, TD1 having the highest RF percentage (36%) closest to the minimum (i.e. FF), and TD3 which had 33% are more stable and better than TD2. Inferentially, the presence of multiple RF had a negative influence on the sound pitch of the talking drums at NTR, and caution should be taken to minimize its occurrence.

At MTR, TD3 had the highest number of RF and the lowest CV. The RF Values in TD3 were found to have the least deviation from each other, compared with TD1 and TD2. Regardless of the CV derived from all the TDs, not less than 97% of all RF obtained were closer to the FF. this means that nearly all of the resonance frequencies were also fundamental frequencies. This is an indication that all talking drums characterized based on sound frequency were stable and reliable at MTR. Therefore, this study deduced that there is no major effect of the RF on the pitch of sound at MTR.

On the other hand, FF at NTR was significantly different with respect to leather covers for TD2 only. This suggests that the cow womb with lower FF at NTR is better as a leather cover for making talking drums, especially where a lower pitch of a sound is to be ensured. However, at MTR, values of FF and RF obtained at cow womb were significantly higher than goat skin, for TD3 only. Since a higher sound frequency at MTR depict a better pitch and aids a wider frequency range, cow womb was better than goat skin.

Meanwhile, there were no significant differences in the effect of cover leather on the mean total sound frequency (FF and RF) for all the talking drums at NTR and MTR. Hence, the cow womb has not adequately shown an edge over goat skin. Therefore, this study did not confirm in generality the superiority of cow womb leather cover over goat skin, for obtaining a better pitch of sound in a talking drum. Notwithstanding, it exhibited a greater potential for preferential usage.

The contribution of the force of play on FF and RF was significantly noticed among all the talking drums, at NTR. The FF & RF values obtained at a heavy force of play were significantly higher than at a light force of play. As earlier mentioned, the occurrence of lower sound frequency at NTR is more beneficial than higher sound frequency – this is because only a low pitch is required to render the quality of the talking drum at NTR.

Furthermore, the predominance of red lines at (b) and (d) as displayed in the spectrogram confirms that more frequencies were produced and were louder when heavy force was used to play the talking drum. Since a significant difference occurred for RF with respect to the force of play at NTR, it can be argued that heavy force of play resulted in the turnout of multiple RFs, causing inconsistency in the sound frequency of the talking drums. Consequently, the resulting higher FF and RF from the heavy force of play is disadvantageous. Therefore, a heavy force of play at NTR is to be discouraged.

Contrarily, there were no significant differences between the mean total of FF and RF obtained at the light and heavy force of play respectively, at MTR. As such, the force of play does not affect the pitch of the sound generated from a talking drum when played at MTR.

Furthermore, the intersperse significant variations in FF obtained for the position of play at NTR indicate that TD1 highlighted up to be significantly lowest, and performed best, while it can be deduced from TD3 that FF obtained at the center was significantly best. For TD2, FF from up, center, and down were not significantly different from each other. Also, the mean total of FF & RF were not significantly different from each other. This showed that the influence of the position of play on sound frequency is not significant at all times. However, this intersperse variation may have been caused by the drummer's discomfort to play at the desired positions and/or the instability of the talking drums at NTR, as reported above.

At MTR, FF and RF were significantly better at the center position for TD3, but the position of play did not generally affect the sound frequencies. As a result, this study cannot confirm that position of play significantly influence the sound frequency of a talking drum at MTR. However, it is still appropriate to suggest that drummers should ensure playing at the center position since it contributed to the best performance of FF for TD3 at NTR and MTR.

The sound frequencies obtained in this study was lower to [15] for talking drum made from the same wood species but performed within the range reported by [5, 7] for talking drums made from G.arborea, Brachystegia eurycoma, Aningeria robusta, and Cordia mellina wood. The better frequency in the work of [15] could be associated with the different types of hourglass shell shapes used in their study. Also, the sound frequency recorded in this study at NTR was similar to what was obtained in the work of Olaoye and Oluwadare [20] at the lowest pitch of the talking. Whereas, the higher pitch of sound obtained at MTR confirms the report of [14, 15, 21, 22] - that a higher pitch will be attained with respect to tension on the rope.

4.2 Amplitude

Abokhalil [23] described the amplitude (A) of a wave with intensity and loudness as the maximum displacement of the medium elements from its equilibrium position. Similarly, the amplitude of a sound wave was defined as the loudness or the amount of maximum displacement of vibrating particles of the medium from their mean position when the sound is produced [24]. Therefore, a higher amplitude value means a louder sound.

The results obtained at NTR and MTR showed that while a heavy force of play resulted in a significantly louder sound, leather covers (goat skin/cow womb) did not. A closer look at the spectrogram revealed that louder sound frequencies were produced with heavy force, owing to the predominance of red lines. Also, the distinct white line at (d) distinguished the loudest RF.

On the other hand, at NTR, the sound produced from the center and down positions were significantly louder than up, while there was no significant loudness at MTR along with the positions of play. The inconsistency of sound frequency at NTR may be responsible for amplitude variation which occurred along with the positions of play.

This study thus opined that drummers are compelled to play the talking drum with a heavy force of play to generate louder sound. Just as this is tenable, a large force of play at NTR needs to be discouraged as it will also introduce an unwanted frequency, as earlier discussed. Alternatively, the use of an amplifier may be adopted to improve the sound intensity and in turn, a louder sound.

4.3 Sound damping time (SDT)

The sustainability of sound for a longer duration has been identified as an important property for sound characterization [9]. The SDT measures the time taken for a sound emanating from a talking drum to go into silence or loss its vibration energy after striking [15]. Hence, a higher SDT value describes a longer sound.

Of the factors examined at NTR, only force of play had a significant effect on SDT, with a heavy force of play contributing to a higher SDT and in turn a longer sound. At MTR, there was intersperse variation of SDT across the talking drums with respect to leather covers, however, the mean result showed that goat skin was better for SDT. Similar to what was obtained at NTR, heavy force of play was confirmed to produce a longer sound, at MTR.

In congruence, the longer SDT shown at (b) and (d) of the spectrogram implies that the longest SDT was found at MTR, and also confirms that a longer duration of sound was attained at a heavy force of play. Inferentially, a heavy force of play at MTR is essential where a longer duration of sound is required.

4.4 Excited surface impact

The ESI which measures the impact of force on the leather covers revealed that cow womb is more sensitive and responsive to force impact than goat skin, owing to its higher value of ESI. As such, it is expected to be less deformed when force is applied and consequently vibrate better than goat skin cover. However, since the values were insignificantly different, it can be assumed that both leather covers performed similarly.

It should be recalled that it is a lower sound pitch at NTR that qualifies a good talking drum. Therefore, the significant correlation between FF and ESI (at NTR) for goat skin is disadvantageous, as it shows that goat skin leather cover aid high pitch of sound with increasing force impact. However, other significant relationships recorded in Table 7 are beneficiary, thus cow womb leather cover is preferential.

5 Conclusion

The sound properties of talking drums made from G.arborea wood were successfully characterized from the surface leather covers, force of play, position of play, and excited surface impact, at no tension and maximum tension on the rope. The sound properties obtained compared favorably with what has been recorded in literature. Notwithstanding, the influence of leather covers on the sound properties was not generally established, but cow womb leather cover was a preference. Similarly, general variation in properties of sound generated at the up, center, and down positions was not found. Meanwhile, a heavy force of play contributed a major role in the characterization of the sound properties, thus, careful consideration must be given to the force used in playing the talking drums. Most importantly, adequate tension on the rope was essential in rendering a quality sound property of the talking drums. Hence, materials and factors that can enhance tension on the rope should be stimulated.

Declaration

Conflicts of interest or competing interests: No conflicts of interest or competing interests

Data and code availability: Secondary data have been referenced

Supplementary information: No supplementary information applicable

Ethical approval: No ethical approval was required

Role of funding source: No funding was provided for this study

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THOMAS EDWARD RICHARDSON

JULY 9, 1940 TO JANUARY 22, 2021

Bill Gastmeier
HGC Engineering

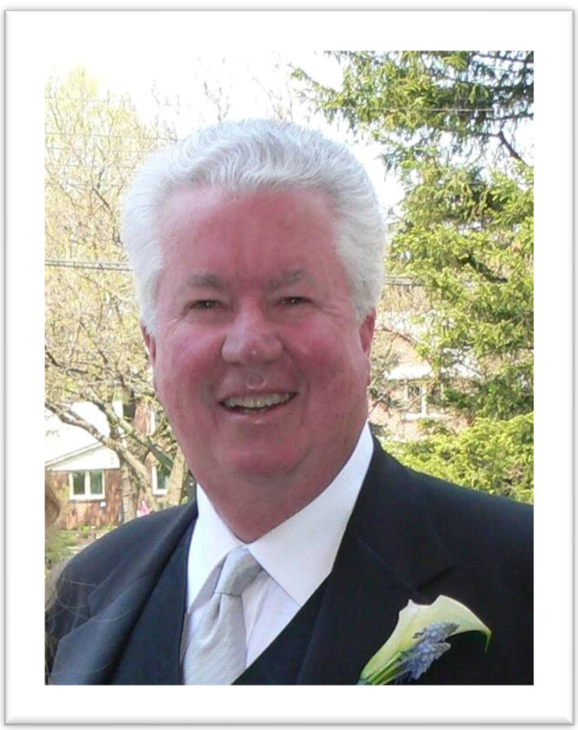
Thomas Edward Richardson passed away on January 22, 2021. Many of you will remember Tom in his ownership role at Sound Solutions and as a CAA member, sponsor and frequent exhibitor at our conferences. At HGC Engineering, we clearly remember Tom as the first supplier to call on us when we put out our shingle. He was a frequent collaborator and colleague over the years.

Tom was born in Toronto and was a student at Ridley College in St. Catharines. He attended the University of Waterloo and through the co-op engineering program became interested in the construction industry. In 1967 he co-founded the company which became Sound Solutions where he was still working part-time until his untimely death.

Tom secured the rights to Tectum which was used in many school projects across Canada. He tirelessly grew his line of acoustical products and showed it to as many architects as possible. Sound Solutions was one of the early manufacturers of fabric wrapped fiberglass acoustic panels in North America. In the 70's and 80's the panels were shipped and installed all over the US, and even to the middle east.

Ed Makarchuk, Principal of Sound Solutions offers these memories. "Our group at Sound Solutions will miss Tom immensely. He was a great leader, mentor and friend. He had a way of making all of us smile anytime he was in the office".

Tom is survived by Lynda, his wife of 56 years, their children Kelly, Robin and Bryan, three grandchildren and his sister Kathy.

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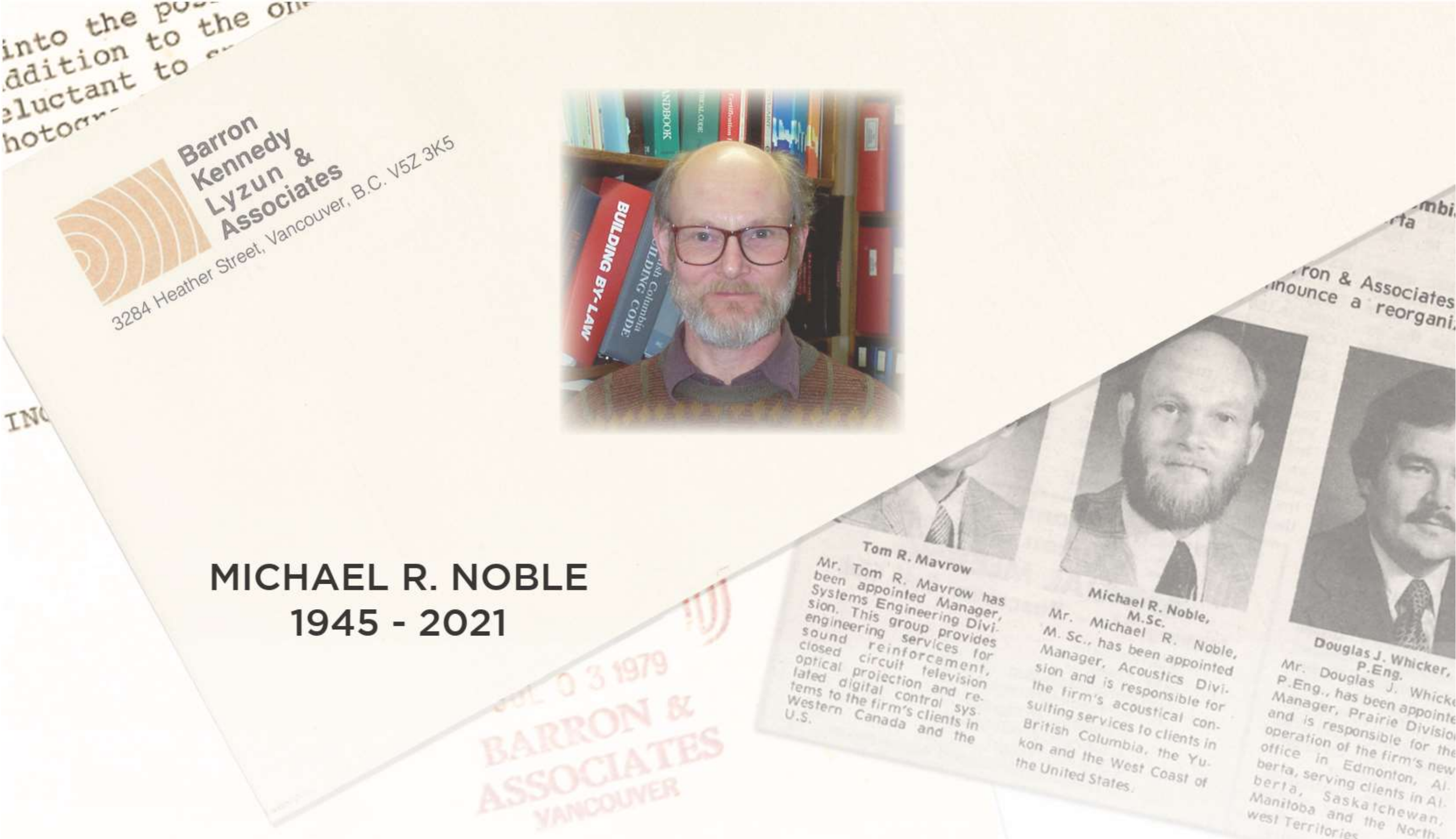

MICHAEL R. NOBLE
1945 - 2021

Michael R. Noble, a former partner of BKL Consultants Ltd., passed away at the North Shore Hospice (North Vancouver, British Columbia) on October 31, 2021, after a sharp decline in his health. He will be deeply missed by his wife, Krysha; daughters, Claire and Jane; sons-in-law, Andrew and Serge; and his four grandchildren. He will also be missed by friends and colleagues.

Mike grew up and was educated in the Wirral, United Kingdom, and earned his degree in applied physics at the Liverpool College of Technology in 1968. While attending college, he was a Research Assistant for Unilever Research Ltd. In 1969 Mike decided to move to Canada to attend graduate studies at the University of Victoria where he obtained his Master of Science in Acoustics in 1974. He joined the firm of Barron and Associates in 1974 where he practiced as an Acoustical Consultant working on large and small projects throughout Western Canada. Wanting to broaden his experience, in 1980, he joined Vancouver's MacMillan Bloedel Ltd., as an Acoustical Consultant. In 1982 he returned to Barron and Associates (later reorganized as BKL Consultants Ltd.) as a Senior Consultant, Mike advanced to become one of the firm's Principals and remained with the firm for the rest of his career, fully retiring in 2015.

During his career at BKL, Mike established a reputation in architectural acoustics specializing in theatre and sound studio design. Among Mike's theatre design projects, the following are highlights of his efforts: the Terry Fox Theatre in Port Coquitlam; the Banff Centre Music Building Performance Hall Redesign; University of Calgary Rozsa Centre for Performing Arts; and Surrey's Bell Centre for the Performing Arts. Mike also had significant involvement in the studios supporting Hollywood North, including Bridge Studios, Vancouver Film Studio, BCTV TV Studio, and CBC Vancouver Studio.

Mike's experience in all aspects of acoustics and noise control enabled him to provide cost-effective consultation on large and small projects throughout Western Canada. He also presented lectures and short courses on environmental noise assessment, industrial noise control and architectural acoustics to audiences of his peers, municipal officials, trade groups, and architects. Mike identified significant acoustical deficiencies in the LEED Green Building program and in a presentation to the Acoustical Society of America in 2005 urged inclusion of acoustical credits in the LEED rating system. With his background in physics, and his extensive experience, Mike was always the go-to person for all BKL staff seeking advice on any acoustical project. He was affectionately known among office staff as "the fount of all wisdom." Mike's life was cut short all too soon and he is missed by friends, family, and colleagues.

Contributors to this post include Doug Whicker, Dan Lyzun, Doug Kennedy, Tiberiu Spulber, Paul Marks, Mark Bliss, and BKL.

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ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL
FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS
RAYMOND HETU UNDERGRADUATE STUDENT PRIZE IN ACOUSTICS
THOMAS D. NORTHWOOD GRADUATE STUDENT PRIZE IN ARCHITECTURAL AND ROOM ACOUSTICS
ALBERT S. BREGMAN GRADUATE STUDENT PRIZE IN PSYCHOLOGICAL ACOUSTICS

Prix

PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE
PRIX ETUDIANT ALEXANDER G. BELL EN COMMUNICATION ORALE ET AUDITION (2E OU 3E CYCLE)
PRIX ETUDIANT ECKEL EN CONTROLE DU BRUIT (2E OU 3E CYCLE)
PRIX ETUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE (2E OU 3E CYCLE)
PRIX ETUDIANT RAYMOND HETU EN ACOUSTIQUE (1ER CYCLE)
PRIX ETUDIANT THOMAS D. NORTHWOOD EN ACOUSTIQUE ARCHITECTURALE ET ACOUSTIQUE DES SALLES (2E OU 3E CYCLE)
PRIX ETUDIANT ALBERT S. BREGMAN EN PSYCHOACOUSTIQUE (2E OU 3E CYCLE)

Deadline for Applications:
June 30th 2022

Date limite de soumission des demandes:
30 Juin 2022

Consult CAA website for more information
Consultez le site Internet de l'ACA pour de plus amples renseignements
(http://www.caa-aca.ca)

canadian acoustics
acoustique canadienne
Journal of the Canadian Acoustical Association - Revue de l'Association canadienne d'acoustique

Invitation
Numéro spécial "Semaine du son Canada"
Acoustique Canadienne

Un numéro spécial dédié à "La semaine du son Canada - UNESCO" est prévu pour le numéro de juin 2022 de la revue Acoustique Canadienne et que tous les participants sont invités à soumettre un article servant d'actes de conférence et reprenant les éléments présentés durant cette semaine.

Comment en faire partie?

Pour contribuer à ce numéro spécial, les auteurs sont invités à soumettre un article (de 2 pages minimum à 12 pages maximum), sous la rubrique « **Numéro spécial** » dans notre système en ligne au **https://jcaa.caa-aca.ca** avant le **15 avril 2022**. Il est possible de soumettre un même article dans les 2 langues officielles.

Chaque article sera révisé par le comité éditorial de l'Acoustique canadienne qui veillera à ce que les politiques de publications de la revue soient respectées (contenu original, contenu non commercial, etc. – voir les politiques de la revue pour de plus amples détails).

De véritables actes de conférences dans lesquels vous voulez paraître!

Comme tous les numéros de la revue Acoustique Canadienne, cette édition dédiée sera publiée en format papier et envoyée à tous les membres nationaux et internationaux de l'Association canadienne d'acoustique. Une version électronique sera aussi disponible en ligne sur le site internet de la revue. Le contenu de ces numéros sera indexé, donc facilement trouvable au moyen de moteurs de recherche majeurs, tels Google, Bing, etc. Les auteurs sont invités à bien choisir les mots clefs pour maximiser la visibilité de leur article.

Pour toutes questions, vous pouvez communiquer avec Mme Pascale Goday (pascalegoday@gmail.com), éditorialiste invitée pour ce numéro spécial, Romain Dumoulin (deputy-editor@caa-aca.ca), rédacteur en chef adjoint, ou encore Jérémie Voix (president@caa-aca.ca), président de l'Association canadienne d'acoustique.

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

canadian acoustics
acoustique canadienne
Journal of the Canadian Acoustical Association - Revue de l'Association canadienne d'acoustique

Invitation

"Canadian Sound Week" Special Issue

Canadian Acoustics

A special issue dedicated to "Canada-UNESCO Sound Week" is planned for the June 2022 issue of the Canadian Acoustics Journal and all participants are invited to submit an article to serve as a conference proceeding, based on the material presented during this week.

How to be part of it?

To contribute to this special issue, authors are invited to submit an article (from a minimum of 2 pages to a maximum of 12 pages), under the heading "**Special Issue**" in our online system at **https://jcaa.caa-aca.ca** before **April 15, 2022**. It is possible to submit the same article in both official languages.

Each article will be reviewed by the Canadian Acoustics editorial board to ensure that the journal's publication policies are followed (original content, non-commercial content, etc. - see the journal's policies for more details).

Real conference proceedings that you want to appear in!

As with all issues of Canadian Acoustics, this dedicated edition will be published in hard copy and sent to all national and international members of the Canadian Acoustical Association. An electronic version will also be available on the journal's website. The content of these issues will be indexed, and thus easily found by major search engines such as Google, Bing, etc. Authors are invited to choose the right keywords to maximize the visibility of their article.

If you have any questions, please contact Pascale Goday (pascalegoday@gmail.com), guest editor for this special issue, Romain Dumoulin (deputy-editor@caa-aca.ca), associate editor, or Jérémie Voix (president@caa-aca.ca), president of the Canadian Acoustical Association.

ANNOUNCEMENT

ACOUSTICS WEEK IN CANADA

MEMORIAL UNIVERSITY, ST. JOHN'S, NEWFOUNDLAND AND LABRADOR
SEPT 27-30, 202

Acoustics Week in Canada 2022 will be held on September 27-30 2022, in St. John's, Newfoundland and Labrador.

Vue du centreville de St John's

You are invited to be part of this three-day conference featuring the latest developments in Canadian acoustics and vibration. This is the first time Acoustics Week will be held in the province of Newfoundland and Labrador, and reflects Memorial University's growing profile in acoustics research.

The keynote talks and technical sessions will be framed by a welcome reception, conference banquet, Acoustical Standards Committee meeting, technical tour and an exhibition of products and services related to the field of acoustics and vibration.

Take few days before or after the conference to enjoy the area and the cultural activities! While in Downtown St. John's be sure to try some of the world-class restaurants on Duckworth and Water Street. Become an honourary Newfoundlander by kissing a cod and getting screeched-in on George Street, while enjoying endless live music. Right next to downtown is Signal Hill National Historic Site, where Marconi received the first transatlantic radio signal. Signal Hill has great views of the city, and amazing hiking trails. For a longer hike, the East Coast Trail comprises 25 segments along the Atlantic coast of varying difficulty, most within an hour's drive of St. John's.

Venue and Accommodation

The conference will be held at the Sheraton Hotel Newfoundland in St. John's. A block of rooms in the hotel will be available at a special rate of $179/night. Please refer to the conference website for further details and registration: https://awc.caa-aca.ca/index.php/AWC/AWC22

Water Street, St John's

Plenary, technical sessions.

are planned throughout the conference. Each day will begin with a keynote talk of broader interest and relevance to the acoustics community. Technical sessions are planned to cover all areas of acoustics including:

AEROACOUSTICS / ARCHITECTURAL AND BUILDING ACOUSTICS / BIO-ACOUSTICS AND BIOMEDICAL ACOUSTICS / MUSICAL ACOUSTICS / NOISE AND NOISE CONTROL / PHYSICAL ACOUSTICS / PSYCHO- AND PHYSIO-ACOUSTICS / SHOCK AND VIBRATION / SIGNAL PROCESSING / SPEECH SCIENCES AND HEARING SCIENCES / STANDARDS AND GUIDELINES IN ACOUSTICS / ULTRASONICS / UNDERWATER ACOUSTICS

Exhibition and sponsorship.

The conference offers opportunities for suppliers of products and services to engage the acoustic community through exhibition and sponsorship.

The tabletop exhibition facilitates in-person and hands-on interaction between suppliers and interested individuals. Companies and organizations that are interested in participating in the exhibition should contact the Exhibition and Sponsorship coordinator for an information package. Exhibitors are encouraged to book early for best selection.

The conference will be offering sponsorship opportunities of various conference features. In addition to the platinum, gold and silver levels, selected technical sessions, social events and coffee breaks will be available for sponsorship. Additional features and benefits of sponsorship can be obtained from the Exhibition and Sponsorship coordinator and on the conference website.

Students.

Students are strongly encouraged to participate. Students presenting papers will be eligible for one of three $500 Best Presentation Student prizes to be awarded. Conference travel bursaries will also be available to those students whose papers are accepted for presentation.

Registration details.

Please refer to the conference web site: https://awc.caa-aca.ca/index.php/AWC/AWC2022 1

Contacts.

Conference Chair:

Len Zedel
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Ben Zendel
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Flatrock, along the East Coast Trail

Annonce

SEMAINE CANADIENNE D'ACOUSTIQUE

Université Memorial, St. John's, Terre-Neuve et Labrador
Sept 27-30, 2022

La Semaine canadienne d'acoustique 2022 aura lieu du 27 au 30 septembre 2022 à St. John's, Terre-Neuve et Labrador. You Nous vous invitons à prendre part à cette conférence de trois jours concernant les derniers développements en acoustique et vibrations au Canada. C'est la première fois que la Semaine Canadienne d'acoustique aura lieu dans la province de Terre-Neuve et Labrador, ce qui reflète le profil croissant de recherche en acoustique de l'Université Memorial.

View of downtown St John's

Les exposés principaux et les séances techniques seront encadrés par une réception de bienvenue, un banquet, une réunion du comité des normes acoustiques, une visite technique et une exposition de produits et services liés au domaine de l'acoustique et des vibrations.

Prenez quelques jours avant ou après la conférence pour profiter de la région et des activités culturelles! Au centre-ville de St. John's, assurez-vous d'essayer les restaurants de classe mondiale sur la rue Duckworth et la rue Water. Devenez un(e) Terre-Neuvien(ne) honoraire en embrassant une morue et en vous faisant 'Screeched-in' sur la rue George, tout en profitant de la musique live sans fin. Juste à côté du centre-ville se trouve le Lieu historique national de Signal Hill, où Marconi a reçu le premier signal radio transatlantique. Signal Hill a une vue imprenable sur la ville, et des sentiers de randonnée incroyables. Pour une randonnée plus longue, le sentier de la côte Est comprend 25 segments le long de la côte atlantique de difficulté variable, la plupart à moins d'une heure de route de St. John's.

Lieu et hébergement.

La conférence aura lieu au Sheraton Hotel Newfoundland à St. John's. Un bloc de chambres dans l'hôtel sera disponible à un tarif spécial de 179$ par nuit. Veuillez consulter le site Web de la conférence pour plus de détails et pour l'inscription: http://awc.caa-aca.ca/AWC/AWC2022

Rue Water, St John's

Des séances plénières, techniques et des ateliers.

Des séances plénières, techniques et des ateliers sont prévus tout au long de la conférence. Chaque journée débutera avec une plénière intéressante et pertinente pour la communauté de l'acoustique. Des sessions techniques sont prévues pour couvrir tous les domaines de l'acoustique, y compris :

Aéroacoustique / Acoustique du Bâtiment et Architecturale / Bioacoustique / Acoustique Biomédicale / Acoustique Musicale / Bruit et Contrôle du Bruit / Acoustique Physique / Psychoacoustique / Chocs et Vibrations / Linguistique / Audiologie / Ultrasons / Acoustique Sous-Marine / Normes en Acoustique

Exposition et parrainages.

La conférence offre aux fournisseurs de produits et de services la possibilité de faire participer la communauté acoustique par l'exposition et le parrainage.

L'exposition sur le plateau facilite l'interaction en personne des fournisseurs et des personnes intéressées. Les entreprises et organisations désirant participer à l'exposition doivent contacter le coordonnateur de l'exposition et du parrainage pour obtenir un dossier d'information. Les exposants sont encouragés à réserver tôt pour obtenir de meilleures opportunités.

Les étudiants.

Les étudiants sont fortement encouragés à participer. Les étudiants qui présenteront seront admissibles à l'un des trois prix de 500$ pour les meilleures présentations. Des subventions de voyage seront également offertes aux étudiants dont les communications sont acceptées pour présentation.

Pour plus d'informations sur l'inscrition.

Veuillez consulter le site Web de la conférence : http://awc.caa-aca.ca/AWC/AWC2022.

Contacts.

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Flatrock, sur le sentier de la côte Est

CANADIAN ACOUSTICS ANNOUNCEMENTS - ANNONCES TÉLÉGRAPHIQUES DE L'ACOUSTIQUE CANADIENNE

Looking for a job in Acoustics?

There are many job offers listed on the website of the Canadian Acoustical Association!

You can see them online, under http://www.caa-aca.ca/jobs/

August 5th 2015

COVID-19 Situation

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to October 2021. Nevertheless, and as a "warm up", Sherbrooke"s organising committee is currently looking into setting up a little 1-day online celebration for October 2020. You can find more information on the AWC20 and AWC21 websites. Please note that St-John's (NL) will host the AWC2022 conference.

May 13th 2020

Acoustic Training in Canada Database: Help us to help the younger generation and seasoned professionals

CAA is building a comprehensive list of all training programs offered in acoustics in Canada and we need your help! Below is a survey to help us populate that database that will eventually be available on CAA website. Please return all valuable input at your earliest convenience to Mr. DeGagne (wdegagne@caa-aca.ca)!

Dear CAA members, past members and friends, The purpose of this survey is to develop an online database of all the professional, undergraduate, and graduate acoustical courses and training programs offered through universities, colleges, associations, etc. This database would benefit the entire Canadian acoustic community in the following manner: 1. Track the different acoustical courses and training programs offered nationally 2. Allow CAA members to plan their acoustical training and easily select their perfect training program to meet their career aspirations 3. Allow CAA members to compare and contrast courses and training programs from different institutions 4. Allow institutions and the CAA to determine where the training gaps are and to plan for future programs demands To help us populate this database, simply return the following information at your earliest convenience to Mr. William DeGagne (wdegagne@caa-aca.ca), volunteer for CAA: 1. Place of the Course or Training program (university, colleges, etc.): 2. Name of Course or Training program: 3. Approx. date the Course or Training was followed: 4. Level (graduate, undergraduate, college course or professional training program, etc.): 5. Brief description of the Course or Training program: 6. Webpage of Course or Training program: 7. Location of Course or Training program (City, Province): 8. Course or Training program language: Thanks for you help towards the younger generation and seasoned professionals! :-)

May 31st 2021

24th International Congress on Acoustics (ICA 2022)

The 24th International Congress on Acoustics (ICA 2022) will be held at Hwabaek International Convention Center (HICO) in Gyeongju, Korea from October 24 to 28, 2022.

On behalf of the organizing committee, it is our great pleasure to invite you to the 24th International Congress on Acoustics, which will be held at Hwabaek International Convention Center (HICO) in Gyeongju, Korea from October 24 to 28, 2022. ICA2022 will offer the unique opportunity to learn about the study and latest researches as well as to exchange ideas and information on acoustics through plenary lectures, technical sessions, and poster Presentations. In addition, various social programs have been planned for participants to can enjoy the fascinating Korean culture and share our warm spirit of friendship. Koreans have a well-known love of music, from K-pop to Western classical music to reinterpretations of traditional Korean music. It follows then that Koreans are highly sensitive to the quality of sound, not only in musical instruments but also in everyday products and spaces. Thus our technical advancement in acoustics is tied to centuries of musical appreciation. As the cradle of the country's religion, philosophy, arts and of course, music, Gyeongju can offer visitors an insight into the development of acoustics in Korea.

Furthermore, the entire city is an open-air museum full of ancient sites and treasures which include three UNESCO World Heritage Sites. In short, the unique and authentic glimpse of Korean culture through Gyeongju City into Korean culture makes it the ideal backdrop for ICA 2022. We look forward to seeing you in Gyeongju, Korea.

March 14th 2022

À la recherche d'un emploi en acoustique ?

De nombreuses offre d'emploi sont affichées sur le site de l'Association canadienne d'acoustique !

Vous pouvez les consulter en ligne à l'adresse http://www.caa-aca.ca/jobs/

August 5th 2015

Situation COVID-19

En raison de la situation COVID-19, la Semaine canadienne de l'acoustique (AWC) initialement prévue en octobre 2020 à Sherbrooke (QC) sera reportée à octobre 2021. Néanmoins, et comme "échauffement", le comité organisateur de Sherbrooke étudie actuellement la possibilité de mettre en place une petite célébration d'une journée en ligne pour octobre 2020. Vous pouvez trouver plus d'informations sur le site des conférences AWC20 et AWC21. Veuillez noter que St-John's (NL) sera l'hôte de la conférence AWC2022.

May 13th 2020

Répertoire des formations en acoustique au Canada : aidez-nous à aider la jeune génération et nos professionels d'expérience

L'ACA est en train de dresser une liste complète de tous les programmes de formation offerts en acoustique au Canada et nous avons besoin de votre aide ! Vous trouverez ci-dessous un sondage qui nous aidera à alimenter cette base de données qui sera éventuellement disponible sur le site Web de la CAA. Veuillez retourner vos précieux commentaires à M. DeGagne (wdegagne@caa-aca.ca) dans les plus brefs délais !

Chers membres, anciens membres et amis de l'ACA, Le but de cette enquête est de développer une base de données en ligne de tous les cours et programmes de formation en acoustique professionnels, de premier et de deuxième cycle, offerts par les universités, les collèges, les associations, etc. Cette base de données profiterait à l'ensemble de la communauté acoustique canadienne de la manière suivante : 1. Suivre les différents cours et programmes de formation en acoustique offerts à l'échelle nationale. 2. Permettre aux membres de l'ACA de planifier leur formation en acoustique et de choisir facilement le programme de formation idéal pour répondre à leurs aspirations professionnelles. 3. Permettre aux membres de l'ACA de comparer et d'opposer les cours et les programmes de formation de différentes institutions. 4. Permettre aux institutions et à l'ACA de déterminer où se trouvent les lacunes en matière de formation et de planifier les demandes de programmes futurs. Pour nous aider à alimenter cette base de données, il vous suffit de retourner les informations suivantes dans les meilleurs délais à M. William DeGagne (wdegagne@caa-aca.ca), bénévole pour l'ACA : 1. Lieu du cours ou du programme de formation (université, collèges, etc.) : 2. Nom du cours ou du programme de formation : 3. Date approximative à laquelle le cours ou la formation a été suivi. 4 : 4. Niveau (études supérieures, premier cycle, cours collégial ou programme de formation professionnelle, etc :) 5. Brève description du cours ou du programme de formation : 6. Page web du cours ou du programme de formation : 7. Lieu du cours ou du programme de formation (ville, province) : 8. Langue du cours ou du programme de formation : Merci pour votre aide à l'intention de la jeune génération et de nos professionels d'expérience ! :-)

May 31st 2021

MEMBERSHIP DIRECTORY 2022 - ANNUAIRE DES MEMBRES 2022

This member directory is generated from the Canadian Acoustical Association membership database records. Please feel free to update or correct this information directly on http://jcaa.caa-aca.ca.

Ce répertoire des membres est généré à partir des informations de la base de données des membres de l'Association canadienne d'acoustique. Merci de mettre à jour ou corriger toute information directement sur http://jcaa.caa-aca.ca.

Code	Subscription type	Type d'inscription
1	Individual Member	Membre individuel
2	Student Member	Membre étudiant
3	Indirect Subscriber (Canada)	Abonné institutionnel indirect (Canada)
4	Sustaining Subscriber	Abonné de soutien
5	Indirect Subscriber (USA)	Abonné institutionnel indirect (É-U)
6	Indirect Subscriber (International)	Abonné institutionnel indirect (International)
7	Emeritus Member	Membre Emeritus
8	Full-Page Advertisement (1 year)	Publicité pleine-page (1 an)
10	Direct Subscriber	Abonné institutionnel - Direct
13	Half-Page Advertisement (1 year)	Publicité demie-page (1 an)
14	Quarter-Page Advertisement (1 year)	Publicité quart de page (1 an)
15	Retired Member	Membre retraité

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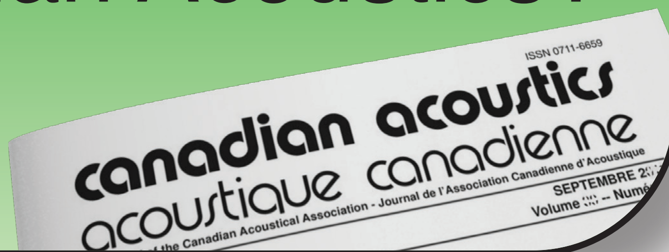

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