NOISE/NEWS INTERNATIONAL

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2018 September

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Features

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NOISE/NEWS INTERNATIONAL

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I-INCE

The International Institute of Noise Control Engineering (I-INCE) is a worldwide consortium of societies concerned with noise control and acoustics. I-INCE, chartered in Zürich, Switzerland, is the sponsor of the INTER-NOISE Series of International Congresses on Noise Control Engineering, and, with the Institute of Noise Control Engineering of the USA, publishes this quarterly magazine and its Internet supplement. I-INCE has an active program of technical initiatives, which are described in the Internet supplement to NNI. I-INCE currently has fifty-one member societies in forty-six countries.

INCE-USA

The Institute of Noise Control Engineering of the USA (INCE-USA) is a non-profit professional organization incorporated in Washington, D.C., USA. The primary purpose of the Institute is to promote engineering solutions to environmental noise problems. INCE-USA publishes the technical journal, *Noise Control Engineering Journal*, and, with I-INCE publishes this quarterly magazine and its Internet supplement. INCE-USA sponsors the NOISE-CON series of national conferences on noise control engineering and the INTER-NOISE Congress when it is held in North America. INCE-USA Members are professionals in the field of noise control engineering, and many offer consulting services in noise control. Any persons interested in noise control may become an Associate of INCE-USA and receive both this magazine and *Noise Control Engineering Journal*.

NNI and Its Internet Supplement

www.noisenewsinternational.net

The primary change in this PDF-only volume of *NNI* is the ability to have "hot links" to references, articles, abstracts, advertisers, and other sources of additional information. In some cases, the full URL will be given in the text. In other cases, a light blue highlight of the text will indicate the presence of a link. At the end of each feature or department, a light blue back to toc will take the reader back to the table of contents of the issue.

The Internet supplement contains additional information that will be of interest to readers of *NNI*. This includes:

- The current issue of *NNI* available for free download
- *NNI* archives in PDF format beginning in 1993
- A searchable PDF of annual index pages
- A PDF of the current *NNI* conference calendar and a link to conference calendars for worldwide meetings
- Links to I-INCE technical activities and I-INCE Technical Reports

From the President of I-INCE

The gathering at the annual INTER-NOISE congress is not only an opportunity for a conference with a great technical program but also an opportunity for those involved with the management of I-INCE to meet. According to the bylaws, the officers, the board of directors, and the general assembly share responsibilities in managing the affairs of the institute. While much business is undertaken throughout the year by email, the board meets on Saturday afternoon and again on Wednesday evening, and the general assembly meets on Sunday before the congress opens.

The board comprises a vice president and the directors at large with primary responsibilities to each of the three geographical regions, but it is the general assembly that is the time for the board to report to the membership as a whole and for the membership to provide guidance on current and future activities for the board. Each member society is invited to provide a representative to participate in the general assembly, and the minutes of the meeting are freely available from the website. An important agenda item is the vote by the assembly on nominations for any vacant positions, such as director at large or congress selection committee positions. At the 2018 general assembly, it was pleasing to see that there were three nominations for the director at large for the Pan-American region. Congratulations to Stuart Bolton, who will now join the board.

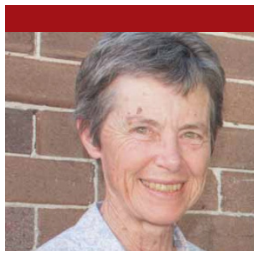
Terms for the board members are between three and four years, and the bylaws define that any member can only serve two terms in the same position, unless there are exceptional circumstances. At the end of 2018, the terms of two longstanding vice presidents come to an end.

Dave Holger has provided 12 years of continuous board service, having commenced as the director for INTER-NOISE 2007 and more recently as the vice president rules and governance. Over the last few years, he has been responsible for updating the bylaws and the rules and duties of the board members. A very important part of the update has been to ensure consistency across the various documents, and Dave has been exemplary at this task. He has agreed to continue on the board for one further year as distinguished board member to assist with the transition of duties of rules and governance to Steve Hambrick.

Samir Gerges leaves our board at the end of 2018 after 13 years continuous service. Samir commenced as the director for INTER-NOISE 2005 and continued as vice president for development and more recently has served two continuous terms as vice president for membership. During his time on the board, Samir has been a continuous advocate for acoustics in the South American region and in the membership role has acted to encourage emerging acoustic societies to consider joining I-INCE. The board has decided from 2019 to devolve the new membership duties to the vice president and the director at large responsible for each of the geographical regions.

At the end of INTER-NOISE 2018, the thanks for a successful conference go to Charlie Moritz and the team. Now we all look forward to the next INTER-NOISE 2019 in Madrid, June 16–19, 2019. (See http://www.internoise2019.org for more.)

Marion Burgess
President, I-INCE



Marion Burgess

From the I-INCE Vice President, Rules and Governance

The International Institute of Noise Control Engineering (I-INCE) is an international, nonprofit, nongovernmental, scientific and engineering organization that is a voluntary consortium of professional societies, organizations, and institutions from around the world that are involved in technical aspects of the engineering control of noise and vibration. The following overview of the I-INCE is based on the rules, procedures, and bylaws of the institute as well as further information available on the I-INCE website (at www.i-ince.org/).

As a consortium of organizations, the I-INCE consists of member societies (currently 54), institutional members (currently 1), and sustaining members (currently 8) and does not have individual members. Member societies must be not-for-profit professional societies that hold goals and objectives consistent with those of the I-INCE and that are open to membership by individual professionals. Institutional members must be not-for-profit educational institutions or research organizations with goals and objectives consistent with those of the I-INCE. Sustaining members are organizations interested in the work of the I-INCE. All applications for membership in any of the three categories are reviewed by the I-INCE Board of Directors and approved by the I-INCE General Assembly. Organizations involved in fields of interest closely related to those of the I-INCE may be admitted by the I-INCE Board of Directors as affiliated organizations of the I-INCE.

The key goals of the I-INCE as articulated in Article 3 of the I-INCE Bylaws are to perform the following tasks:

1. Serve as a federation of professional societies of the world that is dedicated to advancing technical developments in the engineering control of noise and vibration; and to
2. Provide a leadership role in promoting the application of noise and vibration control technology for the benefit of mankind.

Article 3 of the Bylaws goes on to state, "To achieve the Key Goals, the Institute recognizes the needs and responsibilities of noise control engineers in all countries. The Institute seeks to unite these engineers in common purpose through close cooperation with their national professional societies with interests in the engineering aspects of noise and vibration control."

The governance and management of the affairs of the I-INCE is a shared responsibility of the officers, the board of directors, and the general assembly, with specific responsibilities as delineated in the bylaws, rules, and procedures of the I-INCE. The officers of the I-INCE are the president, president elect, immediate past president, the vice presidents, the secretary-general, and the treasurer. The I-INCE Board of Directors consists of the officers, three directors representing the three most recent past INTER-NOISE congresses, three directors-at-large elected by the general assembly, and distinguished board members elected by the board. The I-INCE General Assembly is composed of the I-INCE Board of Directors and one representative of each member society. Institutional members, sustaining members, and affiliated organizations may be represented at meetings of the general assembly as observers without voting rights. In general, the I-INCE Board of Directors and officers manage the affairs of the institute with guidance from the general assembly, as specified in the I-INCE bylaws and rules and procedures.

David K. Holger
I-INCE Vice President, Rules and Governance

David K. Holger

Editor's View

Welcome to the September issue of *Noise/News International*. Along with our usual features, this issue also includes a tutorial outlining some often-overlooked facts on vibration damping and a review of the Noise-Adapt Ireland project, which aims to identify Ireland's adaptation needs for transitioning to the CNOSSOS-EU method for noise mapping. I hope you enjoy these interesting articles.

By the time you read this issue, INTER-NOISE 2018 will have concluded. I hope those of you who managed to make it to Chicago enjoyed the conference (and are already looking forward to Madrid 2019!)—but I also hope you managed to stop by the *NNI* booth at the expo to learn of forthcoming developments at *NNI*, particularly related to changes in our advertisement space.

We are placing our focus on online adverts, and we encourage anyone with an interest in advertising with *NNI* to reach out for more details. You should note that *NNI* enjoys circulation in over 40 nations around the world, serving 51 different professional societies.

Finally, as ever we have updates from all around the world in our NOISE/NOTES feature. There is an interesting link to a Swedish study on the medical and social aspects of aging that suggests older adults in Sweden are hearing better than they were 40 years ago—perhaps we are doing something right in the noise control community!

Eoin A. King, PhD
@NNIEditor

Eoin A. King, PhD

NOISE/NOTES

Eoin A. King, NNI Editor, and Eva Von Dell, NNI Social Media Assistant

NNI is on Facebook and Twitter—we try to keep our readers informed with noise news from all across the globe by highlighting interesting research and projects. Here is a roundup of some of the stories that have been making headlines. Follow @NNIEditor or our Facebook page to stay up to date with all noise-related news.

Noise Reduction Research to Help Whales

In Ottawa, the federal government announced $26.6 million in funding for research to help better understand how noise impacts marine mammals. The funding will support gliders equipped with hydrophones to detect the presence of whales and track how they move through the area.

Throwback to 1970s Noise Monitoring

Citylab recently featured a clip from a 1974 video about noise pollution, released by the (now-defunct) Department of Health, Education, and Welfare, in the United States. It was released as an attempt to raise awareness about noise at the time. It features a high school student, Annette Cook, taking sound-level readings in Atlanta, Georgia.

Birds Can Learn New Languages to Stay Safe!

A new study shows that at least one species of bird (the fairy wren) can learn to associate new calls with known alarm calls, without having to see the callers or a predator. The study, performed by researchers from the Australian National University and the University of Bristol, was published in the journal *Current Biology* earlier this year.

The Noisiest Neighborhoods in New York

In an earlier issue of NNI, we had a feature detailing the national transportation noise map and showed how noise levels vary across the continental United States. More recently, the *New York Times* reported on an analysis of noise complaints in the city to determine the noisiest neighborhoods in NYC.

Improved Hearing in Swedish 70-Year-Olds

A recent study published in *Age and Ageing* showed that older adults in Sweden are hearing better than they were 40 years ago. This was part of the H70 study, which is a large-scale population-based investigation, initiated in the early 1970s, aiming to study medical and social aspects of ageing. The authors found that the largest improvements were seen at 4–6 kHz in men; they suggest that this possibly reflects a decrease in occupational noise exposure.

Passing of Lewis S. Goodfriend

It saddens us to learn that Lewis Stone Goodfriend of Longmont, Colorado, passed away on Monday, July 30, 2018. He was 95. Lewis was a long-serving member of INCE and contributed much to noise control engineering.

Lewis was born in 1923. He was predeceased by his parents, Henry Bernheim and Jane Elizabeth Stone; his sister, Grace; his brother-in-law, Herbert Shaw; his son-in-law, John Chaffee; and his wife, Susan Banker. He leaves behind three daughters, Karen Chaffee, Anne Oberg, and Jane Strandberg; Jane's husband, Steve; a son, Henry; and his nephew, Brandon Shaw. He also leaves behind grandchildren Corey, Lexie, Gracey, Cameron, Ian, Emma, David, Mary Louise, Victoria, Henry, Crane, John, and Brenda; and great grandchildren Hannah and Ellie.

Lewis enjoyed ham radio, traveling, and spending time with his children and grandchildren. He was passionate about continuing to advance his profession and had a lifelong enthusiasm for learning. He loved science, art, and photography, and he enjoyed going for walks and riding his bike. Helping people in both his personal and professional life was very important to him. He will be dearly missed.

Lewis received his degree in mechanical engineering from Stevens Institute of Technology in 1947 and his master of electrical engineering degree from the Polytechnic Institute of Brooklyn in 1952.

Lewis served in the United States Marine Corps from 1943 to 1945. He was a combat veteran on several islands in the Pacific Theater, including Guam, Guadalcanal, and Okinawa, serving as a radio operator.

Earlier in the war, Lewis worked for the Office of Scientific Research and Development on special projects contributing to the successful execution of the war.

Lewis served as president of Lewis S. Goodfriend & Associates from 1953 to 2002. He was a consulting engineer serving clients in the areas of architectural acoustics; noise assessment and control programs for industry, communities, and airports; air-conditioning noise control; and product development.

Lewis was a fellow of the Acoustical Society of America and the Audio Engineering Society. He was a past president and former member of the Board of Directors of the Institute of Noise Control Engineering; senior member of the Institute of Electrical and Electronics Engineers; a member of the Consulting Engineers Council, the American Industrial Hygiene Association, and American Society for Testing and Materials; and served on the Board of Trustees of Stevens Institute of Technology. Lewis also served as editor of the *Journal of the Audio Engineering Society*; *Noise Control*, a publication of the Acoustical Society of America; *Sound and Vibration Magazine Noise Control Engineering*; and the *Noise Control Engineering Journal* of the Institute of Noise Control Engineering.

Lewis authored two books, *Sound in the Theater* and *Acoustics for the Architect*, both with Harold Burris-Meyer.

Europe's Transition to Strategic Noise Mapping under CNOSSOS-EU: Findings from a Data Needs Assessment Report—Noise-Adapt Ireland

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The Noise-Adapt Ireland Project

In accordance with Art. 6.2 of the Environmental Noise Directive (END), the European Commission recently developed Common Noise assessment methods (CNOSSOS-EU) for road, railway, aircraft, and industrial noise, to be used after adoption by member states for the purpose of strategic noise mapping (SNM) as required by Article 7 of the END. The CNOSSOS-EU model will come into effect for the 2022 noise mapping round for all EU nations. The Noise-Adapt Ireland project (see www.noisemapping.ie for more information) aims to identify Ireland's adaptation needs for transitioning to the CNOSSOS-EU standardized noise model and the standardized approach for population-exposure estimation. This article highlights some interesting findings from a data needs assessment report that aimed to identify Ireland's key transitioning needs under CNOSSOS-EU.

Findings from the Report

CNOSSOS-EU introduces five categories of vehicle for road-traffic noise, where formerly there were only two categories, for light and heavy vehicles (CRTN Methodology). The authority responsible for Ireland's national road network is Transport Infrastructure Ireland (TII). This authority's method of classification has limited accuracy in identifying certain classes of vehicle and currently suffers from cross-category overlap between existing TII classification and CNOSSOS-EU classification. If data gaps exist, a default decomposition of heavy vehicles into two categories can be implemented based on the type of road under analysis. Alternatively, if one of the two categories dominates the flow strongly, this category is recommended. However, it is possible that more accurate information may be garnered from regional statistics acquired through traffic counts by regional authorities (e.g., Dublin City Council) or estimated from commercial vehicle registration data collected by the Central Statistics Office (CSO).

Traffic-flow information does not exist for agglomerations outside Dublin City, and average vehicle speeds need to be recorded. In the context of agglomerations, Dublin City Council (DCC) has vehicle-speed monitors in place. The National Roads Authority (NRA) and DCC will need to translate its road categories to spectral α and β coefficient octave bands. Other specific data needs include road-surface gradient, roadside topography, and more detailed spatial information, particularly related to the positioning of traffic lights and stop signs.

In the context of railway noise, Irish Rail will need to gather data on the types of track composing the Irish rail network. It is imperative for practitioners to focus on track base and railhead roughness in the initial stages of CNOSSOS-EU implementation. Data must also be gathered in relation to track-base and sleeper-type as well as brake-type data. In relation to brake-type data, stock category assumptions will have to be made based on vehicle type and vintage and examination of publically accessible photographs (e.g., where brake discs are visible). In the scenario where vehicles have a combination of disc brakes and cast-iron tread brakes, only the latter is recommended for classification. Data sets for elevated structures such as bridges are required. In order to identify elevated structures, data sets may need to be manually generated through field surveys and analysis of aerial photography.

In the context of industrial noise, a database of industrial sites does not currently exist in any agglomeration in Ireland nor in the open countryside, and there has never been any SNM of industrial sites in the Irish context. The first stage of SNM should begin by cataloging all applicable industrial sites within the agglomeration under analysis. CNOSSOS-EU proposes that

each industrial sound source should be measured individually because sources tend to be heterogeneous and emit noise on a relatively continuous basis, so average annual source emission cannot be estimated. In the case where measurement is not achievable, CNOSSOS-EU provides a database of default input values that can be referenced for estimating sound power and source directivity and expected working hours applicable to each source.

In relation to sound propagation, geographic information systems (GIS) are proficient at generating accurate spatial dimensions for buildings along a horizontal plane but not along a vertical plane. In Ireland, precise building-height parameters need to be integrated into future SNM. DCC has a database on all building heights in Dublin City, while applications such as Google Earth have 3-D modelling software that may provide approximate information on building heights on a national basis. Accurate information regarding the position of noise barriers is also required, as even minor inaccuracies in height can result in major discrepancies in noise calculation.

CNOSSOS-EU Limitations

Road Vehicle Propulsion Noise

CNOSSOS-EU applies the same correction coefficient for respective road surfaces to both propulsion and rolling noise. This methodology is problematic because no distinction is made between variation in rolling noise caused by the roughness change associated with the road surface and the variation in rolling noise caused by absorption (Pallas and Dutilleux 2018). It is more relevant to apply a single measure of absorption effect to propulsion noise (Pallas and Dutilleux 2018).

Road Noise Emissions

At the present time, the current calculation of road noise emissions using the 2015/996 Directive is incorrect. This is because the CNOSSOS sound-power coefficients were drawn from the IMAGINE project using the Harmonoise propagation model. The majority of the frequency range (i.e., 63 Hz–8 kHz) predictions by Peeters and van Blokland (2018) calculate that CNOSSOS methodology underestimates noise levels of up to 3 dB due to transference in propagation models. Peeters and van Blokland found that after calculating the sound-emission level using sound-power coefficients presented in the Directive 2015/996 table F-1 and the CNOSSOS propagation model, outputs did not reflect the actual noise emission generated from roadside measurements.

Furthermore, Peeters and van Blokland highlight an inaccuracy in relation to road-surface reflection presented in Directive 2015/996. Directive 2015/996 states, "In this method, each vehicle (category 1, 2, 3, 4 and 5) is represented by one single point source radiating uniformly into the 2-π half space above the ground. The first reflection on the road surface is treated implicitly" (7). The directive assumes a "semi-free field" or "hemispherical" point source, and this assumption does not correspond with the IMAGINE/Harmonoise project. On the other hand, sound-power coefficients have been acquired for a free-field point source radiating into the 4-π space. Hence, "the first reflection on the road surface" (7) is *not* treated implicitly and should therefore not be treated as part of the propagation model. Directive 2015/996 relating to road surface reflection should be disregarded or modified to reflect a free-field (4-π) point source, whereby the first reflection on the road surface should be treated using the propagation model. Peeters and van Blokland modify the current coefficients in the Directive 2015/996 table F-1 (i.e., IMAGINE) to the CNOSSOS propagation model in order to calculate the correct sound-power coefficients for the CNOSSOS methodology.

There is also a discrepancy between the road-traffic emission and the propagation models within the CNOSSOS methodology. As such, the emission model applies a source in a free field, and the propagation model applies a source in a semifree field (i.e., above ground surface) (Salomons and Eisses 2018). This discrepancy can result in an error of 3 dB but may be resolved by a relatively elementary formula of correction (Salomons and Eisses 2018).

Railway Emission Calculation

In implementing the CNOSSOS-EU model in the context of Finland, Kokkonen (2018) expresses concern associated with the fact that railway emission calculation is fundamentally based on railway and wheel roughness. Finland has railway-roughness data for only a single point, and results indicate that there may be up to a 10 dB error when sound power is calculated using the CNOSSOS methodology. Kokkonen emphasizes the lack of guidance in relation to how national measurement of emission values should be considered within the CNOSSOS model, citing the example of absent guidance on how to adjust inaccurate speed correlation.

Aircraft-Noise Modelling

When default aircraft-noise data sets were reviewed, modified, and verified in relation to empirical data, Trow and Allmark (2018) found that noise outputs could vary by +/− 2 dB. More research is required in relation to aircraft-noise modelling, and models should move away from default datasets.

Sound Propagation

CNOSSOS does not provide a ground parameter value, G, for porous asphalt. In their investigation of the CNOSSOS propagation model in the context of the Netherlands, Salomons and Eisses (2018) use a ground parameter value of $G = 0$ for porous asphalt but suggest that $G = 0.5$ is possibly more applicable. Furthermore, in relation to the actual CNOSSOS propagation model, an error exists in how modified heights from equations VI-19 should be applied to VI-20

(Kephalopoulos, Paviotti, and Ledee 2012, 89). Hence, alternative unmodified heights should be used.

In the context of diffraction, the CNOSSOS description of path difference -λ / 20 between the ground model and the diffraction model applicable to flat ground/low barriers and high barriers, respectively, is ambiguous within the CNOSSOS methodology. Screening attenuation in the context of multiple diffraction is also highly problematic. Salomons and Eisses (2018) demonstrate that placing a second noise screen at 500 m from source (with the first screen 1020 m from source) results in a completely unrealistic increase of up to 20 dB in sound at high frequency. This problem derives from the CNOSSOS method of calculating acoustic path length differential under favorable conditions, whereby such an approach does not translate to more than a single diffraction point. Salomons and Eisses propose a solution for multiple diffraction under favorable conditions.

Concluding Remarks

The CNOSSOS-EU process is an ongoing procedure. Findings from the Noise-Adapt Data Needs Assessment Report exclusively refer to Phase A of the CNOSSOS process, with Phase B currently under development. As such, the report reflects this continuous procedure and will be amended appropriately in parallel with future phases required under the CNOSSOS process.

The Noise-Adapt project is being conducted by University College Dublin and Trinity College Dublin and is funded by the Environmental Protection Agency Ireland.

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Vibration Damping—Some Often-Overlooked Facts

By Eric E. Ungar

Abstract

"Damping" refers to loss of mechanical energy from a vibrating system, including dissipation into heat and transport of energy to adjacent structures and fluids. Thus, damping has an appreciable effect on only those mechanical system motions that are dominated by energy loss—for example, at resonances and during buildup or decay of forced vibrations. Viscous damping, with retarding forces proportional to velocity, is generally used for analyses because it leads to simple mathematical treatment; it may provide some guidance, but it represents reality in only a very limited range and may lead to erroneous results outside of that range. Structural damping, with retarding forces proportional to displacement, tends to provide better approximations to reality. Since damping may involve a multitude of mechanisms, it very rarely can be predicted on the basis of first principles and usually must be estimated, resulting in uncertainties in predicted damping-controlled motions.

Primary subject classification: 47.3; secondary subject classification: 47.1

1. Introduction

Although all professionals working in the field of noise and vibration control have an understanding of damping and its effects, it appears that many practitioners—even those with considerable experience—tend to harbor some misconceptions and may overlook some basic concepts. The purpose of the present article is to help remedy this situation. For the sake of simplicity and ease of explanation, I focus on simple models without drawing on the extensive analytical background available in the literature (Ungar and Zapfe 2006; Inman 2007).

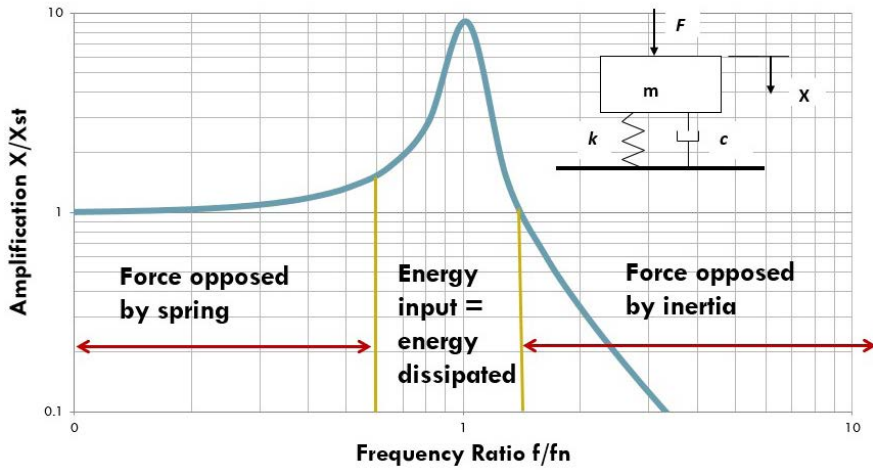

Figure 1. Domains of parameter dominances in steady vibration.

2. Damping and Motions It Affects

"Damping" refers to energy dissipation—that is, to removal of mechanical energy from a vibrating system. In many instances the removed energy is converted to heat (e.g., via mechanical hysteresis in materials or external friction), but damping may also result from transport of energy from the system under consideration to other structural systems or to fluids.

Damping has an appreciable effect only on those aspects of a vibration that are controlled to a significant extent by energy dissipation. Consider, for example, the steady-state response of a sinusoidally excited simple mass-spring-dashpot system, as shown in the inset of figure 1. If the excitation is well below the system's natural frequency, f_n, then the applied force is opposed in essence only by the spring, and if the excitation is well above the natural frequency, the applied force is opposed essentially only by the mass. If the applied force acts in a limited range near the natural frequency, then the spring and the inertia forces in effect cancel out each other, and the response is controlled by the system's energy dissipation capability.

In addition to controlling a system's steady-state response at resonance, damping also controls the buildup of this response—that is, the rate at which the limiting value of this response is reached after an external force is applied. Similarly, damping controls the rate of decay of vibrations after an external force has ceased to act. Furthermore, damping controls not only vibrations produced by applied time-dependent forces but also so-called self-excited vibrations that are produced by steady forces interacting with system motions (e.g., friction-induced stick-slip vibrations of vehicle clutches and brakes and vibrations induced by fluid flows).

Damping also governs the decay of waves propagating freely along structures or in fluids. Moreover, it plays a dominant role in the response of platelike structures to

incident sound and in the transmission of sound through walls—but only at frequencies above the coincidence frequency (the frequency at which the wavelength of free structural motions matches the wavelength in the ambient fluid) (Cremer and Heckl 1988, 247).

3. The Viscous Damping Model and Vibration Decay

Damping in a dynamic system classically has been modeled in terms of an element that provides a retarding force proportional to velocity, often diagramed as a dashpot (see inset, fig. 1). Such damping rarely corresponds to reality, but this model has come into wide use because it leads to equations that can be solved easily and because it yields some results that reasonably represent certain features of a system's dynamic behavior.

The ratio c of retarding force to velocity is called the viscous damping coefficient. For viscous damping elements included in mass-spring-dashpot systems, such as that indicated in figure 2, it generally is convenient to work with the damping ratio ζ, defined as $\zeta = c/c_c$. The parameter c_c is called the critical damping coefficient and is given by $c_c = 2\sqrt{(km)}$ in terms of the spring stiffness k and the mass m.

As is known from classical analytical results, if the mass is deflected from its equilibrium position and released, it will vibrate with decreasing amplitude, as sketched in figure 2—provided that the viscous damping coefficient is not too large. If this coefficient is large enough, the deflected mass will drift toward its equilibrium position without oscillation. The critical damping coefficient cited above marks the dividing line between the two regimes; it is the smallest value of this coefficient for which oscillations do not occur.

A. Information from Vibration Decay Data

One may determine the value of the damping ratio, ζ, from a measured trace like that of figure 2 by considering the natural frequency, ω, of the system and making use of values obtained from the envelope of the oscillations. However, a plot of the logarithm of the (rectified) data versus time on a linear scale, as shown in figure 3, has advantages over a plot like figure 2. Not only does a logarithmic plot permit one to easily determine the damping ratio from the slope of the envelope, but observing the extent to which the envelope deviates from a straight line also enables one to determine how well the measured data corresponds to a simple viscously damped system. For example, if two damping mechanisms or modes are present, one may expect to obtain an initial decay with a steep envelope until the more effective mechanism's action has been attenuated, followed by decay with a less steep slope associated with the less effective mechanism.

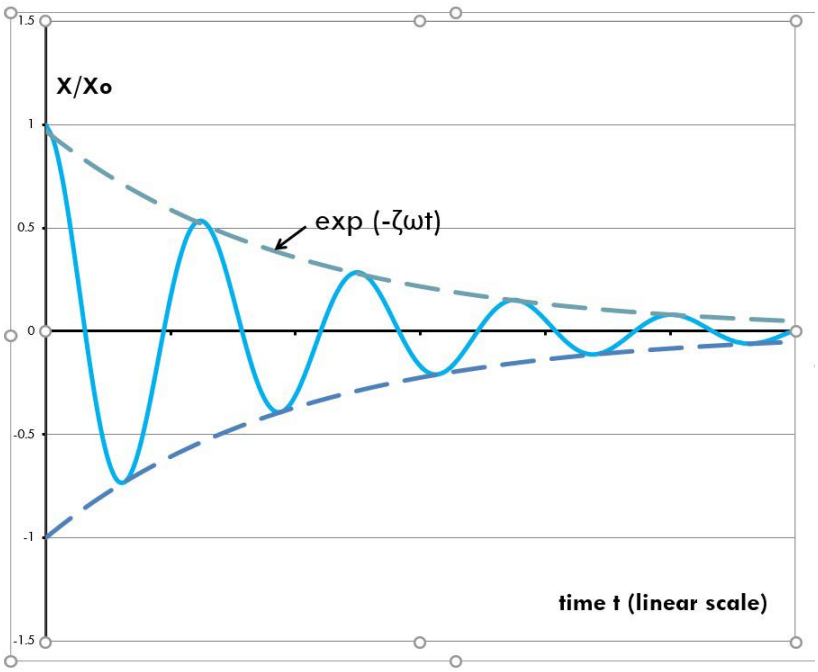

Figure 2. Vibration amplitude decay in system with viscous damping.

B. Decay of Vibrations Produced by Local Impacts

A commonly used approach for determination of the damping of the floor in a given area of a building consists of applying an impact to the floor in the area of interest and measuring the resulting decaying vibrations at a nearby point on the floor. (The impact often is applied by means of a "heel drop," where a person stands on his or her toes and then lets the heels drop onto the floor.) Here and in other situations where damping is measured by observing the vibrations resulting from a local impact, the decay of the vibrations is due not only to energy dissipation in the local structure but also to energy propagation away from the measurement point, with the situation corresponding to that described above with two damping mechanisms present.

The damping that is determined from the early part of the decay curve, which often is considered as representative of the damping of the structure, may be expected to be due to both local dissipation and energy transport. Its use in practice may be fully appropriate if it represents the situation of interest—for example, in relation to evaluating the vibrations expected to be induced by a vibration source to be installed at the measurement location. However, damping evaluated from the early part of the decay

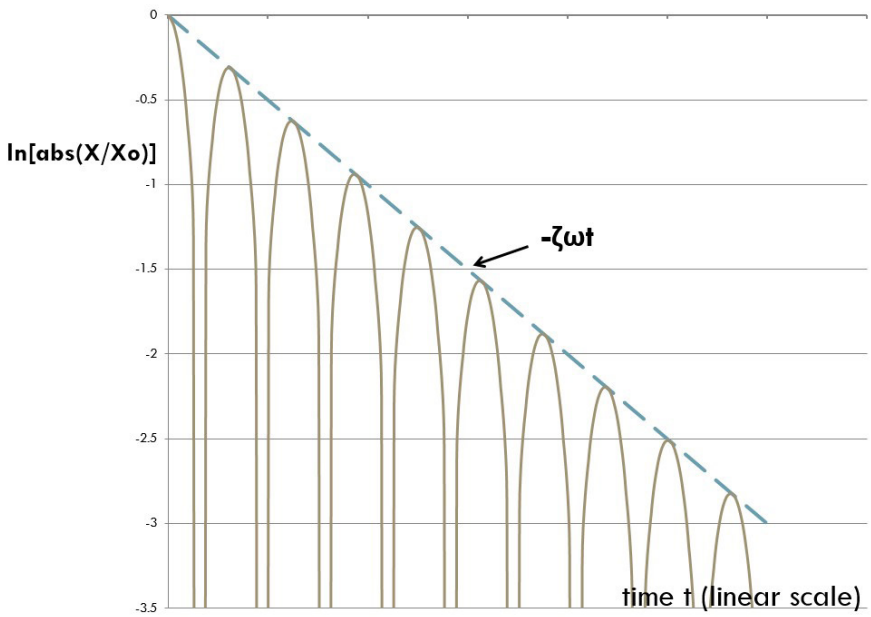

Figure 3. Decay of logarithm of amplitude in system with viscous damping.

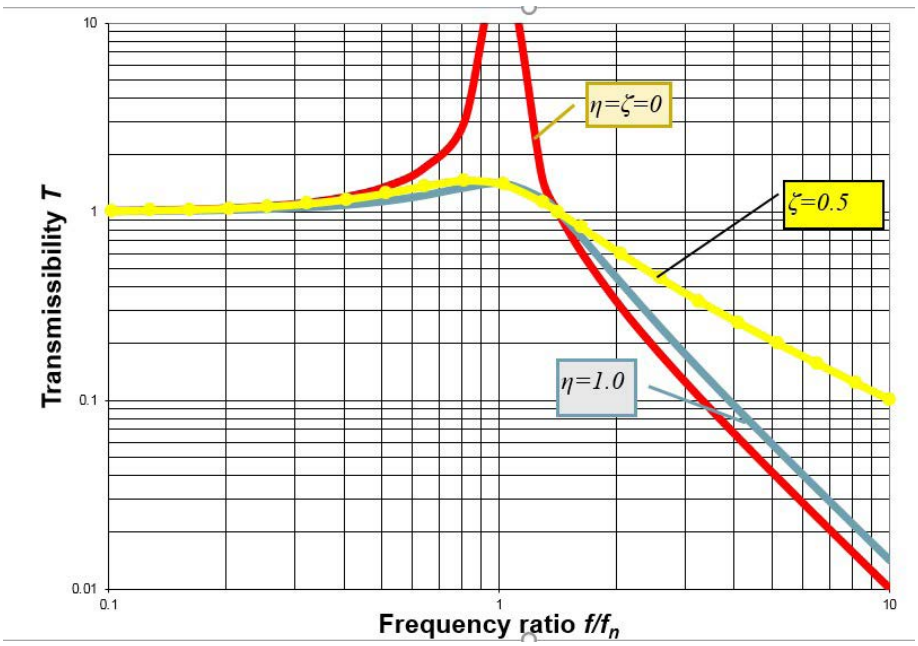

Figure 4. Comparison of viscous and structural damping effects on transmissibility.

curve would overestimate the structural damping; the damping magnitude deduced from the later part of the decay curve (obtained after most of the energy transport has occurred) is likely to better correspond to the structural damping.

4. Structural Damping—A Better Model

Because energy-loss considerations are of primary interest, it makes sense to characterize damping in terms of energy quantities. Perhaps the most widely used parameter used for such characterization is the loss factor η, defined for a steady vibration as the ratio of the energy dissipated per radian (or per cycle, divided by 2π) to the peak energy stored in the system under consideration. These quantities can be obtained as a function of frequency, amplitude, and temperature by direct measurements (Ungar and Zapfe 2006). Measured loss factor data for a wide variety of materials are available in the literature.

Whereas the viscous damping force is proportional to velocity, the "structural" damping force corresponding to a constant loss factor is proportional to displacement. It has been found that in many realistic cases, the loss factor varies little with frequency in the range of interest, so use of a constant loss factor results in more realistic description of a system response than use of a constant viscous damping coefficient. Figure 4, which is a plot of transmissibility (transmitted force/applied force) for a mass-spring-damper system, illustrates an effect of these two damping characterizations. The loss factor value (1.0) for the blue curve has been chosen so that the curve's peak value is the same as that for the yellow curve, which pertains to the viscous damping coefficient of 0.5. Whereas the usually cited viscous damping model implies that greater damping increases the transmissibility at high frequencies (and thus reduces the effectiveness of an isolation system), the more realistic constant loss factor model implies that even a large amount of structural damping increases the high-frequency transmissibility only slightly above that obtained with zero damping.

5. Damping Mechanisms and Estimation

Damping—loss of energy from a structural vibration—may occur via many different mechanisms. These include hysteretic processes in materials due to molecular and granular interactions or electrodynamic effects, as well as propagation of vibrations and sound to neighboring structures and ambient fluids. They also include friction between solids (including at structural connections and other interfaces) and viscous interactions with fluids.

It is important to note that all commonly used damping models, including viscous

damping and structural damping (which is based on the cyclic energy loss), can provide realistic information concerning only the motion differences from one cycle to a subsequent cycle (or cycles) but cannot characterize the motions *within* cycles. For determination of details of the motions within cycles, such as those needed to characterize stick-slip processes, one requires complete and realistic descriptions of the involved physical mechanisms.

The multitude of mechanisms makes it generally impossible to predict the damping in practical structures on the basis of first principles. Only in cases where one damping mechanism is expected to dominate and that mechanism is amenable to analysis (e.g., where a viscoelastic coating is applied to a plate) can one expect to arrive at an approximate prediction.

In most realistic situations, the practitioner must estimate the expected damping, usually relying on experience, and thus is in the somewhat illogical position of predicting a structural response that is controlled by the structure's damping on the basis of an estimated damping magnitude.

6. Concluding Remarks

One should keep in mind that damping is a measure of loss of mechanical energy and thus only has significant effects on motions dominated by energy dissipation.

Viscous damping, in which the retarding force is proportional to velocity, is the most often used damping model because it facilitates calculation. However, in many situations structural damping, in which the retarding force is proportional to displacement, gives more realistic results.

Data obtained from vibration decay measurements need to be evaluated carefully to account for the possible contributions from several modes and damping mechanisms.

Since damping in general results from the simultaneous action of several mechanisms, it generally cannot be modeled on the basis of first principles or quantified accurately. In practice its magnitudes are estimated on the basis of experience, thus injecting uncertainties into predictions of dissipation-controlled motions.

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Pan-American News

S. A. Hambric

Canada

The 176th Meeting of the Acoustical Society of America (ASA) will be held jointly with the 2018 Acoustics Week in Canada meeting of the Canadian Acoustical Association in Victoria, BC, in November 2018. Also in Canada, the 26th International Congress on Sound and Vibration (ICSV26), the annual congress of the International Institute of Acoustics and Vibration (IIAV), will be held in Montreal in July 2019, with the support of the Canadian Acoustical Association.

Two new local chapters of the Canadian Acoustical Associate are being created: one in Toronto, Ontario, which has already held its first meeting, and another one forming in Montreal, Quebec. See more information at caa-aca.ca.

Chile

In April 2017 SOCHA (the Chilean Society of Acoustics; see www.socha.cl), cooperated with the Ministry of Environment of Chile to organize the XVI SEMINARIO DE RUIDO AMBIENTAL DEL MINISTERIO DEL MEDIO AMBIENTE (Seminar on Acoustic Pollution and Environmental Noise Control). More information on this meeting is available here.

USA

In August 2018, the American Society of Mechanical Engineers (ASME) Noise Control and Acoustics Division (NCAD) participated in the INTER-NOISE conference in Chicago, Illinois. In November, it will also be participating in the International Mechanical Engineering Congress and Exposition (IMECE) conference in Pittsburgh, Pennsylvania, by organizing the technical track for Acoustics, Vibration, and Phononics. There will be a total of 13 technical topics along with a congress-wide symposium on NDE (nondestructive) and SHM (structural health monitoring) topics.

At INTER-NOISE 2018, NCAD continued its tradition of honoring a distinguished researcher in the area of noise control and acoustics with the prestigious Rayleigh Lecture, given by Prof. Roger Ohayon, CNAM Structural Mechanics and Coupled Systems Laboratory, France, on computational vibroacoustics in low- and medium-frequency bands. In addition, an NCAD tutorial was held to provide an in-depth examination of a topic of interest to NCAD members. This year's tutorial was given by NCAD group leadership team member Dr. Zheng of Kansas University on the topic of time-domain simulation of multiphysics sound propagation in complex media and environment.

Malcolm Crocker, professor emeritus of mechanical engineering, has been awarded the 2017 Per Bruel Gold Medal for Noise Control and Acoustics from ASME. Crocker was selected to receive the medal "for promoting international collaboration, education and the dissemination of knowledge in noise control and acoustics through the formation of professional organizations, the establishment of journals and congress series and the creation of reference volumes for practitioners."

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Conference Calendar

Below is a list of congresses and conferences sponsored by International INCE and INCE-USA. A list of all known conferences related to noise can be found by going to the International INCE website on the Internet (www.i-ince.org).

June 16–19, 2019
INTER-NOISE 2019
2019 International Congress on Noise Control
Madrid, Spain
http://internoise2019.org/

August 25–28, 2019
NOISE-CON 2019
San Diego, CA, USA
http://inceusa.org

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Information on listings in the Directory of Noise Control Services is available from the INCE-USA Business Office, 11130 Sunrise Valley Dr., Suite 350, Reston, VA 20191-4371 Telephone: +1.703.437.4073 e-mail: ibo@inceusa.org.

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Noise Control in Buildings, by Cyril M. Harris