NOISE/NEWS INTERNATIONAL

Volume 30, Number 1
2022 March

A quarterly news magazine and online digital blog published by I-INCE and INCE-USA

- The Sound of a Motorcycle... Three Points of View
- Noise as a Business Model
- How Can Type Approval Help to Control Motorcycle Noise
- Remote Sensing for Acoustic Vehicle Classification

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Volume 30, Number 1 **2022 March**

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NOISE/NEWS INTERNATIONAL

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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 blog. I-INCE has an active program of technical initiatives. It currently has fifty-one member societies in forty-six countries.

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The Institute of Noise Control Engineering of the USA (INCE-USA) is a nonprofit professional organization incorporated in Washington, DC, 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 blog. 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*.

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Welcome to the March 2022 issue of Noise/News International, a special issue of NNI devoted to Motorcycle Noise.

Eoin A. King Ph.D.

The issue of motorcycle noise has been a growing concern over the last few years. In 2020 the German *Bundesrat* adopted far reaching proposals to limit the sound emission of motorcycles. Ultimately the federal government opposed their proposals, but in recent months there has been renewed international focus on motorcycle noise. In New York City, motorcycles frequently place in the top 10 most bothersome noise sources identified by residents. In Vietnam, motor bikes with frequent horn sounds are the most frequent road traffic noise source. And a recent cross-sectional study in the Alps indicated that for the same L_{Aeq} level, motorcycle noise is more annoying than the other sources of road traffic noise.

In this issue we hear from several experts around the world considering the issue of motorcycle noise. To name but a few, these include César Asensio (Universidad Politecnica de Madrid), who asks if it is time for Spain to revise its motorcycle noise measurement protocols, Simon Shilton (Acustica) updates us on a European Commission study investigating the potential for new sound limits for L-category vehicles, Gijsjan van Blokland (I-INCE) considers how type approval might help to control motorcycle noise, while Deane Jaeger (Intrikit Services) and Alex Bub (OHV Acoustics) consider three different points of view of motorcycle noise.

I hope you enjoy this special issue, and if you have any ideas for future special issues, please feel free to get in touch.

Do you have a good noise control solution that you would like to publish?

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- These are articles providing a reference for practicing noise control engineers.
- They do not reference cutting edge technology but provide documentation of noise control solutions
- The demonstrate expertise in the solution of noise control issues and the use of measurement and modeling techniques
- Since their introduction in 2018, we have received roughly one hundred of these case studies

NCEJ

For more information: https://www.inceusa.org/publications/noise-control-engineering-journal/

NOISE/NOTES

Eoin A. King, NNI Editor

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 to stay up to date with all noise related news.

Taking Aim at 'Noise from Hell'

The New York Times reports on the activities of some French authorities, who are installing "sound radars" in seven cities in France to detect and identify vehicles making excessive noise. The initiative follows a mounting intolerance by the French to street noises, particularly motorcycles and souped-up scooters – a modified scooter crossing Paris at night can wake as many as 10,000 people.

Motorcycling is a very sensual thing

The Guardian in the UK recently reported on the advent of electric vehicles, and how they will eventually extend to motorcycles. The article considers the views from a number of enthusiasts and stakeholders and discussed how many people may be a reluctant to adopt an electric motorbike.

Noise as a Public Health Hazard

Quiet Communities is a nonprofit organization that is dedicated to helping communities reduce health and environmental harm from noise and pollution. It operates through five programs: Quiet American Skies, Quiet Outdoors, Quiet Coalition, Quiet Healthcare, and Quiet Conversation. The new policy statement from Quiet Communities was recently adopted by the American Public Health Association (APHA). The policy calls for national noise standards, enforcement, education, outreach, and action on noise as a public health hazard – which is long overdue in the U.S. APHA champions the health of all people and all communities, and highlights public health issues and policies backed by science.

New UNEP Frontiers Report considers noise and soundscapes

The 2022 United Nations Environment Program (UNEP) Frontiers Report identifies noise as an emerging issue of environmental concern. It recognizes two major shortcomings in the current approach to addressing noise pollution that need to be addressed: the inherent limitation of using a reactive approach to noise control, and thinking of sound only in terms of discomfort. The report notes that there needs to be an extension of the scope of policymaking, shifting from only managing noise pollution to considering environmental sounds as opportunities for promoting healthy living environments for all age, gender and social groups.

Call for Nominations: 2023 Safe-in-Sound Awards

Is your company or one you know passionate about noise control? If your company makes extra efforts to prevent hearing loss, they might be eligible for the Safe-in-Sound Award. Established by NIOSH in 2008 and now co-sponsored by the National Hearing Conservation Association (NHCA) and the Council on Accreditation of Hearing Conservationists (CAOHC), awards are given each year to companies and individuals who have demonstrated excellence or innovation in hearing loss prevention.

If a company you know has that passion and has made such contributions, you can nominate them by June 8, 2022. You can nominate yourself by July 15, 2022. Information about how to apply is on the web at www.safeinsound.us. The website also has useful tips on how to submit a strong application. Join the small group of award winners who have achieved new heights in hearing loss prevention.

Estimating the harmful effects of environmental transport noise

Researchers in UCD (Ireland), recently performed a study to quantify environmental noise-induced harmful effects in Ireland. Annex III of the Environmental Noise Directive (END) describes how harmful effects from environmental noise may be calculated for ischemic heart disease (IHD), high annoyance (HA), and high sleep disturbance (HSD) for road, rail, and aircraft noise for EU Member States (MS). This method was used for this study, and results outline the scale of harmful effects from environmental noise from transport in Ireland.

The Sound of a Motorcycle... Three Points of View

Deane Jaeger, Principal - Intrikit Services LLC, retired Harley-Davidson
Alex Bub, Owner - OHV Acoustics LLC, retired Harley-Davidson

There are few other sources of sound that generate as far reaching an emotional impact as the sound of a motorcycle. The sound of a motorcycle is shaped by many influencing factors and to be a successful product it has to meet the requirements of three distinct and often conflicting perspectives. Motorcycles have to meet government noise regulations that specify the maximum amount of sound that can be generated under certain conditions; the user requires their motorcycle to generate a certain emotional and visceral response and finally the manufacture has to design a product that balances all of these often-conflicting requirements in an economically viable product.

The goal is to meet all local, state, and federal sound regulations as they relate to motorcycles, offer the consumer a stimulating and exciting product and be economically viable to the manufacturer. This includes motorcycles classified as road legal vehicles and those classified as off-highway vehicles (OHV). This is a delicate balance the acoustical engineer strives to achieve.

The Sound of a Motorcycle from a Regulatory Point of View

Original equipment motorcycle manufacturers (OEM) must comply with not to exceed maximum noise levels usually measured in dbA at the time of sale. In addition, in-use noise requirements have been established by various communities to limit the noise impact on community residents. The test procedures used to comply with legislative noise requirements vary by location and consist of testing the motorcycle in motion, referred to as a pass-by test, or with the motorcycle at rest, referred to as a stationary test, or both. Each location usually specifies not only the allowable noise level but the manner in which the vehicle is to be tested. For instance, a pass-by noise test requirement might specify the surface the motorcycle must drive on, the distance the microphone is from the centerline of travel, the vehicle speed, engine RPM, the transmission gear at which the vehicle must enter the test zone and the throttle condition or acceleration rate the vehicle must experience during the testing process. Also, the normal environmental

Motorcycle Pass By test

conditions to ensure an accurate and representative noise test must be followed. Pass-by noise testing can be a costly undertaking. In addition to the cost of sophisticated instrumentation, a test track has to include a large tract of land with acceptable ambient noise levels and the driving surface must be designed to have specific acoustic absorption characteristics. The weather at the test site is a major factor and may limit the testing window. To counter these drawbacks, several manufacturers have developed in-door pass-by testing chambers costing millions of dollars with excellent correlation to outdoor testing results.

A stationary noise test also has its own set of specific operating conditions. The position of the microphone relative to the motorcycle exhaust and the engine speed (RPM) are two important parameters to be followed. Community noise ordinances set to limit the amount of sound produced by a motorcycle rely on stationary noise tests as a simple yet accurate way to control in-use motorcycle noise levels. A stationary noise test is designed to measure exhaust dominate sound because of the placement of the microphone. The location of

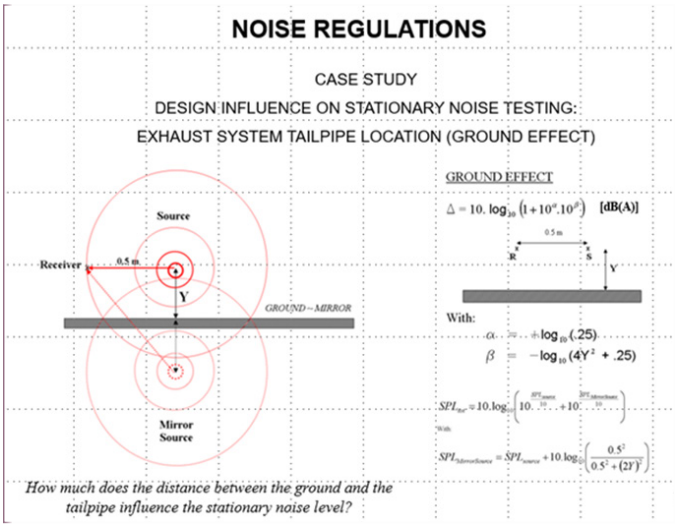

Figure 1

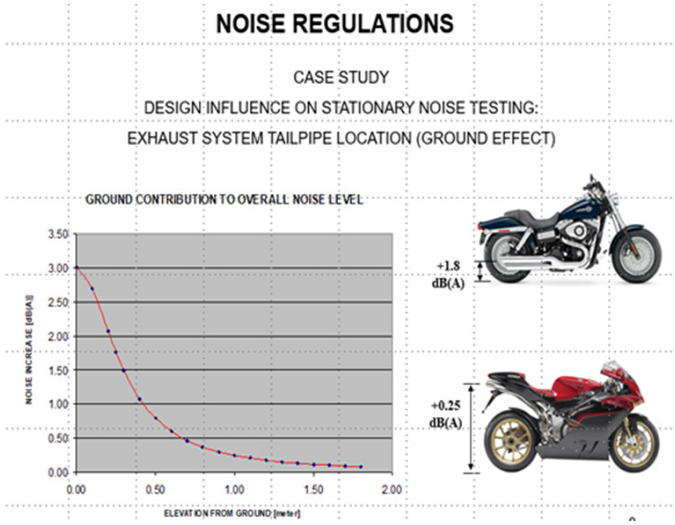

Figure 2

the exhaust outlet relative to the ground (a reflective plane) can have a significant influence on test results. Figures 1 and 2 show the theoretical and actual influence of this reflective plane on exhaust sound levels for different style exhaust systems.

Street legal motorcycles may exceed allowable noise levels due to tampering of the vehicle's original intake or exhaust systems. Changing exhaust and intake components are the usual culprits in raising a vehicle's sound level. Some locations have yearly vehicle inspections to identify noise increasing modifications. Other locations may have roadside inspections that can be effective in identifying tampered exhaust systems. However, this has generated complaints from riders as some aftermarket systems are equivalent to original design and may be noise compliant. These compliant systems should be stamped with the appropriate certification marks, and the examining official needs to look for them before issuing a citation.

The noise level of a motorcycle in use can be significantly influenced by operator behavior. Aggressive riding habits could generate excessive noise from speeding on public highways or revving the engine beyond normal RPM ranges. Police monitoring to identify riders who exceed posted speed limits, rider education such as rider training, TV advertising, radar signs that have vehicle speed reading capabilities etc., all help to alleviate this issue.

The old saying "Less Sound means More Ground", a popular off-road statement, also applies to street riding. Maintaining reasonable sound emission will reduce complaints of motorcycle usage to a minimum.

Motorcycles designed as OHVs pose an additional challenge to manufacturers, local governments, and riders. "Not in my backyard" is a frequent comment when a community learns of a proposed OHV recreation area. This can be related to issues such as noise, zoning, perceived property value impacts, dust, vehicle traffic, lack of parking, and associated activities such as, unlawful camping, partying late into the evening, and playing loud music.

Another issue centers around vague local and state noise regulations. Local regulations are many times lacking in detail or use a general "nuisance" concept to control noise. It is not unusual for a test procedure to lack measurement detail (Linear, Leq, L50 or L90, A weighting etc.), the type of sound level meter to use or even the calibration requirements. Careful research into what the test requirements are is required.

Many local nuisance noise regulations are somewhat subjective and do not use an industry recognized test procedure. In such case, using the **Federal Housing and Urban Development 24 CRF Part 51 Regulation for High Density Residential Areas** may be useful.

The Sound of a Motorcycle from the Riders Point of View

The motorcyclist wants to establish an emotional connection with their motorcycle. Each motorcycle has its own distinctive characteristics that attract the rider. It may be the visuals or the performance but for some motorcyclists it is the sound quality that creates the emotional attraction. What might be music to the ears of one can be an unnerving source of irritation to another. The same is true with motorcycles. The distinctive sound of a Ducati 999 or BMW R90 is measurably different from the rumble of a Harley Davidson cruiser or the whisper of a Honda Goldwing. When designing the motorcycle to meet the sound quality expectations of the rider there are certain

guidelines that should be considered. One must identify and quantify the sounds that the rider likes and dislikes. There are positively perceived motorcycle sounds and there are negatively perceived motorcycle sounds from the user's point of view. The negative sounds include driveline sources such as ticks, knocks, whines, clatter, and rattle. Undesirable chassis sounds include the list of BSR (buzz, squeak, and rattle) offenders. In addition, cooling fans, fuel and water pumps, relays, tire noise and excessive intake honk along with ear shattering exhaust noise need to be addressed.

Desirable sound quality items include smooth consistent mechanical noise without sharp resonances and progressively increasing ICE (intake, combustion, exhaust) sound during vehicle acceleration. Some riders expect a dominant exhaust note or a syncopated idle sound (potato, potato, potato). This sound quality has to be balanced to meet regulatory requirements while emphasizing the sounds riders like and minimizing those that are disliked. Although regulatory noise compliance dictates the upper sound level limits, the character defining the sound needs to be determined and development actions taken to ensure they are achieved. Sounds need to be purposeful and indicative of quality. Figure 3 is an example of an exhaust sound that meets the sound quality expectations of one class of riders. Certain manufacturers have developed their own sound quality metrics based on customer jury testing as a guide to developing model specific sound quality packages. One manufacturer applied to trademark their sound with the US Patent and Trademark Office.

Electric motorcycles (EVs) are not immune from sound quality issues and present a unique sound quality challenge. Because there is a lack of combustion (intake and exhaust) the sound of the driveline becomes the dominant noise source. Tonal frequencies should be adequately spaced to minimize dissonance. Whines and resonances should be understood and controlled to keep from becoming annoying or excessive. The effect on sound quality should be considered during every phase of development including items such as the drive line belt tension. Also, the rider should experience audible feedback when the vehicle is energized, and locomotive power is available.

The Sound of a Motorcycle from a Manufacturer's Point of View

The job of a motorcycle designer is to take the competing requirements and expectations from regulatory, the rider, society and manufacturing and develop a product that satisfies all. The packaging constraints, manufacturing complexity and economics of meeting these requirements can be staggering and not always successful. The delicate balance among all of the stakeholders is many times thwarted by the end user installing aftermarket equipment that skews this balance with the moto "Loud Pipes Save Lives"

The motorcycle exhaust system is a critical component in defining the performance, styling, and sound quality of the motorcycle. Packaging constraints, weight, styling, and cost are all considerations that are assessed in exhaust system design. Some of the design challenges are regulatory requirements, tonal quality, engine tuning, emission control, cosmetic finish and structural durability all wrapped around cost.

There are various predictive tools that can be used to optimize the performance of an exhaust system for both sound and engine performance. Some of the typical silencing approaches

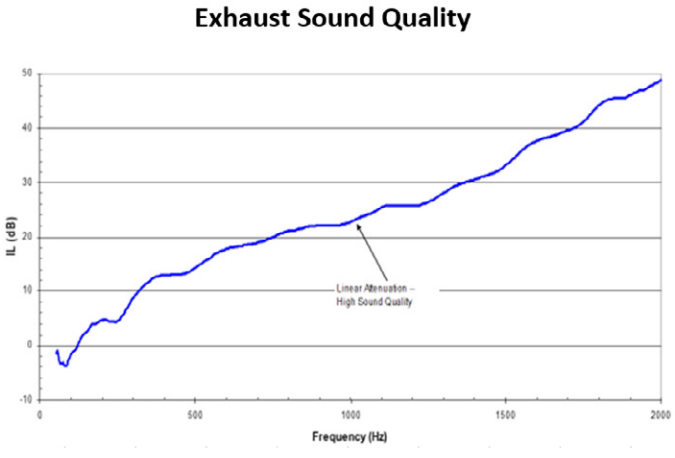

Figure 3

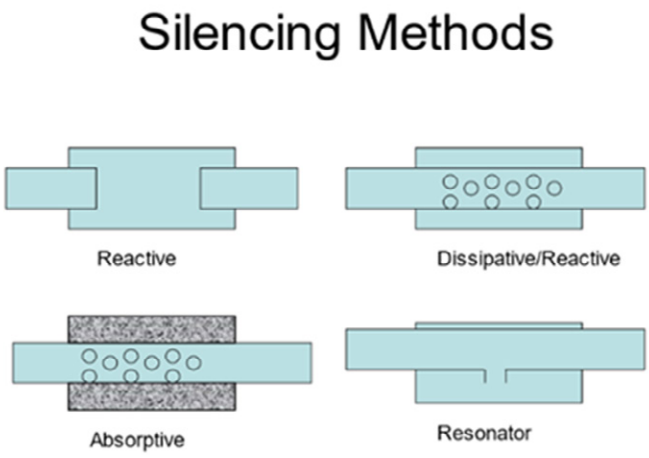

Figure 4

are listed in Figure 4 and each one comes with its pros and cons. A basic muffler design may include a perforated tube and plug whereas a more complex design could include all four acoustic elements along with tail pipe emission control technology as shown in Figure 5.

There is a multifactor relationship among engine performance, exhaust system volume and sound level. As the size of the exhaust system increases, the relative engine performance increases and the overall sound level decreases and conversely. Figure 6 shows the empirical relationship between engine performance and exhaust volume for a noise legal system. Noise legal high-performance motorcycles may have a minimum of 10:1 ratio of exhaust to engine volume whereas a cruiser style motorcycle would be much less. Aftermarket exhaust systems that forego this relationship are typically non-compliant. An exhaust system with good sound quality exhibits a linear insertion loss across a frequency band. There is a consistent increase in sound level with engine RPM and there are no significant resonances. The intake system of a motorcycle also requires a significant amount of design expertise to achieve similar operational goals. Contrary to exhaust sound, the sound of an intake is usally not desireable and subtracts from the overall sound quality of the vehicle. Using predictive tools to optimize airflow and acoustical insertion loss intake noise can be designed out of the sound quality recipe. Similar to the exhaust system the volume of an intake system does have a direct influence on vehicle performance and sound level. Figure 7 is a graph of intake volume and engine displacement.

The sound of a motorcycle can conjure up delight to the user and concern to the bystander. Balancing the often conflicting requirements of regulatory, the consumer and manufacting is a dance of compromise.

Acknowledgements:

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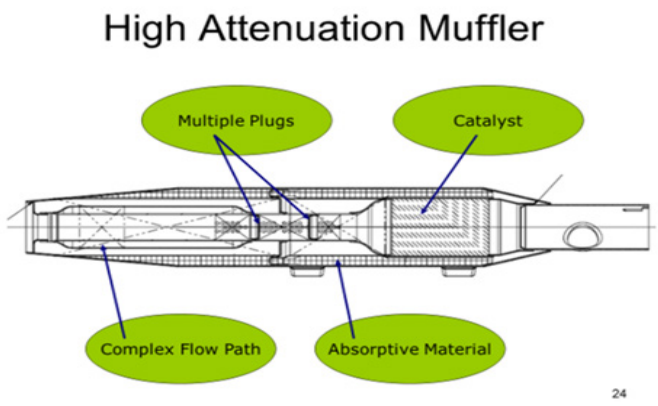

Figure 5

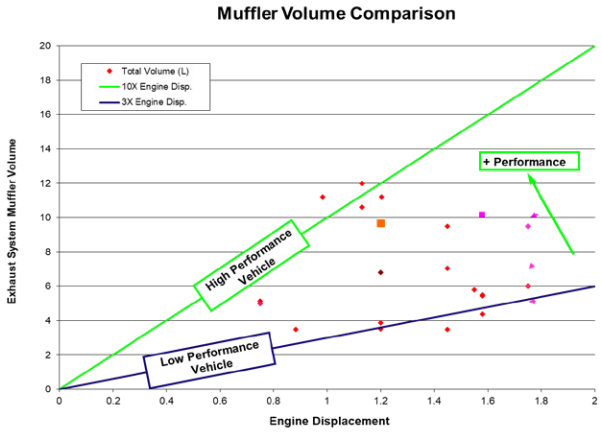

Figure 6

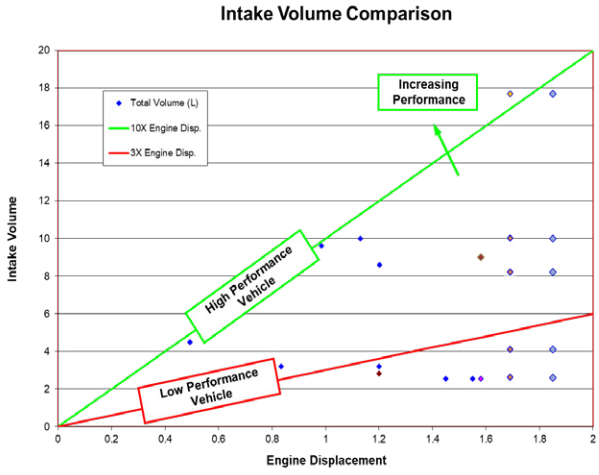

Figure 7

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The 52nd International Congress and Exposition on Noise Control Engineering

Shinichi Sakamoto, Congress President of Inter-Noise 2023

On behalf of the organizing committee, it is our great pleasure to invite you to the 52nd International Congress and Exposition on Noise Control Engineering held in Chiba, Greater Tokyo, Japan, on 20–23 August 2023 (**Inter-Noise 2023**).

Japan has organized the Inter-Noise congress three occasions in the past: Sendai in 1975, Yokohama in 1994, and recently Osaka in 2011. Each congress was a great success. Inter-Noise 2023 will be even better, and the organizing committee welcomes to all our colleagues.

Getting to Japan from anywhere in the world is easy, thanks to the many international flights to Tokyo's two international airports, Haneda and Narita. Chiba boasts being "Japan's No.1" in terms of global access provided by these two international airports. They are respectively ranked first and second Japanese airports in terms of the number of passengers. It takes 30 to 40 minutes by the express buses from these two international airports to Makuhari, Chiba where is congress venue.

In Greater Tokyo area, public transportation such as railway is well developed, and several railway lines are operating directly between Makuhari and central Tokyo with travel time within 30 minutes. You can find the beloved attractions of Tokyo at your fingertips. More information about Chiba is available at http://japan-chiba-guide.com/en/index.html.

Inter-Noise 2023 is expected to be live/in-person congress at this moment. This congress will offer the best opportunities to learn about and share the cutting-edge research with colleagues from all over the world. We believe this congress will be an invaluable experience for all participants and a great opportunity to create friendships and new memories with Inter-Noise family. We look forward to seeing you in Chiba, Greater Tokyo.

Expert Review and Reassessment of the Cost Benefit Analysis Study on Euro 5 Sound Level Limits of L-Category Vehicles

Simon Shilton, Acustica

In 2016/2017, in the context of the revision of the EU type approval framework for L-category vehicles, the European Commission mandated a consortium of experts (Emisia, HSDAC, TNO, and Ricardo) to carry out a study investigating the potential for new sound limits for L-category vehicles at Euro 5 step, including a justified proposal with a Cost-Benefit Analysis of new sound limits options.

The Impact Assessment Institute (www.impactassessmentinstitute.org) and Acustica (www.acustica.co.uk) were commissioned by the European Association of Motorcycle Manufacturers (ACEM) (https://www.acem.eu/), to conduct an independent expert review and reassessment of the 2017 cost benefit analysis (CBA) study published by the European Commission.

In order to support the work of the IAI and Acustica, ACEM also mandated Graz University of Technology (www.fvt.at) to carry out an experimental study on the actual status of noise emitted from eight powered-two wheelers. This study assessed the major noise sources according to their contribution to the overall level of pass-by noise for these vehicles (i.e. intake noise, engine noise, exhaust noise and overall noise) and was carried out by conducting measurements according to the standardized pass-by noise measurement procedure as regulated by UNECE-R 41.04.

The reassessment followed the logic of the 2017 CBA's methodology flowcharts, which calculated benefits from the average sound pressure level reductions alongside each road type for day, evening and night. This is considered a legitimate and rational methodology for assessing the amenity and health benefits, or costs, of changes in noise exposure. Each element of the methodology was then reassessed, identifying potential alternative calculations and their impact on the benefits and costs.

Key findings

By reviewing the assumptions, data and calculations, the reassessment generated alternative benefits, costs and therefore benefit/cost (B/C) ratios for a 2 dB reduction in the noise limits of L-category vehicles and 25% illegal exhausts.

The reassessment study results rely on the veracity of the following assumptions and simplifications, detailed in the text of this report:

- The impact of fractional dB changes in sound pressure levels can be interpolated between the whole number dB increments in the dose-response relationships.
- The UK dose-response relationship is currently the most robust available.
- The reconstructed flow rates generated from various sources are representative.
- The compliance costs provided by the OEMs with the most representative profile can be used to generalise costs for the whole analysis.

Overall, the reassessment of benefits and costs leads to a B/C ratio of 0.82 based on the above assumptions, compared to 2.18 in the 2017 CBA. Due to the absence of sufficient relevant data in the appropriate form and level of detail, in particular on flow rates and compliance costs, this result is subject to high uncertainty. It is a best estimate that serves as an orientation for assessment of the impacts, subject to the clearly stated assumptions. The B/C ratio is sensitive to those assumptions. Taking into account all the potential scenarios and delta analysis detailed in the benefit and cost chapters 3 and 5, a range of B/C ratios an order of magnitude higher or lower than the primary estimate above could result. This result emphasises the high level of uncertainty inherent in the benefit/cost calculations.

NSR testing results from TU Graz confirm the challenging technical interventions required to meet a 2 dB limit reduction and qualitatively support the substantial R&D and manufacturing costs underlying the cost estimates. Robust and accurate cost estimates are however difficult to achieve because of the many systems requiring intervention and are different for different L-category vehicle types.

Cost data are insufficient to generate equivalent benefit/cost ratios for a 5 dB limit reduction. NSR results indicate that a 5 dB limit reduction would likely be infeasible for smaller motorcycles and very challenging or potentially infeasible for larger motorcycles.

Results of the reassessment and the experimental noise source ranking are available to download:

IAI and Acustica - CBA study on Euro 5 sound limits for L-category vehicles [PDF]

TUGraz - Experimental Noise Source Ranking [PDF]

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Should Spain Revise Its Motorcycle Noise Measurement Protocols?

César Asensio, Universidad Politecnica de Madrid

In 2006 the Instrumentation and Applied Acoustics research group (I2A2) was part of the acoustics division of the Automobile Research Institute (INSIA) of the Technical University of Madrid (UPM). The regional authorities required our advice regarding the feasibility of performing vehicle noise measurements inside the workshops during the technical inspection of vehicles (ITV). Noise tests basically referred to the procedure described in the ISO 5130 standard, which, at that time, was still in draft form.

A bibliographic search was carried out, where two fundamental references quickly appeared. Firstly, the draft of ISO 5130 (1), which at the draft stage clearly stated the need to carry out the tests outdoors, on a test site that had to meet a series of very demanding requirements. Alternatively, the draft suggested the possibility of measuring indoors, in a semi-anechoic chamber with a cut-off frequency of 100 Hz. Given the measurement protocol, where low-frequency tonal components drive the measurement result, it seemed clear that performing acoustics test inside the inspection workshop could lead to deviations and uncertainties greater than the 2 dB requirements of the regulation's test protocol. In addition, there was a report from the Transportation Research Laboratory (2) where they addressed the same issue, and showed, by means of comparative tests, the problems and deviations that could arise from taking measurements inside workshops, especially in small ones.

However, the regulatory document that covers whole ITV does not specify that the test site must be outdoors, it only specifies that there must be a distance of 3m to any reflective surface, except the ground. This poses serious problems of consistency and comparability.

Since 2007, from time to time, there have been several inspection entities that have requested our collaboration to optimize the space of their workshops, since maintaining distances of 3 meters is an important limitation for their performance. These same entities have an outdoor space reserved for measurements, but on rainy days (for example) they take the measurements indoors, even though they have noticed that the results are several decibels higher inside the workshop. But the protocol in Spain allows them to do so. They do not even consider the possibility of dispersion due to diffraction or eigenmodes (not their business). They merely apply the protocols at their convenience, without taking into account the technical quality of the measurements.

This has opened up a new business opportunity for some acoustic consultants who offer secret correction factors, drawn up by means of secret protocols that maintain the deviations of the workshop, for all types of motorcycles, within a deviation of less than 2 dB with respect to the optimal conditions (ISO 5130).

On the occasion of this special issue of Noise News International, I have been able to verify that after such a long time period the situation remains the same. The latest protocol (3), from 2020, still does not expressly mention that the tests must be performed in an open space. There are no studies to prove the validity of these huge deviations from the standard. Where are the rights of motorcycle owners? What is the point of these tests if they are not carried out rigorously?

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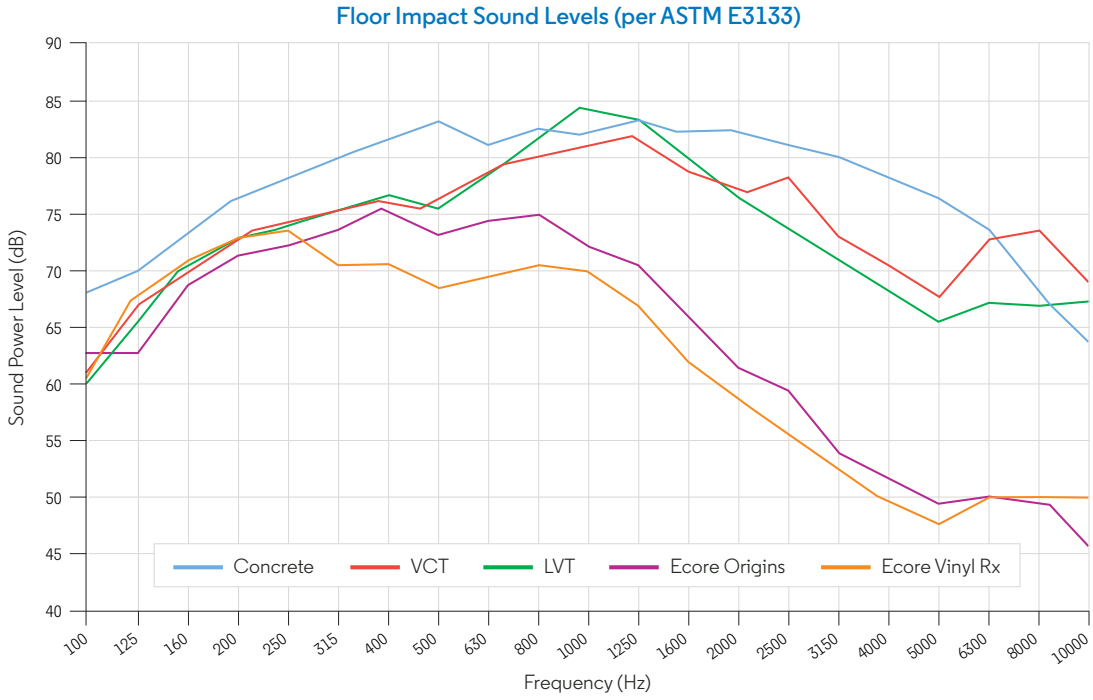

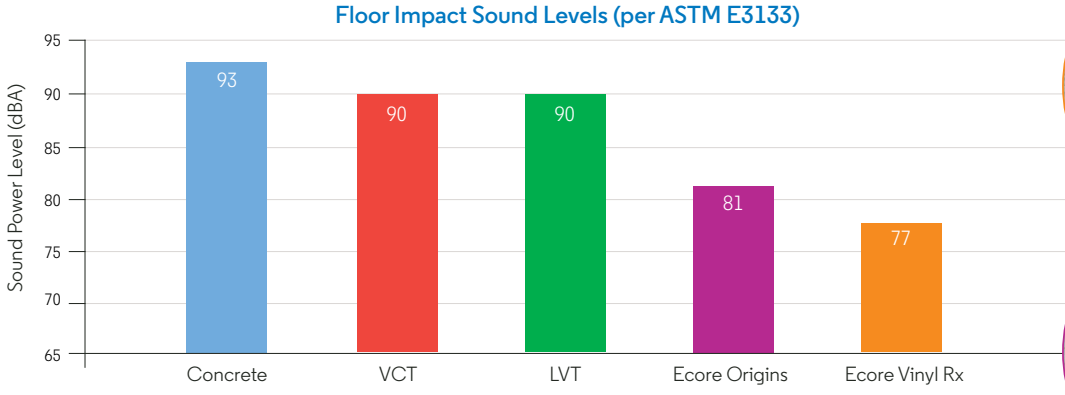

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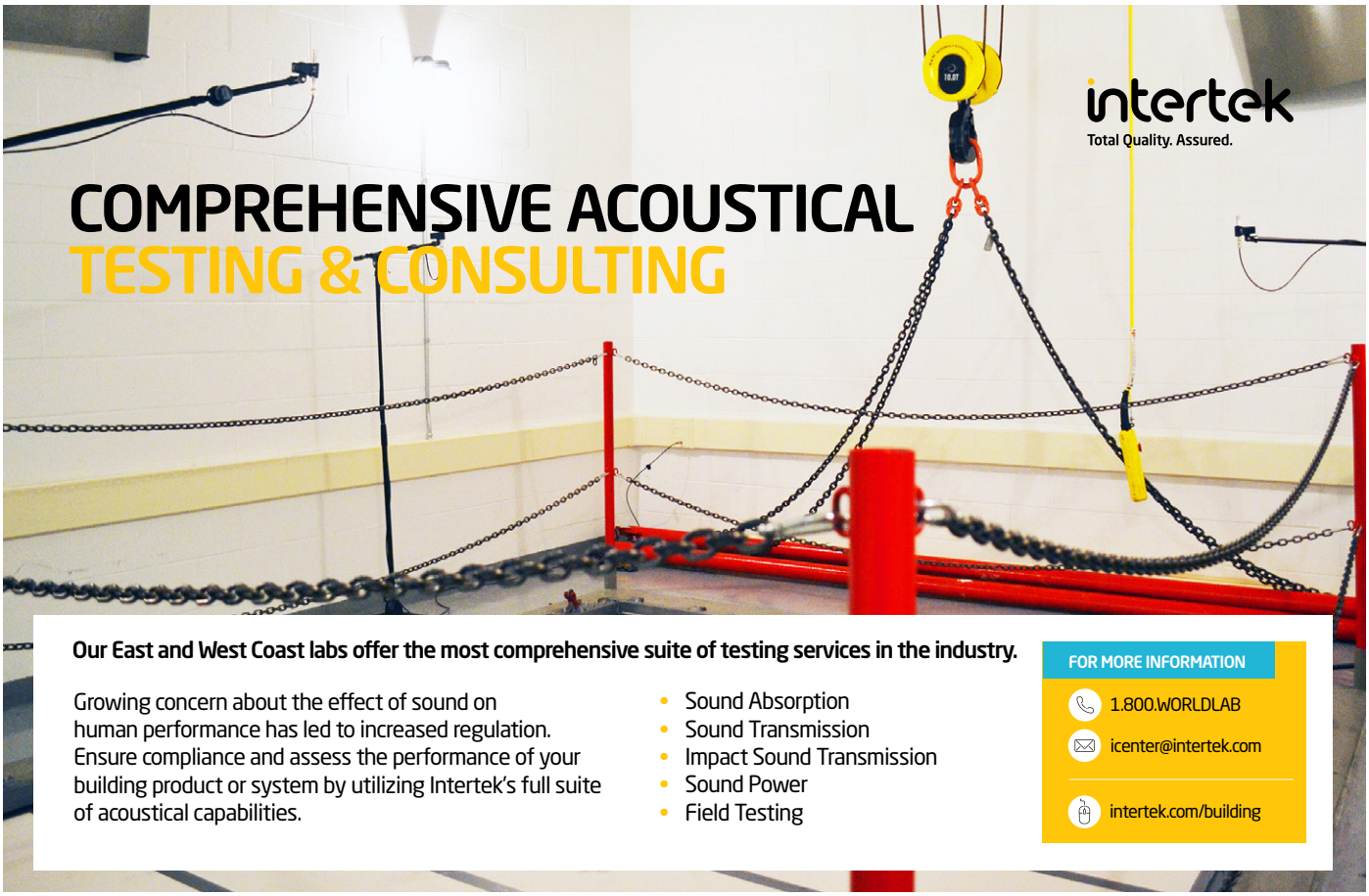
Noise as a Business Model

Dr. Lars Schade and Jan Gebhardt, Umweltbundesamt, Germany

No other class of vehicles embodies the conflict between sound and noise as much as motorcycles – possibly with the exception of sports cars and oldtimers. The same fluctuations of pressure the rider of the motorcycles perceives as powerful sound is felt as infernal noise by many living alongside roads. While riders insist on their freedom, noise plagued residents fear for their health and wellbeing.

The debate is highly emotional. But who is to blame and how could the conflict be healed? The solution could be as simple as building low-noise motorcycles driven by considerate riders. While this may sound naïve to you it is exactly the strategy currently followed. The formal frame work in place to guarantee that (new) motorcycles are low-noise is the worldwide harmonized UNECE type approval scheme: Each time a manufacturer wishes to bring a new motorcycle to market he has to conduct a series of type approval tests to demonstrate that the new type complies with the limit values for sound. And representatives of the rider community regularly appeal to their fellow members to practice a moderate and considerate driving style.

So are we on track to solve the problem? By no means, unfortunately not! With an increasing number of motorcycles on the roads the number of complaints is also on the rise. And it is not only the sheer number of motorcycles that increases, but also the excessive noise of individual vehicles. The German Environment Agency (UBA) took this as a starting point to ask: Is the current type approval test for motorcycles suitable to prevent that brand-new motorcycles are (ab)used to produce infernal noise? To answer this question UBA commissioned a study (UBA 2020) to explore the acoustics of three motorcycles



on an official test track in Germany: a Harley-Davidson Softail Heritage Classic, a BMW R NineT Urban G/S, and a Kawasaki Ninja ZX 10R KRT thus covering a broad range of engine designs. The motorcycles had been homologated according to UNECE-R41.04. They were first subjected to the corresponding approval tests including the "Additional Sound Emission Provisions" (ASEP). As expected all three motorcycles complied with the type approval sound limits. Next, the test drivers were asked to "play" with the vehicles to explore their "acoustic potential". At operating conditions outside the control range of the type approval test, the test drivers managed an increase in the maximum pass-by sound pressure level (SPL) of between 14 to 20 decibels (dB) compared to the single highest SPL measured in the type approval test. Or in a more illustrative form: a difference of 20 dB corresponds to a factor of 200, i.e. a single motorcycle "pushed hard" can be as noisy as 200 identical motorcycles together under type approval conditions. To be sure: The motorcycles were not tuned or manipulated in any way, but rather in an "off the assembly line" condition. This manifests the point often reported by riders: In contrast to former times there is no longer any "need" to manipulate a motorcycle, good sound nowadays comes ex factory. In an additional set of measurements, after market replacement exhausts (RESS) were mounted on the motorcycles and all previous measurements were repeated. Two of the RESS were nearly undistinguishable in their acoustic behavior from the corresponding OEM systems while one raised the SPL in the worst case test by 5 dB. One of the RESS featured an easily removable "dB-eater". Removing this part – in legal terms an act of manipulation – raised the maximum SPL by another 9 dB. A graphic summary of these test results is presented in Figure 1 and Figure 2.

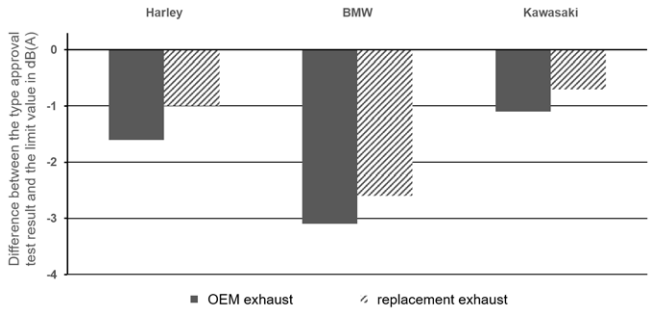


Figure 1: Compliance with UNECE R41.04. Difference between the type approval test result and the limit value

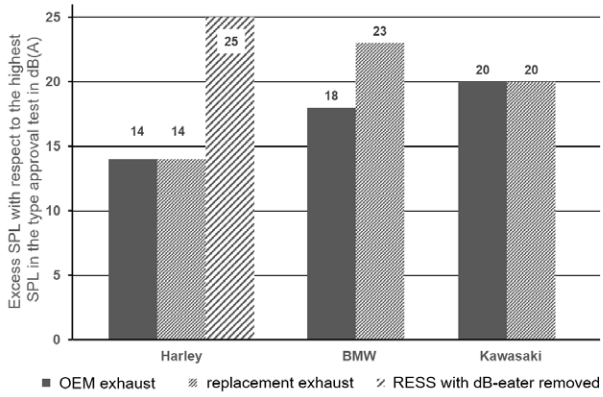


Figure 2: Noise potential of three motorcycles. Difference between the highest SPL outside the type approval control range and the highest SPL within the type approval control range

Where does that leave us? The measurements clearly demonstrate that the current type approval test (aka UNECE R41.04) cannot prevent that a motorcycle, which passes the approval test and complies to the approval limits, can later be driven on public roads in a way to produce excessive noise. The central questions is: Is such an acoustic behavior "natural" and unavoidable or is it rather the intended result of sound design by the vehicle manufacturer? We maintain that the latter is the case.

While not all motorcycles are designed to emanate power, a fair portion of the motorcycle market is affected just like the segment of sports cars among 4-wheeled vehicles. The vehicles in these segments are marketed and advertised as having a particularly emotional and supposedly sporty sound. By use of valves in the exhaust stream and active sound generators more or less any desired acoustic behavior can be achieved. As a result the vehicles meet the type approval limits and nevertheless empower the driver to emit excessive noise in real traffic. A recent UNECE document (IWG-ASEP, 2021) confirms this for cars: "The technologies currently used in systems for noise reduction in motor vehicles of classes M1 and N1 (e.g. flap silencer systems, sound actuators) allow free shaping of the vehicle sound emissions."

Why have UNECE bodies consistently failed in the recent 30 years to put in place proper approval tests without substantial loopholes? Looking at the parties and stakeholders involved in the UNECE process readily reveals the answer: The foundations for the approval tests are laid by the International Standards Organization (ISO), an industry dominated body. At UNECE the contracting parties write the approval tests on the basis of these ISO standards and under massive influence by the vehicle manufacturers' lobby. While the manufacturers' lobby is not to blame that there is no substantial lobby for the many citizens heavily burdened by traffic noise, it must be considered a fact that the urgent interests of those citizens have hardly any advocate in the UNECE process for noise limits for road vehicles. In a nutshell the vehicle manufacturers set their own type

approval rules and ensure that loopholes in these rules allow them to operate their business model with excessive noise.

In light of the above it is either naïve or cynical to demand that UNECE should close the loopholes in the type approval test. If we wish to set the course for socially responsible low-noise mobility we have to require and enforce the principle that vehicles be build to be as low-noise as the state of art allows thus putting an end to noise-enhancing technologies and sound design at the expense of public health. There is no lack of knowledge or technology, there is a lack of political will to protect us all from excessive noise!

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How Can Type Approval Help to Control Motorcycle Noise

Gijsjan van Blokland. Vice President Development and Outreach of I-INCE

The sound of a motorcycle is not always pleasant to listen to. The frequent application of illegal replacement exhaust silencers (IRES) and the often observed very sporty driving style, characterized by high vehicle and high engine speeds produce peak noise levels that exceed those of regular cars and trucks with 10 to 20 dB.

A part of the solution to control the burden on the environment is improving the behavior of the riders in terms of descent usage of their bikes, a part is to be found in enforcing the technical state of the motorcycle and the exhaust system. A third part is to have a system of type approval in order to give market access to only civilized vehicles. However, even "road legal" vehicles can still produce very high noise levels due to the combined effect of relaxing sound limits and shortcomings in the test method. The test conditions are not really representative for the motorcycle operations found in reality and are not robust with respect to tampering devices, such as flaps in the exhaust, closed during type approval and open in the "noisy mode" and electronic devices that enable cycle beating and cheating [1].

Type approval of road vehicles in Europe

It is one of the objectives of the United Nation Economic Commission for Europe (UNECE) to stimulate trade between European countries and with other countries in the world. One of the measures is to remove trade barriers between individual countries by harmonizing the technical specification of road vehicles. If a vehicle is type approved according to the harmonized standard, then all subscribed member countries accept that vehicle, and no extra national specification shall be enforced. Since all European Union countries subscribed that agreement, the regulations define the noise characteristic of al motorcycles entering the market in the EU27. Next to the objective of stimulating international trade is an objective to control negative effects on the environment.

PMR	Current limit dB(A)	Engine Capacity
PMR ≤ 25	73	≤ 80cm^3
25 < PMR ≤ 50	74	80cm^3 < x ≤ 175cm^3
PMR > 50	77	> 175cm^3

Table 1: Limit values in R41 for powered two wheelers of category L3 based on PMR. PMR defines power-to-mass ratio in [W/kg]

The type approval regulations of motorcycle noise are rather bulky since they cover a wide range of motorcycles, including mopeds, small motorcycles, high powered recreational bikes, and all types of three- and four wheelers. For this paper and for the dominant contributor of noise nuisance the focus lies on the medium to high powered two wheelers, category L3, especially those with engine capacity > 175 cm^3.

Regulation no. 41 defines the requirements with respect to sound emission of L3 categories. It defines the maximal allowed sound levels and the test procedure to establish the sound level. Limit values are given in Table 1

Measurement procedure for motorcycles

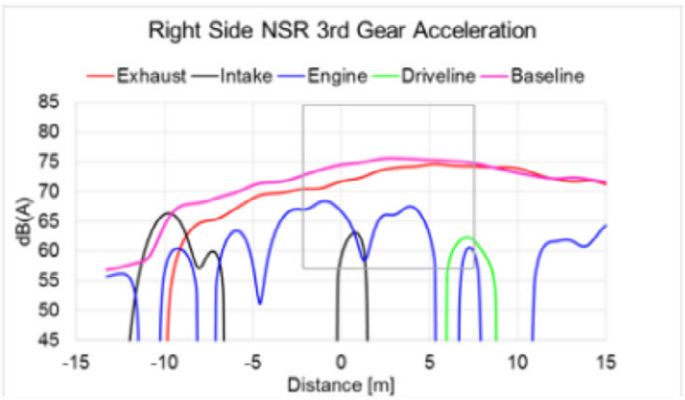
The test procedure used to be very simple. Enter the 40 m long test section with 50 km/h in 2nd and in 3rd gear, push the pedal-to-the-metal, drive 40 m and release the accelerator. Halfway the *LAmax* is measured at 7,5 m distance from the center line.

Recently this procedure is harmonized with normal daily driving conditions and this results in a procedure that is hard to explain and even harder to perform. Basically, it consists of testing the vehicle at 50 km/h under partial throttle condition in front of the microphone at an acceleration value a_{urban} which is defined by the *PMR* (Power-to-Mass Ratio in [W/kg]) by:

$$a_{urban} = 1{,}28 * log(PMR) - 1{,}19$$

This partial throttle acceleration a_{urban} is constructed from a weighted average of a wide-open-throttle (WOT) pass-by and a constant speed (cruise-by) test. The selected gears during the test and consequently the engine speed (since vehicle speed is fixed at 50 km/h), is controlled since in the WOT test a specific target acceleration has to be reached, given by:

$$a_{WOT} = 3{,}33 * log(PMR) - 4{,}16$$



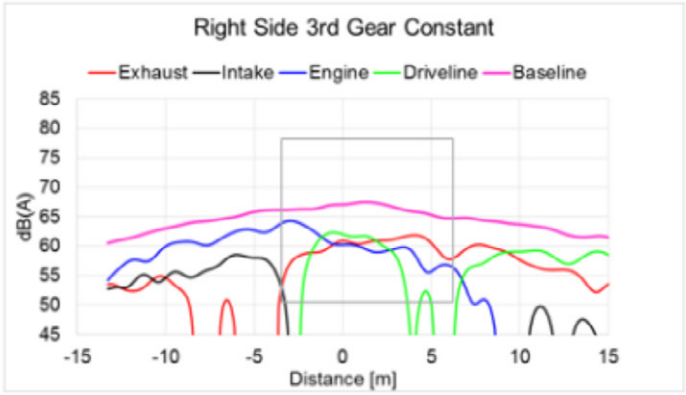


Figure 1: noise source ranking during a type approval test. Vehicle: L3 motorcycle of 800 cm³ and PMR>50. Exhaust is the dominant source during the accelerated (WOT) test while the engine and the driveline are the major systems in the cruise-by test. Source: [2].

For high powered vehicles the weighting between cruise-by and WOT pass-by levels is typically 50/50, while for lower PMR's (35-40) weighting is more like 20/80 (cruise/WOT).

The type approval procedure also includes an Additional Sound Emission Provision (ASEP) that states that at conditions outside of the tested range of engine speed and engine load, the vehicles noise emission shall not deviate from what to expect from the test values. This ASEP unfortunately (for the environment) does not involve real driving conditions at higher speed [2].

Noise source contribution during testing

The contribution of the different noise sources of a motorcycle to the overall noise level during a WOT pass-by test and during a cruise-by test is displayed in Figure 1. Although the traces display the contribution along a 30 m path, most relevant is what happens at the moment of *LAmax* that typically occurs a few meters after passing the microphone. During WOT testing *LAmax* is nearly totally defined by the exhaust. During cruise-by exhaust, driveline and engine are at about the same level.

The variability of some sources observed along the 30 m section can be explained by interference between direct and reflected path from tonal sources and acoustic and mechanical resonances in the drivetrain.

Additionally, a stationary (or fast-idle) test is performed with the microphone 0,5 m from the exhaust(s) at an angle of 45° and an engine speed of 50% or 75% of the rated engine speed. Such test is meant to enable road-side inspections. The relation between the fast-idle test and the level recorded during the accelerated pass-by test is nearly non-existent, as is shown in Figure 2.

How can type approval help to control motorcycle noise

It is clear that type approval cannot restrain the drivers from opening their gas handles and enjoy the high engine speeds and accelerations that will even make regular bikes to become very noisy. But apart from this, there are many areas where type approval regulations can make a difference.

It can regulate the sound emission of the new bikes entering the vehicle fleet. The present R41 limit values seem to be lowered relative to the former EURO4 levels, but that is mainly an effect of the introduction of the new testing procedure. The present levels imply the same technical status as the former levels. The limits have effectively not changed since the nineties and technology is available to lower limit values with 2 dB. In [2][1] the Costs and the Benefits of tightening limits were investigated and it was concluded that a 2 dB lower limit is not only technically feasible but would bring two times more than it will cost.

The ASEP in the present type approval system is limited with respect to the driving conditions found to be causing the majority of annoyance. Extending the speed range would certainly be beneficial for controlling the emitted noise outside of the tested conditions.

Improve stand still test

It is a shared view from all parties involved, motorcycle manufacturers, environmental authorities, experts, public and even the drivers that the sound characteristic of the bike is determined by the choice of exhaust. The manufacturers since their investigations show that the exhaust is dominant in the type approval test procedure, the authorities because their

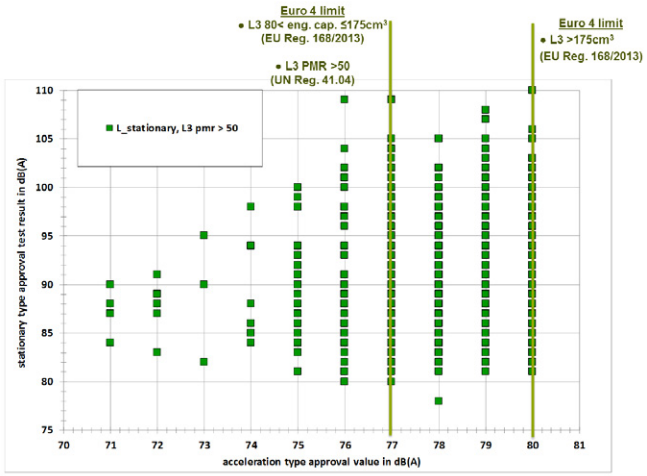


Figure 2: Stationary versus. acceleration test results (L3 vehicles with PMR > 50). The indicated type approval limits refer to the former test procedure that did not include cruise-by conditions. Source: [2].

Figure 3: Road side check of a motorcycle noise compliance. Picture taken from [5]

noise monitoring stations record high peak levels, not explained by vehicle or engine speed, the public because they experience unusual loud bikes and the drivers since they increase their acoustic presence by ordering the right IRES from the internet shop.

Enforcement of "loud pipes" is hampered by the low representativity of the fast idle test. As is shown in Figure 2 a motorcycle that meets the (former) 80 dB limit can have stationary sound levels between 80 and 110 dB. Even when a 5 dB margin is applied during a road side test, a vehicle with an official stationary level of 85 dB(A) testing at 95 dB(A) will be fined while a fellow driver with 105 dB(A) may be considered perfectly legal. There clearly is a need for a more representative stand still test for road side checks.

Nevertheless, you better take care that the fast idle level of your bike is ≤ 95 dB when you want to drive specific scenic roads in the Alps this summer, since the government of the Austrian Bundesland of Tirol applies the fast-idle test level to control noise nuisance along their roads [4] .

Wrap-up of findings

Motorcycles are not a large contributor to overall equivalent traffic noise levels, but they represent significant annoyance due to their high peak levels and their interference with the pleasantness of rural areas on sunny weekends.

The European type approval regulations do limit the sound production of motorcycles, but they do not represent the state-of-art anymore. There is room for a further 2 dB lowering of limit values. Such lowering will cause extra costs but the benefits for society will be much larger [2].

The Additional Sound Emission Provisions and the stationary sound check in the type approval procedure are considered inadequate to control the emitted noise during aggressive driving and to enforce illegal silencers. It is estimated that those two will increase average motorcycle fleet emission with more than 10 dB [3]. This has to be addressed.

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Remote Sensing for Acoustic Vehicle Classification – A News Update From the NEMO Project on the Detection of High Emitters

Erik de Graaff (erikdegraaff@mp.nl) and Bert Peeters (bertpeeters@mp.nl)
M+P, the Netherlands

The noise emission of Powered Two Wheelers (PTW) is often discussed with high emotion, but suffers from objective data. M+P and various partners are developing a remote sensing solution for vehicle noise within the European NEMO project for the objective detection and analysis of High Emitters.

Why is the noise of motorcycles relevant?

Erik de Graaff explains: "The annoyance and health burden related to traffic noise can be split into two issues: the long time averaged noise level (Leq) and peak noise levels due to single events (Lmax). The noise of PTW is normally not an issue for the Leq. Traffic volumes are low and noise levels during cruising are on average lower than for cars, certainly at higher speeds. Noise complaints about PTW are mostly connected to single events. Noise events of PTW attract the attention of local residents, due to high noise levels and/or specific frequency content. We see a big scatter in the noise emissions of PTW. Most of them are as low as normal cars, but some of them are much louder. This is mainly caused by two issues: modified exhaust systems and high acceleration. Both can lead to 15 dB(A) increased noise levels and the combination could lead to a +30 dB(A) in noise level. Added to the increase in dB(A), such PTW emit a strong transient tonal component connected to the firing frequency of the engine. As this tonal component contains more lower frequencies than standard traffic noise, it carries further into the environment and into houses. Also, the human brain is more sensitive to tonal

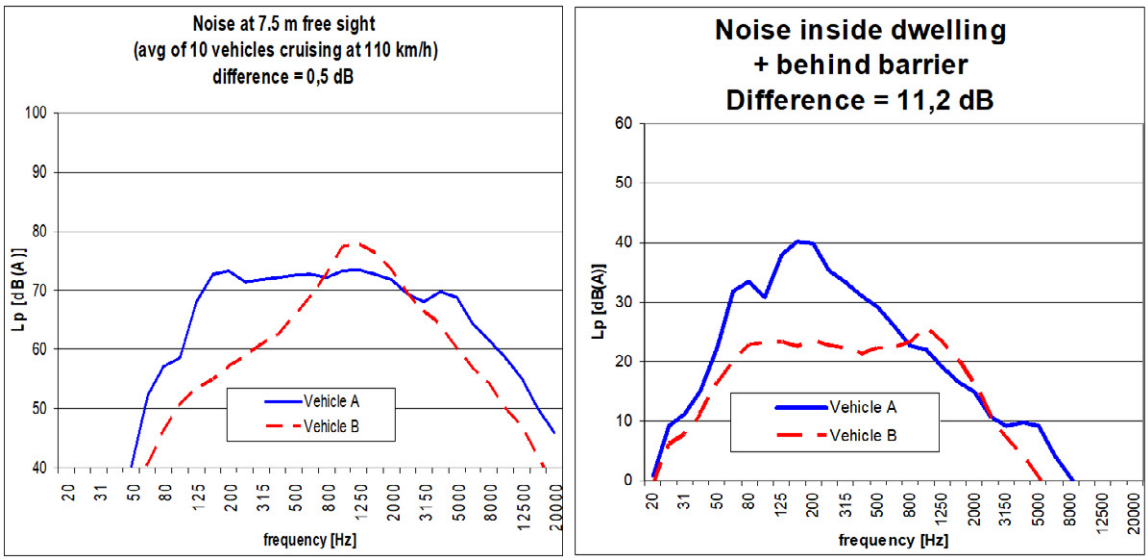

Figure 1: Example of two vehicle types with different noise spectrum, leading to a difference of 0,5 dB(A) outside (left) and 11,2 dB(A) inside a house (right).

Figure 2: Test sites in Munich (left) and Rotterdam (right)

sounds than to broadband noise. Such modified exhaust systems could be illegally manipulated by the owner, e.g. by removing parts or mounting "grey imports". But they could also be legally type approved under the loopholes of older type approval methods. Recent changes in the latest type approval methods significantly reduce the options to bypass the noise reduction requirements of new vehicles. But existing vehicles on the street and their replacement silencers can continue to operate legally under older versions of the type approval method."

What do we need a roadside measurement system for?

Bert Peeters continues: "The general issue is quite clear, but up to now we lack objective data how severe the issue really is. We need these data to be able to separate the real noisy offenders from the regular motorcycle users. What are the numbers of noisy vehicles, what is their driving behavior, what is their technical status, what is the scatter? That is exactly where the NEMO project steps in. With help of remote sensing technology, NEMO aims at developing a roadside measurement system which can detect the noise- and tailpipe emission of vehicles when they pass by in normal traffic. M+P is involved in the noise emissions part, together with Müller-BBM (DE) and SINTEF (NO). A smart camera provides the license plate for each vehicle. Various microphones provide an acoustic signature of the pass by event. Using localization and background noise algorithms, we make sure that the registered noise is indeed coming from the passing vehicle, and not from another nearby vehicle or any other noise source. Multiple sensors register the vehicle behavior in terms of speed, acceleration, position, engine speed etc. Measuring the driving conditions is important if we want to have any chance of relating the data to the vehicle regulations, and also if we want to positively influence the road users' behavior. I have not seen this element in other noise enforcement solutions so far. All data are sent over and stored on a central server, but only after they have been anonymized. Privacy is an important issue at this stage. Last winter we have been testing a prototype version in traffic in the city of Rotterdam, Netherlands. Due to wintertime mainly cars and trucks have been measured and little PTW. A huge amount of interesting data is coming out, but the most interesting question at this point is: *How can we define a high emitter*? We have been studying various approaches, such as an absolute noise level, a certain frequency response, a noise level relative to the type approval value, a noise level as function of acceleration, and various others. What seems to be successful so far is the comparison between the measured noise level for each vehicle and a reference level for similar vehicles under similar conditions, which is derived from the measurement data after a model training phase [see Figure 3]. Besides acoustics there is also a legal side to this question, which we will discuss with our client, the European Commission."

What is coming up?

"This summer we are aiming at more measurement locations with different speed and acceleration behavior and especially with more motorcycles. These measurements will help to improve the remote sensing system and to quantify the accuracy under various conditions. Meanwhile, we will discuss these results with representatives of the Commission, industry, citizen groups and other stakeholders. At this stadium the focus is on data collection and classification methods, not on police enforcement. For enforcement, significant steps need to be taken in the legal framework, both for noise and for privacy. A more likely next step would be a noise based access restriction to certain areas (road tolling, environmental zones), and to raise awareness with owners and drivers of noisy cars and motorcycles."

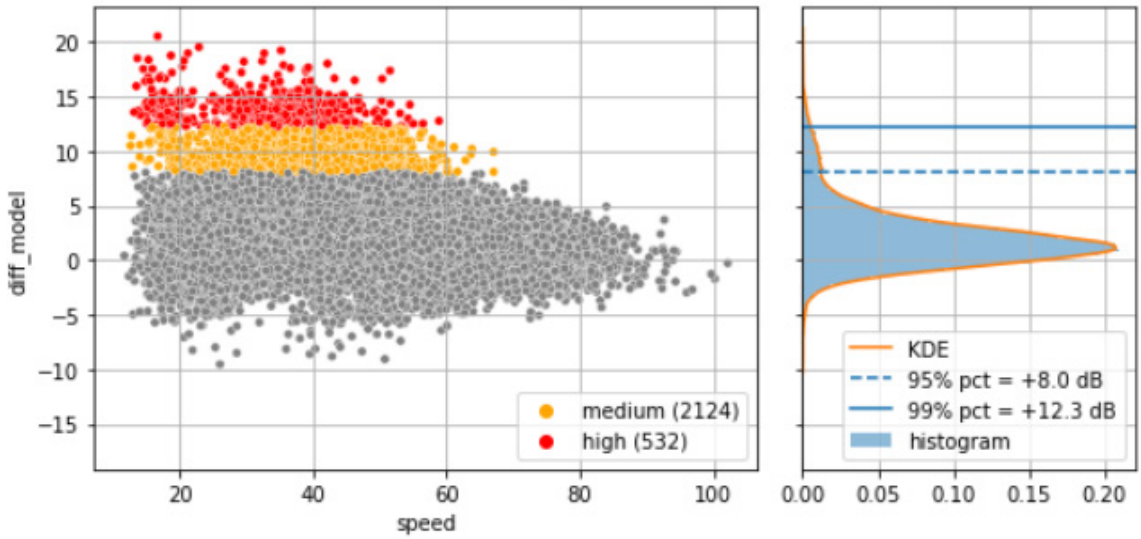

*Figure 3: Example of a High Emitter analysis; **Left**: difference between measured $L_{A,max}$ per pass by event and the reference level for the same pass by; red dots are the highest 1%, orange dots the highest 2 to 5%. **Right**: statistical distribution of these differences.*

References

- Earlier NNI publication on NEMO http://noisenewsinternational.net/nemo-noise-monitoring-of-individual-road-and-rail-vehicles-the-challenges/
- NEMO website https://nemo-cities.eu/
- NEMO Test location Rotterdam https://www.youtube.com/watch?v=p_1Ah7SDeqM

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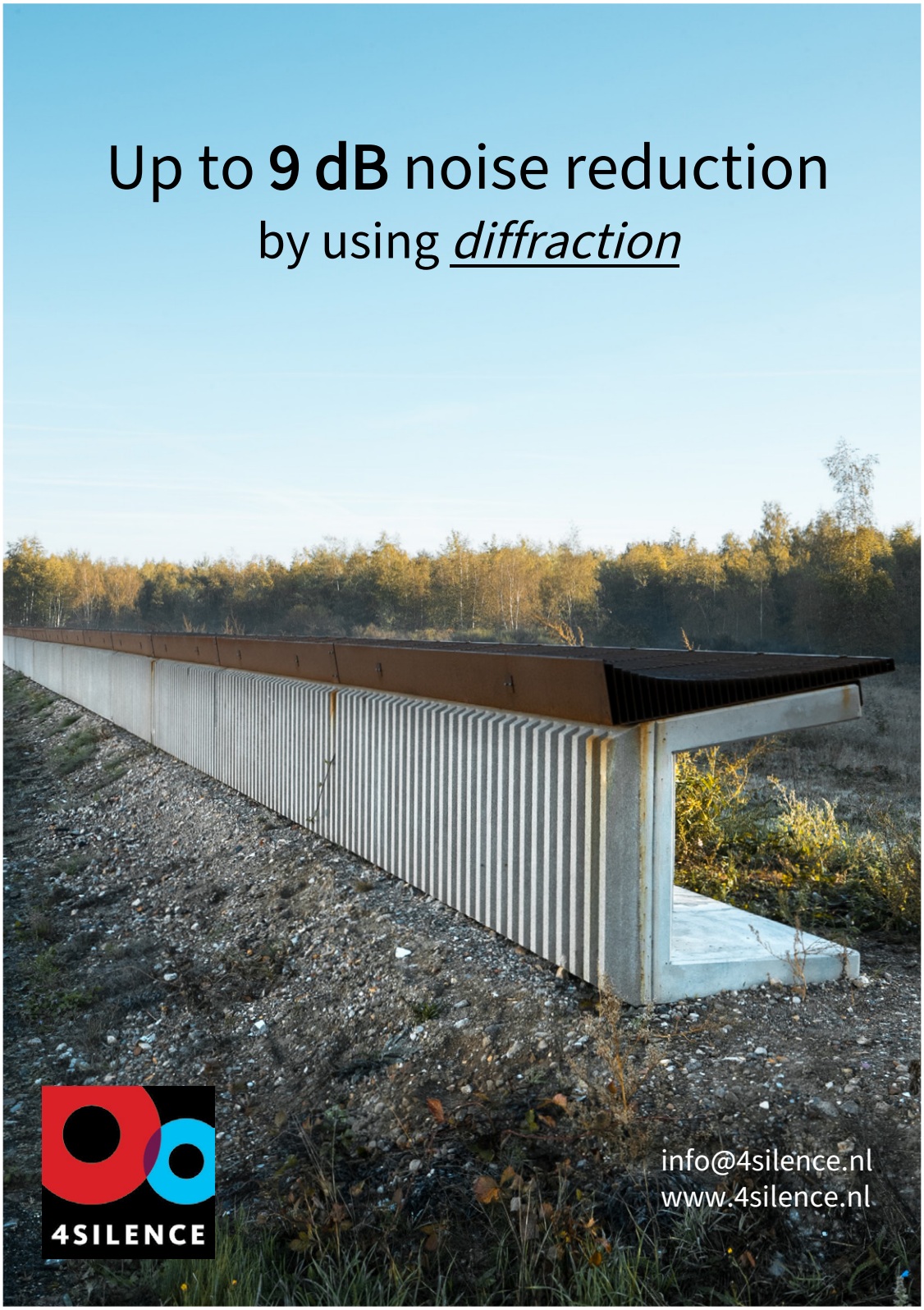

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Motorcycle Noise

Alberto Behar, Ryerson University, Toronto, Canada

Introduction

Here is a very common situation: you are in your front yard, by your swimming pool, enjoying a good book. Nice, sunny day, pleasant breeze. Quiet. Suddenly a harsh noise makes you jump out of your seat and a rush of adrenaline makes all kind of disorders inside your body. You look around for the source of this disturbance and by the time you are up and looking, the source is gone. If you are close to the street, you may smell a whiff of gas. The culprit is gone in a second and again all is quiet.

It also happens on the highway. You are driving nicely, aware of who is around and not being prepared for anything unusual, when, suddenly there is this thunder out of the blue sky and this motorcycle speeds up avoiding cars left and right and disappearing from your site and your hearing in no time.

So, big deal, just a motorcycle speeding away, his driver enjoying the feeling of omnipotence, like being King of the Universe.

Is this a problem of the motorcycle or of the driver?

Let's examine a little bit what's going on. A motorcycle is a bicycle most often driven by a one cylinder, two or four-strokes engine. In this internal combustion engine (ICE) the combustion of the fuel with an oxidizer (usually air) is ignite by a spark plug. The expansion of the high-temperature and high-pressure gases transforms chemical energy into useful mechanical energy that drives the motorcycle.

So, how do manufacturers control noise? They use silencers that are so efficient, that if properly maintained make the noise insignificant!

So, why motorcycles are noisy? Very simple: their owners choose to replace the manufacturer's silencer by so-called "after-market" silencers that reduce very little the noise or modify the spectrum so that they sound "powerful"! Some users even leave the engine without any silencing device. Prof. Fuchs in the Argentinean city of Cordoba once conducted a survey of the motives behind the removing or modifying the silencer. The results were multiple, but the underlying motive was to make them visible! (Or shall we say "important"?).

So, here we have a perfect environmental annoyance generator, very seldom, unfortunately, controlled by the authorities... Now, what about the driver of the motorcycle?

Is there a potential hearing hazard?

Due to the duration of the phenomenon, this noise can be classified as "annoying" and there should be no hazard for permanent noise induced hearing loss to the casual receiver. This, of course, does not apply to people involved in motorcycle maintenance who are exposed for an entire workshift, 5 days a week.

Another exception is for those attending motorcycle racing events. There too noise levels and the duration of the exposure can generate hearing hazard to the attendees.

Now, what is the situation of the person riding the motorcycle? Obviously, he is exposed to the engine noise all the time the engine is on. Also, he is much closer to both the engine and the exhaust (silenced or not). The result is a higher noise levels for longer time periods, and a potentially hazardous situations.

Surprisingly enough, engine/exhaust noise is not the only hazard motorcycle riders are exposed. There is another source, also serious, consisting in the aerodynamic noise created by the turbulent airflow around the helmet— the so-called wind-noise. Several studies were done using essentially similar techniques: a miniature microphone is placed at the rider's ear under the helmet and sound levels are measured in various riding conditions. All these studies show excessive wind noise around the helmet—about 90 dB(A) at 60 km/h and increasing linearly when plotted against the log of speed, to reach 110 dB(A) at 160 km/h!!! (1)

Temporary threshold shift has been reported after only 1 hour of high-speed riding as a subjective complaint of tinnitus. After long periods at high speed, riders commonly report other non-specific complaints such as fatigue, headache and even disequilibrium.

What about the attenuation of the helmet

Does the helmet provide some attenuation to the rider? The answer is "no". Modern helmets offer very poor low-frequency sound attenuation. There is also a phenomenon of resonance at 250 Hz. The source is a turbulent boundary layer, vibrating against the outside of the helmet shell, with its maximum sound energy focused between 250 and 500 Hz. The best protection for the rider is still the use of earplugs.

In summary

Broadly, there are two types of motorcyclists—amateur and professional. Professional riders can be further subdivided into racers, dispatch riders and police motorcyclists. Motorcycle noise hazard is basically dependant on the speed and duration and frequency of the rides (their noise exposure level)

Regarding the annoying side of the noise, the obvious measure is a better policing, something that has proven to be inexistent or inefficient. Switching to electric bike in the future appears as the only viable solution.

(1) McCombe, A., J R Soc Med January 2003 vol. 96 no.1 7-9

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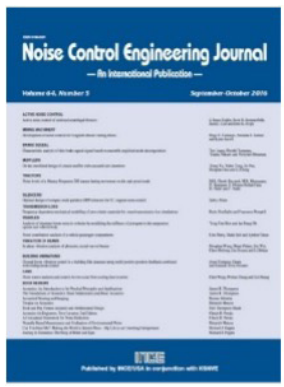

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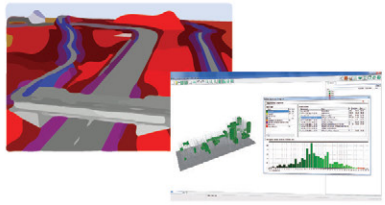

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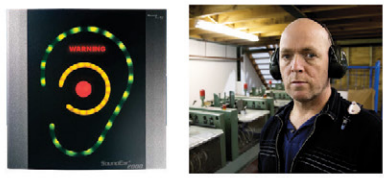

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Lexington KY, USA

AUGUST 21–24, 2022
Inter-Noise 2022
Scottish Event Campus
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OCTOBER 24–28, 2022
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