The road to quieter tires

Low-noise tires are not just a dream; they are partly already here and it is a must in the future that further progress is made, unless our means of road transportation is cut dramatically, or unless we are prepared to sacrifice our acoustic environment

by Ulf Sandberg, Swedish National Road and Transport Research Institute (VTI)

The citation in Figure 1 is not from a recent visitor in Rome, but from the Roman author Martial some 2000 years ago. Anybody who has seen Roman roads that still exist or the streets of old Pompeii can easily imagine the noise created by the wagons rolling down these uneven streets. This sound is the ancient form of tire/road noise.

Today’s tire/road noise is a matter of concern. In fact, it is one of the major environmental problems of modern society and is not stabilized or under control. Most other environmental problems, where schemes such as the Kyoto Protocol exist, try to lower or even reach a status quo of future pollution. Some indicators of the growing problem of noise are social surveys and records of complaints to authorities. For example, in England and Wales, there are now more than double the number of domestic- and transport-related noise complaints to local authorities than there were ten years ago. In Germany, noise exposure from road traffic noise increased steadily during the 1990’s. In the ongoing Swedish property taxation, it was reported from one of the major regions that one in four property owners claimed depreciation due to road or railway noise, despite the fact that the proposed values already took noise exposure into consideration. Yet Sweden is one of the quietest countries in Europe.

Other indications of noise problems are the increasing public reluctance to accept new roads and motorways that authorities decide on; despite the reason often being attempts to bypass traffic in urban areas to solve the associated environmental problems.

Over the next two decades, the traffic planners predict a traffic growth that is likely to result in noise problems in Europe that are much worse than today. For example, it is expected that by 2010, the transported goods in the EU will exceed that of 1997 by about 50 per cent. In 2020 this amount may have doubled compared with 1997. Transportation of people by road will also increase greatly; albeit not as dramatically as for goods. Imagine a situation with more than 50 per cent as much road traffic as today. In the worst-case scenario, the noise-exposed land area may increase by about 50 per cent if no action is taken. A clear trend in Europe is that the concern for quiet recreational areas is increasing. In some countries, such areas will soon be extinct if the trend is not broken. It is impractical to protect large rural areas by noise barriers, therefore the only means are measures related to traffic speeds, the vehicles, tires and the road surfaces.

A fundamental question is: Will the traffic growth and increased noise be accepted at all? Traffic growth reflects a desire to expand commerce across Europe and increase personal travelling. This is what one part of the population wants. Another part wants to limit traffic levels, irrespective of the mechanisms behind traffic growth. Traffic growth will be accepted only when the environmental problems can be solved – in other words, make quieter or fewer tires. The same can be expanded to the road sector – people won’t accept new and faster roads unless the noise can be reduced.

Directive 2001/43/EC, published in 2001 and effective for some tires starting this year, was thought by many to change
this trend. However, tire noise limits set in this Directive, together with tolerances, mean that almost no tires will be rejected. This scenario has been demonstrated in studies in various countries. Furthermore, substantial changes in the Directive are not foreseen within several years. Even a 1-2dB lowering of limits for car tires mentioned in the Directive as a possibility in 2007-2009 would be essentially ineffective. Another feature that limits the effectiveness of the Directive is that it does not relate to retreaded tires; thereby forgetting a major number of tires on the road. Therefore, for the time being, we can forget about Directive 2001/43/EC for tire noise; it is merely a symbol for failing and (currently) useless legislation.

The noise-legislation-related problem that tire manufacturers face is the vehicle noise Directive 70/157/EEC (amended latest in 96/20/EEC). This Directive requires certain noise limits to be met by vehicles driving past microphones at full-throttle in certain gears. Most people expect that tire/road noise would be marginal under such driving conditions, but this is no longer the case. Truck and bus manufacturers require tires that do not create high levels of noise during high-torque operation, thus rejecting some types of tire, and car manufacturers require quieter tires during a combination of moderate-to-high torque operation. As shown in Figure 28.5 of the vehicle noise Directive would indirectly
the future? Unfortunately it is bad news for the tire manufacturer. The present EU Directive, as well as the corresponding ECE regulations, is based on the method specified in ISO 362. There is currently work under way in the groups ISO/TC43/SC1/WG42 and ECE/WP29/GRB to dramatically modify these methods. The latest draft suggests a more realistic driving and loading condition for both heavy and light vehicles. For heavy vehicles, the implication is that tires will be subject to much less tire/road slip than at present, and this will mean a lower tire contribution to the overall vehicle noise; albeit this may be compensated by lowering the noise limit. Current guesses are that the tire noise requirements with the new method and following legislation may be quite neutral compared to today for heavy vehicle tires.

However, for cars, the new method requires testing typically on 3rd and 4th gears, and a simulated part-throttle operation at 50km/h (31mph) instead of the current 2nd and 3rd and full-throttle operation. According to the author’s experience, this means that for many if not most present cars, almost all the noise emitted at type testing will be tire/road noise. For some light vehicles, tire/road noise may be about equal to power unit noise, but rarely lower. It means that the future vehicle noise regulation is likely to be essentially a tire noise regulation, probably far more stringent than the present tire noise directive.

This author has been opposed to this development in the measuring method; preferring a situation where tire noise is regulated by pure tire noise measurements and vehicle noise is regulated by a power unit noise test.

“Today’s tire/road noise is of concern. It is a major environmental problem of modern society and is not stabilized or under control”
where tire noise is marginal. However, the majority has had a contrary opinion; where car manufacturers see the tire as an integral component of the car and not a separate product. Tire manufacturers have been invited to take part in the method development but have hitherto declined this opportunity.

Some tires that may be regarded as low-noise tires already exist. Studies of about 100 car tires with widths 185-195mm and aspect ratios 60-70 per cent (15in rim), revealed a few tires that emitted 4-5dBA lower noise than the average tire on a common asphalt surface (Figure 2). On a corresponding ISO surface, noise levels were 3-4dBA quieter than the average. In addition, one brand new market tire currently under study in one of our projects seems to belong to this group too. These tires are generally winter tires featuring soft rubber compounds and very dense siping. But can their low-noise features be used also for summer tires? Well, most tire experts would probably answer: ‘No’.

However, the tires rolling on our roads are all different ages and conditions and only a relatively small percentage are new. At the same time, we know that tire noise emissions will change substantially with wear and aging. Studies on this subject have been published, but experimental data they include, is too limited to be conclusive. If new tires are noise-optimized for their new condition only, you cannot be sure that they are optimized for the average condition during their operational life.

A couple of examples: Tires often have sipes that are pretty shallow, perhaps only half as deep as the rest of the tread pattern, and grooves that are often wider at the top of the tread than near the bottom. Evidently, a tread pattern may change much with wear. This may be a design feature improving some characteristics, but hardly optimized for noise. Furthermore, for the purposes of

Figure 3: The differing state of wear for two tires. Note the change in the tread pattern between new, half worn and fully worn tires. Much more pronounced differences may occur for some other tires. To summarize, the interaction that occurs between the tread pattern changes and the rubber compound changes may give very complicated noise behavior as a function of time, which may be substantially different from new tires that are studied. The conclusion is that acoustic optimization and testing should consider the tire both when new and in various stages of wear. As a starting point we need to learn more about the age and wear influence on noise

wrote recently (citation modified to provide anonymity): ‘Tire XX is made for the Middle-European winter. I am using them as summer tires (225/45R17) because of good, comfortable, acceptable handling, low noise and low rolling resistance.’ This is not to say that many winter tires would be suitable also for summer use, but it suggests that at least some of them are probably with some sacrifices, for example, wear.

In the future, it will be interesting to see if more low-noise features of winter tires may be merged into summer tires to make them quieter. All-weather tires which are so popular in the US are not so common in Europe and one rarely finds any noise measurements on such tires here. Maybe it is time to study them here?

Tires are generally tested for noise emission only when they are new. However, the tires rolling on our roads are all different ages and conditions and only a relatively small percentage are new. At the same time, we know that tire noise emissions will change substantially with wear and aging. Studies on this subject have been published, but experimental data they include, is too limited to be conclusive. If new tires are noise-optimized for their new condition only, you cannot be sure that they are optimized for the average condition during their operational life.

A couple of examples: Tires often have sipes that are pretty shallow, perhaps only half as deep as the rest of the tread pattern, and grooves that are often wider at the top of the tread than near the bottom. Evidently, a tread pattern may change much with wear. This may be a design feature improving some characteristics, but hardly optimized for noise. Furthermore, for the purposes of
achieving a good initial friction and long lifetime, it is common to use a different rubber compound in the top layer of the tread (giving good friction) than in the major part of the tread (giving low wear). When the top layer rather quickly wears away, tire noise could be quite different. There have been experiments by tire researchers effectively lowering noise emissions for a new tire by fitting a soft rubber compound in a rather thin layer on top of the tread.

Most frequency spectra of exterior tire/road noise display a prominent peak in the 700-1300Hz range. In fact, the characteristics of some of the spectra are such that it would suggest the need to make an adjustment (a noise level penalty) according to ISO 1996-2 for pronounced tonal components. It is, however, debatable whether this concentration of power in a relatively narrow frequency range is objectionable or not. This is not the old, typical tonality feature caused by poor or non-existing randomization of the tire tread pattern. Instead, this quite unfortunate concentration of noise emission is caused by a multitude of coincidental factors sometimes called ‘the multi-coincidence peak’. This situation includes characteristics such as tread pattern pitch, pipe resonances, tangential block resonances, belt resonances, the horn effect and road texture geometry.

Elimination or modification of these frequency-concentrating factors, aiming at a mismatch of them, will be the key issue in order to effectively reduce tire/road noise generation in the near future and there are some possibilities to do so4. The pneumatic tire has been developed over the decades into one of the most sophisticated mechanical components that one can imagine. It provides a rolling performance in most important respects that is amazing. Only a minor defect may show that this performance is not a matter of course but a result of a sensitive design. But it does not go without saying that the pneumatic tire is the only useful device that could provide safe, quiet and economic rolling for a vehicle. If a mere fraction of the resources that have been spent on pneumatic tire development so far were instead spent on development of the composite wheel, what can one achieve then?

Ongoing work in cooperation between a number of organizations and companies, such as Chalmers and VTI in Sweden, the Technical University of Gdansk (TUG) in Poland, Volvo Cars, Nokian Tires, and a retread company (plus a few more participants), attempts to study the feasibility of developing the composite wheel concept into a useful component5. It has already been demonstrated that this wheel has a very large noise-reducing potential if designed properly, and its wet friction and hydroplaning properties should be superior, but it is unknown if it can be made durable enough and what handling and rolling resistance properties one can achieve.

The same project also looks at the possibility of replacing the conventional patterned tire tread with a porous tread. In fact, a few of the most recent tires have some kind of porosity features in their treads, albeit not so obvious to the eye, but there is evidence that such tires are low-noise types. Speculations and some earlier testing suggest that such a porous tread tire may have excellent wet friction and rolling resistance properties, but may
sacrifice wear. Would greater wear (if any) be acceptable? Would side force characteristics be acceptable? Further, a crucial point is if the porous tread can be sufficiently firmly connected to the carcass. The project has engaged as an advisor the author of the porous tread patent, Dr. A. R. Williams who is a highly respected tire researcher and research director with a solid industrial background, as well as Associate editor of this journal.

Other quite radical tire changes that may be considered for low noise purposes, in particular to reduce the multi-coincidence peak, would include a stiffer belt and a softer tread compound. This setup has already been tried to some extent, but handling, side forces and braking characteristics may seriously limit the freedom in design here. However, there could still be some potential for innovation. An interesting challenge is also to combine run-flat technology with noise reduction. One can imagine that some of the run-flat concepts used or considered today may be adapted to provide some exterior noise reduction (although maybe not simultaneous interior noise reduction).

Some 20 years ago, tires filled with polyurethane were tested for noise reduction. VTI and TUG still have some of these tires that are used for testing purposes. This filled tire produced about 3dB(A) lower noise than its pneumatic counterpart (both were pattern-less). It is very interesting to note that urethane-filled tires are no longer considered to be totally unrealistic. Goodyear has signed an agreement with Amerityre (a manufacturer of molded/filled bicycle tires) to attempt developing this concept for automobile use. This author believes that a success for this concept might mean a breakthrough for lower exterior noise too; albeit not at the high frequencies. It is often pointed out by those in the tire industry that noise reduction measures shall be undertaken on road surface improvements (understood as a supplement to the tire noise limits). This view is hardly debated by anybody. However, it is a fact that this is already the case: noise characteristics of road surfaces are already considered to a very large extent and the trend is increasing, as well as further research being underway.

Examples of this include the ongoing EU projects SIRUUS and SILVIA, the huge German Leiser Verkehr project and the even larger Dutch IPG project respectively. Examples also include the fact that the road surface noise characteristics are already considered in several traffic noise prediction models, most detailed in the existing Nordic model, and that the coming HARMONOISE model will include very advanced road surface considerations. This model provides preliminary tools for requiring and evaluating certain road surface types. But more specifically, the SILVIA project aims to provide authorities with more advanced tools for testing, classifying and selecting road surfaces with noise in mind. However, other characteristics will also be considered along with overall cost-benefit recommendations. The ongoing project at VTI to construct an all-rubber poroelastic road surface for noise reduction, as an alternative to noise barriers, is an example of an innovative high-risk approach (Figure 5). Several futuristic approaches have also been tried in the Netherlands.

Some countries have banned certain types of road surfaces due to the excessive noise experienced, or have decided that a major part of the road network shall be covered with low-noise road surfaces. The UK already has a limited form of type approval of road surfaces (HAPAS) with regard to noise.

Finally, it should be mentioned that there is already a large selection of proprietary surfaces offered by road construction companies for which noise reduction is the major commercial argument. The author estimates that there must already be some 30-70 such surfaces on the market in Europe. These would not exist had it not been for the interest among the road authorities to use such products.

Are low-noise tires unsafe tires? No, recent research has indicated that there is no detected conflict between low noise and high wet friction or hydroplaning among market tires of the last decade. Research has also indicated a weak but significant relationship between noise and rolling resistance, implying that work to reduce rolling resistance may often simultaneously result in low noise and vice versa. However, it is speculated that the soft rubber compounds needed for low noise may sacrifice tire wear to some extent. Whether this means poorer economy is an open question since reduced rolling resistance may well outbalance a shorter lifetime.

It is often forgotten that noise exposure in society has a very substantial cost. The EU Green Paper of 1996 estimated that the cost of traffic noise in 17 European countries was 0.65 per cent.
of the GDP. This is comparable to roughly half the cost of road crashes. It means that for society as a whole, any noise reductions achieved by noise source control is worth a lot. Furthermore, it means that society and the consumers should ideally be willing to pay for noise reduction of tires and roads; just as we take for granted that we pay for tire and road safety measures. It would mean that the costs are shifted from noise reduction measures along roads and streets, from reduced property values, from healthcare costs as well as from impaired work efficiency, to increased tire, road and vehicle costs. And wouldn’t we be happy if we need not drive between or hide our homes behind a row of ugly or dirty noise barriers? That is to say noise reduction at source is seldom free of charge, but it saves money and increases wellbeing when it comes to noise emission and exposure. The polluter will automatically have to pay for polluting the road environment. With a proper balance, subject to discussion between authorities and the industry, one can accept increased tire costs for the consumers and achieve a substantially improved environment.

With the above in mind, neither road authorities nor tire and auto makers, or even the consumers and tax payers should be afraid to accept some of the costs of noise reduction measures on tires and roads so long as the overall advantages exceed the costs. Some road authorities seem to reject low noise surfaces if they expect them to cost extra. The problem is that the benefits are seldom, if ever, quantified in order so that the costs and benefits can be considered together.

In a long-term perspective, it seems that tire/road noise from individual tires has not changed significantly during the past century. Tires of the 1980’s did not seem to be quieter than those of decades earlier. Enormous improvements in other characteristics had no counterpart in exterior tire noise, except the obvious elimination of pure tones in tire noise spectra. Evidence of exterior noise improvements between 1980 and 1995 is missing; on the contrary there are some (weak) indications of possible noise increases. Much of speculation is blamed on the increased tire section widths, but also higher speed ratings.

However, in recent years, following the tightening of the latest vehicle noise limits in 1996, some people suggest that a break of the trend has occurred. The major reason would be that after 1996, vehicle manufacturers required quieter tires in order to comfortably pass the vehicle full-throttle test. So far, no scientific studies of this are available, it is just speculation based on logic and on statements from some manufacturers. If the effect is true, it may be substantial for at least some OE tires. However, it is necessary to study whether this is a durable effect (not only typical of new tires) and whether it is limited only to OE tires or also applies to aftermarket tires. It is very important for traffic planners and for the designers of noise prediction models to gain robust knowledge about the actual trend.

A number of research needs have been outlined above and this should be supplemented by pointing out the expectations of the ongoing tire/road noise modeling work. Many universities and other research organizations, and tire industries, have worked for some years on developing advanced mathematical/physical models that aim at providing
"There are VTI resources for measuring pass-by noise and road surface texture, tire/road wet friction and vehicle fuel consumption"

the theoretical/applied/experimental resources of the alliance. VTI already has resources including advanced equipment for measuring pass-by noise and road surface texture, tire/road wet friction and vehicle fuel consumption. Laboratory resources include a unique straight track moving under a loaded test tire with the possibility of varying the ambient and track temperature; ice conditions can also be created to vary tire slip angle and tire slip. A laboratory drum for conducting durability tests is also available.

A large step with regards to availability of information on all aspects of tire/road noise was taken last year when the author and Prof Jerzy A Ejsmont at TUG published the very comprehensive Tire/Road Noise Reference Book3 (Figure 6).

With these resources, and the alliance with Chalmers and TUG, VTI should be an ideal partner for multi-disciplinary research on tires and road surfaces.

Conclusion
Low-noise tires are not just a dream; they are partly here already and it is a must in the future that further progress is made, unless our means of road transportation are cut dramatically compared to the needs, or unless we are prepared to sacrifice our acoustic environment and also partly our health. This, of course, assumes that noise reductions related to tires and road surfaces are undertaken in all possible ways consistent with safe and reasonably economic traffic.

References