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Detailed method for determining the sound power level from a motorsport track

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When calculating the noise from a motorsport track the sound power level of the motorsport vehicles is an essential input as well as the topography of the track. The basic method for determining the sound power of the vehicles is to do a pass-by measurement of the maximum noise on a few vehicles and calculate the sound power level from this measurement. But the emitted sound power varies along the track and this affects the noise in the surroundings as much as the maximum sound power. This paper presents a practical approach for determining the emitted noise from small sections of a track by placing a microphone on a vehicle and combining the data with a GPS for keeping track of the position. This produces a noise image of the track that can be used for calculating noise maps with the general prediction method. The method is developed and tested for motocross and speedway tracks by Dansk Akustik Rådgivning in cooperation with Danmarks Motor Union.

1 Introduction

Motorsport tracks are large noise sources with complex noise propagation from distinct parts of the track and furthermore, the noise emission varies over time. This makes it convenient to handle the noise propagation using the Nordic General Prediction Method [1]. The use of calculation rather than direct measurement in a receiver position also handles the issues with the influence of the weather at large distances.

This is the main reason for the recommendation of calculating the noise rather than using direct measurements in the environment. The recommendation is found in the guideline from the Danish Environmental Protection Agency (EPA) “Noise from motorsport tracks” from 2005 [2].

Normally the use of the motorsport guideline leads to overestimated noise levels in the surroundings when a calculated noise level is controlled by a direct measurement conducted under correct weather conditions described in [3]. This issue is also mentioned in the motorsport guideline [2]. This paper describes a method to achieve better correlation between calculated and measured noise. This is accomplished by incorporating more details in the source model by identifying the parts of the track from which most noise is emitted.

The scope for the method was originally motocross tracks but there is ongoing work to verify the method for speedway and carting tracks.

2 Calculation of noise using the official Danish method

The Danish EPA motorsport guideline [2] gives the official guidelines for administration, measurement and calculation of noise from motorsport in the Danish environment.

2.1 Source data measured at full load

The basic input for the calculation of the noise from a motorsport track is the sound power, L_W, from the vehicles. The motorsport guideline gives two methods for determining the sound power of the vehicles the detailed "declaration method" and the simpler "control method".

The control method uses a simple A-weighted maximum level, $L_{pAmax,fast}$ measurement at a few passages at a close distance to estimate the sound power. The method is meant for internal control during races and training and is performed by the motorsport officials. The control method will not be treated in this paper.

The declaration method describes how to obtain source data for detailed modelling of sound propagation in the environment. The equivalent level ($L_{eq,t}$ per 1/1 octave) is measured over an appropriate period of time, while a number of vehicles pass the microphone. When measured by the declaration method, the sound power, L_W, is:

$$L_W = L_{eq} + 10 \cdot \log(4vat) - \Delta L_{gd} \qquad (1)$$

$\boldsymbol{L_W}$ is the sound power per 1/1 octave frequency in dB re. 1pW.

$\mathbf{L_{eq,t}}$ is the measured equivalent level per. 1/1 octave frequency in dB re. 20µPa, measured over the integration time, $\boldsymbol{t}$

$\boldsymbol{v}$ is the average speed of the vehicles measured in m/s

$\boldsymbol{a}$ is the shortest distance from the microphone to the middle of the track, measured in m

$\boldsymbol{\Delta L_{gd}}$ is the terrain correction

The measurements must be made at a part of the track that forms a straight line and the vehicles must drive at full load with maximum engine power. The measurement distance, *a*, must be 4 to 10 meters and the microphone height must be 1,5 to 1,8 m above the ground.

To produce at valid result for a class of motorsport vehicles (E.g. "125 ccm motocross bikes") 10 passages with 3 different vehicles must be made and the result will be the energetic average of the sound power determinations.

The motorsport guideline encompasses a comprehensive annex with tables of the sound power at full load for all common types of vehicles. But since the guideline was made public in 2005 changes have been made to the vehicles and furthermore noise dampers have found their way into Danish motorsport. This makes it relevant to make new sound power measurements for new calculations.

2.2 Calculation

According to the motorsport guideline calculations must be made according to the Nordic General Prediction as described in [1] this follows the usual Danish practice for industries, construction sites, workshops etc. and all registered Danish consultants in the field of environmental noise are familiar with this. In practice all Danish consultants use the Nordic General Prediction as it is implemented in the SoundPLAN® software package for noise calculations.

For calculations the motorsport track is divided into parts with equivalent noise propagation and the sound power at full load is the basic input. The challenge is that "full load driving" is used over the complete track neither in motocross nor speedway. The guideline states that the noise consultant can evaluate on which parts of the track the noise emission equals "full load" and use a lower noise emission for the parts of the track with "partial load".

The motorsport guideline estimates that in motocross the emission at partial load is at least 10 dB lower that at full load and that in general it can be assumed that the part of a motocross track with full load is 60%. For speedway the part with full load can be assumed to be 100%.

The guideline states that that circumstances on a specific track can lead to other ratios of full/partial load and it is recommended to investigate the driving conditions on the actual track.

The dynamic method described in this paper is a proposal on how to do this investigation.

2.3 Noise limits

The guideline contains comprehensive sections on legal matters of Danish environmental administration of motorsport tracks including noise limits.

The noise limits are set for a reference time of 1 hour given as the noisiest hour during training. The reference hour includes the largest number of drivers and the noisiest type(s) of vehicle on the track. The principle in the noise limits is that the higher the noise is the fewer trainings day pr. week are allowed. This gives a benefit for the motor club running the track to lower the noise to get more training days during the week.

3 The idea behind the Dynamic Method

The first edition of the Dynamic Method for noise pollution from motor sports tracks was developed in 2008 - 2010 in connection with the noise mapping of the motocross track of the Midtsjællands Sports Motorklub close to Slagelse.

The noise from motocross tracks such as the one close to Slagelse, is characterized by the noise of the individual vehicle, predominantly from the situations where the individual vehicle accelerates at full load. The difference in noise emissions from an idling bike and a bike at full load is usually 10 - 20 dB. Full load periods are typically quite short, often only a few seconds at a time. As a motocross track is usually constructed with significant terrain differences in relation to the surroundings, it is important to determine both the extent (duration) and the location of the parts of the track where full load is present to make an accurate noise calculation of the external noise from the track.

It was evaluated that the full/partial load ratio was lower than the recommendations in [2]. But to document the short duration and position of the noise at full load a method was needed. The idea was to combine a noise level measured at a fixed point on a motocross bike (mc) with a record of the position of the mc with a GPS device that is also mounted on the mc. Assuming that there is a strong correlation between the noise level measured on the mc and the noise emitted to the surroundings, it is possible to determine the sound power of the individual parts of the track.

In addition to the measurement of emitted noise while driving through the track and logging the position on the GPS a "calibration" must be made with reference to the sound power determined with the declaration method in the motorsport guideline [2]. Thus, the "calibration" determines the ratio between the noise level measured on the mc and the sound power at full load.

4 Verification

The investigation of the motocross track in Slagelse was reported by Dansk Akustik Rådgivning (DAR) in 2010 [4]. In the report the first version of the Dynamic Method is thoroughly described. The report formed the basis for Slagelse Municipality's processing of the club's application for extension of the training time on the track. In May 2011, the municipality of Slagelse announced environmental approval with the desired extension. However, the decision was appealed to the Nature and Environmental Appeals Board (Natur- og Miljøklagenævnet), which issued its decision on 10 June 2013. This confirmed the decision of the municipality with a number of minor changes as well as a requirement that an onsite measurement should be carried out at the nearest neighbour during a typical training session as a verification of the method.

In August 2013, DAR carried out the measurement at the nearest neighbour during a training session, reported in [5]. The measurement showed good correlation to the calculated noise level and verified the dynamic method.

The basic assumption for the method is that the noise level measured in a fixed position on the mc is proportional to the emitted sound power of the vehicle. Figure 1 shows a series of measurements at different loads. The measurements are made simultaneously on the bike and at fixed microphone positions according to the declaration method.

From figure 1 it is evaluated that there is a simple constant ratio between the noise level measured on the mc and the noise emitted to the surroundings.

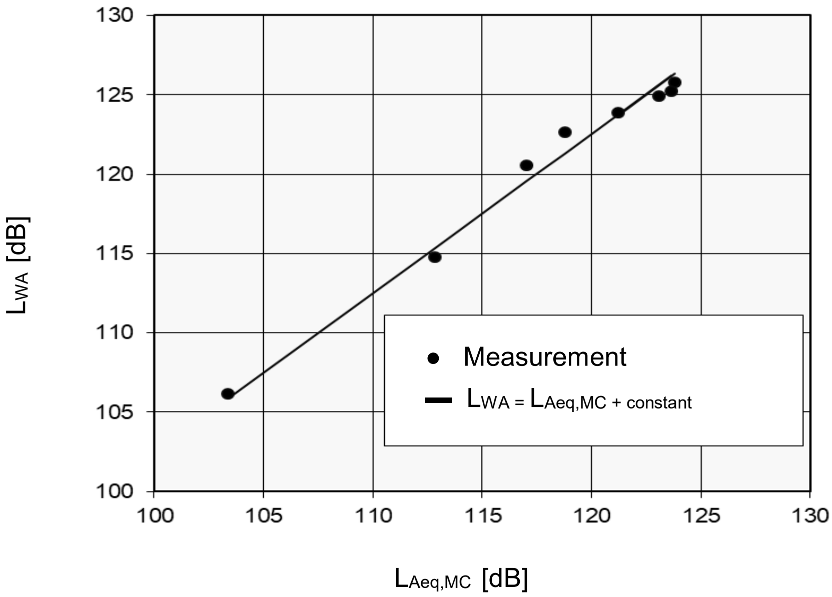

Figure 1 Simultaneous measurement of the sound power, L_{WA} using the declaration method and the sound pressure level, L_{Aeq} measured on the mc at different loads.

5 The Dynamic Method

As described above it is within the frame of the motorsport guideline to examine the way of driving on the track in details and determine the sound power level at partial loads. The difference to a simple guideline calculation using the recommended 60% full load on a motocross track and 100% on a speedway track is that the full/partial load ration is examined in detail forming a table with the actual sound power emitted from sections of the track.

5.1 Motivation and challenges

Usually a detailed examination with the Dynamic Method will lead to a lower full/partial load ratio. This will lead to lower noise levels in the environment and a permit to have more training sessions during the week. However, the measurements and analysis are time consuming and therefore expensive. For the moment the method has only been used on a few motocross tracks and a single speedway track.

In 2016, Dansk Motor Union made an agreement with Dansk Akustik Rådgivning to develop the measurements and analysis from Slagelse to a more general analysis package. The method was improved with the aim to be used on both motocross tracks and on speedway tracks and also on other types of motorsports.

5.2 Measurements for determination of noise for individual track parts

A test driver drives a few laps as in normal training (mapping of the track). The driver has previously been equipped with a rucksack with a sound recorder and a GPS device as seen in figure 2. The sound recorder is connected to a measuring microphone located in a fixed point on the MC's rear panel. While driving on the track, the instantaneous sound pressure level is logged together with the GPS positions. When the starting line is passed the GPS-system generates a mark in the sound recording.

Subsequently, the vehicle's sound power at full load is determined by the declaration method as described in the motorsport guideline. This part of the measurement routine calibrates the sound levels measured on the track to the official full load sound power.

Figure 2 Motocross test driver equipped with rucksack on the back and the microphone mounted at the rear mudguard of the bike.

5.3 Choice of test driver(s)

The choice of test driver has been shown to be quite critical. The more experienced the driver is the more power is given and the more noise is produced. For beginners pauses with the bike idling can be observed while driving around the track. If drivers with different experience levels uses the track within the same hour (the reference averaging time to be assessed to the noise limit) it may be necessary to group the drivers and make the measurements for representatives from each group.

5.4 Data analysis

The analysis is based on measurements made over multiple laps (typically 5 to 6 laps) with the same mc in combination with a “calibration” of the mc. During the “calibration”, a straight track is traversed a number of times with full load and a determination of the sound pressure level on the mc corresponding to the operating condition at full load is made. During the “calibration” stationary measurement microphones are placed next to the test track, and based on these measurements, the mc's sound power at full load is calculated in accordance with the declaration method. The difference between the sound pressure level measured on the bike at full load and the sound power level at full load both measured simultaneously is denoted the mc-constant.

A number of laps (at least 3), which are similar to each other and which do not contain a stop are selected. The average track length for the selected tracks is calculated. The average track length is divided into sections, typically with a convenient length of 10 m. For each section, the sound energy (dose) from a single passage of the mc is calculated.

Based on the measured sound power of the mc, the average path length and the average runtime, the full load sound power is calculated for each section. The full load source for a section is the sound power that would be radiated if the mc had run through the track with full load using the average lap-time determined by the track measurements.

Finally, a table is made for each section of the track, indicating the difference between the full load sound power and the actual measured sound power for each section. This table is the result of an analysis with the dynamic method and can be used directly as a basis for the calculation of the noise propagation.

6 Simplified analysis example

The analysis is illustrated with an example for a simplified speedway track consisting of 4 sections. When driving around the track, speed and noise emission are thought to be constant in each section. See figure 3.

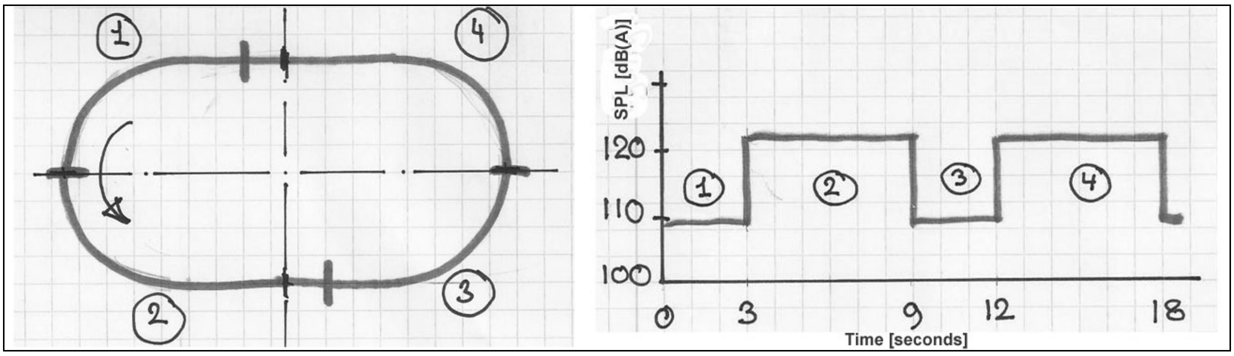

Figure 3 Simplified speedway track divided into 4 sections and the associated sound pressure level (SPL)in the fixed point on the mc as a function of time

The mc-constant, $L_{c,mc,}$ is the difference between the sound power level at full load, $L_{WA,\ full}$ and the sound pressure level, $L_{Aeq,full}$ measured simultaneously on the mc under the full load. In this example the sound pressure level at full load measured on the mc, $L_{Aeq,\ full}$= 122 dB (A) and the sound power at full load, $L_{WA,\ full}$ = 135 dB (A) measured during the "calibration" according to the declaration method. The mc- constant can be calculated as:

$$L_{c,mc} = L_{WA,full} - L_{Aeq,full} = 135 - 122 \ = \ 13 \ dB(A) \qquad (2)$$

$L_{WA,full}$ is the sound power for the section

$L_{Aeq,full}$ is the average sound level measured for the section

$L_{c,mc}$ is the mc-constant

The sound power emitted from the mc to the surroundings in each section of the track in is then calculated as:

$$L_{WA,section} = \ L_{Aeq,section} + L_{c,mc} \qquad (3)$$

$L_{WA,\ section}$ is the sound power for the section

$L_{Aeq,\ section}$ is the average sound level measured for the section

Length, run-through time and average L_{eq} and L_{WA} from the individual sections in the example are shown in Table 1.

Table 1

Section nr.	length s m	Duration t s	Sound pressure on mc $L_{Aeq,\ section}$ dB(A)	mc -constant $L_{c,mc}$ dB(A)	Sound power $L_{WA,\ section}$ dB(A)
1	70	3	109	13	122
2	80	6	120	13	133
3	70	3	109	13	122
4	80	6	120	13	133
Sum	300	18			

For each track section, the sound power level is calculated as dose pr. meter:

$$L'_{WA,\sec tion} = 10 \cdot log(\frac{t \cdot 10^{L_{WA,section}/10}}{S}) \qquad (4)$$

$L'_{WA,\ section}$ is the sound power pr. m for the section

t is the time for the run-through of the section

S is the length of the section

This input fits into the 3D sound propagation software, where the dose level may be set pr. meter. When using L'_{WA} as given above in the noise calculation the corresponding operating time is 1 second pr. lap.

An overview of the result for all track sections can be seen from the difference between if the mc had driven at full load corresponding to the situation during the declaration method and with the same lap time as determined by the measurements on the track.

With the numerical values in the example, the dose level per meter at full load, L'_{WA}, full load, calculated according to formula 5 as follows:

$$L'_{\text{WA, full}} = 10 \cdot log(\frac{t \cdot 10^{L_{WA,full}/10}}{S}) = 10 \cdot \log(\frac{18 \cdot 10^{135/10}}{300}) = 122{,}8 \text{ dB/m} \quad (5)$$

For the simple speedway track in this example, this gives the result of the track analysis shown in Table 2:

Table 2 Result of the track analyses on the simplified speedway track

Section no.	Sound power At full load $L'_{WA,full}$ dB(A)/m	Sound power At actual load $L'_{WA,\ section}$ dB(A)/m	Sound power Difference $\Delta L'_{WA,diff}$ dB(A)/m
1	122,8	108,3	-14,5
2	122,8	121,8	-1,0
3	122,8	108,3	-14,5
4	122,8	121,8	-1,0

7 Acknowledgements

In Denmark motorsport is not a sport with large economic interests. Most of the drivers, coaches and officials are amateurs. The sport cannot offer large consultant fees and the work described here has to some extent been carried out through Gustav Bruun's interest and enthusiasm. During the last couple of years, Danmarks Motor Union has partially funded Gustav Bruuns work on developing the method. Annelin Enggaard has during the years been on the side line as a sparring partner for Mr. Bruun and has been the main author on this paper which summarizes Mr. Bruun's work that was originally in Danish language.

8 References

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