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Sound power levels of motocross courses

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Abstract Noise due to motocross courses demands special attention especially when dwellings in the near vicinity are present. Prognosis of new initiatives and effect of noise reducing measures demands adequate calculation models with accurate sound power information of different classes of motor-bikes. For this reason actual sound power levels of individual motor-bikes of various classes are determined in an appropriate way. Furthermore, the sound power levels of motocross courses as a whole are determined in different situations, taking into account the specific environmental conditions such as local barriers due to sand dunes, forest and other parameters relevant for the sound transmission.
From the results of this investigation proposals are made regarding the most appropriate way to model the sound emission of motocross courses in relation to specific classes and local conditions. The sound emission of individual cross motor-bikes is often verified according to FIM regulations. This so-called FIM-method uses the noise level measured near the exhaust outlet at prescribed r.p.m. However, this method in its present form does not relate accurately with the real sound emission of motor-bikes during the race and therefore with the sound levels in the environment of a motocross course. Modification is required. As an alternative, pass-by tests can be used for the same purpose, which are more appropriate to check the noise level due to individual bikes.

Figure 1: Motocross-course.

1. INTRODUCTION

The total sound emission of motocross courses is relatively high and demands special attention. Assessment of the sound emission is in the Dutch situation very often based on research with respect to the noise emission of motocross courses in 1986 [1]. Meanwhile motor-bikes have evolved technically and therefore acoustically. For this reason, by order of the Royal Dutch Motorcycle Federation a study regarding the actual noise emission of motocross courses has been carried out. In this study the specific effects of local conditions have been considered.

2. AIM OF THE STUDY

The study is aimed at acquiring information about the noise emission of motocross courses, taking into account actual sound powers of motor-bikes of different classes under representative operating conditions, and local characteristics of the course. Also an adequate approach of modeling a motocross course to calculate the sound immission in the adjacent area of course is aimed at.

Furthermore, a comparison is made between the results of the so-called FIM-method [2] for assessment of the allowed maximum sound emission of motor-bikes, and the total sound emission of the course. Figure 1 shows motor-bikes in a motocross course.

3. RESEARCH STRATEGY

To obtain information about the sound power of motor-bikes of different classes respectively of the total course, the following measurements were carried out:

- sound measurements at short distances from characteristic parts of the course (e.g. straights, curves, ramps);
- sound measurements at such a distance of the acoustical center of the course (at least 1.5 times the typical dimensions of the course area) that it can be considered as a point source;
- to get information about the influence of local conditions, such as earth walls and woods near the course, these measurements were done near courses A, B and C, each with different environmental circumstances;
- sound measurements at a distance of about 100 m from the closest part of the course, to be able to verify the calculation model;
- measurements at a distance of 0.5 m of the exhaust pipe of the motor-bike (with an prescribed r.p.m) according to the FIM-method.

From these results the average sound power of separate motor-bikes of different classes were derived, as well as the sound power of the course as a whole, again for each class of motor-bikes.

Based on these sound powers of individual motor-bikes an acoustical calculation model was put up, taking into account the number of motor-bikes simultaneously present on the course and local conditions. This model was verified with the sound levels obtained at greater distances from the course area. A typical example of a course is shown in figure 2.

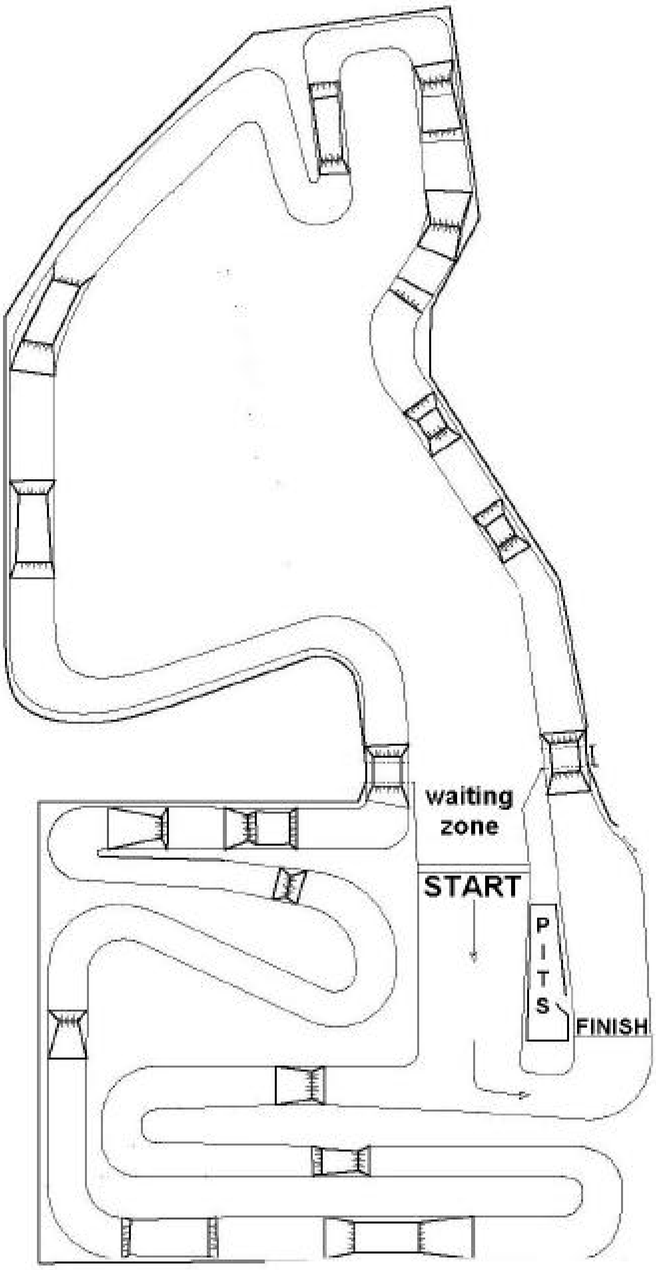

Figure 2: Typical lay-out of a course.

4. RESULTS OF MEASUREMENTS AND CALCULATIONS

Table 1 gives the average sound power levels derived from measured maximum sound levels (at meter reading fast) near the courses, during pass by of individual motor-bikes for different classes. These maximum sound levels relate to parts of the course where the highest sound levels occur.

Besides that, table 1 gives the sound power levels derived from the measured equivalent sound levels at greater distance from the course (> 1.5 d, with d the characteristic dimension of the course) during the race, taking into account the number of motor-bikes attending the specific race. Only those parts of the total measuring time have been used which were acceptable regarding disturbing background noise. If necessary, corrections because of back ground noise have been applied.

Table 1: Sound power levels per motor-bike for different classes (average values), based on measured maximal sound levels near the course respectively on equivalent sound levels at greater distance.

<table>
<tr><th>Class</th><th colspan="5">L_W in dB(A), based on pass by measurements</th><th colspan="3">L_W in dB(A) at > 1.5 x d</th></tr>
<tr><th></th><th colspan="2">Course A</th><th>Course B</th><th>Course C</th><th></th><th>Course A</th><th>Course B</th><th>Course C</th></tr>
<tr><th></th><th>Pos. 1</th><th>Pos. 2</th><th></th><th>Pos. 1</th><th>Pos. 2</th><th></th><th></th><th></th></tr>
<tr><td>50 cc 2s</td><td>118.1</td><td>117.1</td><td></td><td></td><td></td><td>110.6</td><td></td><td></td></tr>
<tr><td>65 cc 2s</td><td>118.5</td><td>118.8</td><td></td><td>118.2</td><td>121.7</td><td>113.1</td><td></td><td>117.1</td></tr>
<tr><td>85 cc 2s</td><td>124.0</td><td>126.2</td><td></td><td>124.4</td><td>126.3</td><td>117.5</td><td></td><td>117.8</td></tr>
<tr><td>250 cc 2s</td><td>125.3</td><td>124.0</td><td>125.2</td><td>132.9</td><td>127.9</td><td rowspan="2">120.7</td><td rowspan="2">118.5</td><td rowspan="2">120.1</td></tr>
<tr><td>450 cc 4s</td><td>127.0</td><td>127.9</td><td>127.6</td><td>133.7</td><td>132,5</td></tr>
<tr><td>Veterans 2s</td><td>125.8</td><td>125.1</td><td></td><td>125.1</td><td>124.7</td><td rowspan="2">121.0</td><td></td><td rowspan="2">120.5</td></tr>
<tr><td>Veterans 4s</td><td>129.3</td><td>129.0</td><td></td><td>127.4</td><td>132.7</td><td></td></tr>
<tr><td>125 cc 2s</td><td>125.7</td><td>125.9</td><td>127.1</td><td>133.1</td><td>130.9</td><td rowspan="2">120.5</td><td rowspan="2">119.3</td><td rowspan="2">118.9</td></tr>
<tr><td>250 cc 4s</td><td>125.2</td><td>133.6</td><td>125.9</td><td>135.9</td><td>130.1</td></tr>
<tr><td>Juniors 65+85cc 2s</td><td></td><td></td><td>121.0</td><td></td><td></td><td></td><td>115.2</td><td></td></tr>
<tr><td>Juniors 85+125cc 2s</td><td></td><td></td><td>126.4</td><td></td><td></td><td></td><td>120.9</td><td></td></tr>
<tr><td>40+class 500cc 2s</td><td></td><td></td><td>125.1</td><td></td><td></td><td></td><td rowspan="2">119.9</td><td></td></tr>
<tr><td>40+class 625 cc 4s</td><td></td><td></td><td>127.5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Superclass 2s</td><td></td><td></td><td>127.5</td><td></td><td></td><td></td><td rowspan="2">122.3</td><td></td></tr>
<tr><td>Superclass 4s</td><td></td><td></td><td>130.3</td><td></td><td></td><td></td><td></td></tr>
<tr><td>“Enduro” class 2s</td><td></td><td></td><td>127.2</td><td></td><td></td><td></td><td rowspan="2">116.7</td><td></td></tr>
<tr><td>“Enduro” class 4s</td><td></td><td></td><td>128.1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Suzuki 125 cc 2s</td><td></td><td></td><td></td><td>125.4</td><td>125.9</td><td></td><td></td><td rowspan="2">117.9</td></tr>
<tr><td>Suzuki 250 cc 4s</td><td></td><td></td><td></td><td>131.6</td><td>130.9</td><td></td><td></td></tr>
</table>

The following should be noted.
Position 1 at course A relates to a part of the course where motor-bikes pass by at relatively high speed; at position 2 motor-bikes accelerate after a curve.
In many races various classes of motor-bikes take part simultaneously. The sound power level of the total course relates to that specific combination.
The so called “Enduro class” relates to motor-bikes which have a special silencer and are for that reason allowed on public roads.

In the so-called “super class” semi-profs attend. They take a larger part of the course with significantly more (sound) power than amateurs. This leads to a higher value of the sound power of the course as a whole.
With measurements at greater distances care should be taken regarding the distribution of motor-bikes on the course. Short after the start almost all motor-bikes are close to each other, so that the distance to the measurement position of this combined sound source varies during that early part of the race. Measurements at greater distance to obtain equivalent sound levels should be carried out long enough after the start to ensure that the motor-bikes have spread out over the complete course. When the motor-bikes are more or less randomly distributed over the course, shorter periods of measuring time are sufficient. This is particularly important when measurements are disturbed by (transient) surrounding noise due to other sound sources which makes it necessary to ignore certain parts of the measurement period.
The sound power levels of the course as a whole are significantly lower than those based on pass by measurements. This is due to the fact that the situation with maximum noise generation (full throttle) occurs at a limited number of specific parts of the course (straights, exiting curves).

The types of motor-bikes that take part in crosses can differ from day to day and from course to course; also the number of motor-bikes per class vary. For the specific race days during which the measurements were carried out, a sound power level, averaged over all motor-bikes, was derived. These values are for course A and B 119 dB(A) and for course C 120 dB(A). For a rough estimate of the noise emission of a course (sound power level per motor-bike) an average value of 120 dB(A) for all motor-bikes could be applied.

New so-called ‘Enduro”-silencers are currently available. To determine the effect of these silencers the sound levels according to the pass by test have been determined. The obtained sound reduction depends on the specific manufacturer. It appears that the additional sound reduction due to the use of Enduro silencers can be up to 8 dB.

5. COMPARISON OF SOUND POWER LEVELS

The average sound power level derived from maximum sound levels near the course – at parts of the course taken with full throttle - are significantly higher than those derived from the measurements at greater distance. This is caused by the fact that motor-bikes drive with the throttle (almost) fully opened only at a relatively small part of the course. A difference between both types of sound power levels of about 8 dB indicates that only 15 % of the total duration of the race refers to the full throttle situation. This important conclusion has to be taken into account when making a calculation model. Which part of the course has to be taken into account depends on the specific lay out of the course.
Semi-profs cause an approximately 2 dB(A) higher sound power level of the whole course compared with the values with amateurs.
The application of so called Enduro silencers leads to approximately 2 to 3 dB lower sound power level of the course as a whole. However, this will only influence the sound emission of a complete racing day if all motor-bikes apply this type of silencer.
The sound power levels of courses in flat land do not differ significantly from those which are digged in. The effect of sound barriers which exist as a consequence of this digged in course parts is less than expected mainly because important parts of the course with high sound emission do not benefit from this circumstance.

6. COMPARISON WITH EARLIER STUDIES

In the report of 1986 [1] it was concluded that the difference in sound power level between various classes is small, and that for practical reasons one could calculate the noise emission of a course by applying a sound power level of 124 dB(A) for each motor-bike. As a first simplified approximation this might be true. However, when noise limits are severe and hard to meet, a more differentiated approach is recommendable, taking into account the specific classes of motor-bikes that usually will attend races at that specific course. In such an actual situation significantly lower sound power levels can be applied, as are determined in our study.

7. FIM-TEST AND OTHER CONTROL MEASUREMENTS

In order to check whether the sound emission of a cross motor meets the limit or not, the so-called FIM-test is applied, executed prior to the race. With this test the sound level at a distance of 0.5 m from the exhaust outlet is determined (see figure 3). At the time of the TNO-study of 1986 the limit was 108 dB(A) with the remark that very soon this limit would be decreased to 104 dB(A); at that time most motor-bikes showed sound levels of 104 to 106 dB(A).

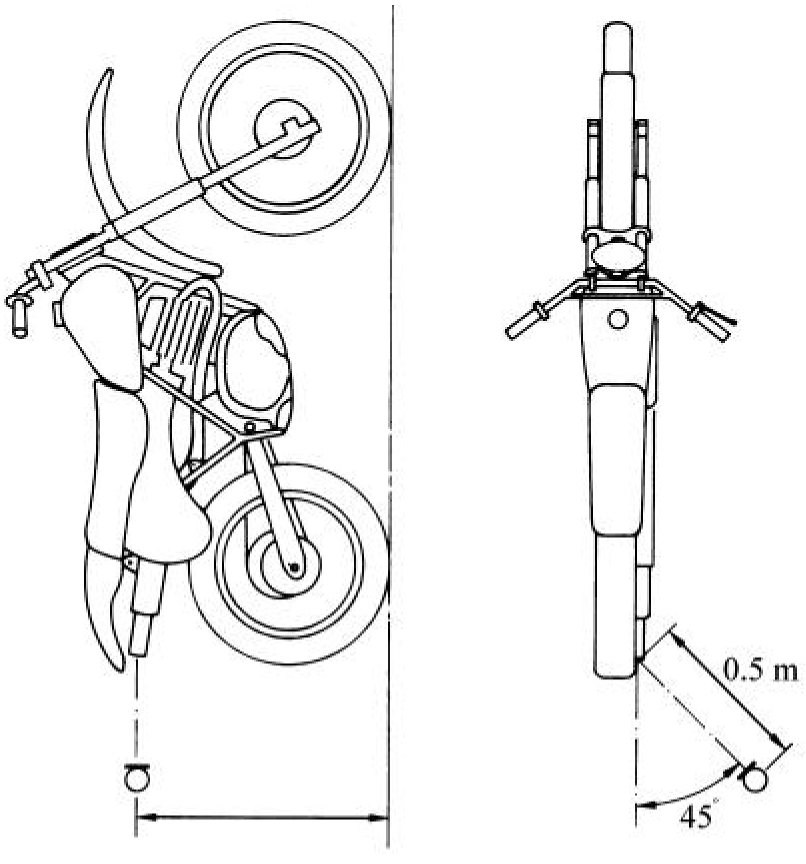

Figure 3: Situation at FIM emission measurements.

At this moment the FIM-limit is 97 dB(A) (meter reading slow), which shows the technically achieved reduction of the sound emission of cross motor-bikes. Neglecting the noise contribution due to the engine block and air intake, this limit corresponds with a sound power level of 103 dB(A). However, the average sound power of motor-bikes appeared to be 120 dB(A), showing no real relationship with the FIM-limit, which is even worse when considering the sound power during acceleration. This poor relationship can also be derived from the fact that the FIM limit was decreased with 11 dB - from 108 dB(A) in 1986 to 97 dB(A) in 2005 - while the effective reduction of the average sound power level of motor-bikes in that period of time appears to be about 4 dB.

As the discrepancies between the FIM sound emission and the sound emission during real race conditions are to large, the FIM method is no suitable instrument to limit the sound power of the course as a whole. A modification of this specific method is recommendable, for instance by simulating the race situation by measuring the maximum sound level during fast acceleration up till the r.p.m as prescribed by FIM regulations. Measurements should be taken at a larger distance than 0.5 m from the exhaust outlet (for instance 1.5 m) to take into account the noise contribution of other parts of the motor-bike such as air inlet and engine block. This is especially true when additional reduction of the sound emission of the exhaust outlet is achieved, making this sound source less dominant in the total sound power of the motor-bike.
Apart from the FIM test, more and more pass by tests are used to check the sound emission of cross motors. If the sound level at 7.5 m distance from the course during acceleration exceeds a specific value the motor-bike is not allowed to attend the race. It is clear that this method has a better relationship with the real sound emission during the race itself.

> N.B. Based on the results (or limit) of the pass by test and the number of motor-bikes attending the race, one could consider the set up of a book keeping system in order to control the total equivalent sound immission at discrete locations near dwellings. This exercise can be done prior to the race to prove that sound limits in permits will be met, or during the race to show that no exceeding of noise limits have taken place.

8. CALCULATION MODEL

As concluded before, it appears that only certain parts of the course are responsible for the total sound power of the course as a whole. This relates to the specific operating conditions of motor-bikes during the race. Practical experience shows that mainly at straight parts of the course and when exiting curves motor-bikes are operated with throttles (almost) fully opened, generating maximum sound power levels. At the other parts of the course (for example before entering a curve or a ramp) the sound emission of the motor-bike can be 15 to 20 dB lower, because the corresponding operating conditions (braking or coasting) mean that hardly any mechanical power is required. Although only 15 % of the duration of the race should be considered with maximum sound power level (see above), from verification calculations it appears that effectively about 8 % of the length of the course should be modeled with maximum sound power level.
This knowledge also serves another purpose. It is very important to know which parts of the course actually contribute to the total sound emission when considering sound reducing measures such as sound barriers. It is no use to erect for instance extensive earth walls as sound barriers near parts of the course that are not or less important for the total sound emission in certain directions.
Based on these observations, calculation models were made with the following characteristics:
- the course as a whole was subdivided in course parts of 10 to 20 m;

- from the measurement results nearby the course of motor-bikes passing by, the sound power levels during maximum sound generation of the motor-bikes were derived;
- on each straight course part and course parts after a curve these maximum sound powers were used; other course parts were neglected;
- taking into account the average speed of the motor-bikes on the course, the average duration of passing was derived for each course part;
- combining this duration time on each course part with the number of motor-bikes in the specific race, the time corrected contribution to the total sound emission of the course was determined;
- with this model the sound levels on the verification positions were calculated.

Table 2 shows the results of these calculations.

Table 2: Comparison of measured and calculated equivalent sound levels due to courses at different positions.

Class		L_{Aeq} in dB(A)	
		Measured	Calculated
Course A			
50 cc 2s		52.0	49.7
65 cc 2s		56.9	53.1
85 cc 2s		62.1	60.9
250 cc 2s / 450 cc 4s		64.3	63.0
Veterans 2s / Veterans 4s		64.1	64.3
125 cc / 250 cc 4s		63.2	62.6
Course B			
125 cc 2s / 250 cc 4s		63.5	63.8
250 cc 2s / 450 cc 4s		63.4	64.3
Superclass 2s / 4s		67.2	67.4
40^{+}class 500 cc 2s / 625 cc 4s		63.5	64.1
“Enduro” class 2s / 4s		60.4	64.0
Course C			
Suzuki 125 cc 2s / 250 cc 4s	Position 1	75.0	74.2
	Position 2	57.8	56.8
125 cc 2s / 250 cc 4s, race 1	Position 1	80.7	84.0
	Position 2	63.0	66.5
125 cc 2s / 250 cc 4s, race 2	Position 1	79.2	79.4
	Position 2	57.8	61.9
250 cc 2s / 450 cc 4s	Position 1	77.6	79.9
	Position 2	60.3	61.6

As can be seen from table 2 the measured and calculated values correspond satisfactory with each other.

To take into account the additional reduction due to woods the damping factors of table 3 have been used.

Table 3 Damping factors regarding additional noise reduction due to woods.

Frequency [Hz]	31	63	125	250	500	1000	2k	4k	8k
Damping [dB/m]	0.00	0.01	0.01	0.01	0.04	0.05	0.04	0.09	0.09

9. EFFECT OF PROVISIONS

The results of measurements show that by application of improved exhaust silencers, the total sound emission of the motor-bike can be reduced substantially (up to 8 dB); see figure 4. It was concluded before [1] that the influence of such improved silencers on the performance of the motor-bike is negligible. However, the application of an improved silencer requires a new set-up of the engine (fine tuning of ignition timing and mixture-ratio) in order to prevent power loss. For this reason owners/users of motor-bikes often have a negative opinion about improved silencers. Also the psychological effect plays an important role ("less noise = less power"). For this reason communication with owners/users is very important.

Figure 4: Example of improved silencer.

Furthermore, application of noise walls or barriers can reduce the noise emission or, as an alternative, the digging in of the course has the same effect. It is not useful to try to optimize the location of noise barriers in relation to certain more noisy parts of the course, if many scattered short parts of the course contribute to the total noise emission. However, if a small number of noisy parts exists, such an optimization might be useful.

Woods have their effect on the noise emission, but can hardly be considered as an additional provision. However, the existence of woods can be taken into account when selecting the location of a new course.

10. CONCLUSIONS AND RECOMMENDATIONS

A significantly lower average sound power level for cross motor-bikes (approximately 120 dB(A)) has been determined compared with the values of 124 dB(A) used up till now based on studies from 1986 and before. In acoustical critical situations more differentiation is recommendable, since certain classes have lower average sound power levels.

The application of optimized silencers can provide an additional noise reduction up to 8 dB.

The results of these developments improve the possibility of obtaining permits for existing and new motocross courses. It also provides extension of the number of races and/or motor-bikes within actual permits for existing courses.

Communication with owners/users of motor-bikes regarding the application of special silencers is recommended in order to stimulate a broader use of these devices.

In calculation models it is sufficient for an accurate prognosis of the noise emission of the total course to only implement sound powers of accelerating motor-bikes at straight course parts and parts after curves. The noise contribution of other parts of the course may be neglected.

It is recommended to modify the FIM control measurements in such a way that a better relationship with the sound emission during the course exists, for instance by measuring the maximum sound level during fast acceleration up till prescribed r.p.m, and at for instance 1.5 m from the exhaust outlet. As an alternative pass by tests could be considered.

REFERENCES

[1] TNO-report GF-HR-02-02 (in Dutch), Noise of motocross courses and means to reduce it, *TNO,* 1986.

[2] FIM, Motocross and motocross technical regulations, version 2005