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Proposal for investigations related to roadside enforcement tests based on pass-by measurements

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23.03.2006

Content

1 Introduction, summary of the results of the BASt investigation (22-R41WG-05)

The efficiency of the current stationary roadside enforcement test, using the ISO 5130 method, is rather poor. From field studies in Germany, carried out by VDTUEV and DEKRA and covering more than 400 motorcycles, is known that only one third of the illegal systems can be detected by this test. A drive by test similar to the type approval test would be much more efficient. The test track setup for the drive by test is shown in Figure 1.

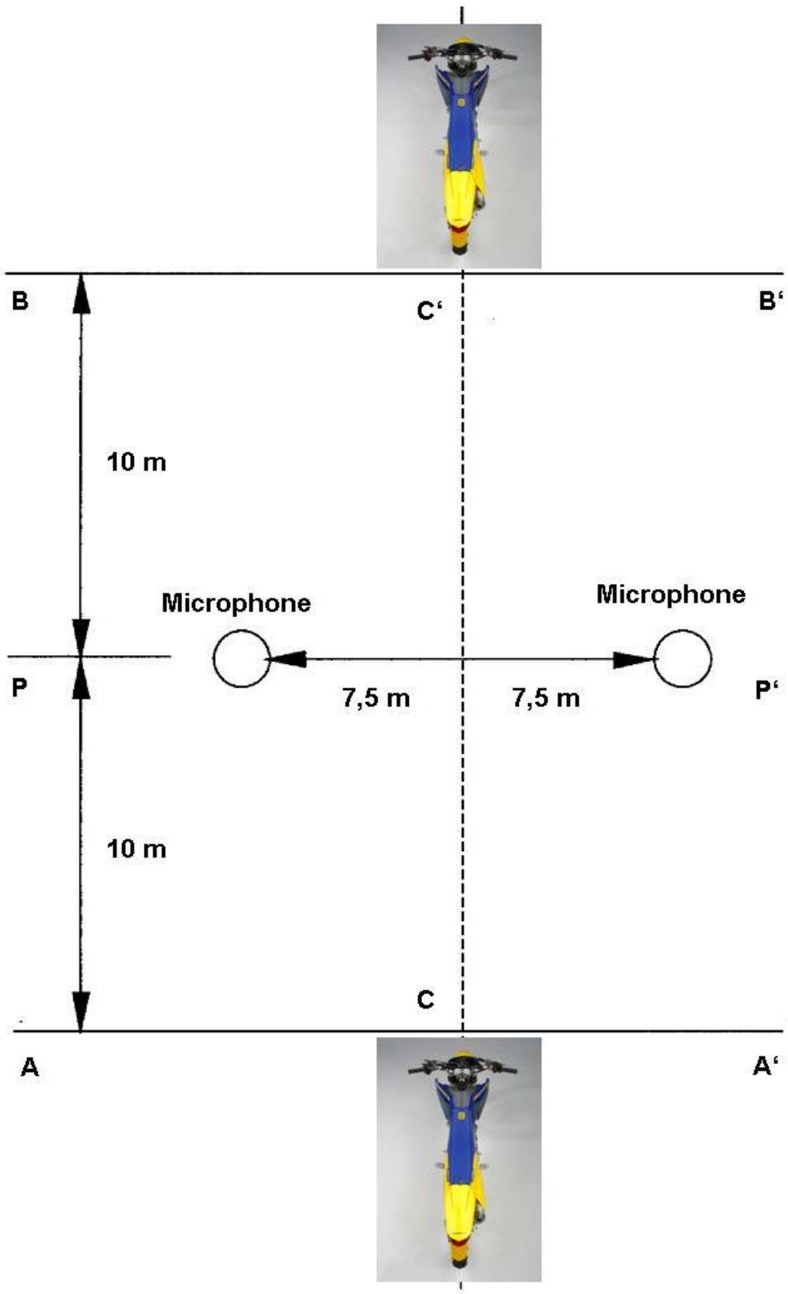

Figure 1: Schematic test track setup

Within BASt's investigations of stationary roadside enforcement noise tests for motorcycles (see 22-R41WG-05) additional pass-by measurements were carried out following the prescriptions of the measurement method, described in the current ECE R41. For a limited number of motorcycles (11) these measurements were carried out twice. Once on a standard ISO test track under type approval conditions and once on a rural road under roadside enforcement test conditions.

The following deviations in comparison to test track measurements had to be accepted for the pass-by roadside enforcement tests:

1. Road surface does not meet the ISO 10844 requirements,

2. Microphones are placed on road shoulder, which might reduce the measurement result due to absorption effects,

3. Obstacles in the vicinity of the road might increase the measurement result due to reflection effects,

4. The speedometer of the vehicle was used to control the entrance speed $v_{AA'}$. This device is not as precise as required for type approval measurements.

The following observations were made / conclusions were drawn based on the comparison of both methods (test track measurement versus roadside enforcement test):

- The road surface influence is negligible as far as dense asphalt or concrete surfaces are used. Open graded surfaces and pavement stone surfaces must be excluded.

- The test track influences mentioned in 2 and 3 above can be kept acceptable small, if rural roads (see Figure 2 and Figure 3) or suburban roads are used, where the buildings are far enough distant from the road.

- The "true" vehicle speed is always lower than the speed indicated by the speedometer of the vehicle, because the latter need a speed "lead" by legislation. The average difference between the exact speed, measured by radar and the speed indicated by the vehicle's speedometer was -3 km/h for the 11 tested vehicles. Roadside enforcement pass-by tests carried out by the police in Germany in 2003 led to an average difference of -5 km/h for 40 motorcycles.

- In order to take into account the influences of the deviations from the requirements for type approval measurements for roadside enforcement tests a tolerance is needed for the comparison of the results with the legal limit values. Although the performed roadside enforcement tests are by far not sufficient in order to verify such a tolerance, it was stated by BASt that this tolerance would be in the order of 2 dB, because some of the above mentioned influences (partly) compensate each other.

Figure 2: Example for a pass-by roadside enforcement test

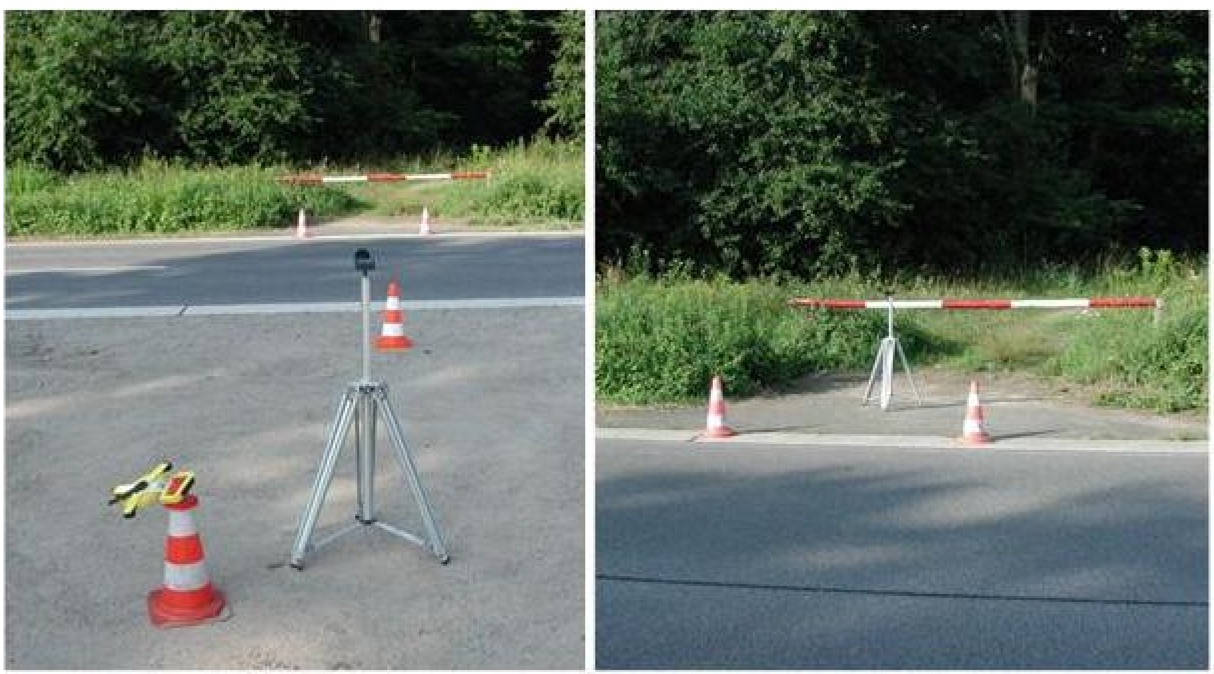

Figure 3: Microphone positions for a roadside enforcement test

The measurement results for the 11 vehicles are summarised in Table 1. Figure 4 shows the comparison of the pass-by tests carried out on a test track under type approval conditions and on a rural road under enforcement conditions. The results correlate quite well and look very promising. The differences range from -1,5 dB up to +0,5 dB.

The results for vehicle 9 represent a good example for the effectiveness of the pass-by test compared to the stationary test. The measured stationary test result has exactly the same value as registered for this vehicle, while the pass by test result under type approval conditions is 7 dB higher than the registered type approval level and still 5 dB higher than the threshold level for Conformity of production (COP). The pass-by test result under roadside enforcement conditions is 0,5 dB lower than under type approval conditions. The stationary test classifies this vehicle as legal, while the roadside enforcement pass-by test classifies it as illegal.

veh no	Manufac-turer	vehicle	engine capacity in cm³	rated power in kW	rated speed in min^{-1}	noise levels in dB(A)						
						registered type approval level	result of test track measurements	result of roadside enforcement measurement	difference	measured type approval level	registered stationary test result	measured stationary test result
1	Suzuki	GSX 600R	599	85	13000	78	83.2	82.4	-0.8	82.0	93	92
2	Honda	CB 900 F Hornet	919	80	9000	79	79.8	79.7	-0.1	79.0	86	84
3	Yamaha	XVS 1100	1063	48	5500	79	80.1	80.6	0.5	79.0	86	86
4	BMW	K12	1171	96	8750	79	80.5	81.0	0.5	80.0	93	91
5	Kawasaki	ZX 900 E	899	105	11000	79	80.5	80.1	-0.4	80.0	93	93
6	Suzuki	Bandit 1200	1157	72	8500	79	80.8	79.6	-1.2	80.0	91	91
7	Suzuki	SV 650	645	53	9000	79	81.5	81.0	-0.5	81.0	90	88
8	Suzuki	SV 1000	996	88	9000	79	83.1	82.1	-1.0	82.0	92	92
9	Suzuki	DR-Z 400 SKS	398	29	7600	79	87.0	86.5	-0.5	86.0	87	87
10	Harley Davidson	VR1	1131	86	8300	80	80.1	80.4	0.3	79.0	90	94
11	BMW	R 1150 GS	1150	62	6750	80	82.6	81.1	-1.5	82.0	86	86

Table 1: Results of pass-by and stationary noise measurements for a motorcycle sample

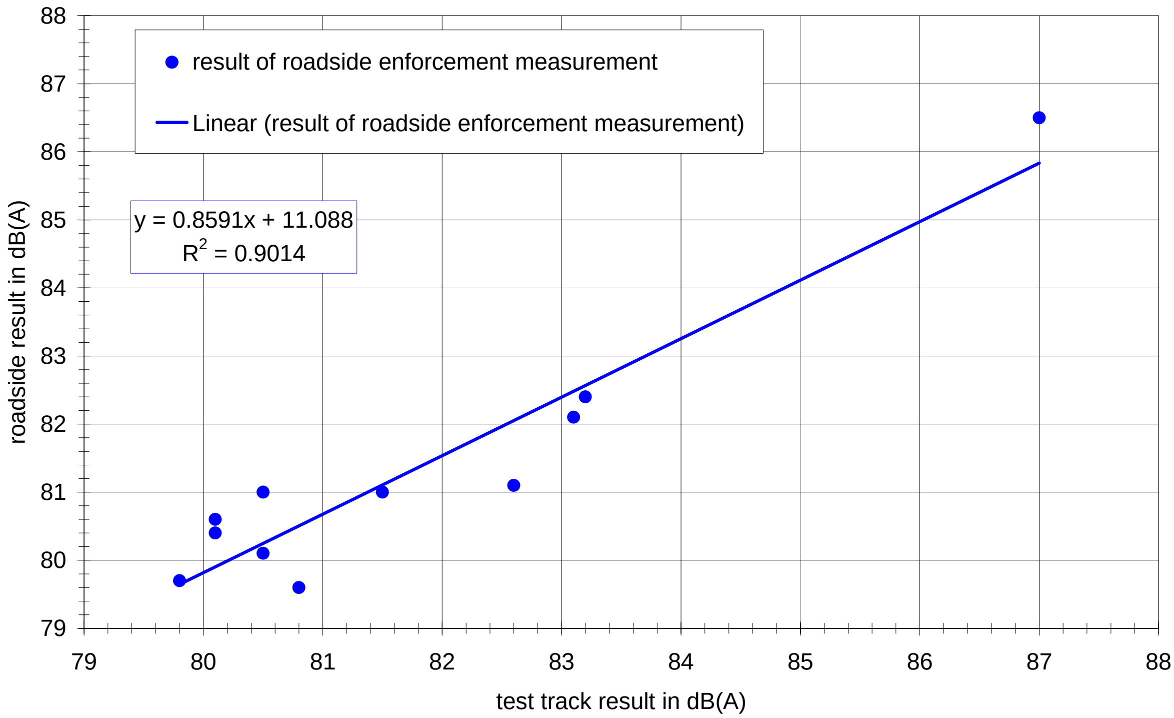

Figure 4: Results of pass-by noise measurements on a test track and a rural road

Another test series was carried out at Kisslegg. Motorcyclists were stopped by the police and stationary noise measurements as well as pass by noise measurements were carried out on a voluntary base. The motorcycle drivers had the possibility to refuse the pass by tests. BASt provided the measurement equipment, but the measurements were carried out by the police. The vehicle's speedometers were used to control the entrance speed of 50 km/h. BASt performed more exact speed measurements using a radar device. In total 35 vehicles could be tested.

For the pass by test up to 8 measurements were carried out per vehicle. Figure 5 shows the variance of the entrance speeds for these 35 vehicles. The entrance speeds varied from 39 km/h up to 55 km/h, but 89% of the measurements were at 50 km/h or below (see Figure 6). Speeds higher than 50 km/h should not occur when using the speedometer of the vehicle. These speeds indicate that the driver sometimes missed the target of 50 km/h.

Measured and registered levels for the stationary test and the pass by test could be compared for 31 vehicles. Average values were used for the pass by test. The comparisons are shown in Figure 7 and Figure 8. The tolerance for compliance was set to +5 dB for the stationary tests and +2 dB for the pass by tests.

22 motorcycles complied to both test with measurement results, when these tolerances were considered (marked by dark blue circles). Just 2 of the remaining motorcycles failed in both tests (marked by red and yellow circles). Another 4 vehicles failed for the stationary test but complied with the pass by test (marked by triangles). 3 motorcycles failed for the pass by test but complied with the stationary test (marked by squares). This demonstrates the poor correlation between both tests and the need for a pass by roadside enforcement test.

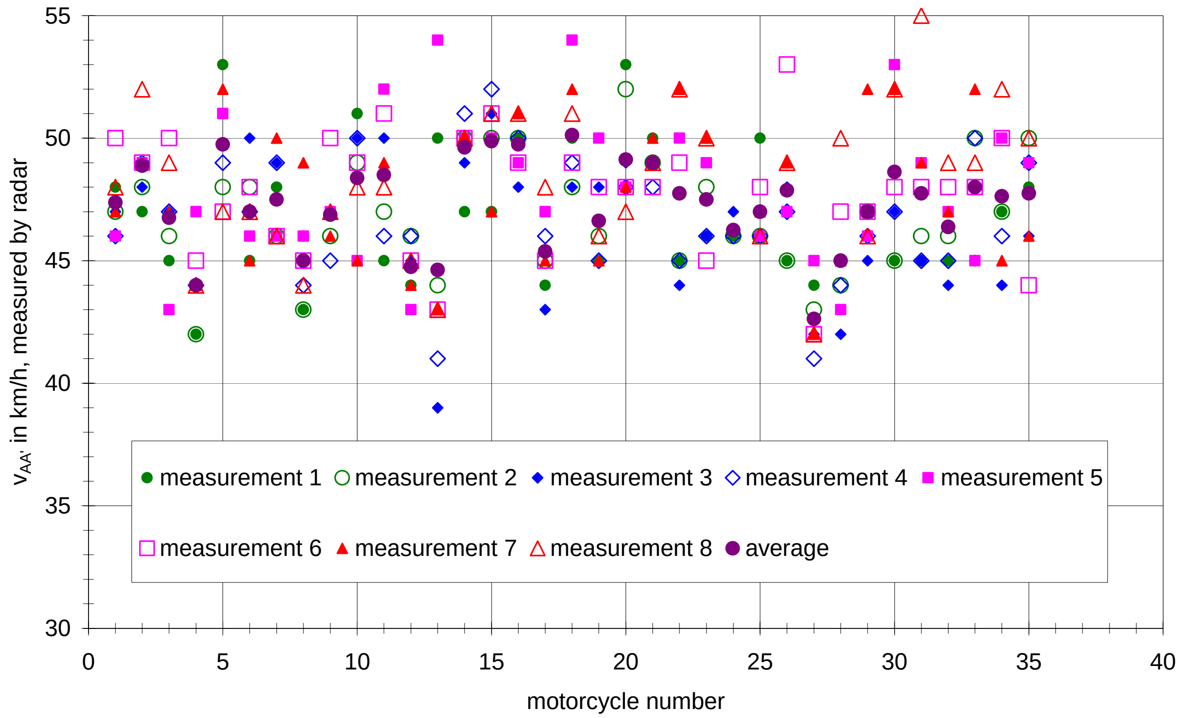

Figure 5: Variance of entrance speeds $v_{AA'}$ for the pass by noise measurements

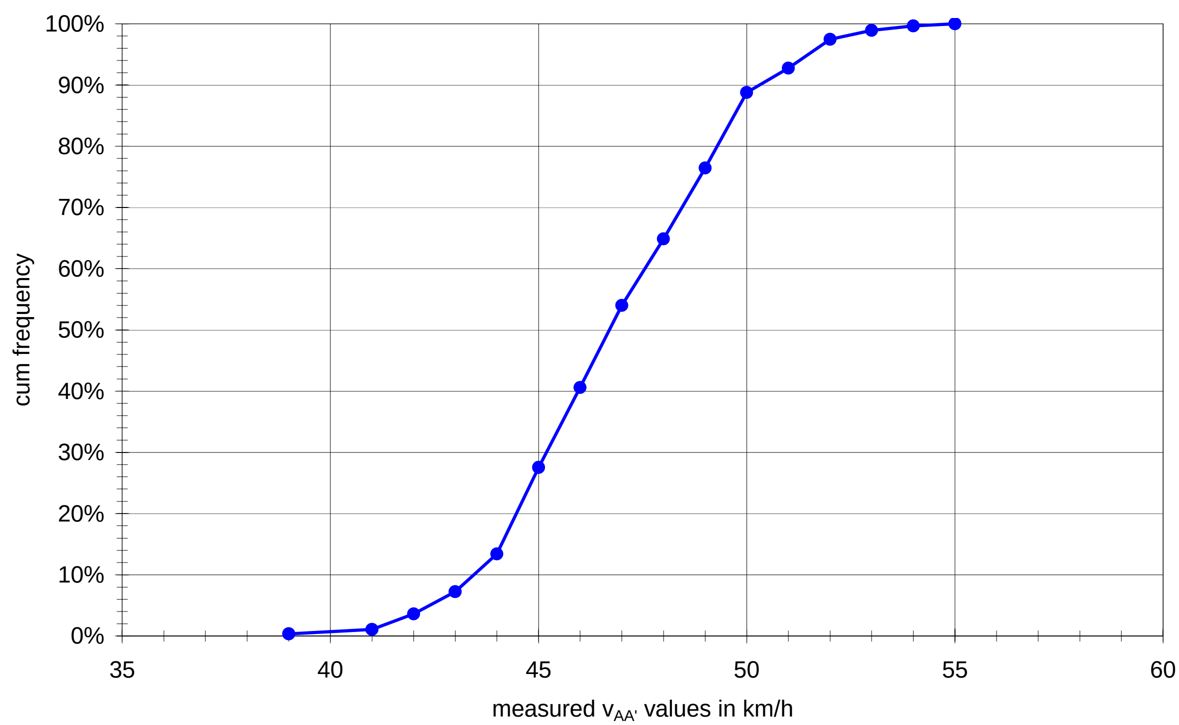

Figure 6: Cumulative frequency distribution of the $v_{AA'}$ values

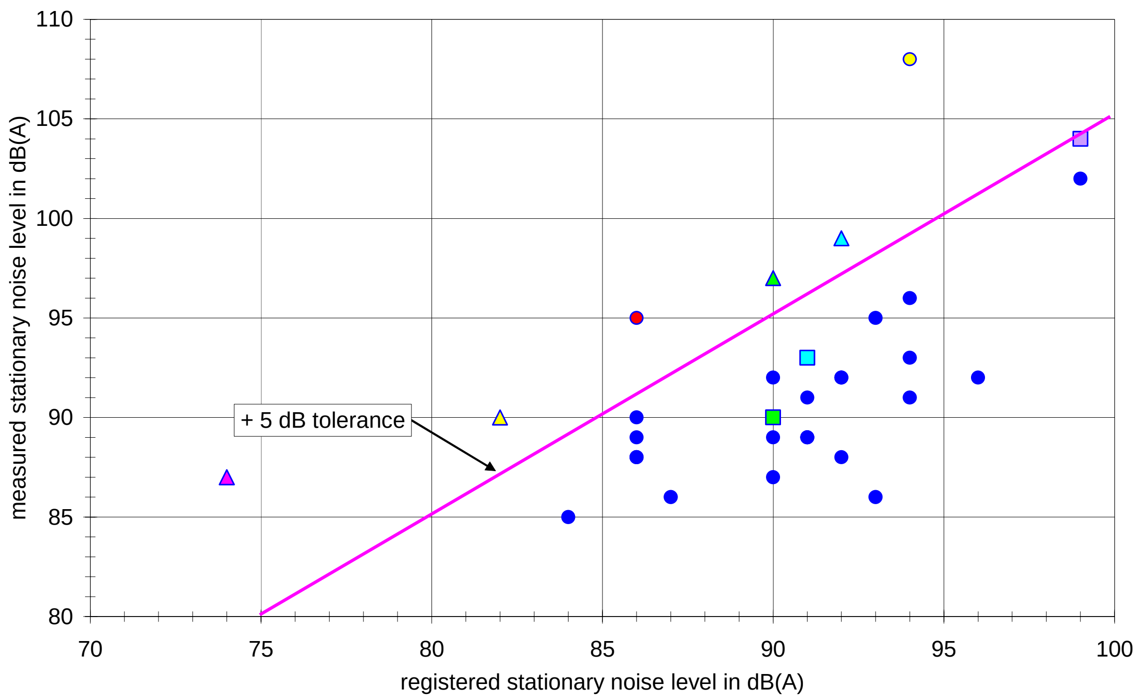

Figure 7: Comparison of measured and registered levels for the stationary test

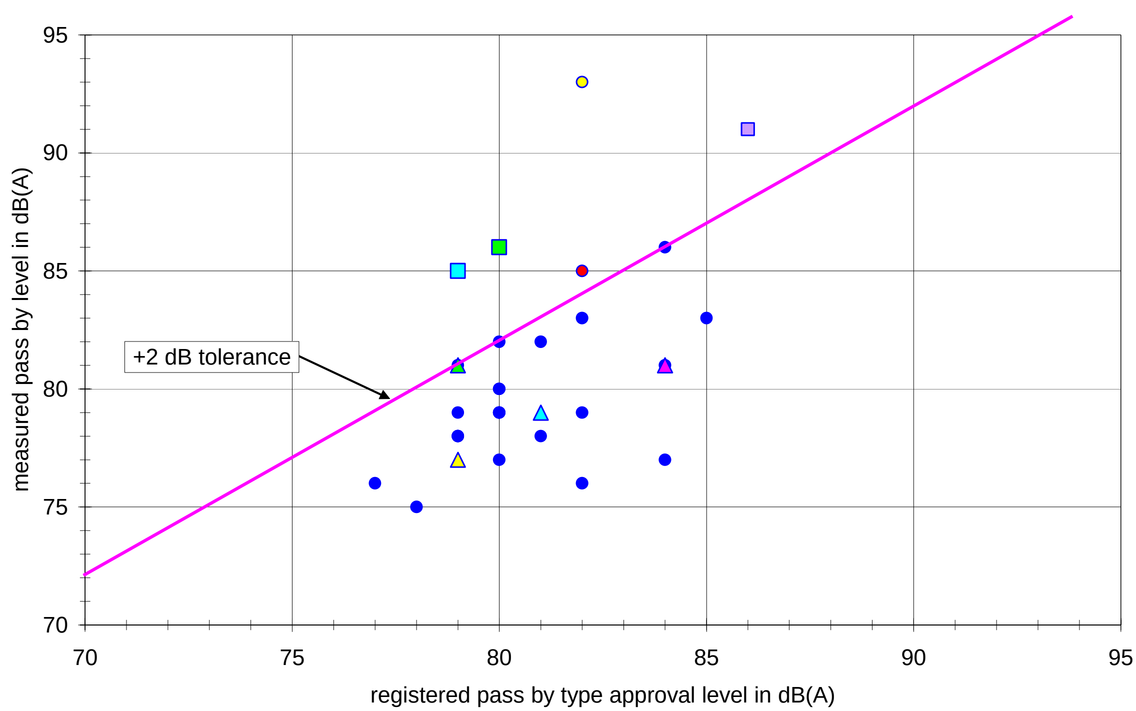

Figure 8: Comparison of measured and registered levels for the pass by test

2 Layout for a roadside pass-by enforcement test

Roadside enforcement tests cannot be performed under ideal conditions and with highly advanced measurement techniques. Therefore the following requirements have to be considered for the development of such test:

1. Test track design as for type approval tests (length, acceleration starting point at AA', microphone positions at PP', end of acceleration at BB'), but less stringent requirements for road surface, test site and ambient noise.

2. Test shall be vehicle speed based in order to avoid engine speed measurements. In order to keep the test as simple as possible the vehicle's speedometer should be used for speed control. The speed range covered shall be low for safety and handling reasons.

3. Test must be applicable for all transmission types.

The specification of minimum requirements must be based on extensive practical tests including a wide variety of test sites and vehicles. The tolerance to be applied to such measurement results is correlated with the test site specifications and inaccuracies caused by the use of the vehicle's speedometer.

A roadside enforcement test cannot be based on the ISO 362, part 2 procedure, because this is far too complicated and time consumptive. On the other hand, it seems also to be inappropriate to use the current R41 procedure for the test, because the vehicle speeds are too high.

It would be more appropriate to base the test conditions on the gearshift prescriptions that are used for test bench measurements within the WMTC procedure (Worldwide Harmonised Motorcycle Exhaust Emissions Certification Procedure). These gearshift prescriptions are derived from a gearshift analysis of motorcycle in-use driving behaviour data. Therefore, it is proposed to perform wide open throttle acceleration tests in 2. gear (for vehicles with manual transmission) with a starting speed $v_{AA'}$ that is identical with the WMTC shift speed during acceleration phases from 1. to 2. gear ($v_{1\text{->}2}$).

This shift speed is defined as follows:

$$v_{1\rightarrow 2} = (0.5753 \bullet e^{(-1.9 \bullet \frac{P_n}{m_k + 75kg})} - 0.1) \bullet (s - n_{idle}) + n_{idle}) \bullet \frac{1}{ndv_1}$$

Equation 1

Where

P_n is the rated power in kW,

m_k is the kerb mass in kg,

n_{idle} is the idling speed in min^{-1},

s is the rated engine speed in min^{-1},

ndv_1 is the ratio between engine speed in km/h and vehicle speed in min^{-1} in gear 1.

The roadside enforcement test for motorcycles with a manual transmission is then performed as follows:

The vehicle enters the line AA' with a constant speed calculated by using Equation 1. To make the test simple, this entrance speed should be stated in the registration document or something equivalent. A wide open throttle acceleration is then carried out until the rear of the vehicle passes the line BB'. The maximum noise level is measured during this acceleration process. The decision how many test are needed and how the final result is calculated should be based on the results of practical tests.

In order to get a feeling about vehicle speeds, accelerations and engine speeds during such a test (e.g. $v_{AA'}$, $n_{AA'}$, $v_{BB'}$, $n_{BB'}$) calculations were performed with those vehicles that have been used for the validation of the WMTC gearshift calculation tool. The corresponding database contains technical data like engine capacity, rated power, rated speed, idling speed, kerb mass and the transmission ratios for each gear for 81 motorcycles with power to mass ratios above 25 kW/t and manual transmissions. The range is 31 kW/t to 474 kW/t.

In order to make the calculations as realistic as possible, the calculations of vehicle and engine speeds during the wide open throttle pass by were based on a normalised power curve as shown in Figure 9. The polynomial approximation function, shown in this figure, was used to calculate the power that is available at any given engine speed (P_max = Pnorm*Pn). The driving resistance power (Pres) needed for constant speed driving was calculated using the prescriptions for the test bench settings within the WMTC procedure.

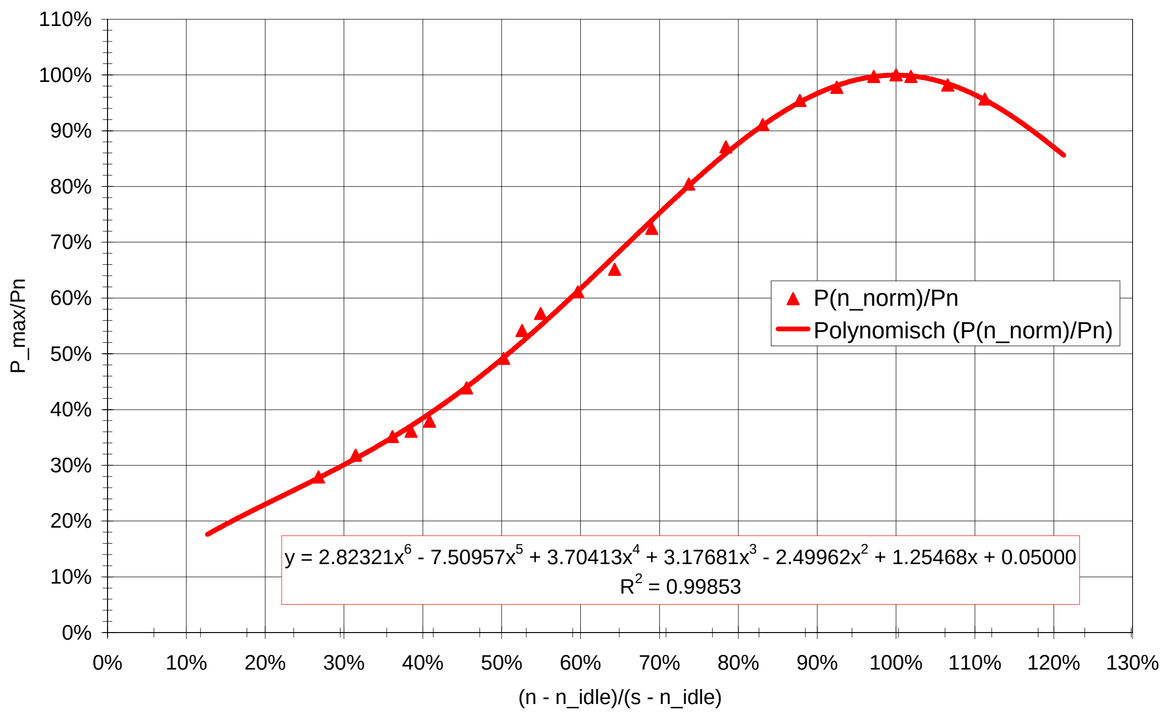

Figure 9: normalised power at full load versus normalised engine speed

$$P\_res = (a_1 * v + a_3 * v^3) / 3600 \qquad \text{in kW}$$

Equation 2

Where

v is the vehicle speed in km/h,

a_1 is the rolling resistance force in N, a1 is a function of the vehicle mass m in kg and calculated as follows:

$$a_1 = 0.088 * m$$

Equation 3

a_3 is the aero drag coefficient in N/(km/h)² and is also approximated as function of the vehicle mass m in kg :

$$a_3 = 0.000015 * m + 0.02$$

Equation 4

The wide open throttle acceleration a_max was then calculated from the difference between the available power Pmax in kW and the power Pres in kW, needed for constant speed driving:

$$a\_max = (P\_max - P\_res) * 3600 / (m*v*kr) \text{ in m/s}^2$$

where

m is the mass in kg,

v is the vehicle speed in km/h,

kr is a factor that takes into account the inertial resistances of the drivetrain during acceleration,

kr is set to 1.1, the vehicle mass is the kerb mass of the motorcycle + 75 kg for the driver.

Examples for vehicle speed, acceleration and engine speed versus distance are shown in Figure 10 to Figure 15. The distance 0 is the beginning of the acceleration (AA'), 10 m represents the microphone sphere (PP') and 20 m the end of the test track (BB').

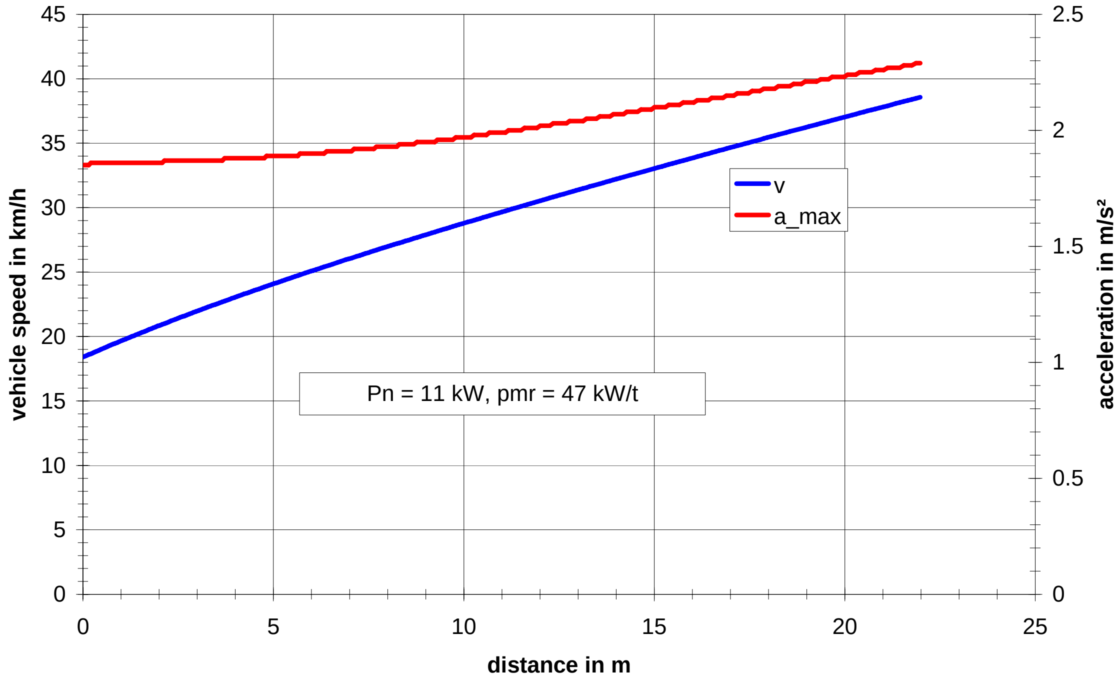

Figure 10: Example for the calculation results of a wide open throttle acceleration pass-by test for a low powered motorcycle

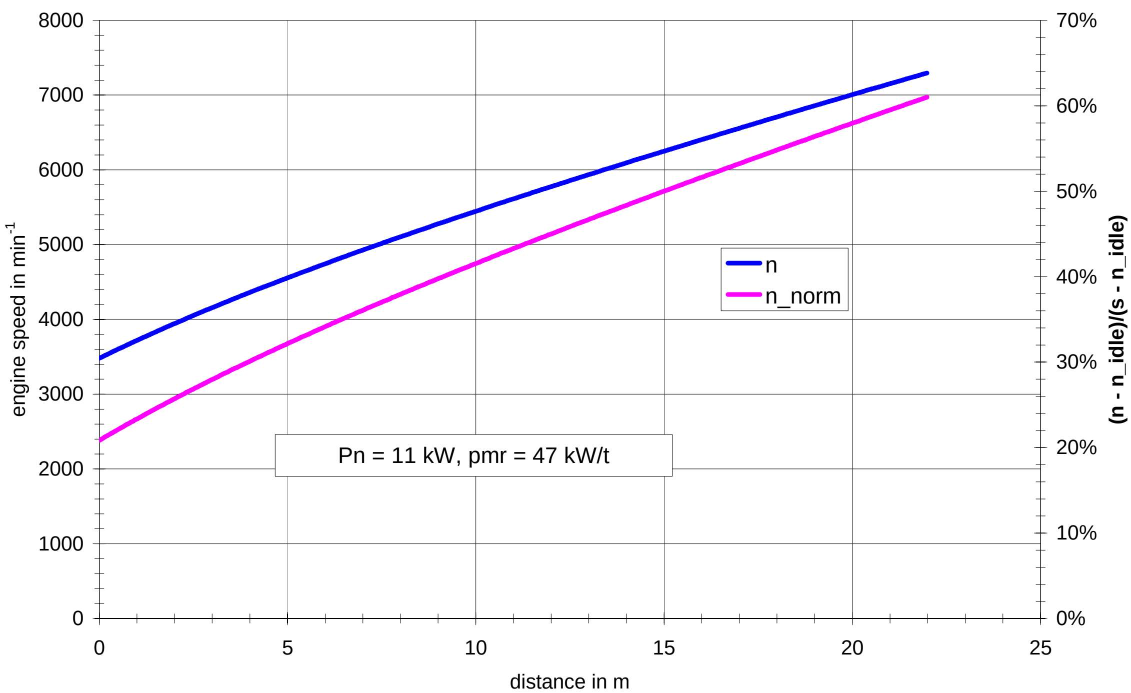

Figure 11: Example for the calculation results of a wide open throttle acceleration pass-by test for a low powered motorcycle

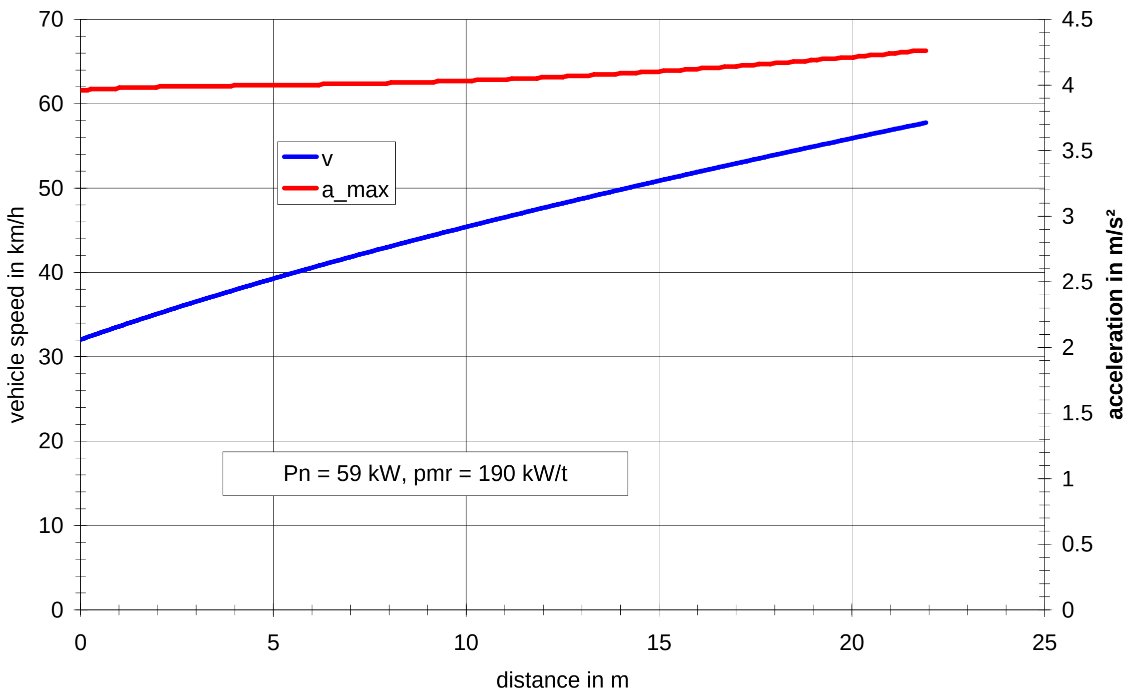

Figure 12: Example for the calculation results of a wide open throttle acceleration pass-by test for a medium powered motorcycle

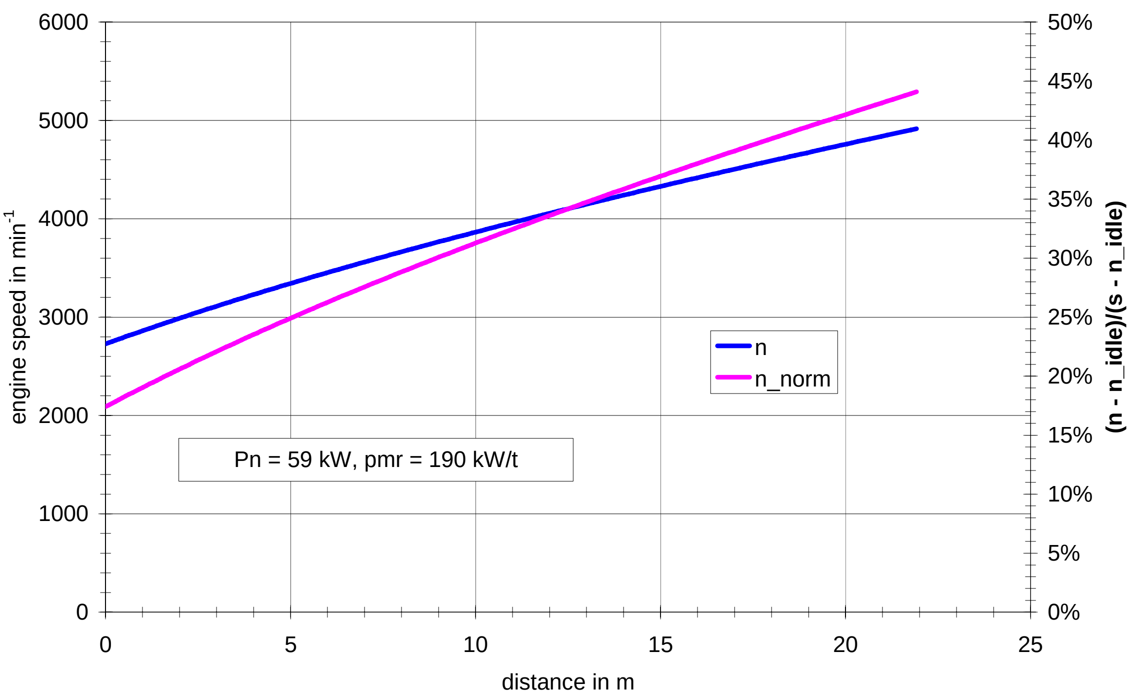

Figure 13: Example for the calculation results of a wide open throttle acceleration pass-by test for a medium powered motorcycle

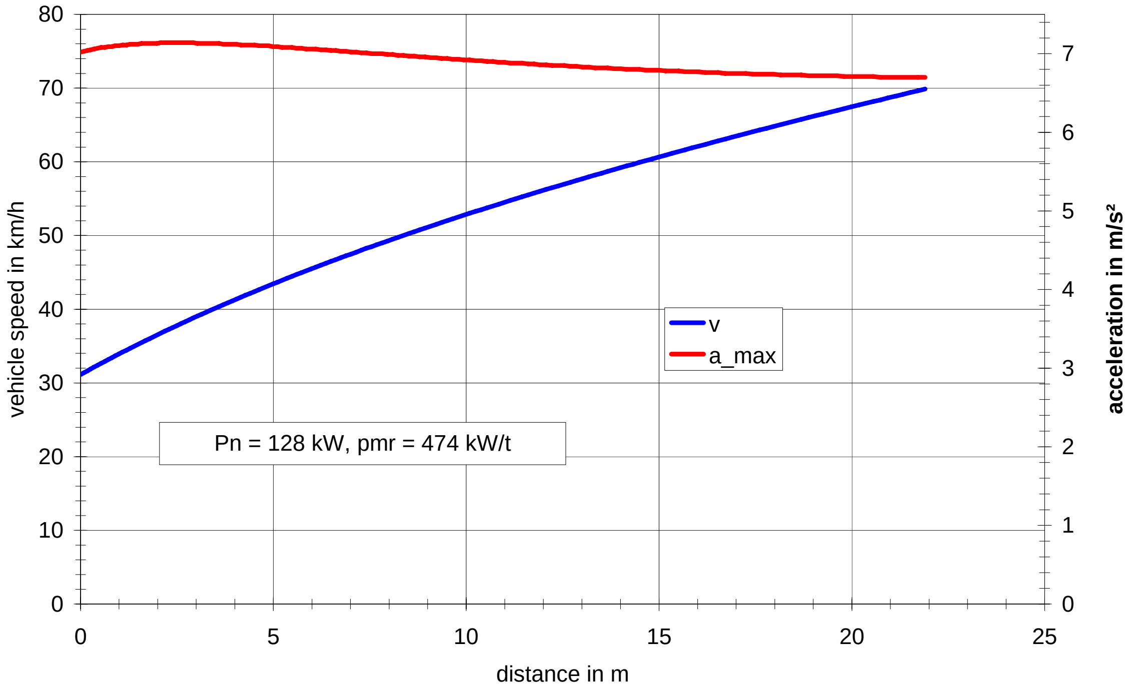

Figure 14: Example for the calculation results of a wide open throttle acceleration pass-by test for a high powered motorcycle

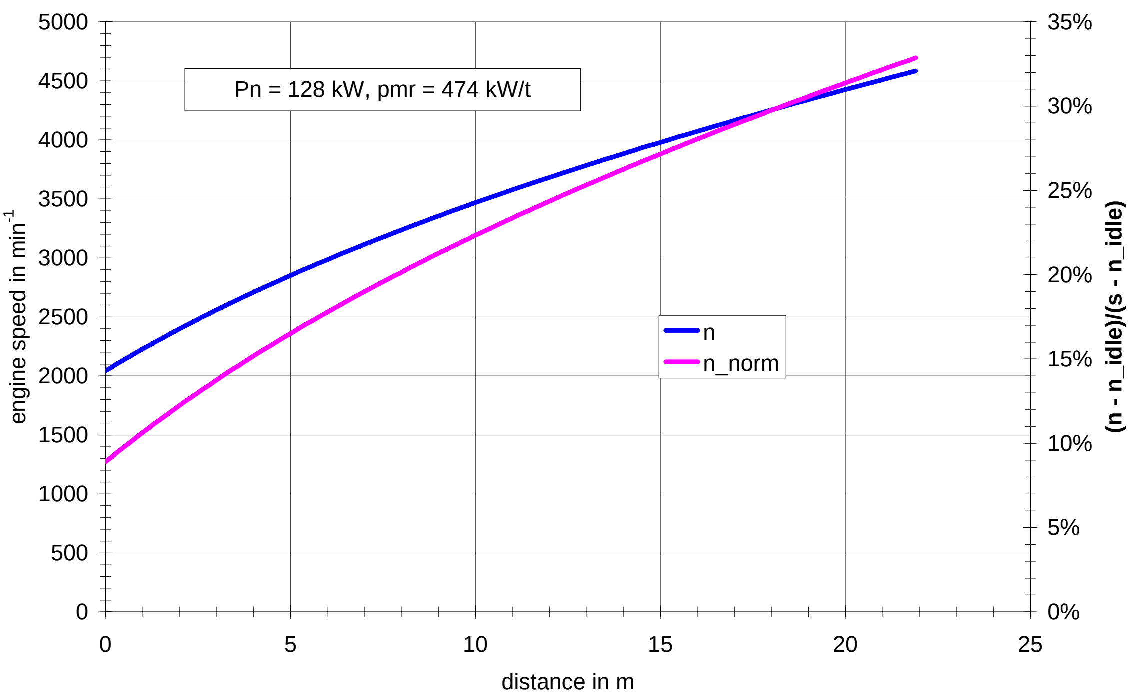

Figure 15: Example for the calculation results of a wide open throttle acceleration pass-by test for a high powered motorcycle

In order to be able to assess the validity of the pass-by calculations similar calculations were made for the current ECE R41 measurement method, but only for motorcycles whose entrance speed was 50 km/h. The results are shown in Figure 16 and Figure 17, plotted versus power to mass ratio. For 14 vehicles of the calculation sample measurement results of the current ECE R41 measurement method are available. These measured values are also shown in the above mentioned figures and are directly compared to the calculated values in Figure 18. Four of the 14 vehicles show significantly high differences between calculated and measured values. The measured values are always lower than the calculated values. These vehicles are highlighted in yellow and light blue in all above mentioned figures. For the rest of 10 vehicles calculated and measured values correlate quite well. Therefore and because some measured values were higher than the calculated values, it was considered unnecessary to adjust or correct the calculated acceleration values.

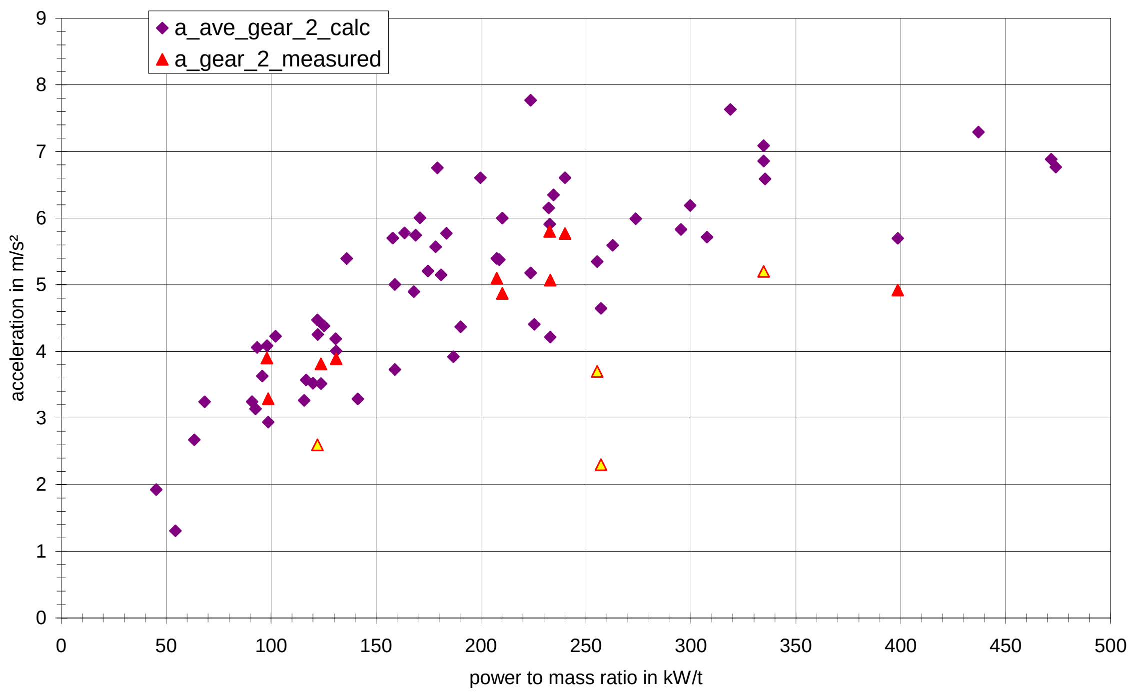

Figure 16: Measured and calculated acceleration values for $v_{AA'}$ = 50 km/h in 2. gear

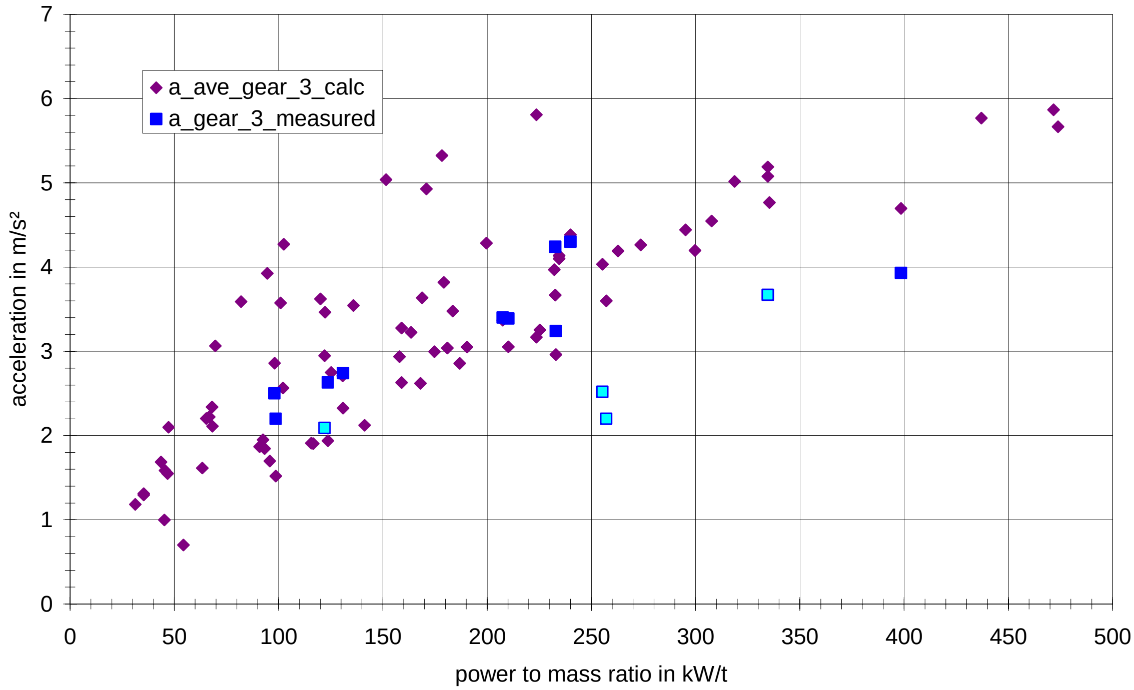

Figure 17: Measured and calculated acceleration values for $v_{AA'}$ = 50 km/h in 3. gear

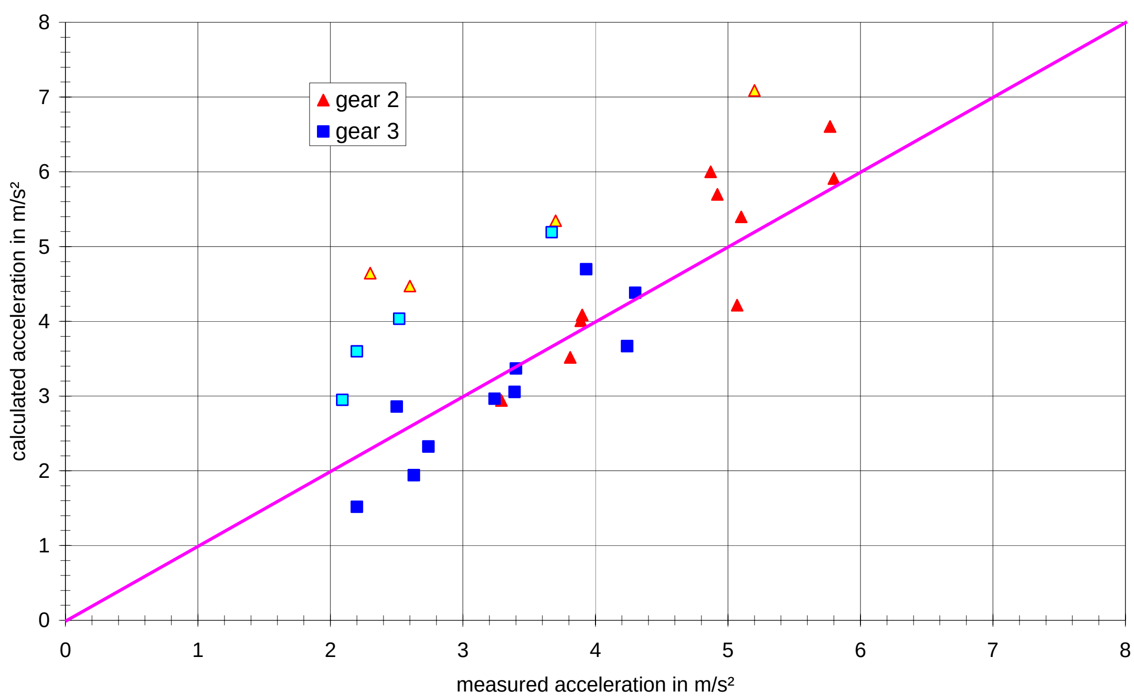

Figure 18: Direct comparison of measured and calculated acceleration values for $v_{AA'}$ = 50 km/h for 14 vehicles

From the calculation results in 2. gear with entrance speeds equal to the WMTC shift speed $v_{1->2}$ vehicle speeds and engine speeds at AA' and BB' and average acceleration values between AA' and BB' plus vehicle length were picked up for all 81 vehicles and plotted versus the power to mass ratio values (see Figure 19 and Figure 20). The vehicle length was set to 2 m. The vehicle speeds at BB' follow pretty good a logarithmic trend line. The approximation function for $v_{AA'}$ can be used to specify the entrance speed for motorcycles with automatic transmissions.

Below 200 kW/t very high engine speeds are reached at BB' in some cases (up to rated speed, see Figure 20). They are even higher than the borderline proposed for ASEP tests (n_norm_max_ASEP). It has to be further investigated, if this is due to the inclusion of some trial motorcycles or weaknesses in the calculation approach. But apart from this the results suggest that this could be a good concept for roadside enforcement tests.

To avoid cycle bypass measures or to make them at least more difficult, the roadside enforcement test should be complemented by additional acceleration requirements. The specifications of such requirements should be based on practical test results.

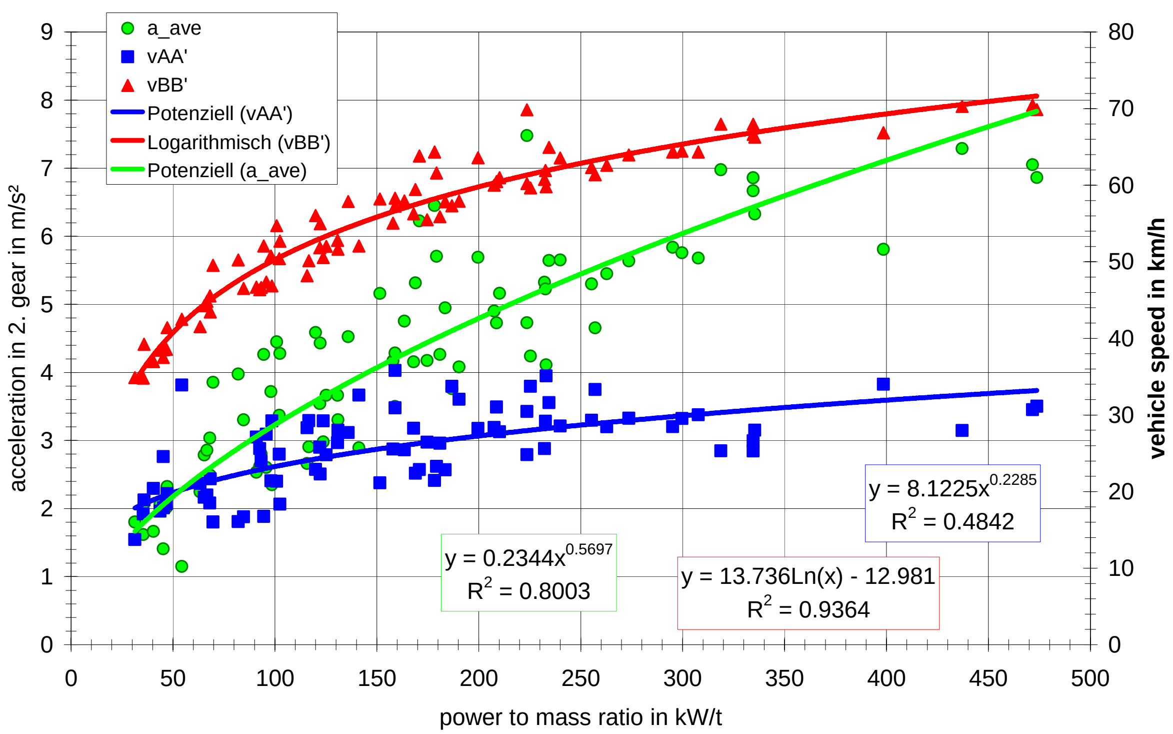

Figure 19: Vehicle speeds at AA' and BB' and average acceleration values versus power to mass ratio

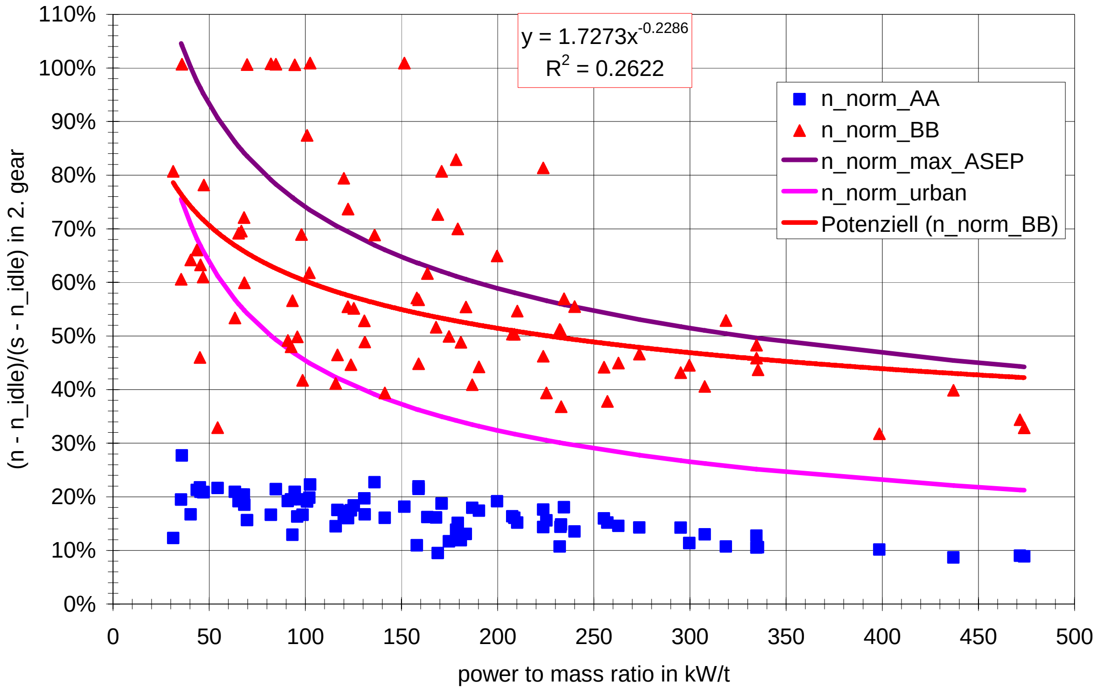

Figure 20: Normalised engine speeds at AA' and BB' and average acceleration values versus power to mass ratio

3 Draft test protocol for roadside enforcement tests

The following test protocol is proposed for upcoming test campaigns:

- In case of manual transmission choose 2. gear for the tests, in case of automatic transmissions choose gear selector position (if any) that ensures highest acceleration.
- vehicle entrance speed $v_{AA'}$:
  - o manual transmission:

$$v_{AA'} = (0.5753 \bullet e^{(-1.9 \bullet \frac{P_n}{m_k + 75kg})} - 0.1) \bullet (s - n_{idle}) + n_{idle}) \bullet \frac{1}{ndv_1} \text{ in km/h}$$

Equation 5

  - o automatic transmission:

$v_{AA'} = 8{,}1225 * (P_n / (m_k + 75\text{ kg}))^{0{,}2285}$ in km/h

Where

P_n is the rated power in kW,

m_k is the kerb mass in kg,

n_{idle} is the idling speed in min-1,

s is the rated engine speed in min-1,

ndv_1 is the ratio between engine speed in km/h and vehicle speed in min^{-1} in gear 1.

- Perform 4 wide open throttle acceleration tests with $v_{AA'}$, measure Lmax during the pass-by at each side of the vehicle. Monitor the background noise.
- Perform these tests twice, once with $v_{AA'}$ indicated by the exact type approval measurement equipment and once with $v_{AA'}$ indicated by the vehicle's speedometer as speed control, but the exact equipment still working in order to enable the determination of the deviations.
- Ideally those test have to be carried out on a certified ISO test track and on a rural road.
- Other parameters to be measured:
  - Vehicle speeds at AA', PP' and BB'
  - Engine speeds at AA', PP' and BB'
  - If possible, measure noise emission, vehicle speed and engine speed between AA' and BB' continuously.