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MEASUREMENT OF THE AIRBORNE NOISE AND THE NOISE AT THE OPERATOR'S POSITION EMITTED BY THE ECOTRAC V-1033 F FOREST TRACTOR

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The paper reports on the measurement procedure and results of measurements of the airborne noise emitted by the ECOTRAC V-1033 F forest tractor. The measurements were carried out in accordance with the International Standards ISO 4872 and 362 for the stationary test condition. The paper further reports on noise measurements at the tractor operator's position conducted in accordance with the International Standards ISO 5131 and 6394. All measurements were performed using the Bruel & Kjaer 4165 type microphone and the 2209 type sound level meter from the same manufacturer. According to ISO 4872, 6393 and 362 the noise level did not exceed the limit values. However, the noise level at the operator's position at full load and at nominal load exceeded the limits. Measures to be undertaken should aim at protecting the driver and improving the cab characteristics.

Key terms:
driver's cab, noise level, operating conditions

Meeting requirements for the protection of the driver and the immediate environment is equally important for both urban traffic road vehicles and earth-moving vehicles. In view of this, efforts are made to develop and improve vehicles. When developing the ECOTRAC V-1033 F forest tractor special attention was paid to protecting against airborne noise both the operator and the workers working in the immediate proximity of the vehicle for most of the working hours.

METHOD AND EQUIPMENT

Measurements were performed in order to establish the sound pressure level at the operator's position and in the immediate environment of the ECOTRAC V-1033 F with the prototype driver's cab. The basic technical characteristics of the ECO TRAC V-1033 F: manufacturer: Tvornica traktora Bjelovar, year of production: 1992, wheel distance: 1260 mm, shaft distance: 1900 mm, tractor length: 4400 mm, outer turning radius: 3500 mm, weight: 1940 kg, power: 33 kW, torque: 153 Nm at 1600 min^{-1}, displacement: 2826 cm^3, number of transmission gears: 8 forward and 2 reverse.

Measurements of the airborne noise emitted by the tractor were conducted in accordance with the International Standards ISO 4872, 6393 and 362, whereas the noise level at the operator's position was measured in accordance with the International Standard ISO 5131. All measurements were performed on Vučjak, on a plateau free of vegetation, close by a forest road as shown in Figure 1.

Measurements were made using the Bruel & Kjaer 4165 type microphone and the 2209 type sound level meter of the same manufacturer. The measurement of the noise emitted by the tractor was conducted in accordance with the International Standard ISO 4872, B-Annex.

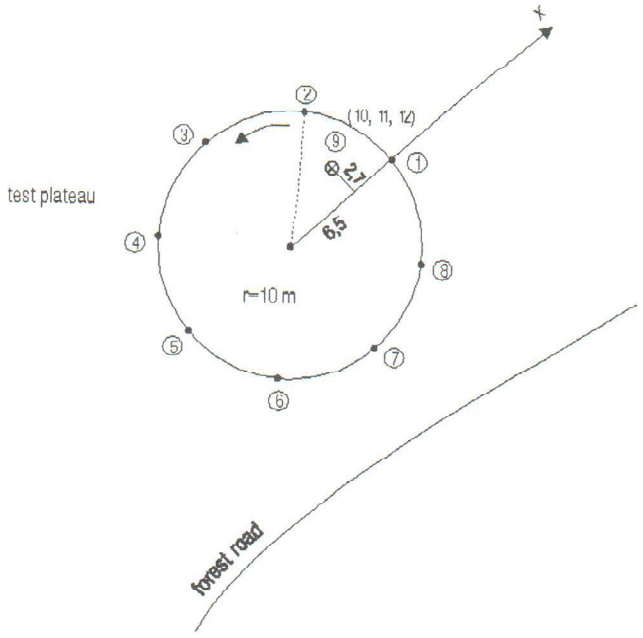

Figure 1 *Test site sketch*

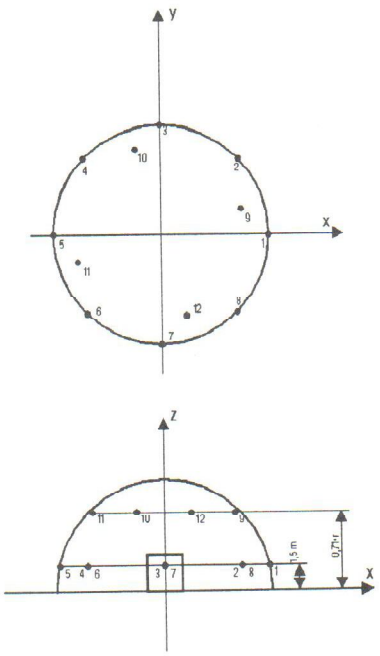

Figure 2 *Microphone position at noise measurement in accordance with ISO 4872*

The microphone positions (measurement positions) are shown in Figure 2. For measuring noise level at measurement positions No. 9, 10, 11 and 12 the microphone was mounted on a 7.1 m long ground-fixed stake. The microphone was located at the meaurement position No. 9. The measurement positions No. 10, 11 and 12 at the height of 7.1 m were obtained by moving the tractor around, not by relocating the microphone. In accordance with the ISO 4872, the coordinates of the measurement position No. 9 were 9 (6.5; 2.7).

During the measurement of the airborne noise emitted by the ECOTRAC V-1033 F the tractor was moving on a macadam forest road with no obstacles likely to reflect a major sound within a radius of 50 m.

The distance from the microphone position to the reference line on the test track was 7.5 m (minimum distance). The microphone was located 1.2 m above the ground level, on both the right and the left sides of the vehicle as shown in Figure 3.

The measurement of the noise level at the operator's position was conducted in accordance with the ISO 5131 recommendations, i.e. with all cab doors and windows closed and the ventilating fans running at maximum setting. The microphone was placed at the side giving the highest sound level as determined during a preliminary check, and it was located 200±20 mm to the side of the

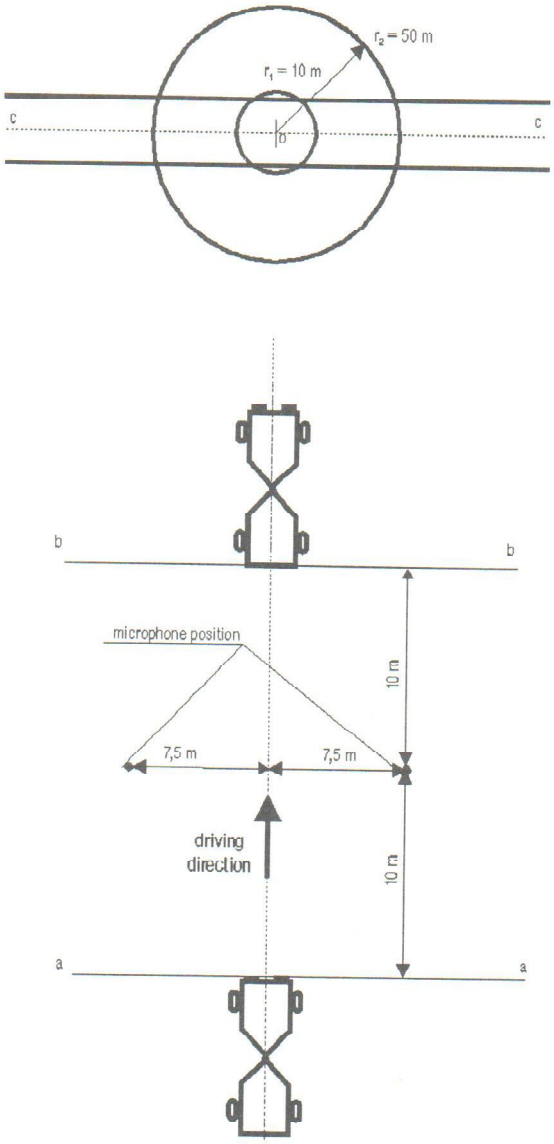

Figure 3 *Microphone positions at noise level measurements in accordance with ISO 362*

central plane of the operator's head. The microphone centre was 790±20 mm above the seat reference point. The seat reference point was determined in accordance with the ISO 3462.

RESULTS

The measurement conditions specified for the machine according to the International Standards were fully taken into consideration.

Noise measurement in accordance with ISO 6393

Measurements were performed at 12 positions (see Figure 2) for three different operating conditions of the engine: at idling, at racing (maximum rpm) and at approximately full nominal load.

The approximately full nominal load of the engine was obtained by breaking, whereby neither the rpm, nor the torque were measured. The results of measurements are given in Table 1.

Table 1 *Measurement results of the noise emitted by the ECOTRAC V-1033 F forest tractor in accordance with ISO 4872 and 6393*

Measurement position	Noise level, dB(A) Operating condition		
	I*	FL	AFNL
1	63.0	82.0	77.0
2	63.5	82.5	81.0
3	62.0	79.0	78.0
4	58.0	77.0	74.0
5	53.5	71.5	68.0
6	59.5	78.0	76.0
7	62.5	81.5	78.0
8	63.0	82.5	80.0
9	64.5	83.0	81.5
10	62.0	81.0	76.0
11	59.5	78.5	75.5
12	65.0	84.0	81.5

* I - idling; FL - racing (maximum rpm); AFNL - approximately full nominal load

The measurement conditions were as follows: barometric pressure: 1054 hPa, relative humidity: 61.5% at the beginning and 59.5% at the end of the measurement, air temperature: 10 °C at the beginning and 14 °C at the end of measurement, wind velocity: negligible air movement, measurement beginning time: 10.47, measurement completing time: 12.12, background noise: 40 dB(A).

The maximum noise level, 84 dB(A), was measured at the measuring position No. 12 at racing. It can be concluded that the noise emitted by the ECOTRAC V-1033 F did not exceed the noise level limits.

Noise measurement in accordance with ISO 362

Measurements were performed at two positions (points) on both, the left and the right sides of the test track. During measurement the tractor was running at a stable speed. The measurements were made at three load conditions of the engine: no-load-condition, half-load condition and an approximately full nominal load condition.

The maximum sound pressure levels indicated during the passage of the vehicle between the two lines A-A and B-B were noted as the measurement result. The running speed of the tractor for all three load conditions was maintained at approximately 3/4 of the speed at which the engine produces its net maximum power.

The test conditions were as follows: barometric pressure: 1054 hPa, relative humidity: 58.5%, air temperature: 14 °C, wind velocity: negligible air movement, measurement beginning time: 12.30, measurement completing time: 12.51, background noise: 39 dB(A) at measurement positions 1, 2 and 3, 35 dB(A) at measurement positions 4, 5 and 6.

The measurement results are given in Table 2. The measurements were performed using the time weighting characteristics "F" (fast).

Table 2 *Measurement results of the noise emitted by the ECOTRAC V-1033 F in accordance with ISO 362*

Measurement No.	Microphone position	Operating condition	Passage time (s)	Average speed (km/h)	Noise level dB(A)
1	L	NL	9.15	2.18	80.5
2	L	HL	9.05	2.21	83.5
3	L	AFNL	7.00	2.85	85.0
4	R	NL	9.10	2.20	81.0
5	R	HL	9.35	2.14	82.0
6	R	AFNL	6.95	2.88	85.0

L - left of the running direction; R - right of the running direction
NL - no-load; HL - half-load; AFNL - approximately full nominal load

The results show that the noise level did not exceed the noise limits at any measurement position and under any operating condition.

Noise measurement at the operator's position in accordance with ISO 5131

Measurements were performed using the time weighting characteristics "S" (slow). Each reading was taken over a five-second period of stabilized running. For each operation condition three measurements were made and the arithmetic mean value of the three readings was calculated. The results of measurement are given in Table 3. The measurements were conducted for the three recommended operating conditions of the engine: at idling, at racing (maximum rpm) and at approximately full nominal load.

Table 3 *Measurement results of the noise emitted by the ECOTRAC V-1033 F at the operator's position in accordance with ISP 5131*

Measurement No.	Operating condition	Noise level, dB(A)			Mean values dB(A)
		1	2	3	
1	I	82.5	82.5	82.25	82.42
2	FL	100.5	100.5	101.0	100.67
3	AFNL	98.5	98.0	99.0	98.0

I - idling; FL - full load; AFNL - approximately full nominal load

The approximately full nominal load condition of the engine was performed by breaking. Measurements were performed under the following conditions: barometric pressure: 1054 hPa, relative humidity: 58.5%, air temperature: 14 °C, wind velocity: negligible air movement, measurement beginning time: 10.47, measurement completing time: 12.12. Within the radius of 20 m around the centre of the measuring site the space was free of any reflecting objects. The sound level meter was calibrated at the beginning of the measurement.

Preliminary measurements: noise level to the operator's left: 82.5 dB(A), noise level to the operator's right 82.5 dB(A), the microphone was placed on the left side.

Table 3 shows that the noise level at full load and at nominal load exceeded the noise level limits. Therefore the octave band sound pressure analysis for the full load (maximum rpm) was made, as the conditions required for the frequency analysis at nominal load were not fulfilled. The frequency analysis results are shown in Figure 4.

The full and the broken lines refer to the maximum rotational frequency (rpm) at full load and at idling. From the diagram in Figure 4 it can be seen that the noise level exceeded the noise limits (N 85) in eight octave bands. It is therefore necessary to undertake measures to protect the driver, or to improve the cab characteristics.

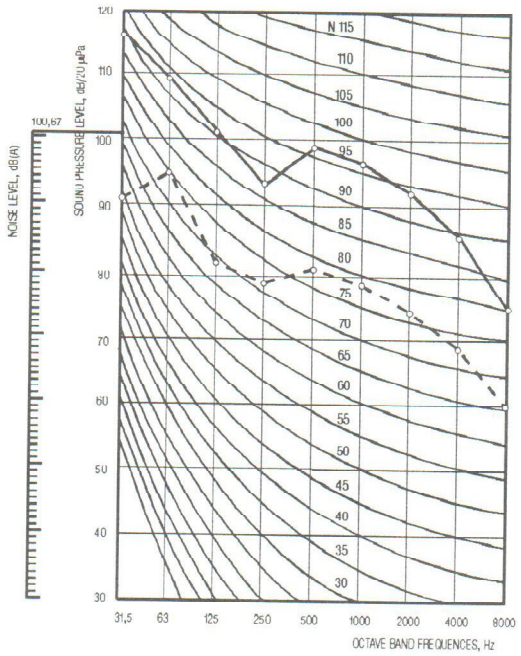

Figure 4 *Octave band sound pressure levels (full line – full load; broken line – idling)*

CONCLUSION

Based on analysis of the measurement results the following conclusions may be drawn: the airborne noise emitted by the ECOTRAC V-1033 F and measured in accordance with the International Standards ISO 4872, 6393 and 362 did not exceed the noise limits in any of the three operating conditions. It is interesting to note that the noise level measured at the operator's position exceeded the noise limit at both, the full load and the approximate nominal load of the engine. Measures should be therefore taken to protect the driver.

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Sažetak

BUKA U KABINI I U OKOLINI TRAKTORA ECOTRAC V-1033 F

Za vozila koja se kreću izvan putova podjednako je bitno udovoljavanje kriterijima koji se odnose na zaštitu vozača i neposredne okoline, kao i za vozila koja se kreću u urbanoj sredini. U sklopu razvoja šumskoga zglobnog traktora ECOTRAC V-1033 F posvećena je pažnja zaštiti od buke vozača traktora i radnika koji tijekom radnog vremena duže borave u njegovoj neposrednoj blizini. Obavljena su iscrpna mjerenja da se utvrdi razina zvučnog tlaka u okolini traktora i razina zvučnog tlaka u kabini, na mjestu vozača. Mjerenja su obavljena na traktoru s prototipnom kabinom. Razina buke koju traktor emitira u okolinu (stacionarni test) mjerena je u skladu sa standardima ISO 4872 i ISO 6393, dok je mjerenje buke pri ubrzavanju traktora obavljeno u skladu sa standardom ISO 362. U kabini traktora na mjestu vozača mjerenje buke obavljeno je prema ISO 5131 i ISO 6394. Za mjerenje je upotrijebljen mikrofon Brüler & Kjaer tip 4165 i zvukomjer istog proizvođača tip 2209. Mjerenja buke u stacionarnom testu tijekom triju različitih radova (prazni hod, maksimalni broj okretaja i približno nazivno opterećenje) pokazala su da ni u jednoj mjernoj točki i ni za jedan režim rada razina buke u okolini traktora nije prelazila granično dopuštene vrijednosti. Jednako je ustanovljeno i pri mjerenju razine buke pri ubrzavanju traktora. Rezultati mjerenja razine buke na mjestu vozača pokazali su da razina buke kako pri punoj brzini tako i pri nazivnom opterećenju prelazi granično dopuštene vrijednosti. Stoga je napravljena i oktavna analiza buke pri punoj brzini. Uočeno je da čak u osam oktava razina buke prelazi granično dopuštene vrijednosti (N 85) te da je nužno provesti sanaciju kabine ili zaštitu vozača.

Ključne riječi:
kabina vozača, razina buke, uvjeti vožnje

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