

UDK 534.836

Zmanjševanje zunanjega hrupa družine vozil T8 na 78 dB (A)**Reduction of External Noise of T8 Vehicle Family to 78 dB (A)**

MOMIR LAZOVIĆ

Članek obravnava postopek izvedbe in rešitve v procesu zmanjševanja zunanjega hrupa na prototipu TAM 141 T8 B oziroma družini vozil T8. Primarni ukrepi so vzeti kot nespremenljivke, ki jih je nujno treba upoštevati pri izbiri sklopov in komponent, da bi dobili ugodnejše začetne pogoje pri zmanjševanju hrupa z dodatnimi ukrepi. Določili smo najbolj sprejemljive obloge motorja, menjalnika in kabine ter ustrezne dušilnike hrupa zavornih agregatov, ki so omogočili doseganje nivoja hrupa 78 dB(A) med vožnjo in 72 dB(A) za zavorne aggregate pri mirovanju vozila. Temperaturni trajnostni test, opravljen med vleko vozila in pri normalni uporabi, je dal pozitivne rezultate, ker sta bila izpolnjena oba kriterija: stopnja hrupa in delovna temperatura motorja ter menjalnika. Vozila družine T8 popolnoma ustreza Smernicam EWG/EGS 92/97, november 1992.

This paper deals with a new approach to the realisation and solution of the problem of external noise reduction in TAM 141 T8 B vehicles and/or the T8 vehicle family. We took primary measures as constants essential for the selection of the assemblies and components. We thus achieved better initial conditions for reduction of noise by secondary measures. We determined the most acceptable antinoise shields for the engine, gearbox and cab, as well as suitable noise absorbers of brake units allowing a 78 dB(A) noise level achieved during operation of the vehicle, and 72 dB(A) for brake units with the vehicle at standstill. Endurance temperature test made when towing the vehicle and during its operation showed positive results, since both criteria — noise reduction and the working temperature of the engine and gearbox — were met. The T8 family fully meets the requirements of the EEC 92/97 Regulations (November 1992).

O UVOD

Želja po povečani varnosti, zaščiti okolja in splošnem tehnološkem napredku sili vse proizvajalce avtomobilov, da uveljavljajo vedno strožje mednarodne predpise, to so pravilniki: ECE R51, ECE R 49/02, ECE R 24 [1]. Nenehno iskanje novih konstrukcijskih in tehnoloških rešitev pri snovanju, konstruiranju in proizvodnji tihih motornih vozil je vplivalo na pomembne spremembe konstrukcije motorja in njegovih podsistemov. Upoštevajoč priporočila raziskovalcev, ki izhajajo iz primarnih ukrepov (motor: mehanski hrup in hrup zgorevanja, hrup sesanja in izpuha, ventilator in polnilnik tlachenega zraka, kompresor itn., transmisija: menjalnik, kardanska gred, pogonska prema, pnevmatike, zavorni sistem, obes kabine itn.) so bili izbrani sklopi in komponente, ki so najbolje izpolnjevali zahteve za zmanjševanje hrupa z uporabo dodatnih ukrepov [2], [3], [4]. Ti so bili podlaga za zmanjševanje zunanjega hrupa pri programu vozil T8. Izdelano je bilo več modelov z zaščito pred hrupom, narejeni so bili številni testi in meritve hrupa med vožnjo, pri mirovanju vozila

O INTRODUCTION

The tendency to increase safety, improve environmental protection and boost industrial development, in general forces vehicle manufacturers to observe ever stringent international regulations, such as ECE R51, ECE R 49/02, ECE R24 [1]. A constant search for new design and technological solutions in relation to conceiving, engineering and production of »silent« motor vehicles has produced major changes in design of an engine, its assemblies, transmission system, tyres and other vehicle assemblies. Considering the recommendations of researchers, made on the basis of primary measures (engine: mechanical noise and noise produced during combustion, intake/exhaust noise, fan and turbocharger, compressor, etc.; transmission: gearbox, propeller shaft, drive axle, tyres, braking system, cab suspension, etc.), such assemblies and components have been chosen as best meet the requirements for noise reduction on the T8 vehicle family. Several models of noise encapsulation with a view to reducing external noise have been made, and endurance temperature tests conducted in use and under special operating conditions. We sought the best ratio between the design and encapsulation,

ter izvedeni trajnostni temperaturni testi v posebnih razmerah. Iskali smo tudi najboljše razmerje med konstrukcijo protihrupne zaščite, uporabljenih dušilnikov zvoka, temperaturne obremenitve prizadetih sklopov in komponent ter stopnjo hrupa. Izbrana je bila najugodnejša rešitev, ki hkrati izpoljuje več kriterijev, nazadnje izbrani motor je izpolnjeval kriterij emisije izpušnih plinov po ECE R 49/02 (Euro 1), vozilo pa emisijo hrupa 78 dB(A) po StVZO 49, in 1967 KDV 8b. Izdelan je bil prototip vozila TAM 141 T8 B, ki izpoljuje obe zahteve.

1 OSNOVNA IZHODIŠČA

Upoštevano je bilo pravilo razvoja, da nadaljujemo delo pri končani razvojni fazi nekega prototipa vozila, ki bo hkrati začetna faza novega prototipa. Temelj za razvoj protihrupne zaščite je bilo vozilo TAM 122 T8 B, v naslednji fazi vozilo 141 T8 B, z vodno hlajenim motorjem Cummins BT 5.9 145 10 in na koncu TAM 141 T8 B z motorjem Cummins B 5.9 — 145 10 z Euro 1. Optimirana sta bila sesalni in izpušni sistem, druge standardne rešitve pa smo obdržali: uležajenje motorja, ventilator, kompresor itn. Obdržali smo transmisijo: menjalnik, kardansko gred in pogonsko premo. V zavorni sistem z ABS so bili vključeni dušilniki zvoka, določene so bile tudi ustrezne nizkoprofilne pnevmatike. V prvi verziji protihrupne zaščite je bil zunanji hrup znižan z uporabo notranjih blatnikov in brez dodatne kabinske protihrupne zaščite motorja, v drugi pa je bila protihrupna zaščita na-rejena brez notranjih blatnikov in z dodatno zaščito motorja pod kabino. Vozilo je imelo tovorni prostor s ponjavo, kar je za hrup tudi pomembno.

2 METODOLOŠKI POSTOPEK IZVEDBE

Glede zastavljenega cilja izvedbe prototipa, načrtovanih razvojnih aktivnosti ter razpoložljivih virov, je bila določena naslednja metodologija dela [1]:

- določen in izbran je bil ustrezni motor (v našem primeru motor Cummins B5.9 — 145 10), ki je ustrezal obema kriterijema: izpušnim plinom (Euro 1) po ECE R 49/02 in čim nižjemu hrupu;
- vgrajen je bil motor in temu konstruiran ustrezni sesalni in izpušni sistem, z minimalnim hrupom in v mejah dovoljenega tlaka in protitlaka;
- preverjeni so bili parametri motorja: podtlaki v sesalnem sistemu in protitlaki v izpušnem sistemu, glede na značilnosti motorja;
- zasnovane, projektirane, konstruirane in izdelane so bile obloge motorja in menjalnika kot sekundarni ukrepi za zniževanje hrupa vozila;

noise absorbers applied, temperature loads of affected assemblies and components, as well as the noise level. The best solution chosen was that simultaneously meets several criteria. The selected engine fully met the exhaust gas emission criterion according to ECE R 49/02 (Euro 1) Regulation, and vehicle noise emission of 78 dB(A) in compliance with StVZO 49 and 1967 KDV 8b. A prototype of the TAM 141 T8 vehicle was made that meets both criteria required.

1 STARTING POINTS

In accordance with the development rule, we continued with the work from the final development phase of a certain vehicle prototype that, at the same time, provided the initial phase of a new prototype. We used the TAM 122 T8 B vehicle as the basis for development of noise encapsulation, the TAM 141 T8 B fitted with water-cooled BT5.9 — 145 10 Cummins engine was used in the next phase, and the TAM 141 T8 B with the B 5.9 — 145 10 (Euro 1) Cummins engine in the final phase. We optimised the intake/exhaust system and kept other standard solutions, such as engine suspension, fan, compressor, etc. The existing transmission system (gearbox, propeller shaft and drive axle) remained the same. Noise absorbers were integrated in the ABS (anti lock) braking system and relevant low-profile tyres were determined. With the first noise encapsulation version, the external noise was reduced by applying interior mudguards and without any additional cab engine noise protection. With the second version, the interior mudguards were omitted and additional engine protection under the cab was used. The vehicle had a truck cargo body with a tarpaulin which also greatly affected noise level reduction.

2 METHODOLOGICAL APPROACH TO IMPLEMENTATION

Considering the objective set for realisation of the prototype, implementation of planned activities and sources available, the following work methodology was determined [1]:

- to define and choose a suitable engine (in our case it was the B 5.9 — 145 10 Cummins engine) meeting the requirements of both criteria: exhaust gas emission (Euro 1) according to the ECE R49/02 Regulation, as well as ensuring the lowest noise level achievable;
- to mount the engine and design a matching intake/exhaust system ensuring minimum noise level with permissible pressure and back pressure still within limits;
- to check the engine parameters: sub-pressure in the intake system and back pressure in the exhaust system with regard to the engine characteristics;
- to conceive, plan, design, and make the engine gearbox shields as secondary measures for vehicle noise level reduction;

— določeni in izbrani so bili ustreznih dušilnikih hrupa zračnih ventilov zavornega sistema glede tlaka v zavorni instalaciji, lokaciji ventilov v zračnem delu zavornega sistema, oblike in dimenzijs dušilnikov ter stopnje dušenja hrupa;

— določene in izbrane so bile ustreznih nizkoprofilne pnevmatike;

— opravljene so bile meritve hrupa vozila: med vožnjo, v mirovanju in v uporabi po ECE R 51/01, 1967 KDV 8b, oziroma StVZO 49 [5], [6];

— preverjen je bil celoten sistem s trajnostnim temperaturnim testom topotno preobremenjenih sklopov in komponent, z vleko vozila in v normalni uporabi;

— optimiran je bil sistem protihrupne zaščite;

— izdelana je bila dokumentacija za uskladitev po predpisih KDV ali StVZO.

Pot k izvedbi je bila kombinacija analitično-eksperimentalnega postopka, pri čemer so bile iskane najboljše rešitve s spremembami v modelu protihrupne zaščite, to so debelina protihrupnih oblog, debelina pločevin in lokacije oblog na vozilu.

3 IZHODIŠČNO STANJE HRUPA

To stanje hrupa vozila je bilo določeno in izmerjeno takole:

— z analitično-eksperimentalno metodo so bili določeni vsi glavni sistemi motorja in vozila glede hrupa (sesanje, izpuh, hlajenje polnilnega zraka, zavorni sistem, pnevmatike, difuzor itn.);

— vozilo je bilo montirano kot šasija s kabino (ŠK) z izbranimi sklopi in komponentami;

— vozilo ni imelo protihrupne zaščite;

— vozilo in motor sta bila ustrezeno servisirana;

— z vozilom je bilo prevoženih okoli 1000 km zaradi utekanja;

— za meritve hrupa ŠK je bila opravljena še meritve hrupa vozila s tovornim prostorom in ponjavo po ECE R 51/01 in 1967 KDV 8b ali StVZO 49 [5], [6].

Slike 1 in 2 prikazujeta osnovna načela meritve hrupa, pri tem so bili mikrofoni postavljeni na višini 1,2 m od tal, oddaljenost od vozila pa je bila predpisana s standardom.

Primerjave stanja hrupa med ŠK ter ŠK s tovornim prostorom in ponjavo so podane v pregл. 1.

Rezultati meritve hrupa v preglednici 1 povedo, da je hrup med vožnjo manjši za 0,7 do 1,7 dB(A), če ima vozilo tovorni prostor, kar pomeni, da ta preprečuje širjenje hrupa in ga usmerja k tlom (posebej še hrup menjalnika in transmisije), poleg tega del hrupa absorbira tovorni prostor. Pri mirujočem vozilu, posebno pri meritvi hrupa zavornih agregatov, vpliva tako, da je hrup celo večji, ker ga usmerja bočno na obe strani.

— to define and choose suitable noise absorbers for the brake system air valves, with regard to the pressure of the brake installation system, the position of the valves in the air braking system, geometry and dimensions of the noise absorbers as well as the noise reduction level;

— to define and choose suitable low-profile tyres;

— to carry out measurements of the vehicle noise during its use, during operation and when the vehicle comes to a standstill, according to ECE R 51/01, 1967 KDV 8b and/or StVZO 49 [5], [6];

— to check the whole system by running an endurance temperature test of thermally overloaded assemblies and components when towing the vehicle or during regular vehicle use;

— to optimise the noise encapsulation system;

— to elaborate documentation for the homologation procedure according to KVD or StVZO.

The steps taken for realisation were a combination of analytical and experimental approaches, where the best solutions had to be found by modifying the noise encapsulation model (thickness of shields, sheet metal and positions of such shields on the vehicle).

3 REFERENCE NOISE LEVEL

The noise level of the basic vehicle was determined and measured under the following conditions:

— by applying an analytical and experimental approach: all major systems of the engine and the vehicle were determined in terms of noise (intake, exhaust, charge air intercooling, braking system, tyres, diffuser, etc.);

— the vehicle was assembled as a chassis with cab (ŠK) with selected assemblies and components;

— the vehicle had no noise protection;

— the vehicle and the engine were properly serviced;

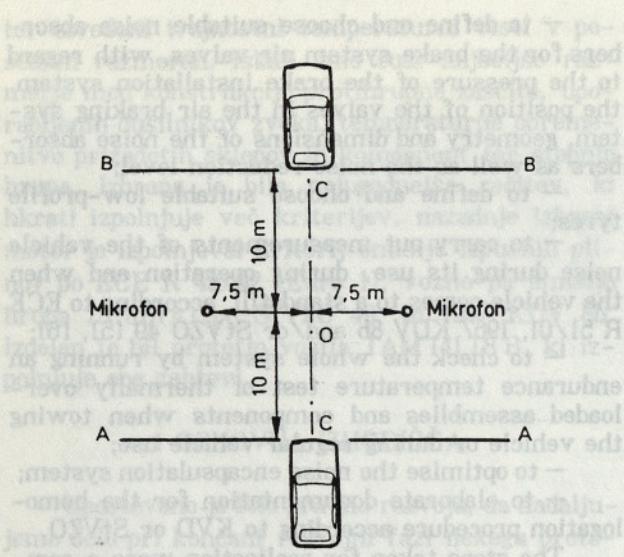
— the vehicle covered about 1000 km for running-in purpose;

— additional to the noise measurement of ŠK, we also measured the noise of the vehicle with a cargo body and a tarpaulin according to ECE R 51/01 and 1967 KDV 8b or StVZO 49 [5], [6].

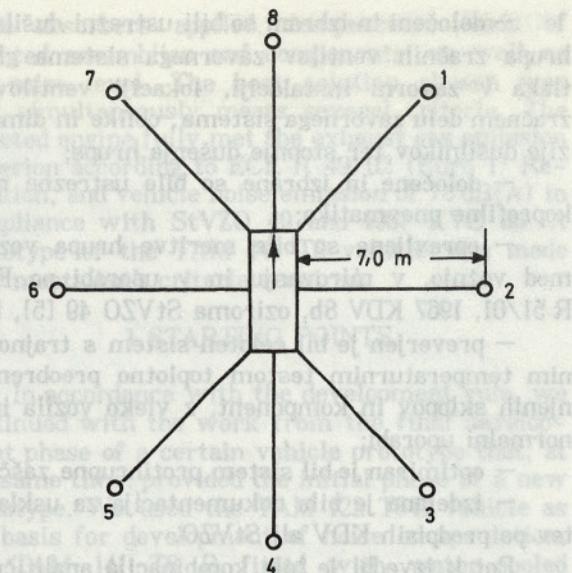
Figures 1 and 2 illustrate the basic noise measurement principles, with microphones fitted at a distance of 1.2 m from the ground. The distance from the vehicle was in compliance with the prescribed Regulation.

Table 1 shows the comparison of noise level between chassis + cab and chassis + cab + cargo body with a tarpaulin.

The results given in table 1 show that during the operation the noise was lower by 0.7 to 1.7 dB(A) if the vehicle had a cargo body. This means that a cargo body prevented the noise from expanding and directed it towards the ground (especially the noise produced in the gearbox and transmission). Part of the noise was absorbed by the cargo body itself. If the vehicle was at a standstill, the cargo body made the noise increase by directing it sideways, especially when measuring brake units noise level.



Sl. 1. Merjenje hrupa vozila med vožnjo
Fig. 1. Noise measuring of moving vehicle



Sl. 2. Merjenje hrupa mirujočega vozila
Fig. 2. Noise measuring of standing vehicle

Preglednica 1
Table 1

TAM 141 T8 B - 4.25 (brez protihrupne zaščite) (without noise encapsulation)	Mesto mikrofona Microphone position	Šasija s kabino Chassis with cab (ŠK)	Šasija s kabino + zaboj s ponjavo Chassis with cab + Cargo body (ŠK + zaboj)
Hrup med vožnjo v III prestavi menj. pri 1850 vrt/min - dB(A) <i>Noise of accelerated vehicle in the third gear at 1850 rpm - dB(A)</i> (dovoljeni nivo je 78 dB(A)) <i>(Reference level = 78 dB(A))</i>	Levo Left Desno Right	82.0 82.0	81.3 80.3
Hrup okoli vozila pri mirovanju merjen v 8 točkah - dB(A) (dovoljeni nivo je 78 dB(A)) <i>Noise of standing vehicle measured at eight points - dB(A)</i> <i>(Reference level = 78 dB(A))</i>	1 2 3 4 5 6 7 8	78.9 79.3 76.3 73.5 76.9 79.1 80.1 78.2	80.4 79.9 76.8 73.9 76.4 79.4 80.9 80.0
Hrup zavornih agregatov - dB(A) (dovoljeni nivo - 72 dB(A)) <i>Brake units noise - dB(A)</i> <i>(Reference level = 72 dB(A))</i> R-Regulator tlaka - Pressure regulator D-Delovna zavora - Service brake P-Parkirna zavora - Parking brake	R D P	77.9 95.6 92.0	82.6 96.0 89.5

4 DODATNI UKREPI ZA ZMANJŠEVANJE HRUPA

Izmerjene vrednosti izhodiščnega stanja hrupa vozila povedo, da so dodatni ukrepi nujno potrebni, da bi lahko hrup zmanjšali na predpisanih 78 dB(A). Dodatni ukrepi pomenijo vgradnjo posebno konstruiranih komponent protihrupne zaščite, ki naj bi preprečile širjenje hrupa po eni strani in absorbirale del hrupa po drugi.

To pomeni, da z dodatnimi ukrepi preprečuje-
mo širjenje hrupa predvsem z izolacijo in absorpcijo. Z izbranim motorjem za vozilo TAM 141 T8 B, z močjo 108 kW (145 KM), ni mogoče doseči zahtevanega hrupa 78 dB(A) vozila brez dodatnih oblog ob motorju in menjalniku.

Dodatni ukrepi, uporabljeni pri vozilu TAM 141 T8 B:

- izolirani so bili prehrupni sklopi: motor in menjalnik z dodatnimi oblogami z absorpcijskim dušenjem hrupa;

- vgrajene oblage ob motorju in menjalniku so iz jeklene pločevine ali plastike (poliester ali poliuretan) in absorpcijskimi protihrupnimi oblogami FAIST 1791/40;

- narejena je bila toplotna izolacija proti-
hrupnih oblog na mestih izpostavljenih delov v
območju izpušne cevi in glušnika, s hkratno re-
šitvijo kroženja zraka zaradi hlajenja motorja in
delov električne napeljave;

- narejena je bila pravilna in tehnično ustrez-
na montaža sklopov in delov, da bi preprečili do-
datne vibracije in s tem hrup;

- izpeljano je bilo dušenje hrupa zračnih ven-
tilov zavornega sistema z ustreznimi dušilniki;

- opravljeni so bili nadzor, preizkušanje in
meritve hrupa vozila in zavornih agregatov ter
meritve temperatur motorja in menjalnika pri
normalni in intenzivni uporabi.

4.1 Oblage protihrupne zaščite

Narejena sta bila dva vzorca protihrupne za-
ščite z določenimi spremembami posameznih kom-
ponent z namenom, da bi izboljšali in optimirali
oblage. Nosilni deli oblog (sl. 3; 1 do 4) so iz
pločevine debeline 2,5 mm in so pritrjeni na
vzdolžnike okvira, spodnje pločevine (sl. 3; 5, 6)
pa so debeline 1,25 mm in so z nosilnimi deli po-
vezane s sponkami — zapirali. Spoj z zapirali daje
dovolj togo konstrukcijo, ki preprečuje samovzbu-
janje vibracij, ker ima določen delež v skupnem
hrupu vozila. Kabinski del oblog (sl. 3; 7, 8) je
tudi iz pločevine debeline 1,25 mm. Zaradi dušenja
hrupa so vsi deli oblog protihrupne zaščite pre-
vlečeni s protišumno maso debeline 2 do 3 mm.

4 SECONDARY MEASURES TO REDUCE NOISE LEVELS

The measured values of the reference vehicle noise level illustrate that it is of vital importance to take secondary measures so as to reduce noise to the prescribed level of 78 dB(A). Additional measures require mounting of specially designed noise encapsulation components to prevent noise from expanding and, on the other hand, to absorb part of this noise.

This means that, by taking secondary measures, the expansion of noise is prevented above all by appropriate insulation and absorption. The selected engine for the TAM 141 T8 B vehicle with an output of 108 kW did not warrant the required vehicle noise level of 78 dB(A) unless an additional noise protection shield was fitted on the engine and gearbox.

The secondary measures taken in the case of the TAM 141 T8 B vehicle:

- insulation of too noisy assemblies: engine and gearbox with additional noise absorption shields;

- fitting of sheet steel/plastic (polyester or polyurethane) shields and absorption anti-noise shields FAIST 1791/40;

- thermal insulation of anti-noise shields of the exposed parts in the area of the exhaust pipe and the silencer and air circulation for the purpose of cooling the engine and parts of electric wiring;

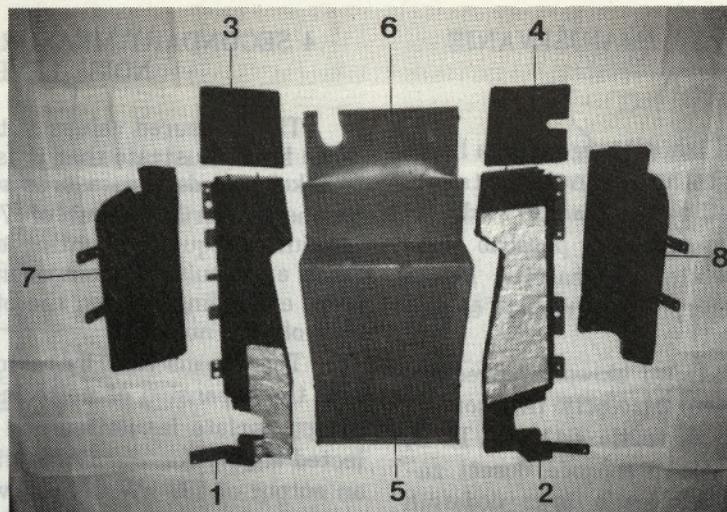
- correct and technically suitable fitting of assemblies and components with a view to preventing additional vibrations and, consequently, noise;

- noise absorption of the braking system air valves by using suitable absorbers;

- inspection, testing and measurements of the vehicle and brake units noise, as well as measurements of engine and gearbox temperature under conditions of normal and extensive use.

4.1 Anti-Noise Shields

Two models of encapsulation with specific modifications of individual components were made with a view to improve and optimise the anti-noise shields. The carrying parts of the shields (Figure 3; 1 to 4) were made of 2.5 mm sheet and were fitted to the frame side members, the lower sheets (Figure 3; 5, 6) were 1.25 mm thick and connected with carrying parts by means of clamps — locks. The connection with locks ensured a sufficiently rigid structure preventing self-excitation of vibrations, which had a certain share in the overall noise of the vehicle. The cab shields (Figure 3; 7, 8) were also made of 1.25 mm sheet. All encapsulation shields were coated with an anti-noise compound, 2–3 mm thick.

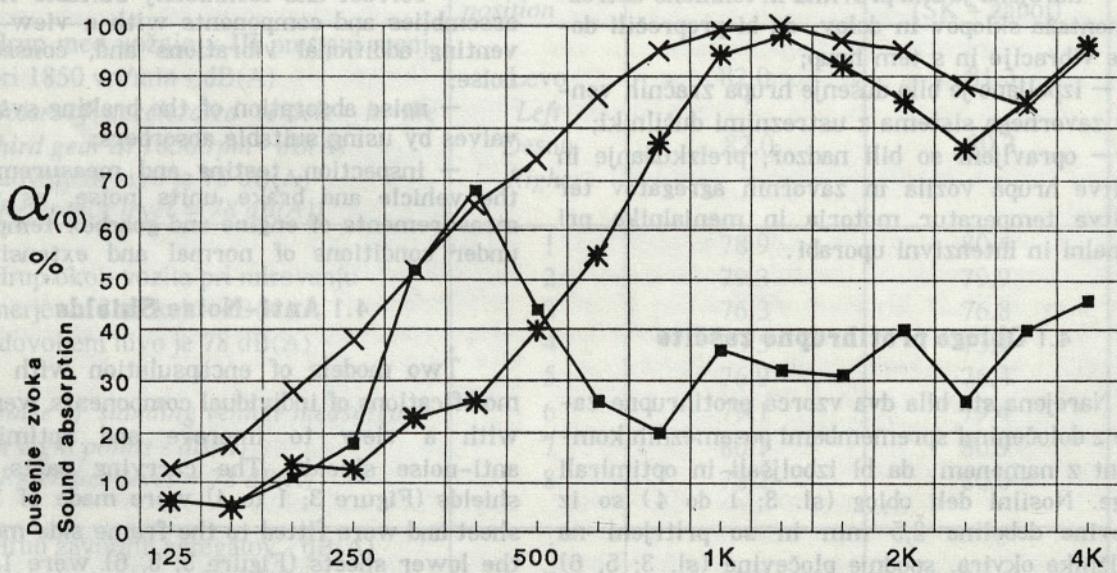


Sl. 3. Obloge protihrupne zaščite

Fig. 3. Noise protection shields

Na tako pripravljene obloge je nalepljena protihrupna pena FAIST M1791/40, ki je osnovni absorpcijski material. Stopnja dušenja hrupa obloge FAIST je prikazana na diagramu (sl. 4). Razdalja med oblogami in okrovom motorja ter menjalnika je določena v odvisnosti od vzbujevalne frekvence sistema motor – menjalnik – obese in hitrosti dušenja oziroma stopnje dušenja protihrupnih oblog. Upoštevana je tudi zahteva po preprečevanju pregrevanja delov motorja, menjalnika in električnih delov, ki je rešena z nemotenim kroženjem zraka.

Pasted on to the thus prepared shields was anti-noise foam FAIST M 1791/40, which was the basic absorption material. The noise absorbing degree of the FAIST shield is shown in the diagram (Figure 4). The distance between the shields and the crankcase, as well as the gearbox casing was determined as a function of the frequency of excitation of the system engine-gearbox-suspension and the absorbing velocity and/or absorbing degree of the shields. Overheating of the engine parts, gearbox and electric parts was prevented by undisturbed air circulation.



Sl. 4. Stopnja dušenja hrupa poliestrske pene FAIST M 1791/40

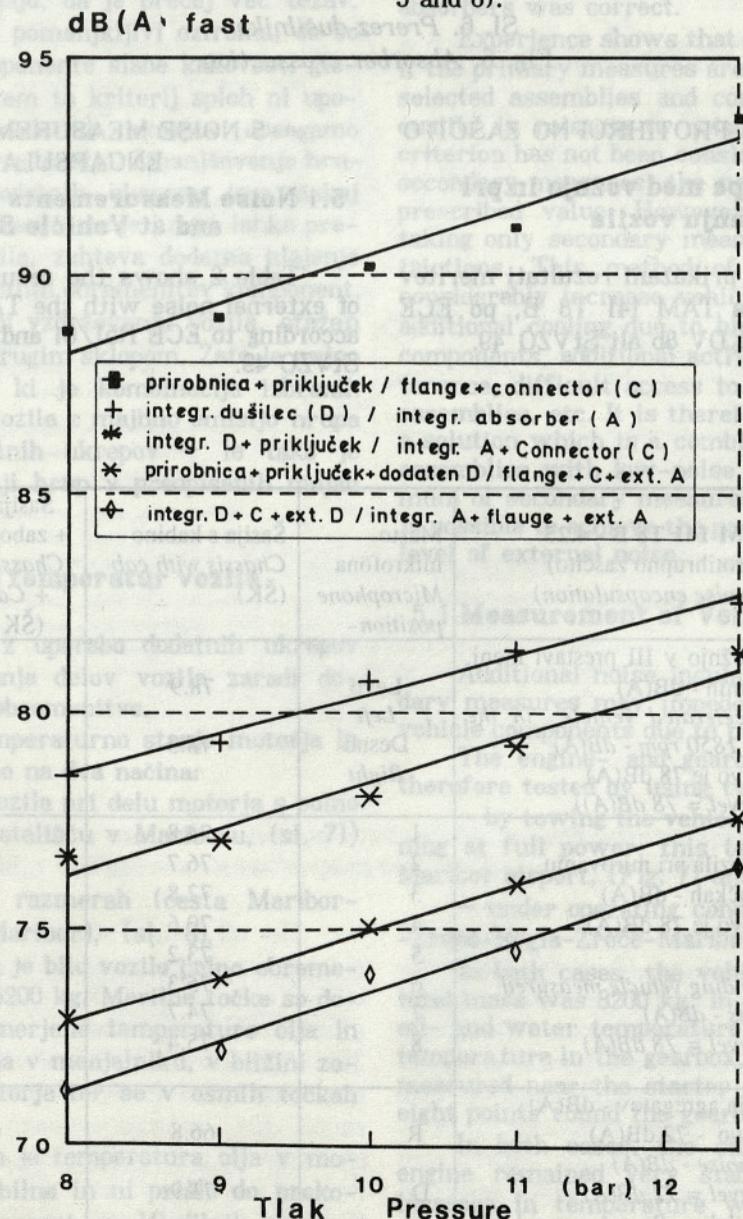
Fig. 4. Sound absorption coefficient of polyester foam FAIST M 1791/40

4.2 Dušilniki hrupa zavornih ventilov

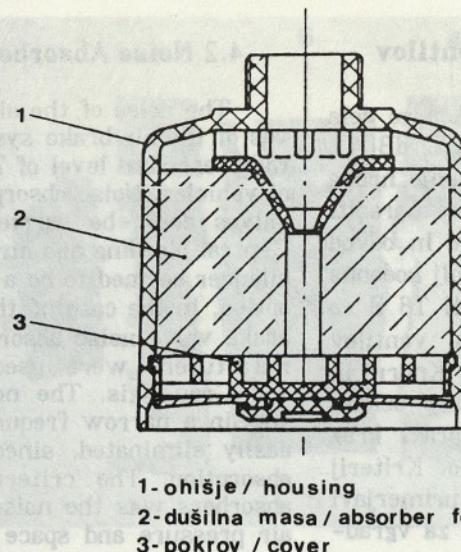
Hrup izpusta zraka iz ventilov zračnega dela zavornega sistema je treba zmanjšati na 72 dB(A), predpisanih za to kategorijo vozil. Dušenje hrupa odzračevanja zavornih ventilov je mogoče narediti na več načinov. Centralno odzračevanje in odvod v glušnik izpušnega sistema se zdita bolj sodobna in cenejša varianta. Pri vozilu TAM 141 T8 B so uporabljeni dušilniki hrupa zavornih ventilov znanih proizvajalcev: Bosch, Wabco, Knorr in Grau-Agis. Hrup zavornih ventilov je v ozkem frekvenčnem območju in se lahko odpravi brez večjih problemov, ker je dušenje veliko. Kriterij za izbiro dušilnikov je stanje hrupa v primerjavi s tlakom zraka ter prostorska možnost za vgradnjo (sl. 5 in sl. 6).

4.2 Noise Absorbers for Brake Valves

The noise of the air discharge from the valves of the air brake system had to be reduced to the prescribed level of 72 dB(A) for this category of vehicles. Noise absorption in bleeding the brake valves could be carried out in several ways. Central bleeding and air discharge to the exhaust silencer seemed to be a more modern and cheaper option. In the case of the TAM 141 T8 B vehicle, brake valve noise absorbers of well known manufacturers were used: Bosch, Wabco, Knorr and Grau-Agis. The noise of the brake valves was in a narrow frequency range, so it could be easily eliminated, since there was considerable absorption. The criterion for the selection of absorbers was the noise level in relation to the air pressure and space for installation (Figures 5 and 6).



Sl. 5. Raven hrupa dušilnika zavornih ventilov v odvisnosti od tlaka zraka
Fig. 5. Absorber noise level of brake valve conditioned by air pressure



Sl. 6. Prerez dušilnika

Fig. 6. Absorber crosssection

5 MERITVE HRUPA S PROTIHRUPNO ZAŠČITO

5.1 Meritve hrupa med vožnjo in pri mirovanju vozila

V preglednici 2 so prikazani rezultati meritve zunanjega hrupa vozila TAM 141 T8 B, po ECE R 51/01 oziroma 1967 KDV 8b ali StVZO 49.

Preglednica 2

Table 2

TAM 141 T8 B - 4.25 (s protihrupno zaščito) (with noise encapsulation)	Mesto mikrofona Microphone position	Šasija s kabino Chassis with cab (ŠK)	Šasija s kabino + zaboj s ponjavo Chassis with cab + Cargo body (ŠK + zaboj)
Hrup med vožnjo v III prestavi menj. pri 1850 vrt/min - dB(A) <i>Noise of accelerated vehicle in the third gear at 1850 rpm - dB(A)</i> (dovoljeni nivo je 78 dB(A)) <i>(Reference level = 78 dB(A))</i>	Levo Left Desno Right	78.9 78.3	77.4 78.0
Hrup okoli vozila pri mirovanju merjen v 8 točkah - dB(A) <i>Noise of standing vehicle measured at eight points - dB(A)</i> (dovoljeni nivo je 78 dB(A)) <i>(Reference level = 78 dB(A))</i>	1 2 3 4 5 6 7 8	74.8 76.7 72.8 70.6 73.2 75.3 74.7 75.4	74.8 76.7 72.3 71.4 72.1 74.9 75.9 75.4
Hrup zavornih agregatov - dB(A) <i>Brake units noise - dB(A)</i> (dovoljeni nivo - 72 dB(A)) <i>(Reference level = 72 dB(A))</i> R-Regulator tlaka - Pressure regulator D-Delovna zavora - Service brake P-Parkirna zavora - Parking brake	R D P	66.8 71.9 72.0	62.9 71.9 70.9

5 NOISE MEASUREMENTS WITH ENCAPSULATION

5.1 Noise Measurements During Operation and at Vehicle Standstill

Table 2 shows the results of measurements of external noise with the TAM 141 T8 B vehicle according to ECE R51/01 and/or 1967 KDV 8b and StVZO 49.

Hrup na ustju izpušne cevi je bil 85 dB(A). Mejna vrednost ni predpisana, a rabi za primerjavo in oceno zunanjega hrupa vozila v uporabi.

Notranji hrup v kabini (ni predpisani) pri vožnji v peti prestavi menjalnika in hitrosti 80 km/h je bil 70,6 dB(A). Hrup med vožnjo, hrup zavornih agregatov in hrup okoli vozila je bil v predpisanih mejah. Rezultati meritev kažejo, da je bil hrup vozila s protihrupno zaščito zmanjšan za 2,3 do 3,9 dB(A) v primerjavi z meritvami hrupa na vozilu brez protihrupne zaščite. To kaže, da je učinkovitost zaščite zelo dobra. Po drugi strani je bila učinkovitost dušilnikov hrupa zavornih ventilov kar primerna, rezultati dušenja med 19 in 24 dB(A), odvisno od tipa zavore. To pomeni, da je bila izbira dušilnikov pravilna.

Izkušnje opozarjajo, da je precej več težav, če so osnovni ukrepi pomanjkljivi oziroma, če so izbrani sklopi in komponente slabe kakovosti glede hrupa ali, če pri tem ta kriterij sploh ni upoštevan. Z uporabo dodatnih ukrepov dosegamo hrup pod predpisano vrednostjo. Zmanjševanje hrupa z uporabo le dodatnih ukrepov ima nekaj omejitev. Ta način zmanjševanja hrupa lahko precej poveča maso vozila, zahteva dodatno hlajenje zaradi povečanih topotnih obremenitev komponent, dodatne aktivnosti pri vzdrževanju vozila, otežen dostop k motorju in drugim sklopom. Zato je nujno treba najti rešitev, ki je kombinacija izbranih kvalitetnih sklopov vozila z majhno emisijo hrupa in minimalnih dodatnih ukrepov — le tako je mogoče dosegiti zunanjji hrup v predpisanih mejah ali celo nižjih.

5.2 Meritve temperatur vozila

Izolacija hrupa z uporabo dodatnih ukrepov lahko otežuje delovanje delov vozila zaradi dometne toplotne preobremenitve.

Zaradi tega je temperaturno stanje motorja in menjalnika preverjeno na dva načina:

- z vlečenjem vozila pri delu motorja s polno močjo, izvedeno na letališču v Mariboru, (sl. 7) in

- v uporabnih razmerah (cesta Maribor-Zreče-Rogla-Zreče-Maribor), (sl. 8).

V obeh primerih je bilo vozilo polno obremenjeno, skupna masa 8200 kg. Merilne točke so določene tako, da so merjene temperature olja in vode v motorju in olja v menjalniku, v bližini zaganjalnika in alternatorja ter še v osmih točkah okrog menjalnika.

V obeh primerih je temperatura olja v motorju ostala zelo stabilna in ni prišlo do prekomernega zvišanja temperature. Hladilnik in ventilator s hidrosklopko sta dimenzionirana tako, da ne pričakujemo nobenih težav v motorju.

The noise at the exhaust pipe outlet was measured to be 85 dB(A). There was no limiting value prescribed. It served for comparison and evaluation of external vehicle noise during operation.

The internal noise in the cab (not prescribed either) when driving in 5th gear and the speed of 80 km/h was 70.6 dB(A). The noise during operation, the noise of brake units and around the vehicle was within the prescribed limits. The measurement results showed that the noise of the vehicle with encapsulation was reduced by 2.3 to 3.9 dB(A) in comparison with the measurements of noise on a vehicle without encapsulation. This was an indication that encapsulation was very efficient. Equally, the efficiency of the noise absorbers for the brake valves was fairly good, amounting between 19 to 24 dB(A), depending on the brake type. This means that the selection of absorbers was correct.

Experience shows that more difficulties arise if the primary measures are in-adequate, or if the selected assemblies and components are of poor quality in relation to noise emission, or if this criterion has not been considered at all. By taking secondary measures, the noise will be below the prescribed value. However, noise reduction by taking only secondary measures has certain restrictions. This method of noise reduction can considerably increase vehicle weight, it requires additional cooling due to higher thermal loads of components, additional activities in vehicle maintenance, difficult access to the engine and other assemblies, etc. It is therefore imperative to find a solution which is a combination of high quality assemblies with low-noise emission and a minimum of secondary measures. Only in this way it is possible to achieve the prescribed or even lower level of external noise.

5.1 Measurement of Vehicle Temperatures

Additional noise insulation by taking secondary measures may impede the operation of the vehicle components due to presumed thermal load.

The engine- and gearbox temperature were therefore tested by using two methods:

- by towing the vehicle with the engine running at full power; this test was performed at Maribor airport, (Fig. 7) and

- under operating conditions (route Maribor-Zreče-Rogla-Zreče-Maribor) (Fig. 8).

In both cases, the vehicle was fully loaded, total mass was 8200 kg. In addition to measuring oil- and water temperature in the engine and oil temperature in the gearbox, the temperature was measured near the starter and alternator and at eight points round the gearbox.

In both cases, the oil temperature in the engine remained very stable and no excessive increase in temperature was recorded. The oil cooler and the fan with hydro-coupling were dimensioned in such a way that no trouble in the engine was to be expected.

TRAJNOSTNI TEMPERATURNI TEST MOTORJA IN MENJALNIKA

Engine & Gearbox Endurance Temperature Test

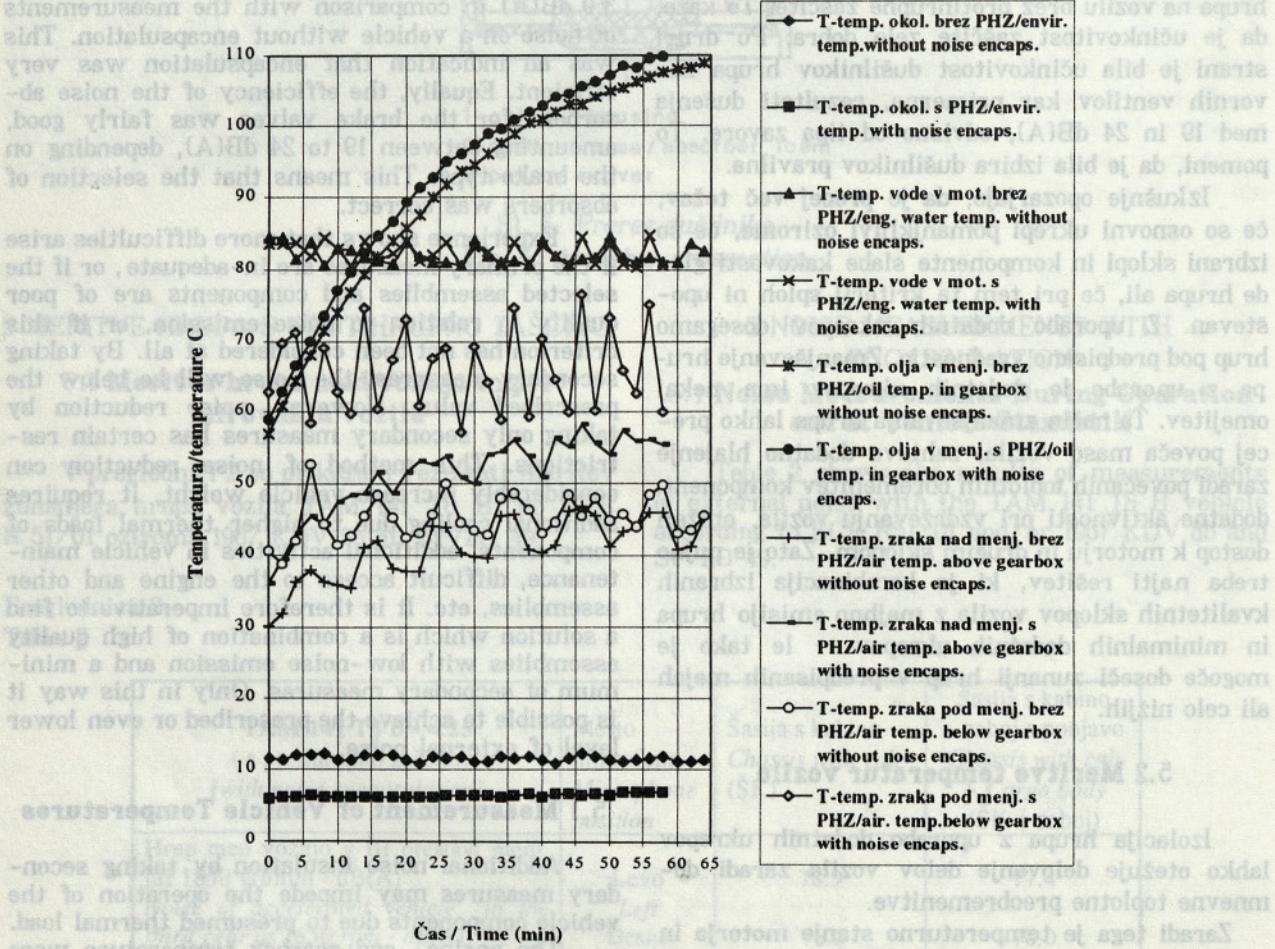
Primerjava temperatura olja v motorju in menjalniku ter okoli menjalnika Z in BREZ.

PROTIHRUPNE ZAŠČITE (metoda vlečenja vozila)

Comparison of oil temperature in engine, gearbox and gearbox surrounding WITH and WITHOUT ANTI-NOISE ENCAPSULATION (towing of vehicle)

Pogoji pri meritvah/Measuring conditions: $n(\text{mot/engine}) = 2600 \text{ min}^{-1}$ $V_{\text{const}} = 34 \text{ km/h}$

Tlak polnilnega zraka/air pressure:

 $p = 1.05 \text{ bar}$ 

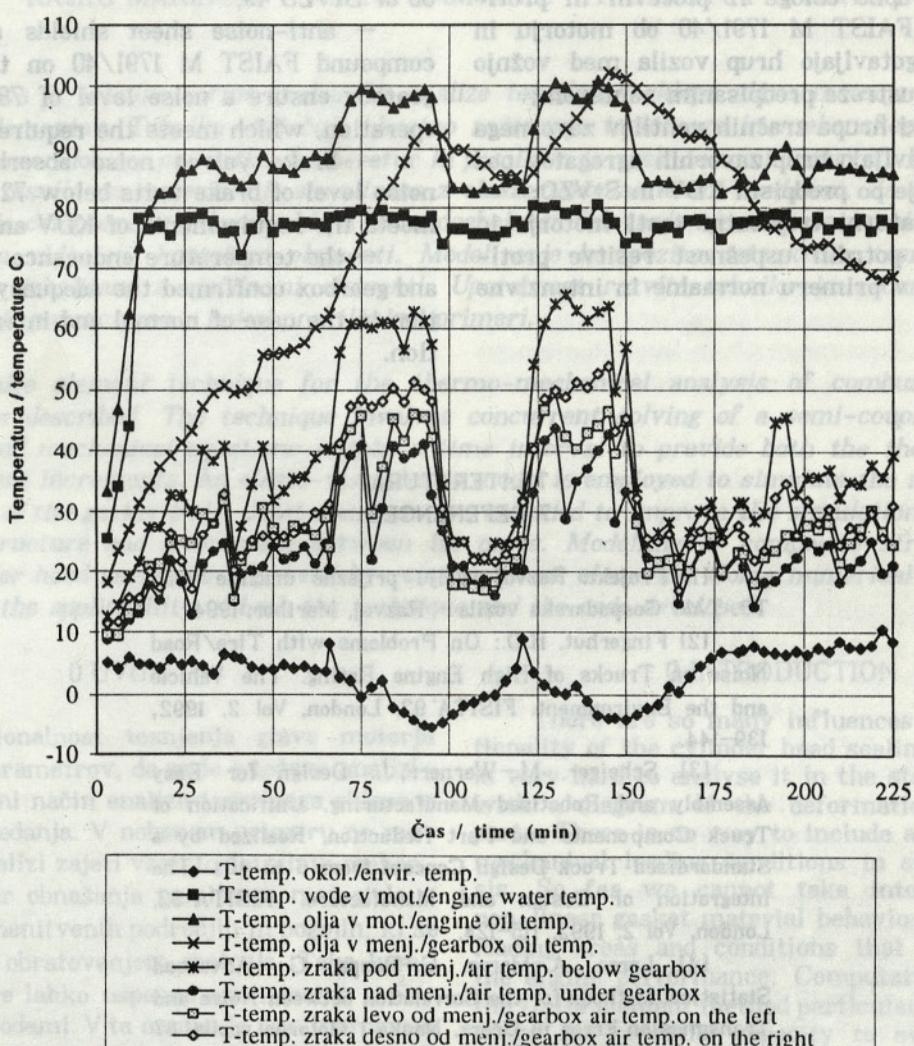
Sl. 7. Temperaturno stanje motorja in menjalnika, določeno z vleko vozila
Fig. 7. Temperature of engine and gearbox when towing the vehicle

Temperatura olja v menjalniku se v obeh primerih zvišuje in se ustali pri 85 do 90 odstotkih največje dovoljene temperature olja v menjalniku (130°C). Diagram tudi kaže, da so v primeru vožnje vozila s protihrupno zaščito temperature okrog menjalnika bistveno višje, posebej pod menjalnikom. Za to sta dva vzroka: prvi, ker je izpušna cev speljana od desne na levo stran vozila pod menjalnikom in drugi, topli zrak od motorja se kopiči pod menjalnikom, kar vpliva na določeno vrtenčenje v območju menjalnika in izpušne cevi ter preprečuje močnejše hlajenje.

The oil temperature in the gearbox showed a tendency to increase in both cases and it stabilised at a level of 85 to 90% of maximum permissible oil temperature in the gearbox (130°C). The diagram also shows that, with a vehicle operating with encapsulation, the temperatures round the gearbox were essentially higher, particularly under the gearbox. There were two reasons for that: first - the exhaust pipe running from the right to the left side of the vehicle under the gearbox, and the second - warm air from the engine accumulated under the gearbox,

TEMPERATURNI TEST VOZILA S PROTIHRUPNO ZAŠČITO

Vehicle temperature test with noise encapsulation



Sl. 8. Temperaturno stanje motorja in menjalnika v uporabi
Fig. 8. Temperature of engine and gearbox during exploitation

Ugodnejše stanje nastane takrat, ko je vklopljen ventilator motorja. Obtok zraka je močnejši, kar se opazi pri znižanju temperature v menjalniku in okrog njega. V normalni kakor tudi pri intenzivni uporabi ni pričakovati problemov, tudi ne pri kratkotrajni preobremenitvi motorja in menjalnika. Dodatna vgradnja ventilatorja in cevi zraka za hlajenje menjalnika ni potrebna in bi le povečala ceno.

which caused turbulence within the range of intensive cooling. The conditions improved when the engine fan was activated. Air circulation was more intensive, which showed in a temperature drop in the gearbox and round it. No trouble was to be expected during normal or intensive use, now with shorttime overload of engine and gearbox. Additional installation of a blower and air cooling pipes for cooling the gearbox was not necessary and would only cause an increase in price.

6 SKLEP

ENGINES AND GEARBOX ENDURANCE TEMPERATURE TESTS

V TAM Gospodarska vozila d.o.o. je bil na-rejen prototip vozila, ki izpolnjuje predpise ECE R 49/02 (emisija izpušnih plinov E1) in EEC 92/97, oziroma 1967 KDV 8b in StVZO 49;

- protihrupne obloge iz pločevin in proti-hrupne mase FAIST M 1791/40 ob motorju in menjalniku zagotavljajo hrup vozila med vožnjo 78 dB(A), kar ustreza predpisanim zahtevam;

- dušilniki hrupa zračnih ventilov zavornega sistema, zagotavljajo hrup zavornih agregatov pod 72 dB(A), kar je po predpisih KDV in StVZO;

- temperaturni trajnostni testi motorja in menjalnika so potrdili uspešnost rešitve proti-hrupne zaščite v primeru normalne in intenzivne uporabe.

6 CONCLUSION

At the company TAM Industrial Vehicles Ltd., a vehicle prototype has been made which meets the requirements of ECE R 49/02 (exhaust gas emission E1) and EEC 92/97 and/or 1967 KDV 8b or StVZO 49;

- anti-noise sheet shields and anti-noise compound FAIST M 1791/40 on the engine and gearbox ensure a noise level of 78 dB(A) during operation, which meets the requirements;

- brake valves noise absorbers ensure a noise level of brake units below 72 dB(A), which meets the requirements of KDV and StVZO;

- the temperature endurance tests of engine and gearbox confirmed the adequacy of encapsulation in the case of normal and intensive exploitation.

7 LITERATURA 7 REFERENCES

- [1] Projekt: Razvoj okolju prijazne družine vozil T8. TAM Gospodarska vozila - Razvoj, Maribor, 1994
- [2] Fingerhut, H.D.: On Problems with Tire/Road Noise on Trucks of High Engine Rating. The Vehicle and the Environment. FISITA'92, London, Vol 2, 1992, 139-144.
- [3] Scheiger, M.-Wernerr, J.: Design for Easy Assembly and Robotised Manufacturing. Unification of Truck Components and Part Reduction, Realized by a Standardised Truck Design Concept from 6 to 40 t. The Integration of Design and Manufacture, FISITA'92, London, Vol 2, 1992, 115-124.
- [4] Lorea, A.-Marrs, G.-Ruspa, G.: Advanced Statistical Methods for the Correlation between Noise and Transmission Error in Gears, Nauka i Motorna vozila' 87 (2.285-2.290), Beograd, 1987.
- [5] Amtsblatt der Europäischen Gemeinschaften Nr. L371: Richtlinie 92/97 Kraftfahrzeugtyp hinsichtlich des Geräuschpegels, 1992.
- [6] Pravilniki in standardi: ISO 362, 8 b. KDV 1967, StVZO 49, ECE R 51/01.

Avtorjev naslov: dr. Momir Lazović, dipl. inž.
TAM Maribor d.d. – Razvoj
Ptujska cesta 184
62000 Maribor

Author's Adress: Dr. Momir Lazović, Dipl. Ing.
TAM Maribor Development Ltd.
Ptujska cesta 184
62000 Maribor, Slovenia

Prejeto: 13.6.1995
Received:

Sprejeto: 31.8.1995
Accepted: