faults of cars, fault diagnosis, inspections of cars

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THE INSPECTIONS OF CARS IN THE SCOPE OF TRAFFIC SAFETY AND ENVIRONMENTAL PROTECTION – THE PRESENT SITUATION AND THE PROSPECTS OF DEVELOPMENT

Summary. This paper presents study results of the possibilities of car inspections development. The studies have been conducted for ten years. The applied methodology is compared to possibilities of examination methods which are facilitated in each type of modern examination equipment. The structure of car faults, which was detected during periodical inspections, have been compared to the structure of the faults which was detected by applying the examination methods with are not used by common inspection methodology.

BADANIA SAMOCHODÓW W ZAKRESIE BEZPIECZEŃSTWA W RUCHU DROGOWYM I OCHRONY ŚRODOWISKA – STAN OBECNY I PERSPEKTYWY ROZWOJU

Streszczenie. W pracy przedstawiono wyniki 10 lat badań dotyczących rozwoju możliwości w zakresie badań technicznych pojazdów. Porównano stosowaną metodykę z możliwościami jakie stwarzają poszczególne typy urządzeń pomiarowych. Porównano strukturę uszkodzeń pojazdów jakie wykryto podczas badań technicznych ze strukturą uszkodzeń jakie wykryto przy pomocy metodologii nie stosowanej w badaniach kontrolnych.

1. INTRODUCTION

All cars which takes part in the road traffic must be periodically examined in the majority of European countries. The range of inspections and their frequency are determined according to the law in each country. The methodology and frequency is determined by domestic legislation. The international legislation determines only common technical requirements for the particular systems of a car. The ECE regulations for vehicle determine technical requirements, provisions for the periodic technical inspection for these, requirements for service and a way of tests, for systems which are important to traffic safety and environmental protection like brake system, pneumatic tires, safety belts, seats, headlamps, direction indicators, emission of gaseous and particulate pollutants, including visible pollutants etc. The agreements of Economic Commission for Europe establish rules for periodical technical inspection of wheeled vehicles. In each country the rules shall cover the categories of wheeled vehicles concerned and the frequency of its inspection, the equipment and parts to be inspected, test methods by which any performance requirements are to be demonstrated and conditions for granting inspection certificate and their reciprocal recognition. The range of periodical inspection and detailed methodology are determined separately in each country.

The majority of equipment for car examination, in the scope of traffic safety and environmental protection, is produced by a few well-known European producers. The use of the same examination equipment in many countries imposes application of the similar but not precise enough methodology, despite the lack of international legislation on cars inspection. The producers of examination equipment restrict the range of cars inspection due to limited possibilities of their own products. The check methodology of many vehicle systems which are important for traffic safety such as suspension systems in vehicles L category (two- or three-wheeled vehicles like motorcycles), retarders in vehicles M and N category (vehicles having at least four wheels and for carrying of passengers and goods) hasn't been worked out yet. Also the tests for some systems like suspension systems in M_1 vehicle category (having a maximum mass not exceeding 3.5 tones) hasn't been explicitly determined yet.

2. FAULTS OF VEHICLES

Over three thousand vehicles were examined in order to define technical condition and typical faults in the scope of traffic safety and emission of pollutants. The analyses concentrated on the possibilities of diagnosing any faults which can be determined using conventional diagnosing methods, classified for kind of fault (pointing the exact system). The way of mending the fault was also defined. Specification of vehicle types and examined car age has been presented in Fig. 1.

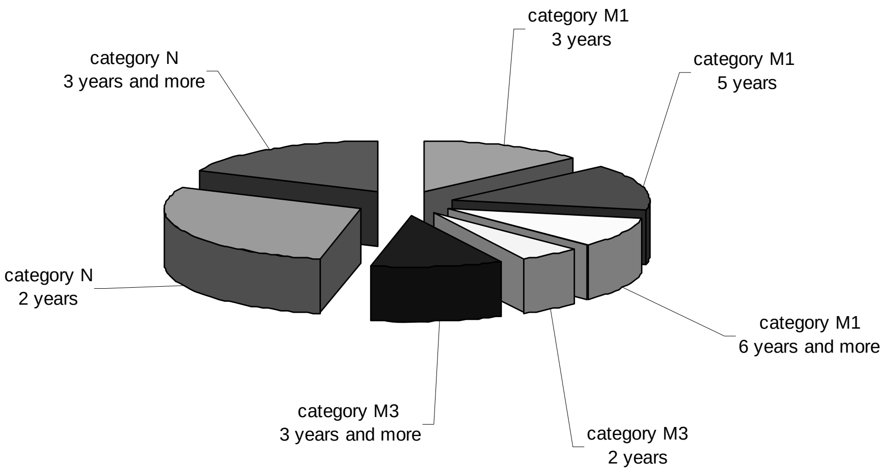

Fig. 1. Specification of examined vehicle types and ages
Rys. 1. Struktura rodzajowa i wiekowa badanych pojazdów

Examination results have been presented in Fig. 2. The analysis of faults for each category of examined vehicles can be classified in the following groups: faults which cause higher emission of toxic compounds and higher level of noise, faults which have direct impact on driving safety (brake system, steering system, suspension system), indicators and lights, non-emission faults of power transmission system, faults of elements and chassis systems which deteriorate the comfort of driving. For N category vehicles forty nine per cent out of total number of faults were connected with traffic safety and thirty three percent were connected with gases emission or fuel consumption. For vehicle M_1 category twenty six per cent and for M_2 and M_3 category twelve per cent of faults were connected with traffic safety. Most of the damages (aprox. 40%) including those of importance for road safety were not indicated by common periodical inspections.

The study which was carried out by others [1] established that the most common component failure is that of the engine (41%) and that the most common cause of failure is the over-running (21%). The total contribution to the cause of failure of manufacturing or design errors, raw material defects and storage procedures is 33%. The high proportion of failures due to improper repairs (18%) represents an area where increased training in the reconditioning and regular periodical inspections may yield significant dividends.

The study of the effects of technical inspection of heavy vehicles on road accidents, which was conducted in Norway [2, 3], showed that the overall injury accident rate of these vehicles is nearly the same as for passenger cars, but accidents involving heavy vehicles more often result in fatalities or serious injuries than accidents involving passenger cars only. The analysis show that the increasing the number of technical inspection of heavy vehicles is associated with a reduction in accident rate.

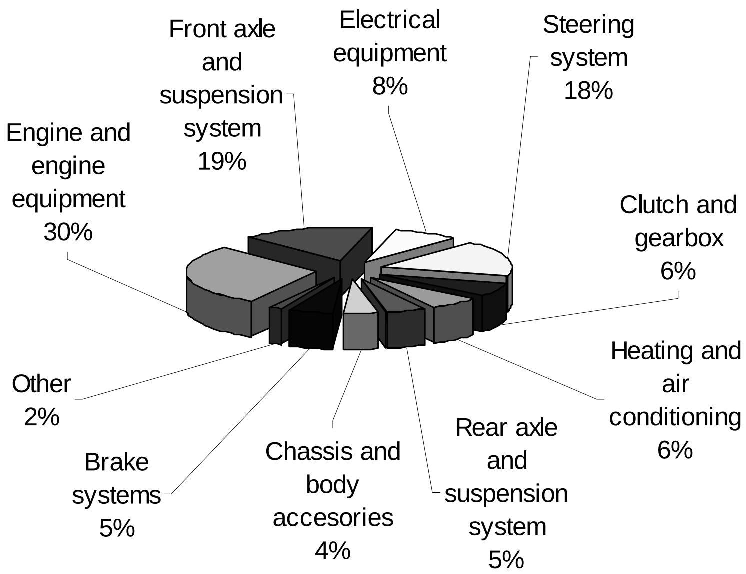

Fig. 2. Structure of vehicle faults
Rys. 2. Struktura usterek pojazdów

Similar investigations were done in the USA, Canada and Mexico. The percentage of commercial motor vehicle accidents with the involved mechanical defects as a contributing factor has been estimated as 5% [4]. The broad defect categories for brakes, tires, wheels, and load securing system account for the majority of defect related accidents. The number of technical defects was strongly reduced when vehicles were presented for inspection regularly. It therefore seems clear that inspections are very effective in improving the technical condition of vehicles [3]. Technical defects in vehicles are associated with the increase in accident rate, and the periodic inspections lead to the repair of technical defects.

3. METHODS OF TECHNICAL INSPECTIONS

3.1. Emission of toxic compounds and higher level of noise

The requirements for vehicles concerning a level of the pollutant emission are determined by ECE Regulation No. 83 according to Revision 3, Regulation No. 24, Regulation No. 96 and Regulation No. 101. These regulations concern the exhaust emission at normal and low temperature, the emission of visible exhaust pollutants, evaporative emissions, emissions of crankcase gases, the durability of pollution control exhaust devices and on-board diagnostic (OBD) systems of motor vehicles, the measurement of the emission and fuel consumption.

The minimum inspection requirements in the scope of environmental protection have been determined by ECE Agreement Rule No. 1 concerning the adoption of uniform conditions for periodical technical inspection of a wheeled vehicle and the reciprocal recognition of such inspections. According to this Agreement, the check of exhaust emission of vehicles with positive – ignition engines (spark ignition engines) includes visual inspection of the exhaust system, visual inspection of any emission control equipment fitted by the manufacturer in order to check that it is complete and in a satisfactory condition, measurement of the carbon monoxide (CO) content of the exhaust gases when the engine is idling. However, in cases when the exhaust emissions are controlled by the advanced emission control system such as a three-way catalytic converter that is lambda-probe controlled, determination of the efficiency of the vehicle's emission control system is realized additionally by measuring the lambda value.

The inspection of vehicles with compression ignition engines includes visual inspection of any emission control equipment fitted by the manufacturer in order to check that it is complete and in satisfactory conditions. Exhaust gas opacity to be measured during free acceleration (no load from idle up to cut-off speed) with gear lever in neutral and clutch engaged.

The methodology which is applied during periodical inspection is mainly in accordance with ECE requirements. During the inspection for spark ignition engines the contents of carbon monoxide and hydrocarbons in exhaust gases are measured. The lambda value is calculated using the simplified Brettschneider equation. For compression engines exhaust gas opacity is only measured. The limit values are determined according to the law regulations. The law limit values are not very restrictive as those of the requirements of vehicle producers. In many cases vehicle which was examined during the periodical inspection and which technical conditions met law requirements but it is faulty according to producer recommendations [5, 6]. The contents of nitric oxides in exhaust gases have not been measured.

The level of noise requirements for vehicle has been determined by ECE Regulation no. 51. The measurement of level of noise during the periodical inspection is carried out only in justified cases.

3.2. Brake system

The requirements for vehicle in the scope of the braking of vehicles are determined by ECE Regulation No. 13-H and Regulation No. 13 according to Revision 6. The performance prescribed for braking systems is based on the stopping distance and the mean fully developed deceleration. The performance of a braking system shall be determined by measuring the stopping distance in relation to the initial speed of the vehicle or by measuring the mean fully developed deceleration during the test. The stopping distance shall be the distance covered by the vehicle from the moment when the driver begins to actuate the control of the braking system until the moment when the vehicle stops. The initial speed shall not be less than 98% of the prescribed speed for the test.

The mean fully developed deceleration (d_m) shall be calculated as the deceleration averaged with respect to distance over the v_b to v_e, according to the formula:

$$d_m = \frac{v_b^2 - v_e^2}{25.92(s_e - s_b)} \tag{1}$$

where: v_0 – initial vehicle speed in km/h, v_b – vehicle speed at 0.8 v_0 in km/h, v_e – vehicle speed at 0.1 v_0 in km/h, s_b – distance travelled between v_0 and in v_b in metres, s_e – distance travelled between v_0 and in v_e in metres.

The speed and distance shall be determined using instrumentation having an accuracy of ± 1 per cent at the prescribed speed for the test. The d_m may be determined by other methods than those the measurement of speed and distance. In this case, the accuracy of the d_m shall be within ± 3 per cent. For the approval of any vehicle, the braking performance shall be measured during road tests.

In the case of a motor vehicle authorized to tow an unbraked trailer the combination performance shall be verified by calculations referring to the maximum braking performance actually achieved by the motor vehicle alone (laden) with the engine disconnected, using the formula:

$$d_{M+R} = d_M \frac{P_M}{P_M + P_R} \tag{2}$$

where: d_{M+R} – calculated mean fully developed deceleration of the motor vehicle when coupled to an unbraked trailer, in m/s^2, d_M – maximum mean fully developed deceleration of the motor vehicle alone achieved during test with engine disconnected, in m/s^2, P_M – mass of the motor vehicle (laden), P_R – maximum mass of an unbraked trailer which may be coupled, as declared by the motor manufacturer.

Vehicles which are not equip with an anti-lock system shall meet requirements in the scope of distribution of braking among the axles. The adhesion utilization curves for the front and rear axles shall be calculated by the formula:

$$f_i = \frac{T_i}{N_i} = \frac{T_i}{P_i + z \cdot \frac{h}{E} \cdot P \cdot g} \tag{3}$$

where: i – axle index, P_i – normal reaction of road surface on axle i under static conditions, N_i – normal reaction of road surface on axle i under braking, T_i – force exerted by the brakes on axle i under normal braking conditions on the road, f_i – adhesion utilized by axle, g – acceleration due to gravity, z – braking rate of vehicle, P – mass of vehicle, h – height of centre of gravity of vehicle, E – wheelbase.

The braking rate of vehicle can be calculated using the formula:

$$z = \frac{J}{g} = \frac{T_1 + T_2}{P \cdot g} \tag{4}$$

where: J – deceleration of the vehicle.

For all states of load of the vehicle, the adhesion utilization curve of the rear axle shall not be situated above that for the front axle, for all braking rates between 0.15 and 0.8. The value of braking rate of vehicle, for the values of theoretical coefficient of adhesion (k) between tyre and road between 0.15 and 0.8, shall met for the following requirement:

$$z \geq 0.1 + 0.7(k - 0.2) \tag{5}$$

The curves shall be plotted for both load conditions, unladen and laden vehicle, where provision is made for several possibilities of load distribution. One test shall be carried out when the front axle is the most heavily laden.

Vehicles equipped with anti-lock systems must maintain their performance when the service braking control device is fully applied for long periods. Compliance with this requirement can be checked by means of the tests. From an initial speed of not less than 50 km/h, on a surface with a coefficient of adhesion of 0.3 or less, the brakes of the laden vehicle shall be fully applied for time t. During which time the energy consumed by the indirectly controlled wheels shall be taken into consideration and all directly controlled wheels must remain under control of the anti-lock system. The vehicle’s engine shall be stopped or the supply to the energy transmission storage device cut off. The service braking control shall be fully actuated four times in succession with the stationary vehicle. When the brakes are applied for the fifth time, it must be possible to brake the vehicle with at least performance prescribed for secondary braking of the laden vehicle. The braking test shall be conducted with the engine disconnected and idling. The braking time t shall be determined as above 15 seconds.

The utilization of adhesion (ε) by the anti-lock system takes into account the actual increase in braking distance beyond the theoretical minimum. The antilock system shall be deemed to be satisfactory when the condition $\varepsilon \geq 0.75$ is satisfied.

The adhesion utilized (ε) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_M),

$$\varepsilon = \frac{z_{AL}}{k_M} \tag{6}$$

The coefficient of adhesion k_M shall be determined by weighting with the dynamic axle loads,

$$k_M = \frac{k_f \cdot F_{fdun} + k_r \cdot F_{rdyn}}{P \cdot g} \tag{7}$$

where:

$$F_{fdyn} = F_f + \frac{h}{E} \cdot z_{AL} \cdot P \cdot g \tag{8}$$

$$F_{rdyn} = F_r + \frac{h}{E} \cdot z_{AL} \cdot P \cdot g \tag{9}$$

F_i – normal reaction of road surface on axle i under static conditions, F_{idyn} – normal reaction of road surface under dynamic conditions with the anti-lock system operative on axle i in case of power-driven vehicles, k_f – factor of one front axle, k_{fr} – factor of one rear axle.

The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheel and the corresponding dynamic load on the axle which is broken.

During the periodical inspections the examination of brake systems includes only common tests, consists of measurements of force exerted by the brakes on wheel under normal braking conditions on the road or on the rollers (plates) of a measuring stand. The braking rate of vehicle can be calculated using formula 4. The minimum values of braking rate are determined in the law regulations [6, 7]. The technical conditions of equipment which regulated braking forces on wheel and anti-lock systems have not been examined.

3.3. Steering system, axles, suspension system and chassis

The requirements for steering system, axles and suspension system have not been determined by EEC regulations yet. Inspection methodology consists of checking the components of systems according to producer requirements.

The check methodology of suspension systems, chassis and wheel alignment is determined by the producers of examination equipment. The suspension systems of vehicles M_1 and N_1 category are examined applying one of the two methods, the resonance principle (the Boge method) or EUSAMA principle. The suspension testers measure the ability to absorb the shocks. The percentage value is obtained by calculating resistance against the presented weight of the vehicle.

In the EUSAMA method the percentage rate of ability to shock absorption is defined as:

$$T_{EU} = \frac{F_{weel-min}}{F_{well-st}} \cdot 100 \tag{10}$$

where: $F_{weel\text{-}min}$ – minimal normal reaction of plate surfeace on wheel in conditions of resonance,
$F_{weel\text{-}st}$ – normal reaction of plate surfeace on wheel in static conditions.

In the resonance (Boge) method the percentage rate of ability to shock absorption is calculated using the formula:

$$T_R = 100 - \frac{(F_{AX} \cdot C_1 + C_2) \cdot A_{max}}{C_3} \tag{11}$$

where: F_{AX} - normal reaction of plate surfeace on axle during static conditions, A_{max} – maximum value of vibration amplitude, C_1, C_2, C_3, – empirical coefficients.

Four thousand cars were examined in order to compare both methods [8, 9]. The results of examinations (Fig. 3) show that for each of the methods separate pass/fail criteria for various type of suspension should be elaborated.

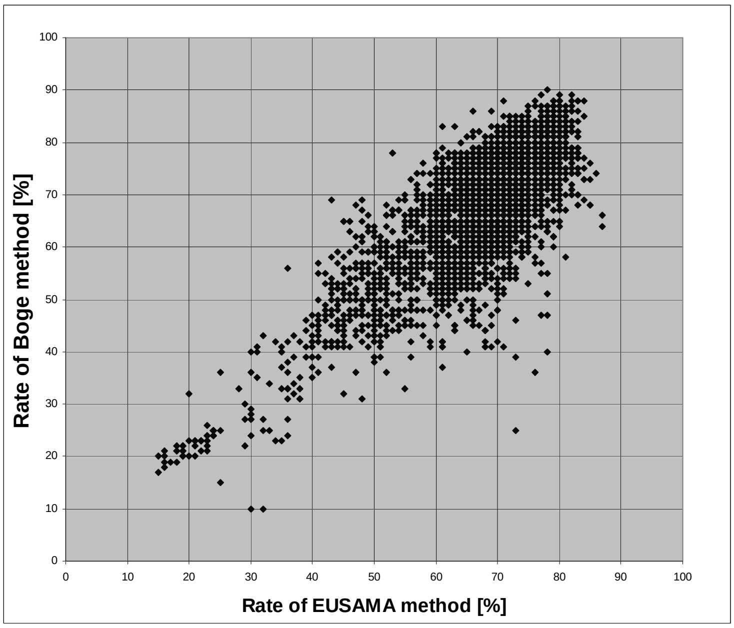

Fig. 3. The results of examinations of car suspensions using EUSAMA and Boge methods
Rys. 3. Wyniki kontroli zawieszeń samochodów osobowych przy zastosowaniu metod EUSAMA i Boge

4. CONCLUSION

The methodology of examination of technical conditions which has been used during periodical inspections of vehicles was elaborated over forty years ago. It is necessary to elaborate new diagnosing methods enabling to find damages regarding traffic safety and environmental protection.

One of the possible methods which could be applied is the evaluation of the technical condition of vehicle considering the values of parameters of performance of particular systems from OBD and detectors mounted as special equipment.

The test results show that there is a strong need of elaborate methodology of inspection for some vehicle systems which are important for road safety such as ABS systems in heavy vehicles N_3 and M_3 categories, retarders, speed limitation devices.

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