

CONCERNING EVALUATION OF STABILITY OF MOTOR VEHICLES CARRYING DANGEROUS GOODS

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Abstract

The issue of active safety when carrying movable cargo is considered of vital importance since people's health and safety are involved. All cargo possessing fluid properties are covered by one common definition of 'fluid goods' the substance possessing insignificant shearing and tensile strengths which affect considerably the quantity and the direction of the vector of inertia loads affecting motor vehicles.

In order to evaluate the vehicle stability against rolling over the test on the bench with the tipping platform, as well as the road test with performance of maneuvers according to the prescribed law of motion are considered obligatory.

Complex tests of about 50 vehicles of different categories including tank trucks, articulated vehicles, mobile fire-fighting appliances, mixer trucks and ready-mix delivery trucks have been performed at the Central Proving Ground.

As the main type of dynamic test, in our opinion, testing method and standard requirements for "lane change $S_n = 20m$ " test should be accepted.

The most dangerous load in dynamic testing corresponds to 70% tank filling. Therefore, it is proposed to accept filling coefficient 0.7 when active safety tests of vehicles with fluid cargo are performed.

The research and testing for developing methods and requirements for evaluation of stability of vehicles carrying fluid cargo must be continued.

Keywords : *transport, vehicles, vehicle carrying fluid, safety, vehicle stability, lateral stability*

The issue of active safety when carrying movable cargo is considered of vital importance since people's health and safety are involved. All cargo possessing fluid properties are covered by one common definition of 'fluid goods'. The most representative examples from the standpoint of dynamic effect during transportation are ductile-viscous and stiff-viscous fluids. Actually, those can be the substances in granular, liquid or gaseous state, that is, in such state when under the influence of small loads which may occur due to variations of transportation velocity vector (acceleration, breaking, turning) the displacement of transported cargo occurs and, as a result, the change of position of centre of mass which in its turn affects transportation safety conditions. Thus the fluid cargo is the substance possessing insignificant shearing and tensile strengths which affect considerably the quantity and the direction of the vector of inertia loads affecting motor vehicles.

The uniform definitions with concrete physical characteristics allow development of standard requirements to stability and steerability of vehicles carrying movable goods and the uniform methodology of reliable evaluation of the mentioned properties. Thus there is the possibility to establish correct correlation between the definitions 'movable' and 'immobilized – rigidly secured' cargo. The first is general and the second is particular.

Currently the standard requirements are focused on the secured cargo. What concerning the vehicles with fluid cargo, the requirements and the testing methods apply as to a particular case of a vehicle with rigidly secured cargo.

In order to evaluate the vehicle stability against rolling over the test on the bench with the tipping platform, as well as the road test with performance of maneuvers according to the prescribed law of motion are considered obligatory.

Complex tests of about 50 vehicles of different categories including tank trucks, articulated vehicles, mobile fire-fighting appliances, mixer trucks and ready-mix delivery trucks have been performed at the Central Proving Ground.

When performing the bench tests the standard values are the lateral stability angle α (min) and the banking angle of the sprung mass φ (max) in the cross-sectional plane passing through the mass centre.

What concerning the operation in hard road conditions, the standard values of the lateral stability angle must be determined in accordance with the dependence prescribed in the document. Retained as a standard property, there must also be sprung mass banking angle φ .

The sprung mass banking angle values of approximately 8° and more mean considerable deterioration of lateral stability and that has led to ceasing the vehicle road testing in a number of cases. Small banking angles of $4^\circ - 5^\circ$ obtained during testing will not give a driver and a controller enough information about the banking stability allowance. In such conditions there was an accident when the semi-trailer as a part of articulated vehicle rolled over during the abrupt change of travel direction.

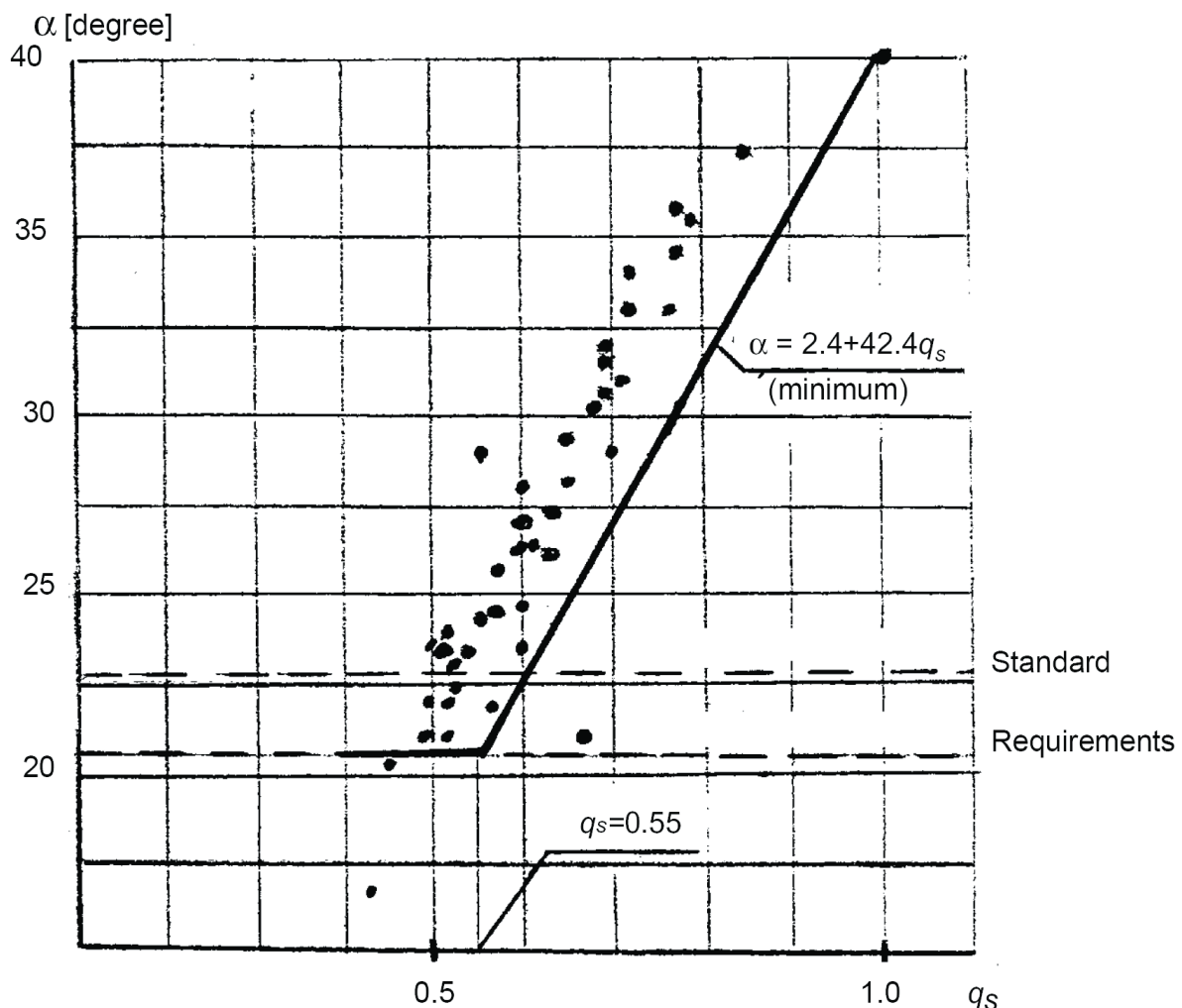


Fig. 1. Dependence of roll-over angle on lateral stability coefficient

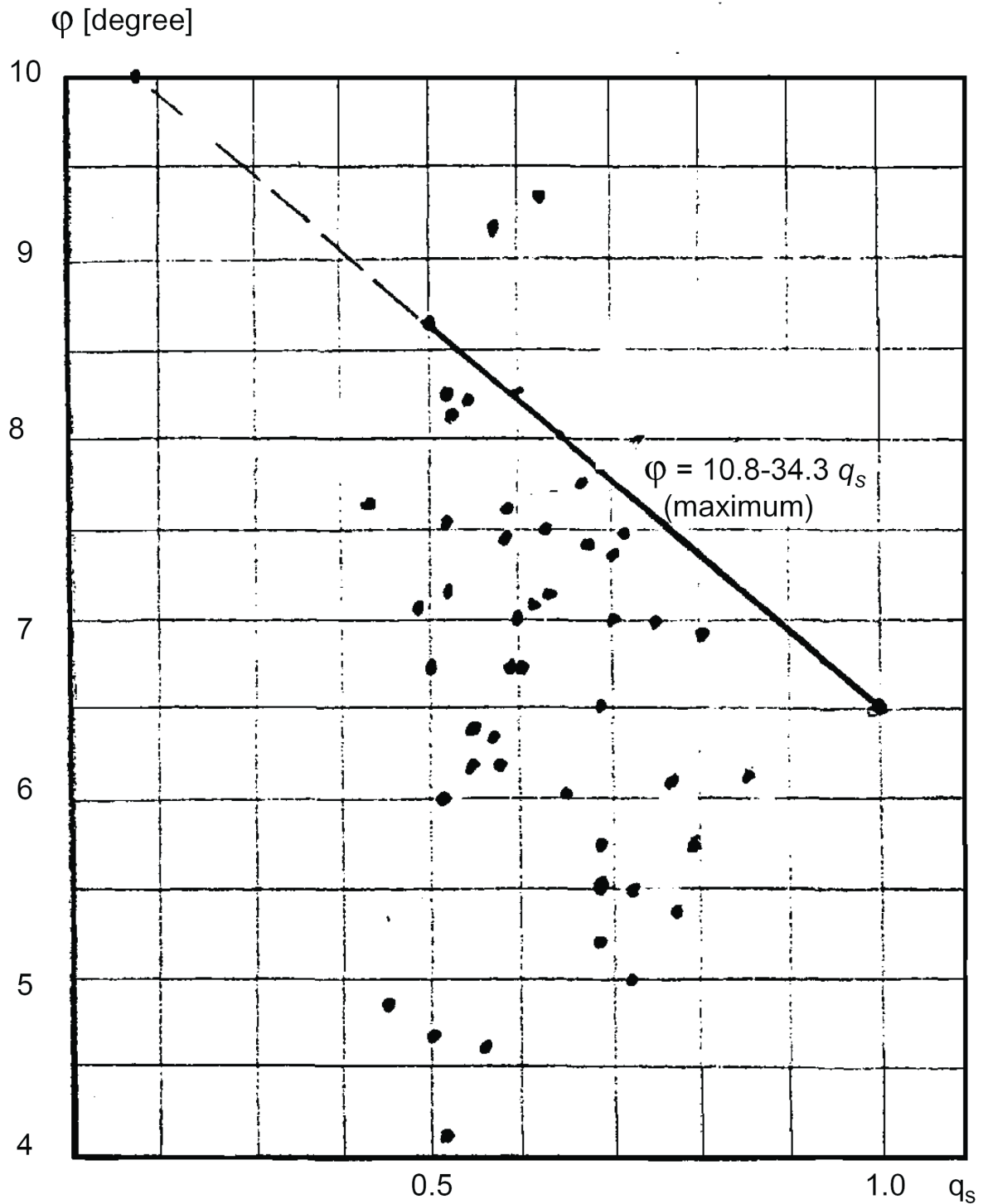


Fig. 2. Dependence of sprung mass banking angle on lateral stability coefficient

Figures 1 and 2 show limit values α and φ in the lateral stability coefficient function:

$$q_s = 0.5 B h,$$

where:

B - the average value of the vehicle wheelspan,

h - the calculated height of the mass centre above the bearing surface.

It follows from the given diagrams that values α and φ depend on the designed lateral stability coefficient.

It is worth mentioning that minimum acceptable roll-over angles 21° and 23° provide the required level of lateral stability mainly on roads without sharp turns.

The proposed test involving circular driving maintaining constant radius $R = 50$ m can be accepted providing the speed is gradually increasing at constant rate up to 51 km/h, which corresponds to lateral acceleration of 4 m/s^2 .

Increasing the radii can result in decreasing the length of trajectory (a section of a circle) due to the limited sizes of the dynamic platforms.

As the main type of dynamic test, in our opinion, testing method and standard requirements for 'lane change $S_n = 20\text{m}$ ' test should be accepted. When performing the maneuver the following values must be measured and registered: the speed of the travel through the measured section, the steering wheel turning angle, the lateral acceleration, the sprung mass banking angle.

The limit speed values V_{lim} when performing the maneuver must not be less than the ones shown in the table depending on the vehicle category.

Tab. 1. Dependence of the speed limit values V_{lim} from the vehicle category (Fig. 3.)

No.	Vehicle category	V_{lim} , km/h
1	N_1	66.5
2	N_1 1/	62.5
3	N_2	56.0
4	N_3 2/	53.0
5	N_3 3/	51.5
6	$N_2 + 0$ 4/(semi-trailers)	45.5
7	$N_2 + 0$ 4/(trailers)	44.5
8	$N_2 + 0$ 4/(semi-trailers)	49.5
9	$N_2 + 0$ 4/(trailers)	47.5

Notes for the Tab. 1.:

- 1/ - for vehicles with all-wheel drive,
- 2/ - for vehicles with gross vehicle weight not exceeding 20 tons,
- 3/ - for vehicles with gross vehicle weight exceeding 20 tons,
- 4/ - for trailers and semi-trailers of all categories.

The chart of limit speeds distribution performing maneuver V_{lim} with regard to standard values for different vehicle categories is given in Fig. 3. Requirements concerning V_{lim} are in compliance with document R283 and make up 95% of values accepted at RD for basic vehicles.

What follows from the chart is the fact that the major part of the test objects corresponds to the requirements. In case when the lower values V_{lim} were obtained, additional expertise tests according to standard procedures were performed to evaluate the possibility of operation without speed limiting or for setting the limit.

When performing maneuver 'lane change' the extreme situation of lane change caused by a sudden appearance of an obstacle is simulated. During the test, a driver's controlling actions through the marked section of the trajectory are extremely limited: the accelerator pedal will be released; the turning of the steering wheel will begin at the control marker on the lane.

This type of testing represents one of the basic tests applied for vehicle stability and steerability evaluation in accordance with standard documents of the Russian Federation.

To determine the vehicle lateral transient behaviour international standard ISO 7401 prescribes the performance of the following tests:

- step input,
- sinusoidal input,
- random input,
- pulse input.

The performance of step input for trucks and articulated vehicles is limited by the sizes of testing sections and is practically possible only for single vehicles with maximum speed of 60 km/h.

The performance of three other tests mentioned above aims at evaluation of phase-frequency characteristics of vehicle reactions in response to steering wheel turning.

The basic standard parameter is the maximum average speed at the trajectory sections. The driver, at that, is supposed to maintain the prescribed highest possible speed, controlling the fuel feed, and that contributes considerable amount of subjectivism in the obtained results.

The standard requirements for these types of tests have not been developed yet.

Tests similar to the ones prescribed by documents ISO 3888 - 'double change of lane' – are also performed with controlling the speed and are especially dangerous: the obligatory installation of safeguard wheels at the sides of a test vehicle is required.

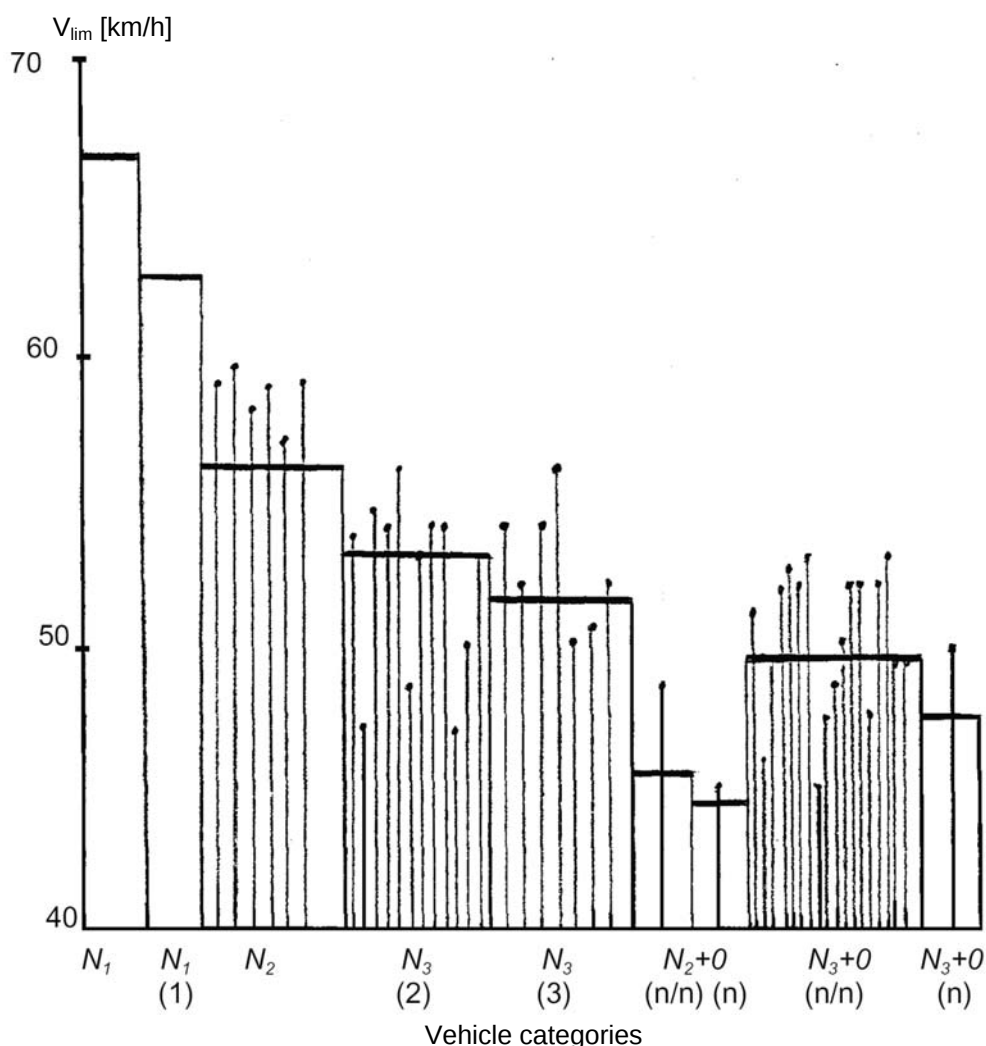


Fig. 3. Chart of limit speed distribution when performing maneuver "lane change $S_n = 20m$ " (— - standard requirements for corresponding vehicle categories)

Thus, the considered types of testing, in our opinion, cannot be regarded as the optimum to employ when preparing the standard requirements for a draft UNECE Regulations.

The issue of vehicle tanks ballasting requires additional consideration.

When the tanks are filled with standard load to obtain the gross vehicle weight, the load corresponds to standard documents applicable to vehicles.

However, the evaluation of effects of tank filling levels on roll-over stability carried out by experimental calculation methods allows us to come to the following conclusion.

The most dangerous load in dynamic testing corresponds to 70% tank filling. Therefore, it is proposed to accept filling coefficient 0.7 when active safety tests of vehicles with fluid cargo are performed.

Thus, the most dangerous, with regard to the rolling over possibility, is the version of 70% filling of the tank with water which corresponds to the gross vehicle weight carrying fuel (petrol, kerosene, diesel fuel).

The research and testing for developing methods and requirements for evaluation of stability of vehicles carrying fluid cargo must be continued.