SELECTED TRANSVERSE STABILITY PROBLEMS RELATED TO ARTICULATED VEHICLES BUILT TO CARRY LIQUID CARGO

DOI 10.2478/ntpe-2018-0073

2018
Volume 1
Issue 1
pp. 581-587

dr hab. inż. Marek Jaśkiewicz, prof. PSk.
Kielce University of Technology, **Poland**
dr hab. inż. Dariusz Więckowski
Automotive Industry Institute, **Poland**
J. Matijosius
Vilnius Gediminas Technical University, **Lithuania**

Abstract. The paper deals with problems connected with the transportation of dangerous cargo in articulated road tankers. The problems related to transverse stability of articulated vehicles have been discussed. The rig and experimental tests carried out to explore the transverse stability problem have been presented. Attention has been paid to the specificity of articulated road tankers. The necessity of rig and field testing of vehicles of this kind has been emphasized. The specificity of the transportation of such articulated vehicles by sea has been highlighted.

Keywords: dangerous cargo, road tanker, road transport

INTRODUCTION

When transporting dangerous cargo, especially liquids and gases (flammable, infectious, toxic, and radioactive), extreme care must be exercised. For such jobs, special vehicles (usually tankers) are built, predominantly in the form of tractor and tank semitrailer units. Subjective assessments of vehicle behaviour, although not requiring sophisticated equipment and exclusively based on feelings of the drivers of the vehicles under test, are undoubtedly very important; nevertheless, they are hardly comparable with each other, even if similar vehicles can be tested at the same time. The comparisons of different vehicles, even of a similar class, when the test drives are carried out in different periods, cause even more problems and controversies. The accidents with rollovers of such vehicles are particularly dangerous because of the extent of the resulting losses. At the turn of the 20th and 21st centuries, almost 10000 such accidents with heavy articulated vehicles happened in the USA every year (Winkler, 2003). Relatively low transverse stability of vehicles of this type combined with insufficient experience of vehicle drivers is particularly conducive to such accidents. This is additionally enhanced by the fact that vehicles of older design have no rollover warning systems (Polkovics, 1998). Modern vehicles are provided with various driving aids and warning systems, such as ESP (Electronic Stability Program), VDC (Vehicle Dynamic Control), or Roll-Over Prevention System. However, systems of this kind are of no use when tractor and tank semitrailer units are transported by sea. In such a situation, the vehicle does not move in relation to the ship deck but both the vehicle and its cargo still undergo the accelerations that arise from the ship's movement on the sea surface.

In road traffic, adequate driver's skill becomes very important. In many countries, drivers are trained with using training vehicles provided with appropriate protective devices. At present, vehicle driving simulators must obligatorily be used for the driver training (Lozia et. Al., 2010). Semitrailers are often provided with a steering axle, with this function being performed by the rear axle of the semitrailer bogie. Such a solution is chiefly applied to facilitate the vehicle manoeuvring in confined areas where the semitrailer is loaded or unloaded. Another important objective is to reduce the wear of tyres of semitrailer bogie. The steering axle is locked either by the driver when the manoeuvring is completed or automatically when the vehicle exceeds a

Contact address: m.jaskiewicz@tu.kielce.pl, d.wieckowski@pimot.eu

predefined speed (Janczur, 2004). When the vehicles of this kind are transported by sea, driver's skill becomes unimportant, but the external accelerations still exert a real impact.

THE ISSUES RELATED TO TRANSVERSE STABILITY OF ARTICULATED VEHICLES

The basic measure of transverse stability is the static stability factor (SSF) defined as the transverse acceleration limit (and expressed in gravitational units [g]) at which wheel lift-off occurs. This limit is determined on a special test rig (Fig. 1). At the instant when the wheels on the unloaded vehicle side are lifted off, the maximum angle of static transverse stability is measured and the tangent of this angle, sometimes referred to as tilt table ratio (TTR), is the static stability factor (or static rollover limit).

Fig. 1. Test rig (tilt table) for determining the static transverse stability.
Source: Automotive Industry Institute.

The maximum values of the transverse acceleration a_y at which the wheels on the unloaded semitrailer side may be lifted off the road (with a high value of the tyre-road adhesion coefficient) may be calculated from the following equation (Januszewski and Więckowski, 2004):

$$a_y = g \cdot tg\varphi_s \ [m/s^2] \quad (1)$$

where:

g – acceleration of gravity; $g = 9.81\ m/s^2$

φ_s – static stability indicator angle [°]

The maximum values of the velocity V_{40} of uniform vehicle motion along a circle with a radius of 40 m may be calculated as follows (Lozia et al., 2010):

$$V_{40} = \sqrt{40 \cdot a_y} \quad (2)$$

For heavy goods vehicles (HGV), the transverse stability threshold (i.e. SSF) is below 0.5 g. Articulated vehicles with low height of the centre of mass can reach the said limit of 0.5 g, but this threshold may drop below 0.25 g at unfavourable distribution of mass of the cargo. For a typical tractor-semitrailer unit, this stability threshold may be of the order of 0.35 g (Januszewski et al., 2004). Fig. 2 shows the probability of rollover of a five-axle tractor-semitrailer unit as a function of the transverse acceleration limit (SSF) (Januszewski et al., 2004).

The transverse acceleration limit values are lower in real road traffic conditions. Figs 3 and 4 show transverse acceleration limit values as functions of the tank filling ratio for two different tank cross-sections, at a uniform vehicle motion along a circle (Fig. 3) and at a lane-change manoeuvre (Fig. 4) (Winkler, 2003). It can be seen in the graphs that the circular cross-section is more favourable.

Fig. 5 shows changes in the positions of the theoretical centre and arm of oscillation of a liquid in the tank in the case of different shapes of the tank cross-section (Januszewski et al., 2004). The positions of the theoretical centre and arm of oscillation of a liquid in the tank may also change as shown when the tractor-semitrailer units are transported by sea.

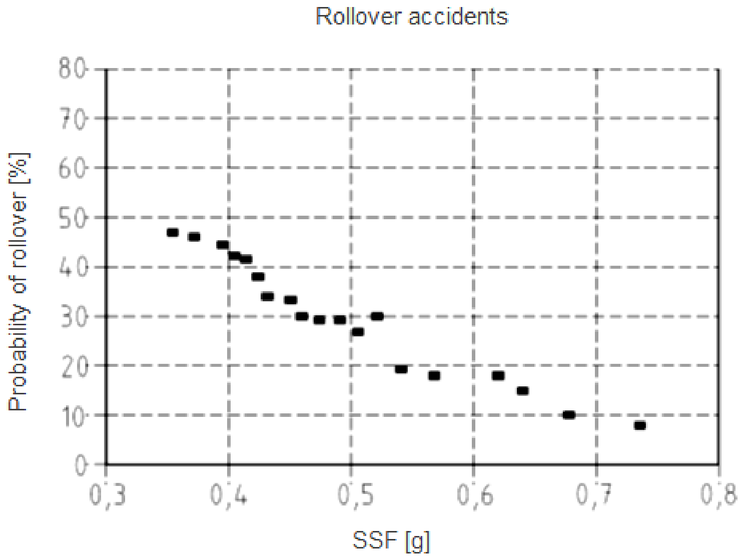

Fig. 2. Probability of rollover of a five-axle tractor-semitrailer unit as a function of the transverse acceleration limit (SSF).

Source: (Januszewski et al., 2004)

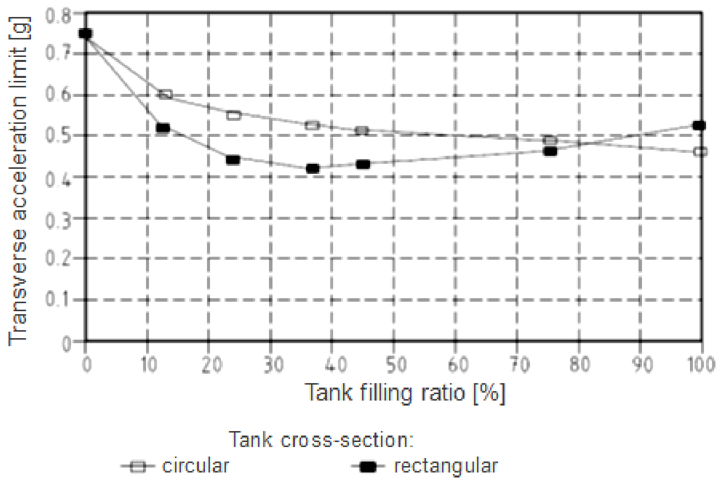

Fig. 3. Transverse acceleration limit values as functions of the tank filling ratio for two different tank cross-sections, at a uniform vehicle motion along a circle.

Source: (Winkler, 2003)

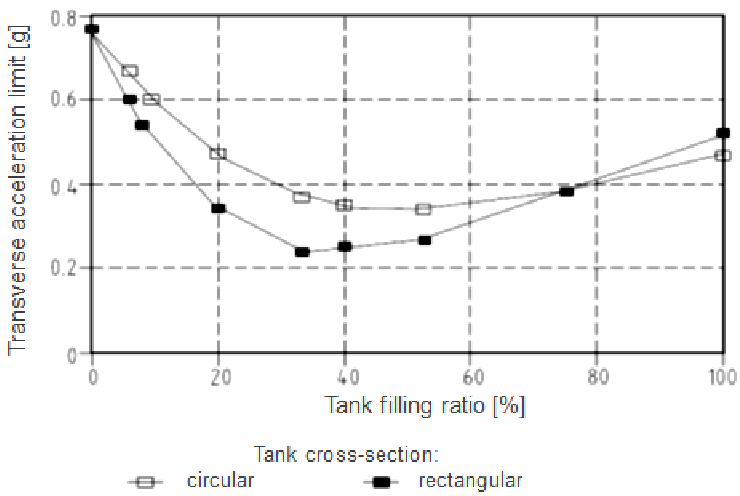

Fig. 4. Transverse acceleration limit values as functions of the tank filling ratio for two different tank cross-sections, at a lane-change manoeuvre.

Source: (Winkler, 2003)

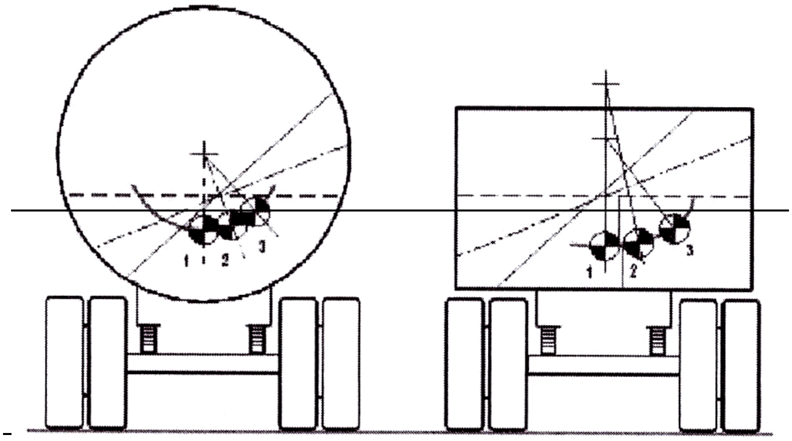

Fig. 5. Changes in the positions of the theoretical centre and arm of oscillation of a liquid in the tank for different shapes of the tank cross-section.
Source: (Januszewski et al., 2004).

The transverse acceleration limit values are specific to individual vehicle types and should be determined by testing on a testing track. Tests of this kind are carried out at the Automotive Industry Institute (PIMOT), see Figs 6 and 7. Changes in the semitrailer roll angle vs transverse acceleration at a uniform vehicle motion along a circle have been shown in Figs 8 and 9 (Januszewski et al., 2004).

Fig. 6. View of a tractor and tank semitrailer unit prepared for experimental tests on a testing track.
Source: Automotive Industry Institute

Fig. 7. View of a tractor and tank semitrailer unit during a test on a testing track.
Source: Automotive Industry Institute

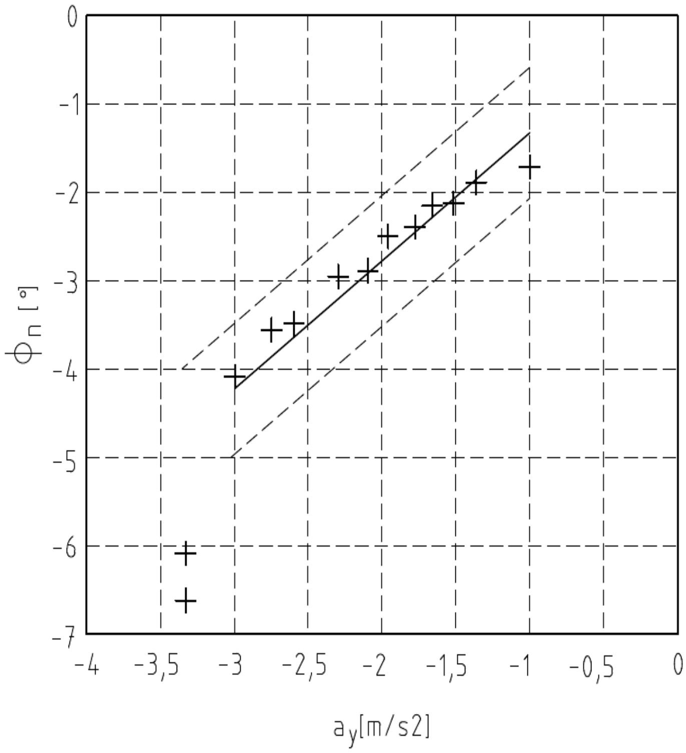

Fig. 8. Changes in the semitrailer roll angle vs transverse acceleration at a uniform vehicle motion along a circle: right turn.

Source: (Januszewski et al., 2004)

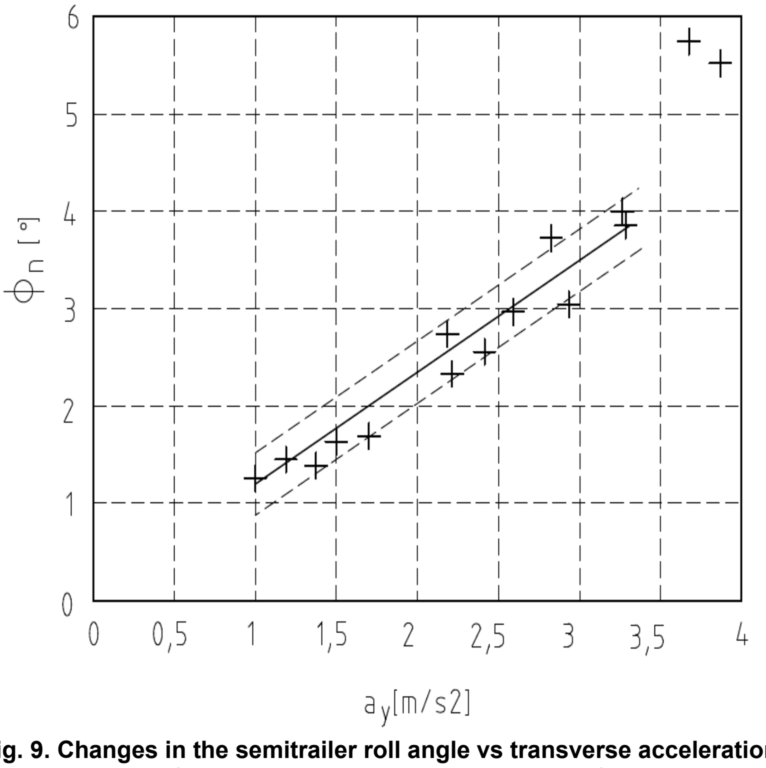

Fig. 9. Changes in the semitrailer roll angle vs transverse acceleration at a uniform vehicle motion along a circle: left turn.

Source: (Januszewski et al., 2004)

The use of the steering axle of the semitrailer bogie did not result in any improvement in the dynamic properties of a tractor-semitrailer unit unless the unit was manoeuvred in confined areas. During the tests, the semitrailer was observed to move outside the circular path. Apart from that, in comparison with the tests with the steering axle being locked, the inner semitrailer wheels were lifted off and the transverse stability was lost at a lower transverse acceleration (Janczur, 1998).

RECAPITULATION

The experimental testing of the transverse stability of articulated vehicles is a very important part of the measures taken to achieve an adequate level of the active safety of such vehicles. This may be well supplemented by possibilities of carrying out tests on vehicle driving simulators. The accidents with rollover of heavy articulated vehicles, especially with tank semitrailers, are particularly dangerous chiefly because of the extent of the resulting losses and hazard to the surroundings and the environment. A factor highly conducive to such accidents is the relatively low transverse stability of vehicles of this kind. A considerable impact is also exerted by insufficient experience of vehicle drivers, although this aspect may be improved, with no side effects, by training drivers on vehicle driving simulators. A simulator should ensure adequate training of the drivers and help to raise their qualifications, as appropriate for the vehicle being simulated. It should make it possible to train drivers within the scope of skilled use of the equipment of driver's cab of a modern motor truck or truck-tractor, correct operation of vehicle control mechanisms, mastering the practical skill of driving a vehicle in various configurations and with various cargo types (as regards the overall dimensions, mass, arrangement, etc.), in various weather and terrain conditions and at diverse traffic intensity, adherence to traffic regulations, correct reactions to road signs and traffic signals, taking correct measures in case of a simulated vehicle failure, recognition of potential hazards and correct reacting to dangerous situations in road traffic, adapting of driving techniques to local conditions (e.g. various road conditions, traffic impediments, water, snow, ice, drought, contamination of road surface, driving uphill and downhill), mastering the skills of economical driving and route planning, optimum use of engine torque, correct gear change, use of brakes, use of the braking system during downhill drives, and correct carrying out of manoeuvres on a manoeuvring yard [6]. The use of driving simulators enables repeated practising of certain manoeuvres and situations, while this is impossible when a real motor vehicle is driven by a trainee. Thus, the level of drivers' skills and sense of responsibility may be raised without exposing them and other traffic participants to a risk of accidents.

These issues should be viewed otherwise in the context of transporting tractor and tank semitrailer units by sea. In such a case, the systems the vehicles are provided with are of no use. The tractor-semitrailer unit does not move in relation to the ship but it still undergoes the accelerations that arise from the ship's movements on water. Changes in the positions of the theoretical centre and arm of oscillation of a liquid in tanks of different shapes of the tank cross-section have an impact on the maintaining of stability of a tractor-semitrailer unit when transported by sea.

REFERENCES

Winkler C. (2003). Rollover of Heavy Commercial Vehicles. UMTRI Research Review.

Polkovics L.W. (1998). Trucks Roll-over or not, as well?. Proceedings of 6th Mini Conference VDIA, Budapest.

Janczur R, Pieniążek W, Januszewski W, Więckowski D. (2004) Badanie wpływu osi skrętnej wózka naczepy na kierowalność i stateczność pojazdu członowego (Experimental research of influence of steering axle of semi-trailer dolly on steerability and stability of articulated vehicle). Czasopismo Techniczne Mechanika z. 7-M/2004, Kraków, pp. 273-282.

Januszewski W, Więckowski D. (2004). Wybrane testy badań kierowalności i stateczności pojazdów (np. członowych) przewożących niebezpieczne ładunki (Selected tests of steering and stability measurements of vehicles (e.g. tanks) for dangerous goods). Zeszyty Naukowe Politechniki Świętokrzyskiej Mechanika Z. 79. Wydawnictwo Politechniki Świętokrzyskiej, Kielce, pp. 359-368.

Januszewski W, Więckowski D, Pieniążek W, Wolak S. (2004) Eksperymentalne badanie bezpieczeństwa czynnego pojazdu członowego ciągnik siodłowy naczepa-cysterna (Experimental testing of an articulated vehicle, i.e. a tractor and tank semitrailer unit).

The 2nd Scientific and Technical Conference "Rozwój techniki samochodowej a ubezpieczenia komunikacyjne (Development of automotive technology vs motor insurance)" Radom, 16-17 June 2004 pp. 99-109.

Lozia Z, Cup A, Mitraszewska I, Piętka T, Więckowski D. (2010) Wymagania minimalne dla „symulatorów wysokiej klasy" stosowanych w szkoleniu kierowców (Minimum requirements for "top-of-the-range simulators" used for drivers training). Logistyka 4/2010, CD1.

Date of submission of the article to the Editor: 06/2018
Date of acceptance of the article by the Editor: 08/2018