

A Methodology to Assess Road Tankers Rollover Trend During Turning

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ABSTRACT

An experimental methodology is proposed to measure the rollover propensity of road tankers when subjected to lateral perturbations derived from steering manoeuvres. The testing principle involves subjecting a scaled down sprung tank to the elimination of a lateral acceleration, to analyze its rollover propensity as a function of various vehicle's operational and design parameters. Initial acceleration is generated through putting the scaled tank on a tilt table supported by a hydraulic piston. The controlled release of the fluid in the hydraulic system generates a perturbation situation for the tank, similar to the one that a vehicle experiences when leaving a curved section of the road and going to a straight segment. Durations for the maneuver and initial tilt angles characterize both the corresponding intensities of the steering maneuver. The use of this methodology to analyze the effect of fill level, initial acceleration and tank shape on the rollover propensity of a sprung tank suggests that for high fill levels an oval tank is up to three times more prone to rollover than the circular tank, while for low fill levels such tank is up to two times less prone to rollover than the circular tank. It is suggested that the proposed methodology be used to realistically analyze the effectiveness of alternative tank shapes and slosh suppression devices, as well as suspension dimensions and characteristics.

Keywords: Road tanker, rollover trend, steering manoeuver, tilt table, experimental scheme, road safety

CITATION: Romero, J., Betanzo-Quezada, E. and Lozano-Guzman, A., "A Methodology to Assess Road Tankers Rollover Trend During Turning," *SAE Int. J. Commer. Veh.* 6(1):2013, doi:10.4271/2013-01-0682.

INTRODUCTION

As a result of cargo slosh and the high position of their center of gravity, road tankers are 60% more prone to rollover than other classes of trucks [1]. The effect of cargo sloshing on the vehicle represents a complex phenomenon due to the many factors involved, including the cargo shifting and the sloshing forces [2], where the cargo motion depends on the tank size and geometry, the physical properties of the liquid and the type of maneuver performed [3]. A number of experimental and theoretical studies have been thus performed aiming at finding the most representative factors affecting road tankers stability [4,5,6,7,8,9]. In the case of cars aggressive, even centrifugal testing test has been proposed to assess the lateral load transfer and rollover performance of such vehicles [10, 11]. During a rapid evasive maneuver, a partially filled road tanker is more prone to rollover than a fully loaded road tanker [12]. Moreover, the effect of sloshing forces on the rollover trend of road tankers

has been found to be a function of tank's shape and fill level, as shown in Figure 1 [13], where the circular tank becomes more prone to rollover at high fill levels.

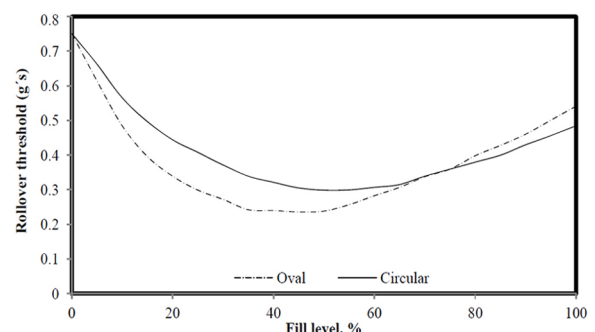


Figure 1. Effect of tank shape and fill level on the rollover threshold during a 0.5 Hz transient maneuver [13].

In this paper an experimental methodology is proposed to analyze the dynamic response of scaled down tanks to lateral perturbations associated to steering maneuvers. Justification of the proposed methodology derives from the need for a specific and safe method to test rollover propensity of road tankers.

TESTING RIG AND METHODOLOGY

The proposed experimental scheme herein was inspired by a standard testing methodology involving a tilt table to assess the passive safety of buses' superstructure. According to such methodology, a tilt table is used to elevate a full size bus up to the point of its rollover, to further measure the level of damage suffered by its superstructure as a result of its fall on the pavement [14]. In the methodology proposed herein, a tilt table supporting the tested tank, is inclined up to a certain angle thorough the use of a hydraulic actuator. From this original position the tilt table experiences a controlled descending motion by opening the relief valve of the hydraulic circuit. This motion pretends to simulate for a vehicle a steady state turning to a straight road transition. Figure 2 illustrates a schematic representation of the testing rig, comprising a hydraulic piston that places into position an instrumented tilt table. Instrumentation on the tilt table includes force transducers at both sides of the tank in order to assess the rollover propensity of the tank. The spring located at the end of the tilt table displacement is intended to provide a realistic end-of-maneuver effect. The force transducers operate on the basis of a strain gage bridge arrangement. The tested tank in this illustration is a leaf-spring-suspended 25-liters capacity vessel.

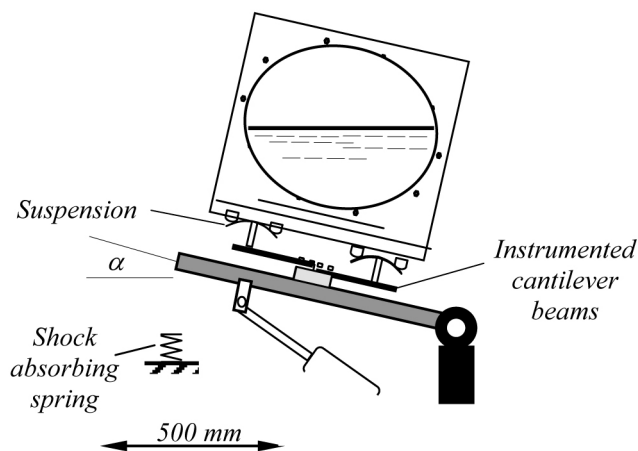


Figure 2. Schematic representation of the testing rig.

This experimental scheme is used to study the effect that fill level, initial acceleration and tank shape, have on the rollover propensity of the tested tank. The testing factors were defined as follows: i) fill level; ii) initial position of the tilt table that represents different initial lateral acceleration; iii) the tank shape; and iv) the relief valve opening position

that defines the speed at which the tilt table descends. Table 1 list the corresponding testing matrix.

Table 1. Testing Matrix

Factor	Levels						
Fill level (%)	23	37.5	50	62.5	75	87.5	92
Equivalent Initial Lateral	0.105 g		0.201 g		0.274 g		
Relief valve opening position	10 different positions						
Tank shape	Oval			Circular			

The rollover propensity of the scaled spring-supported road tankers in this paper was measured in terms of the Load Transfer Ratio (*LTR*), defined as [15]:

$$LTR = \frac{|F_{z,L} - F_{z,R}|}{F_{z,L} + F_{z,R}} \quad (1)$$

where $F_{z,L}$ and $F_{z,R}$ are the forces on the left and right sides of the device, respectively. *LTR* metric has shown to be a realistic measure of the rollover trend of heavy trucks in general, reaching a maximum value of 1 when the full weight of the vehicle is supported on the tires on one side of the vehicle, which indicates a potential rollover situation.

RESULTS AND DISCUSSION

Results are described in terms of the time history of the suspension forces, and of the maximum *LTR* values attained during the maneuver.

Time Domain Response Data

Figure 3 shows a sample time history of suspension forces for a situation involving both tank shapes and a single fill level. The following characteristic responses are note from this figure: i) a first opposite peak occurs as a result of the initiation of the descending motion of the tilt table; ii) different oscillations take place during the development of the maneuver; and iii) a final peak occurs at the end of the descending motion of the tilt table. This sequence is followed by the damping out of the sloshing motion. According to these data, the magnitude of the peak force at the end of the maneuver would be influenced by both, the duration of the maneuver and by the value of the natural sloshing period of the fluid. Consequently, while peak values at the end of the descending motion of the tilt table were found in all of the tests, their magnitude greatly depended on the magnitude of the initial acceleration, the fill level and of the perturbation duration.