FISH-HOOK SUV-TYPE VEHICLE SUSPENSION ANALISYS

SUMMARY

1 Introduction **2**

2 Project Description **2**

3 Vehicle specifications: **6**

3.1 Technical characteristics **6**

3.2 Wheel alignment **7**

4 Test results **8**

4.1 Fish Hook **8**

1 Introduction

The purpose of this analysis is to compare the vehicle dynamics of a SUV-type of vehicle provided with a conventional suspension system with a Creuat suspension system.

This report contains all the relevant results of tests carried out by the CarSim simulation program for the named “Fish-Hook” test case.

2 Project Description

The table below shows the test program of this analysis:

			Test conditions	
			V_x	Z Surface
	Test	Description	Km/h	m
1	Fish Hook test	Characterization of the tendency to roll of the vehicle during a fish hook test	80	0.0

The Fish-Hook test has been characterized following the specifications of the NHTSA

DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
49 CFR Part 575
[Docket No. NHTSA-2001- 9663; Notice 3]
RIN 2127-AI81
Rollover Resistance

Speed:
The test speed during this test was held constant at 50 mph (80 Km/h) for all the test cases.

Handwheel angle:
Fishhook maneuver handwheel angles are calculated with lateral acceleration and handwheel angle data collected during a series of six Slowly Increasing Steer tests (a total of three left-steer and three-right steer tests are performed). For each Slowly Increasing Steer test, a linear regression line is fitted to the lateral acceleration data from 0.1 to 0.375 g. Using the slopes of these regression lines, the handwheel angles at 0.3 g are determined for each individual test ($\delta_{0.3\ g}$).

The Fishhook maneuver steering angles are calculated by multiplying $\delta_{0.3\ g}$ by a steering scalar (SS). The default steering scalar is 6.5. $\delta_{Fishhook\ (Default)} = 6.5 \times \delta_{0.3\ g}$

B. Fishhook Maneuver

The fishhook maneuver, uses steering inputs that approximate the steering a driver acting in panic might use in an effort to regain lane position after dropping two wheels off the roadway onto the shoulder. In the NPRM notice, we described it as a road edge recovery maneuver. It is performed on a smooth pavement rather than at a road edge drop-off, but its rapid steering input followed by an overcorrection is representative of a general loss of control situation. The original version of this test 19 was developed by Toyota, and variations of it were suggested by Nissan and Honda. NHTSA has experimented with several versions since 1997, and the present test includes roll rate feedback in order to time the counter-steer to coincide with the maximum roll angle of each vehicle in response to the first steer.
Fishhook maneuver in terms of the automated steering inputs commanded by the programmable steering machine and illustrates the roll rate feedback. The initial steering magnitude and countersteer magnitudes are symmetric, and are calculated by multiplying the handwheel angle that would produce a steady state lateral acceleration of 0.3 g at 50 mph on level pavement by 6.5. The average steering input is equivalent to the 270 degree handwheel angle used in earlier forms of the maneuver but, as in the case of the J-Turn , the procedure above is an objective way of compensating for differences in steering gear ratio, wheelbase and understeer properties between vehicles. The fishhook maneuver dwell times (the time between completion of the initial steering ramp and the initiation of the countersteer) are defined by the roll motion of the vehicle being evaluated, and can vary on a test-to-test basis. This is made possible by having the steering machine monitor roll rate (roll velocity). If an initial steer is to the left, the steering reversal following completion of the first handwheel ramp occurs when the roll rate of the vehicle first equals or goes below 1.5 degrees per second. If an initial steer is to the right, the steering reversal following completion of the first handwheel ramp occurs when the roll rate of the vehicle first equals or exceeds -1.5 degrees per second. The handwheel rates of the initial steer and countersteer ramps are 720 degrees per second. To begin the maneuver, the vehicle was driven in a straight line at a speed slightly greater than the desired entrance speed. The driver released the throttle, coasted to the target speed, and then triggered the commanded handwheel. The nominal maneuver entrance speeds used in the fishhook maneuver ranged from 35 to 50 mph, increased in 5 mph increments until a termination condition was achieved. Termination conditions included simultaneous two inch or greater lift of a vehicle's inside tires (two-wheel lift) or completion of a test performed at the maximum maneuver entrance speed without two-wheel lift. If two-wheel lift was observed, a downward iteration of vehicle speed was used in 1 mph increments until such lift was no longer detected. Once the lowest speed for which two-wheel lift could be detected was isolated, two additional tests were performed at that speed to check two-wheel lift repeatability.

The Fish Hook test is a test that stresses the roll-over tendency of vehicles by inducing it with a typical emergency maneuver. The name of this test is taken for the shape of the path follow for the vehicle.

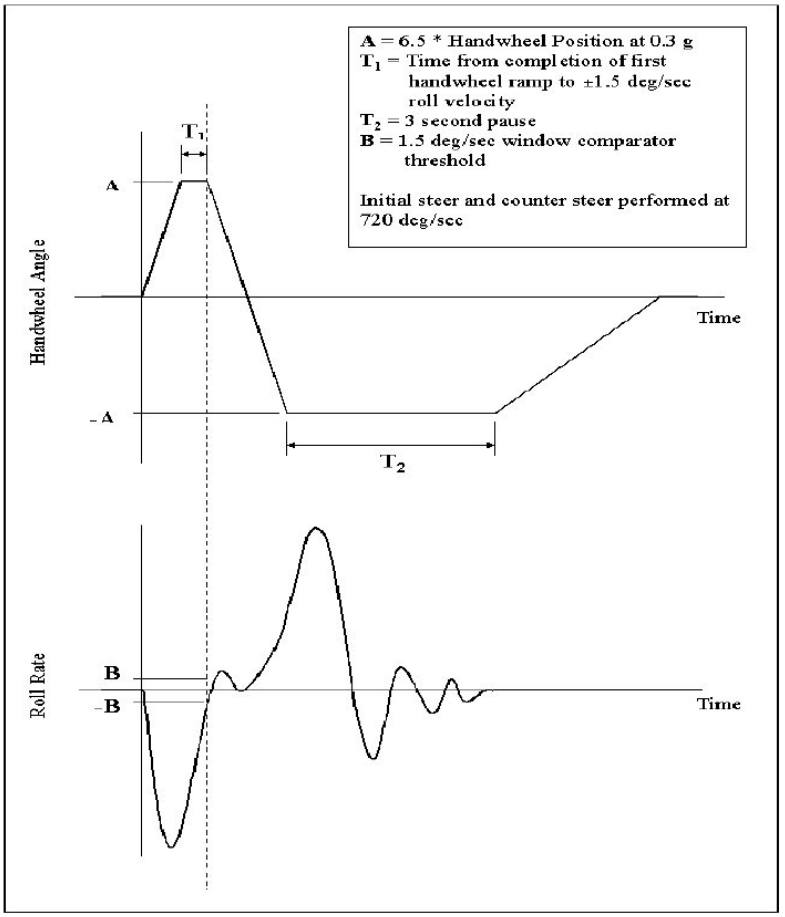


Figure 2. NHTSA Fishhook (with roll rate feedback) maneuver description.

For the vehicle parameters used, the steering wheel angle at 0.3g was determined to be 37º on both suspension configurations. This implies that the understeer factor on both configurations was made not to be different.

The Fishhook maneuver steering angles are calculated by multiplying $\delta_{0.3\ g}$ by a steering scalar (SS). The default steering scalar is 6.5.

$\delta_{Fishhook\ (Default)}$ = 6.5 x $\delta_{0.3\ g}$ = 6.5 x 37º = 240.5º.

The initial steer and counter steer performed at 720º/s

The time to pass of 0º to 240.5º steering wheel angle was 240.5º/ (720º/s)=0.33 s (time to pass of 0º to 240.5º steering wheel angle)

The time for completion of first handwheel was 0.55s on both configurations.

The time to pass of 240.5º to -240.5º steering wheel angle was 0.33s x 2 0 0.66s

The time for completion of second handwheel was 3s on both configurations

Description of the tested Suspension configurations:

Conf 1	Conventional Suspension
Conf 2	Creuat Suspension + Incremented Pitch Elasticity (%) + Incremented Roll Damping (%) + Identical Roll Elasticity + Partially freed axle crossing (-%) + Softened Vertical Rebound (-%)

Conventional suspension data Matrices

```
SYSTEMSPECS Type=[CREUAT_GENERIC].  Copyright (c) Creuat S.L. 2003 (1.0)
SPRINGS MATRIX (ROW 0) (N/MM)  = [ 28.0, -3.0,  0.0,  0.0]
SPRINGS MATRIX (ROW 1) (N/MM)  = [ -3.0, 28.0,  0.0,  0.0]
SPRINGS MATRIX (ROW 2) (N/MM)  = [  0.0,  0.0, 55.0,-10.0]
SPRINGS MATRIX (ROW 3) (N/MM)  = [  0.0,  0.0,-10.0, 55.0]
DAMPERS MATRIX (ROW 0)N/MMS-1) = [  3.0, -0.3,  0.0,  0.0]
DAMPERS MATRIX (ROW 1)N/MMS-1) = [ -0.3,  3.0,  0.0,  0.0]
DAMPERS MATRIX (ROW 2)N/MMS-1) = [  0.0,  0.0,  3.0, -0.3]
DAMPERS MATRIX (ROW 3)N/MMS-1) = [  0.0,  0.0, -0.3,  3.0]
```

Creuat suspension data Matrices

```
SYSTEMSPECS Type=[CREUAT_GENERIC].  Copyright (c) Creuat S.L. 2003 (1.0)
SPRINGS MATRIX (ROW 0) (N/MM)  = [ 20.0, -3.0,  0.0,  0.0]
SPRINGS MATRIX (ROW 1) (N/MM)  = [ -3.0, 40.0,  0.0,  0.0]
SPRINGS MATRIX (ROW 2) (N/MM)  = [  0.0,  0.0, 55.0, 20.0]
SPRINGS MATRIX (ROW 3) (N/MM)  = [  0.0,  0.0, 20.0, 25.0]
DAMPERS MATRIX (ROW 0)N/MMS-1) = [  2.0, -0.3,  0.0,  0.0]
DAMPERS MATRIX (ROW 1)N/MMS-1) = [ -0.3,  3.5,  0.0,  0.0]
DAMPERS MATRIX (ROW 2)N/MMS-1) = [  0.0,  0.0,  3.0,  1.0]
DAMPERS MATRIX (ROW 3)N/MMS-1) = [  0.0,  0.0,  1.0,  2.0]
```

The modifications made on the Creuat suspension parameters when compared to the conventional system were made to increase the car stability without changing other characteristics like comfort.

In fact, by reducing the stiffness to vertical movement we may have increased the comfort of the car, although this was not the purpose of this test.

3 Vehicle specifications:

3.1 Technical characteristics

Dimensions			
	Length		5000 mm
	Width		2500 mm
	Height		3000 mm
	Length between wheels		4000 mm
	Width between wheels		1900 mm
Engine	Size		5000 cc
Sprung mass			1900 Kg
Unsprung mass			
	Front		100 Kg
	Rear		120 Kg
Axle Load			
	Front		1000 Kg
	Rear		900 Kg
Rear – wheel drive			Viscous – Gear ratio 4.4
Front suspension (Conventional system)	*Parts number*		
		Spring	25 KN/m
		Damper	2.7 KN/ms^{-1}
	Stabiliser		20 KN/m
Rear suspension (Conventional system)	*Parts number*		
		Spring	31 KN/m
		Damper	3.3 KN/ms^{-1}
	Stabiliser		34 KN/m
Nominal steering			
	Front Gear ratio		20.0 deg/deg
	Rear Gear ratio		20.0 deg/deg
Wheels	Rim dimension		R16
	Tire width		275 mm
	Lateral force slope		0.17

3.2 Wheel alignment

The wheel alignment of the vehicle was done with the vehicle in the test condition (with instrumentation, without driver):

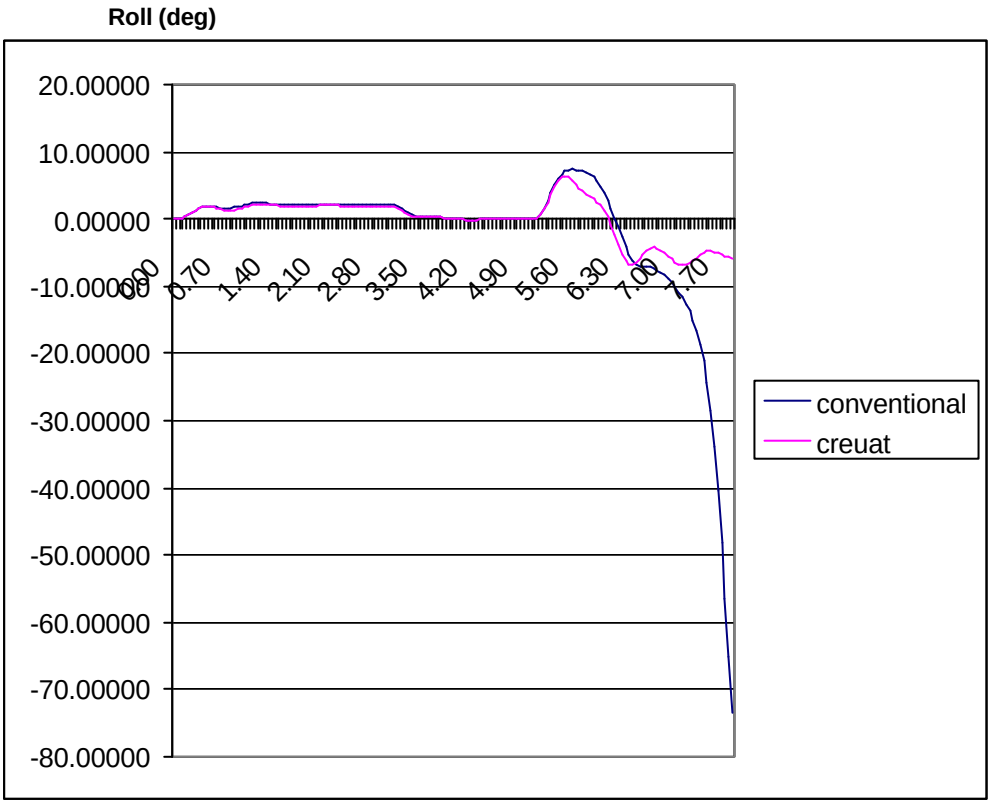
		Left	Right
Front	Camber	0.0º	0.0º
	Caster	2.0º	2.0º
	Kingpin inclination	12.0º	12.0º
Rear	Camber	0.0º	0.0º
	Caster	1.0º	1.0º
	Kingpin inclination	-	-

4 Test results

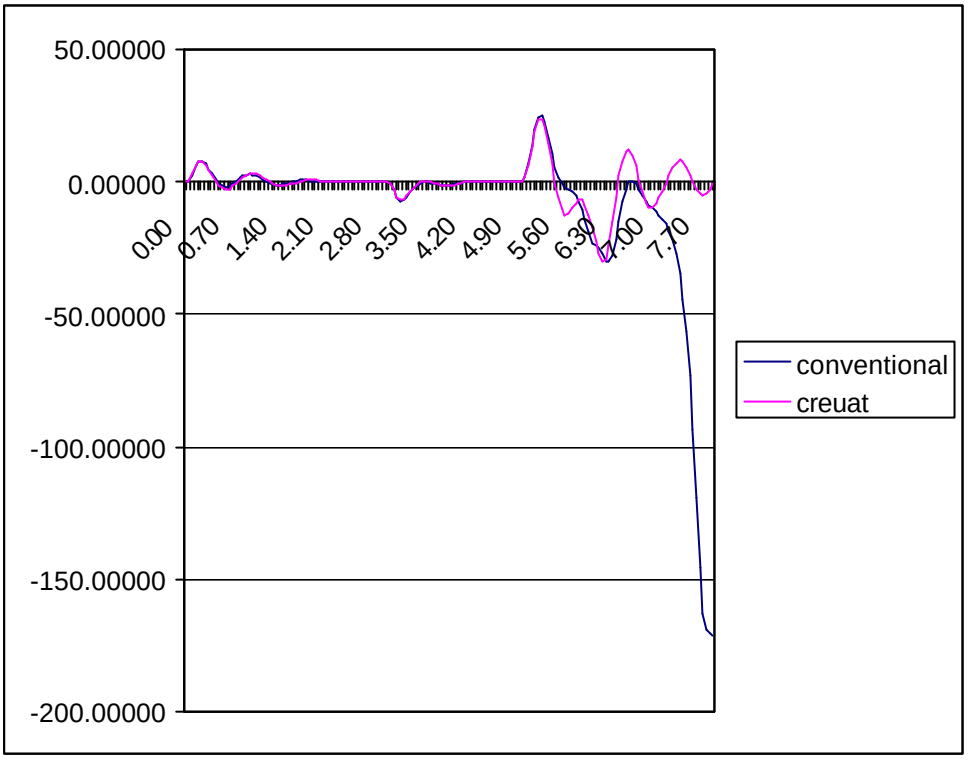
4.1 Fish Hook test

General conditions

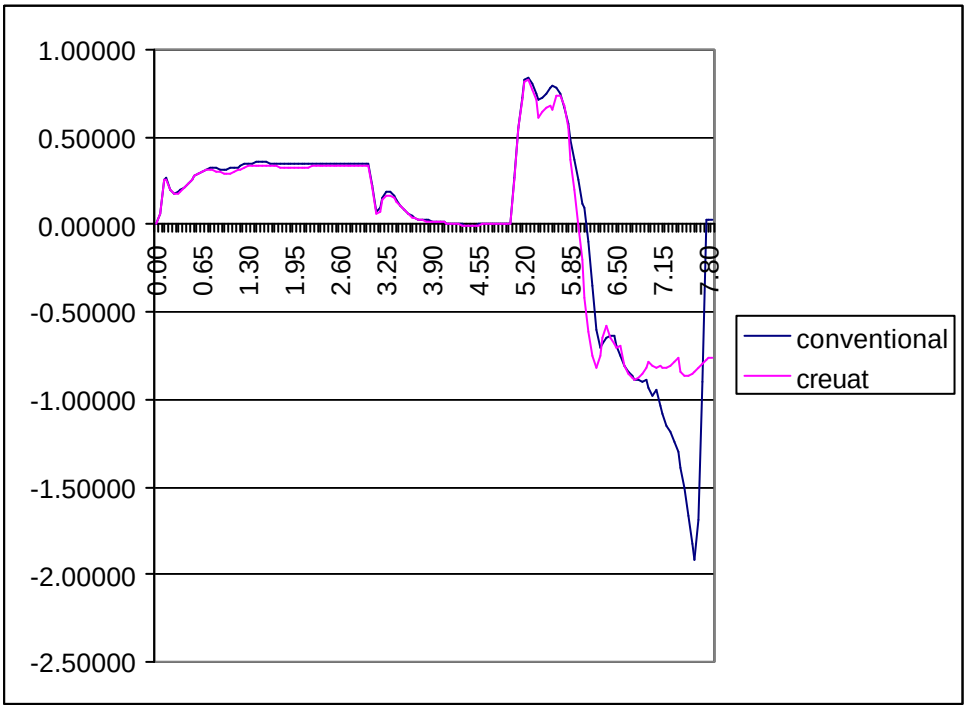
Road surface:	Asphalt
Friction surface:	0.85
Sample Frequency:	500 Hz



Roll rate (deg/s)



Lateral acceleration (g´s)



Yaw rate (deg/s)