ACCELERATIONFACTORSANDMAXIMUMSPEEDS UNDERCONDITIONSOFIDLEACCELERATION

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INTRODUCTION

When analyzing low speed collisions, the basic questions which require consideration are what was the speed of impact and what was the injury potential of the collision? In many low speed accidents, damage is lacking or insufficient to employ damage-based analysis methods, so the best method may be momentum analysis. To employ momentum analysis requires certain parameters be known or, if not known, estimated.

Case in point: two vehicles are stopped one behind the other. The foot of the driver of the second vehicle slips from the brake pedal. Under no more power than developed by the idling engine, the second vehicle moves forward and impacts the rear of the first vehicle. If the vehicle's acceleration rate is known, closing (impact) speed can be estimated using the following equation:

$$V_c = \sqrt{V_o^2 \pm 2*a*d} \qquad \text{Eq. 1}$$

Because the impacting vehicle was stopped before acceleration, $v_0 = 0$. The distance between the vehicles, d, is either known or estimated. Finally, the only unknown variable is "a", the average acceleration prior to impact, of the impacting vehicle.

Various tables suggest acceleration rates for normal and rapid acceleration, but little or no information is published concerning acceleration rates under idle engine power only. The focus of this research was to correct the lack of information about acceleration rates and maximum speeds that are attainable when only idle engine power is applied.

TABLE 1 - Acceleration Test Results

Vehicle Year, Make & Model	Total Weight (lb)	g - Analyst: Forward Avg. g	Forward Peak g	Reverse Avg. g	Reverse Peak g	Laser Gun: Maximum Speed Forward (mph)	Maximum Speed Reverse (mph)
1994 Nissan Sentra	2832	0.04	0.07	0.03	0.04	3	2
1996 Ford Escort	2899	0.03	0.05	0.02	0.03	4	3
1990 Plymouth Acclaim	3381	0.02	0.03	-----	-----	3	-----
2000 Daewoo Nubira	3396	0.04	0.06	0.02	0.02	3	3
1988 Chevrolet Celebrity	3494	0.01	0.02	0.01	0.02	4	4
1994 Nissan Ultima	3514	0.03	0.05	0.02	0.03	3	3
1995 Ford Mustang	3560	0.04	0.07	0.03	0.04	4	5
1999 Pontiac Grand Am	3592	0.02	0.02	0.02	0.02	-----	-----
2000 Toyota 4 Runner	4176	0.03	0.06	0.02	0.03	3	3
1994 Mercury Gr. Marquis	4350	0.03	0.05	0.02	0.04	4	3
1994 Mercury Villager	4519	0.03	0.05	0.03	0.04	4	4
1993 GMC Jimmy	4532	0.02	0.04	0.02	0.04	3	2
1997 Chevrolet Tahoe	5921	0.04	0.09	0.02	0.02	3	3
1992 Toyota Camry	-----	0.03	0.06	0.02	0.03	4	4

TABLE 2 - Statistical Analysis of Test Results

	Forward		Reverse		Maximum Speed	
	Average	Peak	Average	Peak	Forward	Reverse
Mean	0.029	0.051	0.021	0.031	3.5	3.25
Median	0.03	0.05	0.02	0.03	3	3
Standard Deviation	0.009	0.019	0.006	0.009	0.519	0.866
Minimum	0.01	0.02	0.01	0.02	3	2
Maximum	0.04	0.09	0.03	0.04	4	5

TESTING

Fourteen vehicles with automatic transmissions were tested for acceleration and maximum speed under idle acceleration in both forward and reverse directions. Peak and average acceleration were measured using a Valentine Research G-Analyst. Maximum speed was measured using a Laser Technology Inc. LTI 20/20.

Each test vehicle was driven to the test site by its owner so the engine was warm when the vehicle was tested. The vehicle and owner were weighed on InterComp Competition Scales.

Following vehicle weighing, the G-Analyst was installed in the vehicle and calibrated by the operator (the operator's weight was recorded prior to testing). The LTI 20/20 was calibrated. The course was level within 0.01% and the LTI 20/20 was located at one end.

The driver of the vehicle was instructed by the G-Analyst operator, who rode with the vehicle, to remove his foot from the brake pedal and allow his vehicle to accelerate along a pre-selected course under engine idle power only - he was instructed not to depress the accelerator pedal.

When the vehicle reached maximum speed as determined by the LTI 20/20 operator, the vehicle was stopped. Maximum acceleration, average acceleration, and maximum speed were recorded.

The test was repeated with the vehicle in reverse and data recorded as in the forward tests.

DATA AND ANALYSIS

Table One shows the results of the accelation tests. Vehicles were listed by measured weight.

A statistical analysis of the test data from

Table One was performed. The results of this analysis appears in Table Two.

A comparative analysis of vehicle weights, engine sizes and acceleration rates was also performed. This compilation appears in Table Three. Vehicle engine sizes were obtained from VINAssist. The vehicles for which engine sizes were not available were not included in this table.

The most striking result of these tests is the consistency of the maximum vehicle speeds, particularly moving forward. This was despite the wide variety of vehicle platforms tested. Results varied little with vehicle weight and engine size even as vehicle weight more than doubled.

Mean forward average acceleration was 0.029 g with standard deviation of 0.009 g. Median forward average acceleration was 0.03 g.

Average forward acceleration correlated poorly with engine size and vehicle weight. The same can be said for peak forward acceleration, although the range was somewhat larger than for average acceleration. Table Four lists the correlation coefficients between engine size, vehicle weight, peak forward acceleration, and average forward acceleration.

Most consistent across a large range of vehicle weights and engine sizes was maximum forward speed. In all cases, this speed was 3 or 4 miles per hour. Mean maximum forward speed was 3.5 miles per hour, ranging from 3 to 4 miles per hour. Reverse maximum speed showed a somewhat greater variation, ranging from 2 to 5 miles per hour

CONCLUSIONS

When evaluating and applying these results, it is significant that average and peak acceleration and maximum speeds varied little from vehicle to vehicle. It is also significant that these parameters varied little across a wide range of vehicle weights and engine sizes. Probably of most interest is the consistency of maximum speeds.

Referring to Equation 1, regardless of the distance traveled by a vehicle under idle engine power, V_C (closing velocity) would not be expected to exceed 4 miles per hour. This establishes an upper limit for the scenario outlined above and similar scenarios.

The test described comprises a limited number of vehicles. Further tests are desirable to validate the results obtained and increase the database of such information.

Tests should also be conducted using a measuring device such as a fifth wheel or accelerometer to validate G-Analyst and LTI 20/20 results and to provide precise acceleration and velocity profiles of test vehicles. It is hypothesized that peak acceleration is achieved early in the profile, but tests should be conducted to confirm this hypothesis.

It would also be of interest to investigate how average acceleration and maximum speeds vary with surface slope.

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TABLE 3 - Comparision of Weight, Engine Size, and Acceleration

Vehicle Year, Make & Model	Curb Weight (lb)	Engine Size (L)	Acceleration Rate	
			Avg. g	Peak g
1994 Nissan Sentra	2397	1.6	0.04	0.07
1996 Ford Escort	2505	2.0	0.03	0.05
1990 Plymouth Acclaim	2869	2.5	0.02	0.03
1988 Chevrolet Celebrity	2956	2.8	0.01	0.02
1994 Nissan Ultima	3111	2.4	0.03	0.05
1995 Ford Mustang	3154	3.8	0.04	0.07
1999 Pontiac Grand Am	3179	3.4	0.02	0.02
1994 Mercury Grand Marquis	3923	4.6	0.03	0.05
1994 Mercury Villager	4044	4.3	0.02	0.04
1993 GMC Jimmy	4106	3.0	0.03	0.05
1997 Chevrolet Tahoe	5431	5.7	0.04	0.09

TABLE 4 - Correlation Coefficients

Engine Size v. Peak Forward Acceleration	0.34
Engine Size v. Average Forward Acceleration	0.42
Vehicle Weight v. Peak Forward Acceleration	0.15
Vehicle Weight v. Average Forward Acceleration	0.21

VIRGINIA'S "SMART ROAD" OPENS

The world's first all-weather road test facility build especially for scientific research in the transportation field opened on March 23, 2000 in Blacksburg, VA. The facility, known as the "Smart Road," is the result of a partnership between the Virginia Department of Transportation (VDOT), the Virginia Tech's Transportation Institute, and FHWA. VDOT owns the land on which the facility is built; Virginia Tech operates the facility. FHWA participated in the design and funding of an experimental highway lighting system.

The present length of the "Smart Road" is a 1.7 mile stretch of a two-lane roadway equipped with 400 electronic sensors, video cameras, and 75 weather towers that can create rain, snow, and icing conditions. It features 14 instrumented pavement sections and embedded magnetic strips for measuring lane-keeping and driver behavior.

The experimental lighting system section is 1.2 km long and provides for a wide variety of luminaire selections, pole spacings, and changes in mounting heights. The system will serve as a test facility for new and novel highway lighting designs, visibility studies, as well as to evaluate the interaction between fixed lighting, headlighting, and signing, and roadway markings under different weather conditions. TFHRC designed and built the computer-based lighting control system that allows for instantaneous changes of many of the lighting parameters from a central command post.

The test tract cost $12-$15 million and was funded by VDOT but is reimbursable by FHWA.

More than 70 research projects are underway now at the facility for both private industry and government agencies.

The Smart Road test facility is the result of a movement started in the 1980s to connect Blacksburg to Interstate 81 and Roanoke to the north. Smart Road is projected to be a part of Interstate 73, eventually linking Blacksburg to I-81.

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