

Suspension Variables Influencing Static Vehicle Wheel Alignment Measurements

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ABSTRACT

This paper is part of a bigger research effort that aims to capture the influences of static wheel alignment measurement accuracy for road going vehicles. Vehicle alignments can and often are the bottleneck in automotive and truck assembly lines and a greater understanding of the issues are very valuable. The alignment equipment in this research has been tuned and adjusted to minimize external variables and the team of authors have 300+ vehicle measurements. Of the many things that influence the accuracy and repeatability of vehicle suspension alignment measurement and adjustment, the measurement procedures can be the most significant. This includes but is not limited to alignment machine setup and vehicle tire pressures.

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INTRODUCTION

Vehicle wheel alignments are very time consuming in the automobile assembly process [1, 2, 3, 4, 5] and are critical to optimum vehicle performance yet the accuracy of its measurement is not very well characterized [6, 7, 8, 9, 10]. This research effort includes hundreds of passenger vehicle wheel alignment measurements in the Motorsports Research Building at the University of North Carolina at Charlotte. The design of experiments works to capture the various influential factors. Many things that influence the accuracy and repeatability of the vehicle suspension alignment measurement were evaluated. This includes but is not limited to adjustment configuration, suspension design, static alignment settings, and bushing stiffness.

As with earlier work by this research team, [11] measurements were made with a Hunter Pro-Align with DSP700 wheel sensors and all vehicles were reviewed and any with suspension damage were rejected prior to measurement. The collection of vehicles measured included the category of small front wheel drive, full size rear drive, seven passenger SUV, sports car, and race car. Since a correlation was made between the softness of the suspension and variability, two very softly sprung vehicles were included

Accuracy of the equipment is not a big part of this study since after a strong attempt to measure it, we were not able to achieve measurements that could sense any reasonable measurement errors. The equipment resolves to 0.01° and our calibration equipment was only accurate to 0.05° . Repeatability was evaluated by performing repeated measurements on the same day, a week apart, and over several months. Typically, ten repeats were made during each session and the standard deviation was compared.

Table 1. List of Test vehicles

Vehicle no.	Vehicle type	Model
V1	Small FWD	2005 Mini Cooper
V2	Full sized RWD	2005 Mercedes E320 CDI
V3	7 passenger SUV	2007 Acura MDX
V4	FWD luxury sedan	1991 Cadillac Coupe DeVille
V5	RWD luxury sedan	2001 Grand Marquis
V6	RWD Sports Car	1999 Porsche 911 Cabriolet
V7	NASCAR race car	UNC Charlotte NASCAR Sprint Cup race car
V8	Lowered FWD coupe	Toyota Celica
V9	Sporty RWD Sedan	Lexus IS250
V10	RWD Sports Car	Honda S2000 CR

The majority of the previous variability in suspension adjustment and measurement was determined to be from the stiffness (or lack thereof) of the suspension bushings [11]. This was found to be the case even for static suspension settings far from the norm. The NASCAR® race car with its 6+° LF camber had some of the lowest variation in the whole test. Further evaluation would reveal strong measurement errors without increased variability from incorrect tire pressure and inaccurate platform levelness.

TEST MEASUREMENT DETAILS

For this research, a full vehicle alignment measurement included camber and toe-in for the left front (LF), RF, LR, and RR wheels. Caster sweeps were also performed, (typically a +17° to -17° steer sweep for both front tires). Due to the time restrictions in a shop environment, wheel alignment technicians may be under pressure to shortcut certain alignment protocols. Some shortcuts may be trivial and some are very sensitive. Variables studied include such things as correctly compensating the alignment heads for angular correction, tire pressure errors, and levelness errors in the measurement platform inducing wedge (a corner or cross weight preload). Influence on the suspension parameters camber, caster, toe, cross camber and cross caster variation are presented.

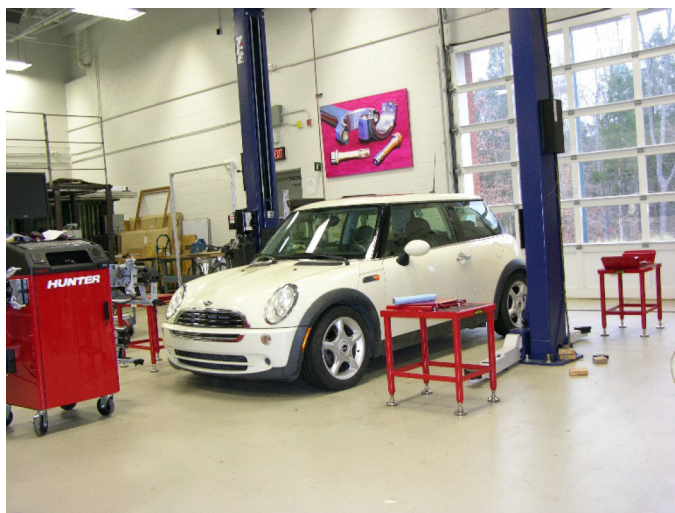


Figure 1. Vehicles are initially aligned to the two-post lift work area (vehicle V1)

STATISTICAL APPROACH

A total of 304 full vehicle measurements were completed. Although some more specialized measurements were not run ten times, most of the vehicle measurements were repeated ten times and the primary assessment approach was to compare the values and standard deviation of these measurements. If the measurement values are extraordinary, (the NASCAR 6° LF camber) that information is presented as well.



Figure 3. Vehicles are then raised, the heads are attached and compensated, (vehicle V2) and then raised again and lowered for every alignment measurement test.

TEST PROTOCOL

The test protocol was repeated for all tests except for tests of the influence of protocol variables.

TEST VEHICLES AND CONDITION



Figure 2. The “DSP700” alignment heads were attached to the wheel rims and compensated for angular errors prior to each test session (vehicle V3)

The vehicle was lifted off the wheel stand bearing plates between each alignment measurement.

1. To avoid wedge effects, the top of the bearing plates were leveled with an LS Starrett brand 98Z-12 spirit level [12], which has a resolution of 80-90 arc seconds or a levelness of 0.6 mm (0.025”) on a 1.4m (55”) track.
2. The front and rear of the vehicle were then jounced to settle the suspension.
3. Digital ‘compensation’ was performed on the DSP700 heads to correct for wheel bearing to mounting flange misalignment prior to each test.
4. All alignment measurements included Caster Sweeps.

5. The vehicle was jounced again prior to the recording of final readings.

All of the vehicles measured in this research have no visible or evident wear. Bushings look like new, no measurable deflection could be produced in ball joints, and no damage or scrapes are visible on any suspension members. Measurements were made several cars including a small front drive car ([figure. 1](#)), a full-sized rear drive car ([figure. 2](#)), an SUV ([figure. 3](#)), two Luxury Sedans ([figures 4 and 6](#)), a sports car ([figure. 5](#)), and a NASCAR race car. There were also a few special tests done on a lowered FWD coupe, a second sports car, and a sporty RWD Sedan (see [table 1](#)).



Figure 4. The luxury RWD sedan performing a caster sweep (vehicle V5)

Although much of the review is based on previous results, additional observations required more intensive study on a particular vehicle.

Test vehicle V2 ([figure 2](#)) was used in this way and may be the most wheel aligned vehicle in North America. At our latest test, we had measured the wheel alignment on this vehicle over 160 times.



Figure 6. At the end of testing, the vehicles were raised, the heads removed, the bearing plates and stands backed away, and here, vehicle V6 is ready to be lowered to the ground.

In addition, our previous research provided a correlation between softness of the suspension and wheel alignment repeatability. Because of this, we added two vehicles chosen specifically due to their soft suspension reputation. These were the 1991 Cadillac DeVille and 2001 Mercury Marquis. Although very old for our testing, both vehicles appeared to have been very well maintained and suspension components and bushings were in surprisingly good shape.

ALIGNMENT EQUIPMENT DETAILS

Suspension repeatability was assessed by performing complete alignment measurements repeatedly and using the standard deviation of the measurements as a reference. To assess stability of the measurement, we did this across weeks and months on the same vehicle.

All of the testing was performed on a Hunter ProAlign ([Figures 2 and 4](#)) with DSP700 wheel sensors ([Figure. 3](#)) wheel alignment machine.

Alignment Equipment Calibration and Accuracy

We found the accuracy and repeatability of the alignment equipment to be more accurate than any of the systems we used to measure it. The measurement resolution of the alignment heads is 0.01° and it is difficult to find a sensor with the usual ten times higher accuracy. As a result, we measured the zero values with a 300mm L.S. Starrett spirit level [12] and the angle change with a digital angle indicator [13]. The dilemma is that the spirit level has an accuracy of 0.024° and the digital gage only has a 0.05° accuracy. In no measurement were we able to achieve measurements that could sense any reasonable measurement errors. Our certainty of readings was therefore only 0.05° ; however, we reported the instrument 0.01° resolution in the findings.



Figure 5. Vehicle bushings underwent large binding forces due to lateral suspension scrub on droop so one protocol was to back cars out of the shop quickly (vehicle V4)