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Crash Test 2 Force Balance Results and Analysis

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*In other words, **DO NOT** let any disagreement you may have with things stated in this document reflect poorly upon the Crash Team or the organization hosting the crash testing. The author bears any and all responsibility for this document's contents.*

Force Balance Background

Historically, Force Balance is a mathematical model which allows one to calculate stiffness values for an "unknown" vehicle based upon the stiffness values of a "known" vehicle and the damage crush profiles of both vehicles. The basis of this model is "Equal but Opposite Force", Newton's Third Law of Motion.

This method is often applied when there are either (A) no stiffness values available for a vehicle due to a lack of tests or (B) due to angle of impact and/or override/underride issues the available stiffness values for a vehicle and its impact surface are not applicable. For further explanation and a detailed analysis of the calculations involved, see "**Balancing Collision Forces in Crush/Energy Analyses - Second Edition**" by Nathan Shigemura and Andrew Rich which is available through - ***https://store.iptm.org/products/***

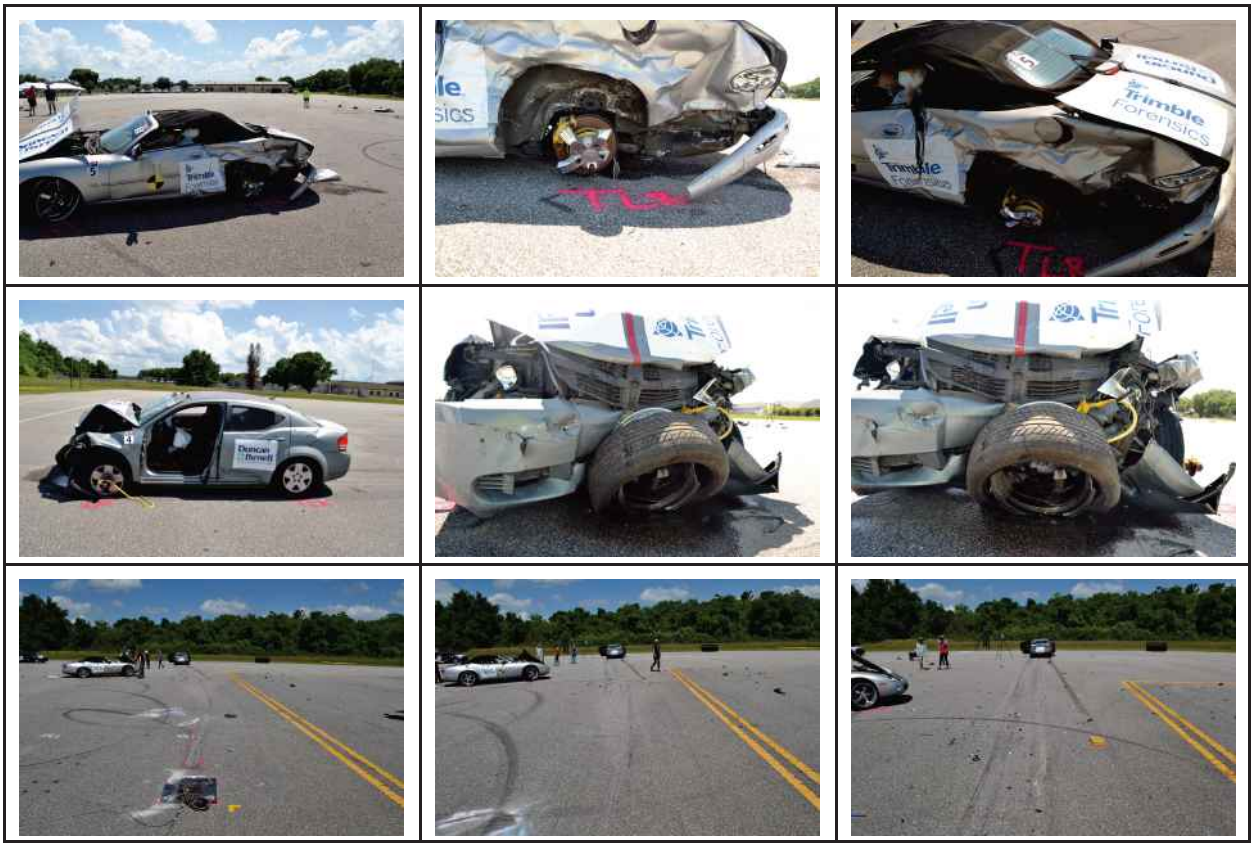
The 4N6XPRT StifCalcs® program has a Force Balance calculation module as a part of the program. This module does the basic stiffness calculations of the original Force Balance model, and has added the additional calculations for Kinetic Energy Equivalent speed and Delta-V for both vehicles, and the closing speed between the two vehicles, which is displayed on the "KNOWN" vehicle page. Because of these additional calculations, application of this method to crashes where crush data is available is useful as a check upon EDR/CDR downloads. It is also useful in collisions where EDR/CDR downloads are not available due to the age of the vehicles (i.e. - lack of EDR/CDR Support) or equipment/power failure.

Crash Test Overview

This crash involved the front end of a 2010 Dodge Avenger impacting the left rear axle of a 2001

Jaguar XK8. The Dodge is an EDR/CDR supported vehicle. The Jaguar is not. Several accelerometers were placed into the Jaguar to help gather instrumentation data to guide the analysis when attempting to reconstruct the collision as if it was a “real” collision on the roadway.

As a result of the crash, the entire right rear wheel broke off from the Jaguar and was embedded in the front of the Dodge. This tire left scrape marks from the rim and tire “skid” marks from the sidewall and tread of the tire as it rubbed on the ground from impact to rest.



There are no crash tests in the NHTSA Crash Test database for the Jaguar. There are a total of seven (7) tests for the front end of the Dodge and it same/similar vehicles.

Due to the lack of tests and therefore side stiffness values for the Jaguar, along with the fact that the impact was over the rear axle instead of between the axles where most side tests are conducted, any speed from crush analysis goes beyond simply punching data into a CRASH III program.

Additionally, the lack of EDR/CDR in the Jaguar, needing to account for and distribute the tire braking forces across five (5) tires instead of four (4) with regard to the Dodge Avenger post impact travel, and the fact that the Dodge Avenger also suffered a Left Front tire deflation as a result of the collision, all serve to increase the difficulty of analyzing post impact speeds for the Dodge and thus increases the difficulty of establishing collision speeds. The spin of the Jaguar, three (3) tires instead of four (4), and the dragging of the Left Rear axle instead of a tire serve to

do the same thing with regards to establishing post impact speeds for the Jaguar. The lack of good post impact speeds for both vehicles lessens the accuracy of any speed determinations obtained by Conservation of Linear Momentum calculations.

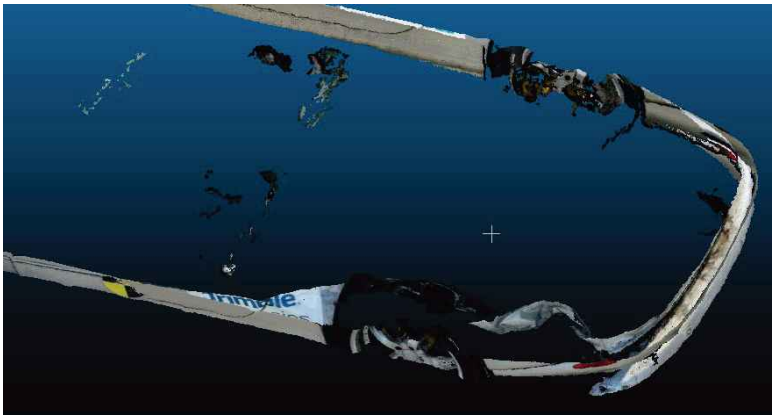
A Force Balance approach to evaluating the collision speeds from the damage to both the Dodge and the Jaguar removes some of the difficulty as it does not rely on any post impact evidence beyond the residual crush to the two vehicles.

Preparation

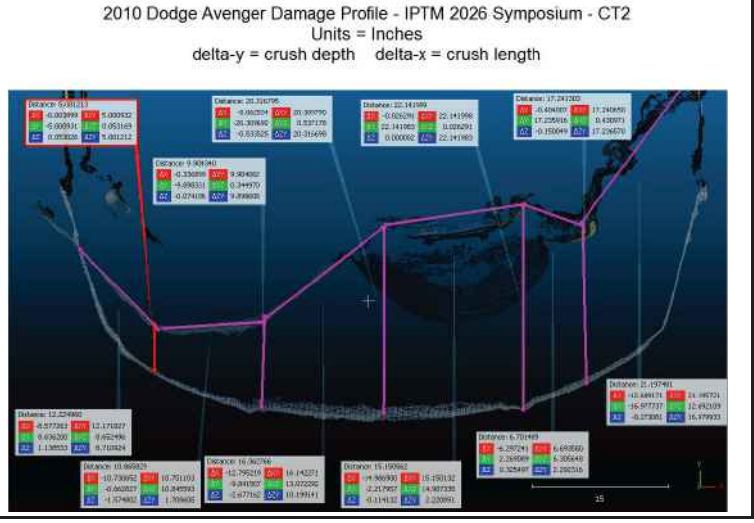
In order to conduct any speed from crush analysis, there needs to be crush, and that crush needs to be measured. To do this, I used Recon-3D running on an iPhone 15 Pro Max. Both vehicles were scanned Pre- and Post- crash, "merged" using Cloud Compare, and then "sliced" at the crush deformation level, again using Cloud Compare

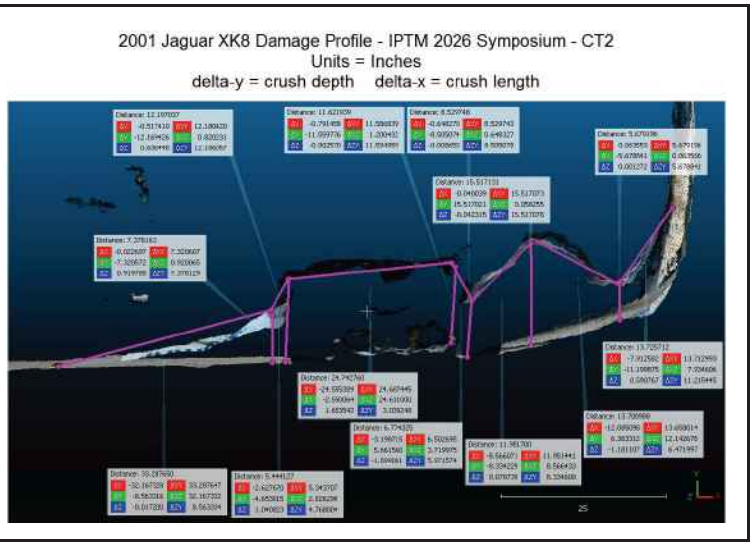
Recon-3D Vehicle Scans - Pre / Post / Merged		
Pre-Test	Post-Test	Merged
		
		

Sliced
<- Jaguar / Dodge ->



While you are still in Cloud Compare, once you have your slice, make sure it is oriented so that the X and Y axis can be used for the Crush depth and length measurements. For this test, the slice was aligned so that the y-axis defined the crush depths, and the x-axis defined the crush length measurements. From there, first the crush measurements were defined at the “critical” or “bend” points in the damage profile. The vertical lines between the undamaged and damaged profiles show where I judged these points to be. The delta-x dimension associated with each line is the crush depth for that point. The lateral lines between each vertical line along the profile were used to find the incremental crush lengths. Those measurements are the delta-y dimension associated with each line. While these are unequally spaced measurements instead of the equally spaced measurements most people are more familiar with, they do a better job of defining the crush profile, and, the Force Balance tool within 4N6XPRT StifCalcs® was designed to use either equally or unequally spaced crush measurements.





Other methods of obtaining the crush measurements are available, including Total Station, higher end scanners, and Manual Measurements out at a scene or in a tow yard. The method described

above, however, is the easiest, quickest, and most accurate for me working within my budget.

Calculation Setup

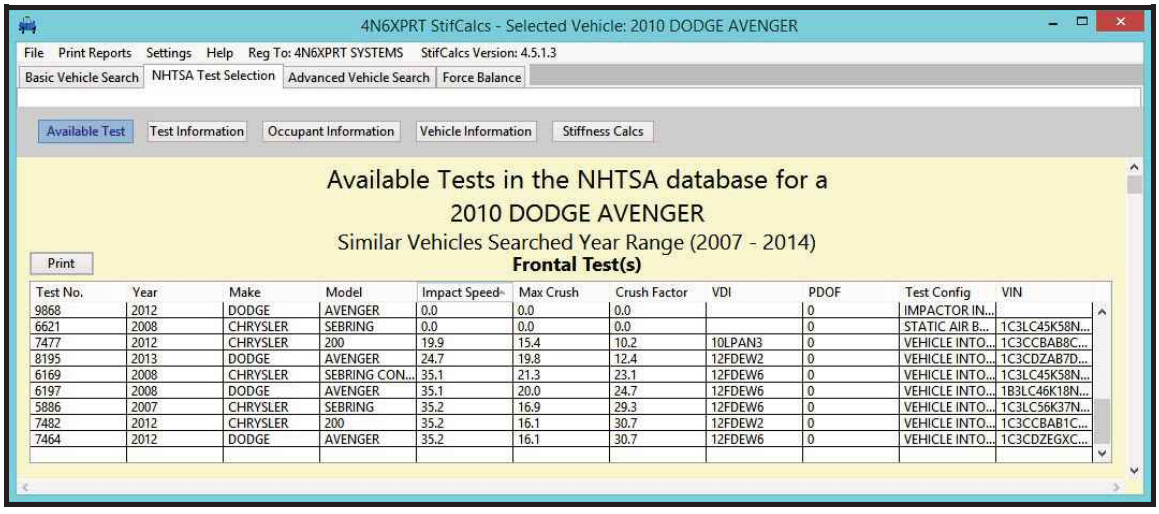
Once you have good crush measurements for your vehicles, you need to setup the calculations. For this process, I will be using the Force Balance tool contained within 4N6XPRT StifCalcs® program.

Step 1 - Obtain stiffness values.

To illustrate what you would find when looking at the NHTSA database within the 4N6XPRT StifCalcs® program for Jaguar tests, here is what you would find. When you conduct a search based on the Make, Model, and Year Range specific to the 2001 Jaguar XK8, there are no tests available at all. Searching the entire database for tests on Jaguar, there are eight (8) tests for the X-Type model, one (1) is a side test, the other seven (7) are front tests, and three (3) tests for the XF model, all of them front tests.

2001 Jaguar XK8 No tests in desired Year Range	All Jaguar - X-Type 8 tests - 7 Front - 1 Side	All Jaguar - XF 3 Tests - All Front
		

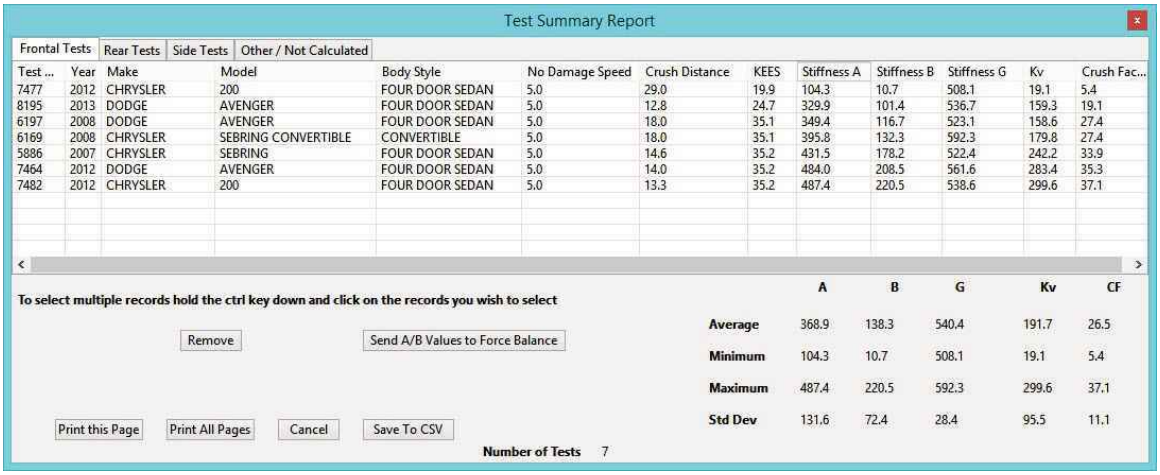
So, next we look to see what is available for the front of the 2010 Dodge Avenger within the 4N6XPRT StifCalcs® program. There are a total of seven (7) tests where stiffness values can maybe be calculated -



Test No.	Year	Make	Model	Impact Speed	Max Crush	Crush Factor	VDI	PDOF	Test Config	VIN
9868	2012	DODGE	AVENGER	0.0	0.0	0.0		0	IMPACTOR IN...	
6621	2008	CHRYSLER	SEBRING	0.0	0.0	0.0		0	STATIC AIR B...	1C3LC45K58N...
7477	2012	CHRYSLER	200	19.9	15.4	10.2	10LPAN3	0	VEHICLE INTO...	1C3CCBAB8C...
8195	2013	DODGE	AVENGER	24.7	19.8	12.4	12FDEW2	0	VEHICLE INTO...	1C3CDZAB7D...
6169	2008	CHRYSLER	SEBRING CON...	35.1	21.3	23.1	12FDEW6	0	VEHICLE INTO...	1C3LC45K58N...
6197	2008	DODGE	AVENGER	35.1	20.0	24.7	12FDEW6	0	VEHICLE INTO...	1B3LC46K18N...
5886	2007	CHRYSLER	SEBRING	35.2	16.9	29.3	12FDEW6	0	VEHICLE INTO...	1C3LC56K37N...
7482	2012	CHRYSLER	200	35.2	16.1	30.7	12FDEW2	0	VEHICLE INTO...	1C3CCBAB1C...
7464	2012	DODGE	AVENGER	35.2	16.1	30.7	12FDEW6	0	VEHICLE INTO...	1C3CDZEGXC...

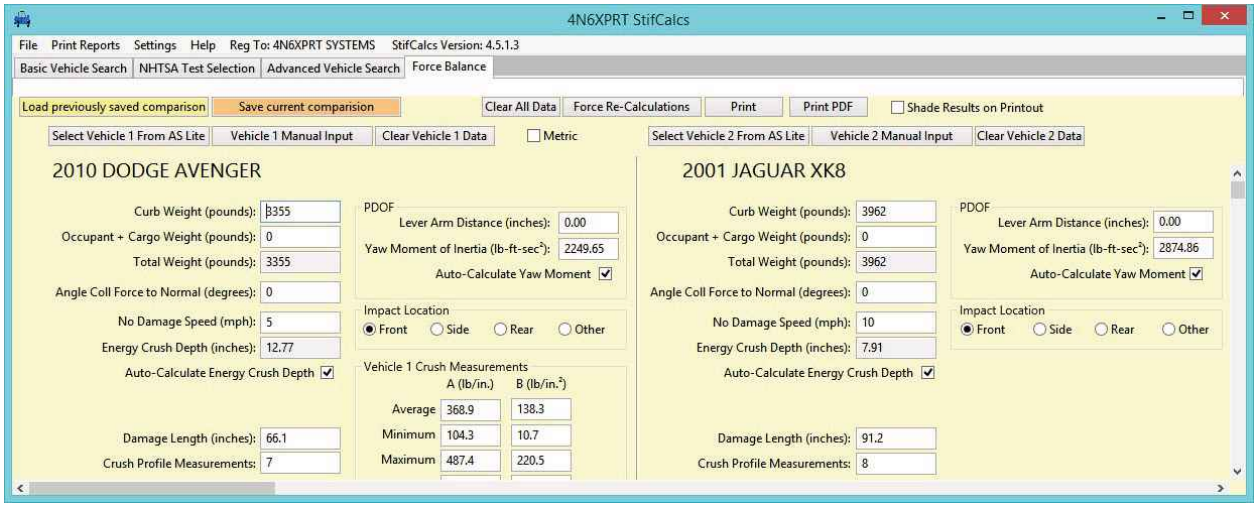
When the user clicks on the PRINT button in the upper left above the test list box, you get a Test Summary of stiffness values based on the information contained in the database -

2010 Dodge Avenger Front Stiffness Test Summary



The tests have been sorted based on the “A” stiffness value.

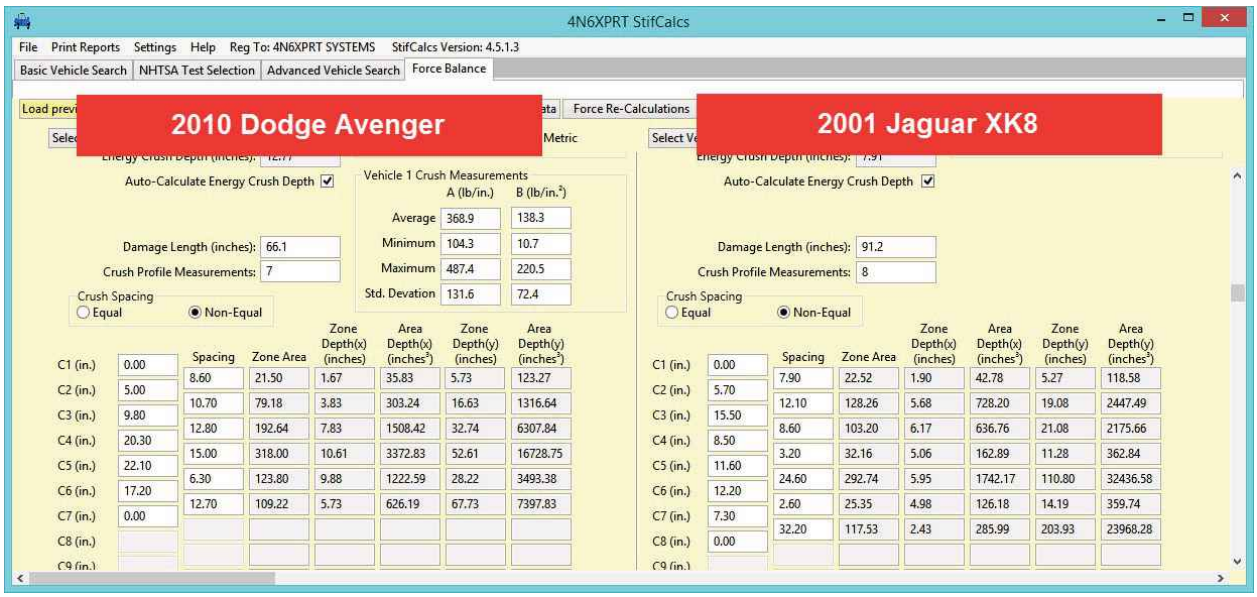
The full set of seven (7) tests are then ported into the 4N6XPRT StifCalcs® Force Balance module by clicking on the “Send A/B Values to Force Balance” button. That will open the Force Balance module with the stiffness values in place. After you have completed the basic data input for the two vehicles, it will look something like this.



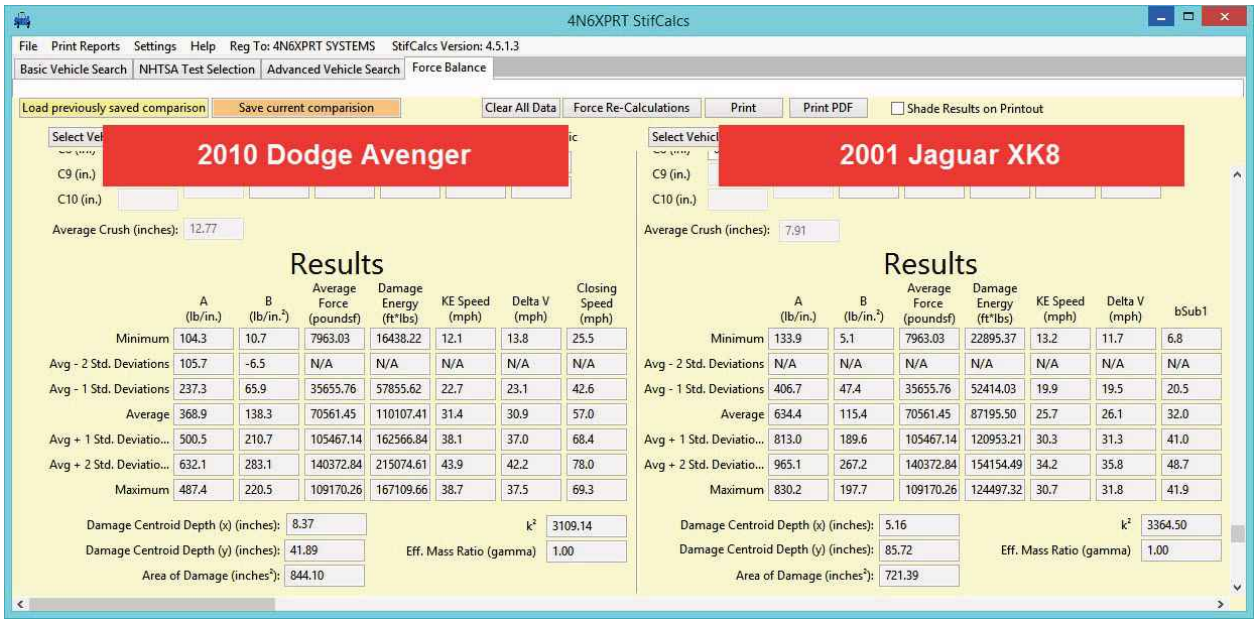
Note that the Lever Arm Distance for both vehicles is initially set to ‘0' as is the Angle Coll Force to Normal. This is a good starting point as it will give you the minimum speeds and calculated stiffness values in the results.

Scrolling down, you now input the crush profile data from your notes. For non-equal spacing, I

let the program tell me what the total Damage Length is, and then enter it.



If everything is completed and entered properly, then scrolling down a bit further shows the calculated results.



In general, we have a good solution when the instrumented results are within +/- 1 Standard Deviation of the values obtained using the AVERAGE A-B Stiffness values obtained from the NHTSA tests. The other way of stating this is that, when you have a good stiffness data set, when you have a good set of crush profile measurements, and when you have crush deformation that is consistent with how the stiffness values are derived (i.e. - the force is essentially parallel to the ground, not vertical in either an upwards or downwards direction) the expectation is, your actual collision speeds will be within the range of +/- 1 Standard Deviation of the calculated speeds

using the force balance approach. See some additional notes and caveats at the end of this write up for other considerations that need to be kept in mind.

In this case the instrumented closing (i.e.- impact) speed was 66-68 mph. Which is just at or below the Closing speed calculated using the +1 Standard Deviation Stiffness Values. The speed calculated using the Average Stiffness Values is 57 mph, which again, given the setup of the Lever Arm = 0 and Collision Force Angle = 0, is lower than actual, and is expected to be given that there is a significant lever arm involved.

Along with the comparison of the Closing Speed, when available, the delta-v speeds should be compared. The delta-v for the Dodge Avenger from the ACM is 26-29 mph. When looking at the calculated delta-v at the +1 Standard Deviation level, the calculated delta-v for the Dodge Avenger is about 8 mph higher than that which was measured by the ACM

The Jaguar has several delta-v's, which are dependant upon where they were measured and how they were determined/calculated. Those speeds are:

"ACM" delta-v	27 mph
Spin Analysis delta-v	32-34 mph
Rear Seat delta-v	~40-42 mph
"Full Evaluation" delta-v	~ 38.5 mph

These are "defined" as -

* **"ACM" delta-v -** This is the delta-v measured by the ride along accelerometer at the position that the ACM would normally be positioned.
* **Spin Analysis delta-v -** This is the Point of Impact to Point of Rest (and yes, in this case they truly are "points" speed calculated through a spin-analysis similar to what is contained in the "**Fundamentals of Traffic Crash Reconstruction**" by Daily-Daily-Shigemura, which is sold through IPTM. Because the Jaguar started with a speed of 0 mph, all of the post impact speed is also its delta-v.
* **Rear Seat delta-v -** This is the delta-v measured by the ride along accelerometer mounted on the vehicle centerline on a cross bar member that is positioned directly behind the Rear seat back. This delta-v has been eliminated from the comparisons due to its primarily reflecting the delta-v of the rear of the vehicle as it spins out of the path of the Dodge, rather than the delta-v of the entire vehicle.
* **"Full Evaluation" delta-v -** This is what was determined by people experienced in the data available from a variety of accelerometers to be the appropriate delta-v for the Jaguar given the totality of the data available.

The delta-v calculated for the Jaguar at the +1 Standard Deviation level is ~ 31 mph. While ~7 mph below the "Full Evaluation" delta-v, it is right inline with the delta-v from the ACM position and the delta-v calculated from Spin Analysis.

A visual examination of the Jaguar would approximate the PDOF going through the rear axle of the Jaguar.

Expert AutoStats® shows that the distance from the rear axle to the Center Gravity is ~53 inches.

Expert AutoStats®

2001 JAGUAR XK8 2 DOOR CONVERTIBLE

Angle Measurements

Angle Front Bumper to Hood Front		degrees
Angle Front of Hood to Windshield Base		degrees
Angle Front of Hood to Windshield Top		degrees
Angle of Windshield	28.3	degrees
Angle of Steering Tires at Max Turn	27.1	degrees

Center of Gravity

Inches from ground	20.83	Inches from side of vehicle	39.50
Inches behind front axle	48.96	Inches in front of rear axle	53.04
Inches from front bumper	86.96	Inches from rear bumper	100.04
Inches from front corner	95.51	Inches from rear corner	107.56

Tip-Over Stability Ratio = 1.42 Stable

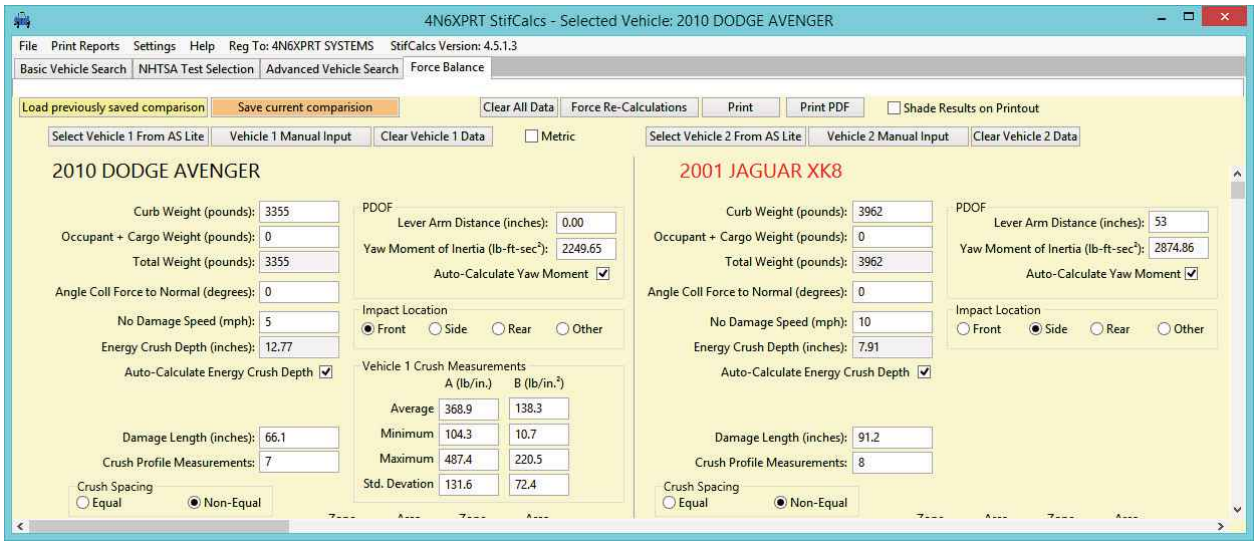
NHTSA Static Stability Factor (calculated) Star Rating = ****

Moments of Inertia

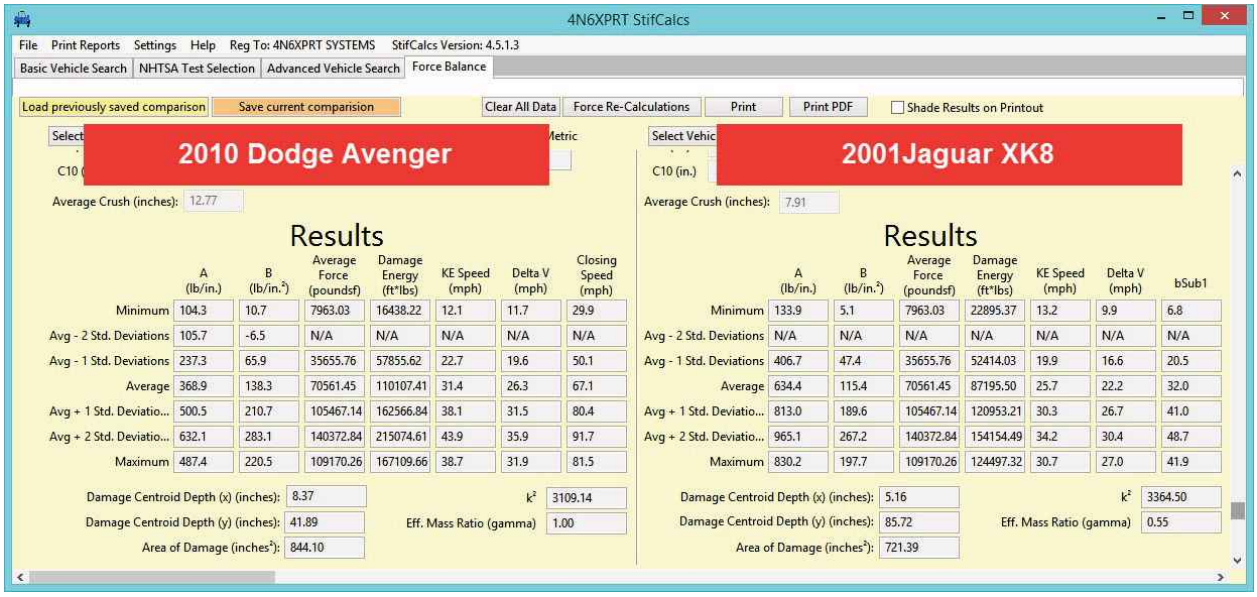
Yaw Moment of Inertia	2874.86	lb*ft*sec²
Pitch Moment of Inertia	2773.38	lb*ft*sec²
Roll Moment of Inertia	563.16	lb*ft*sec²

Expert AutoStats® Registered to: 4N6XPRT Systems Serial Number: 26R-930512AQ...

Using the information from Expert AutoStats® the Lever Arm dimension for the Jaguar is adjusted to 53 inches.



The change to the Jaguar Lever Arm, but no other changes, gives the following results.



	A (lb/in.)	B (lb/in.²)	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (mph)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.7	29.9
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	19.6	50.1
Average	368.9	138.3	70561.45	110107.41	31.4	26.3	67.1
Avg + 1 Std. Deviatio...	500.5	210.7	105467.14	162566.84	38.1	31.5	80.4
Avg + 2 Std. Deviatio...	632.1	283.1	140372.84	215074.61	43.9	35.9	91.7
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

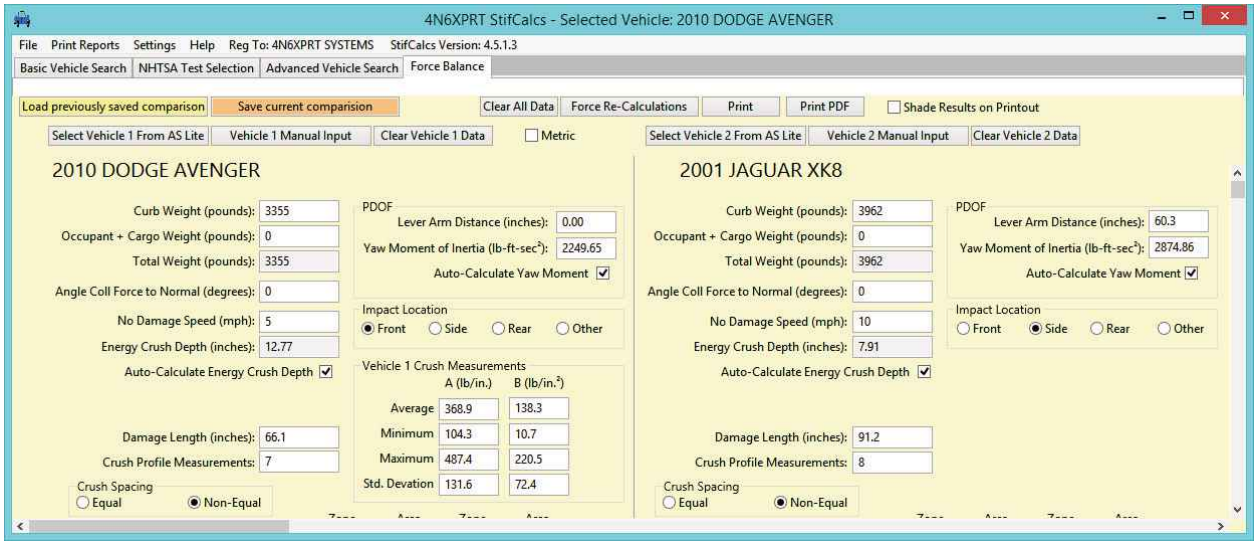
	A (lb/in.)	B (lb/in.²)	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bSub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	9.9	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	16.6	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	22.2	32.0
Avg + 1 Std. Deviatio...	813.0	189.6	105467.14	120953.21	30.3	26.7	41.0
Avg + 2 Std. Deviatio...	965.1	267.2	140372.84	154154.49	34.2	30.4	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	27.0	41.9

Changing the lever arm to reflect impact directly over the rear axle increases the speed calculated for a given set of crush measurements and stiffness values. This can be seen in the results where the Closing Speed calculated using the Average Stiffness Values has increased from 57.0 mph when the Lever Arm = 0 to 67.1 mph when the Lever Arm = 53. Given that the instrumented speeds were 66-68 mph, this is directly in the middle of those speeds.

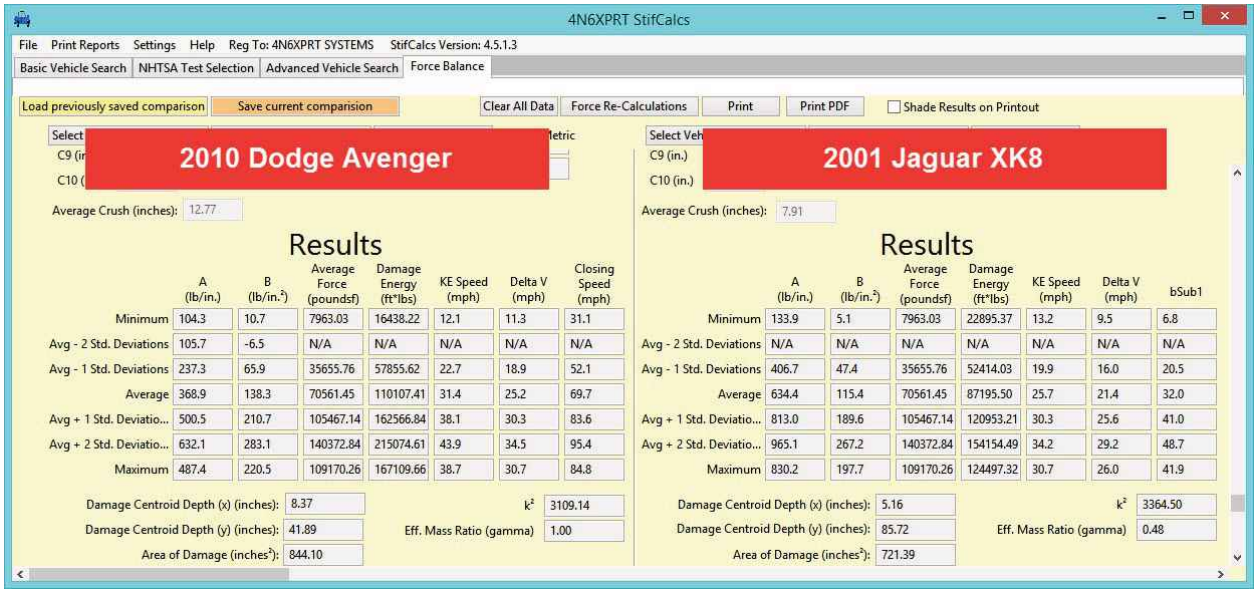
Comparing the delta-v speeds for the Dodge on the same line (Average), the 26.3 calculated speed is right in line with the ACM speed.

Looking at the Jaguar delta-v's on the Average line, the calculated delta-v of 22.2 mph is about 16 mph low compared to the "Full Evaluation" value, 10-12 mph below the Spin Analysis value, but only ~5 mph below the ACM value.

Closer examination of the video indicates that the actual Dodge Avenger centerline impact point on the Jaguar was closer to 60.3 inches behind the Center of Gravity (i.e. - slightly behind the rear axle of the Jaguar). Making that change to the lever arm -



Produces the following results -



The ~7 inch increase in the lever arm results in a ~2-3 mph increase in the closing speed, so that the Closing Speed calculated from the Average Stiffness Values is no 69.7 mph. Which is just over the instrumented closing speed of the Dodge Avenger at impact.

Comparing the delta-v speeds for the Dodge on the same line (Average), the 25.2 mph calculated speed is again right in line with the ACM speed.

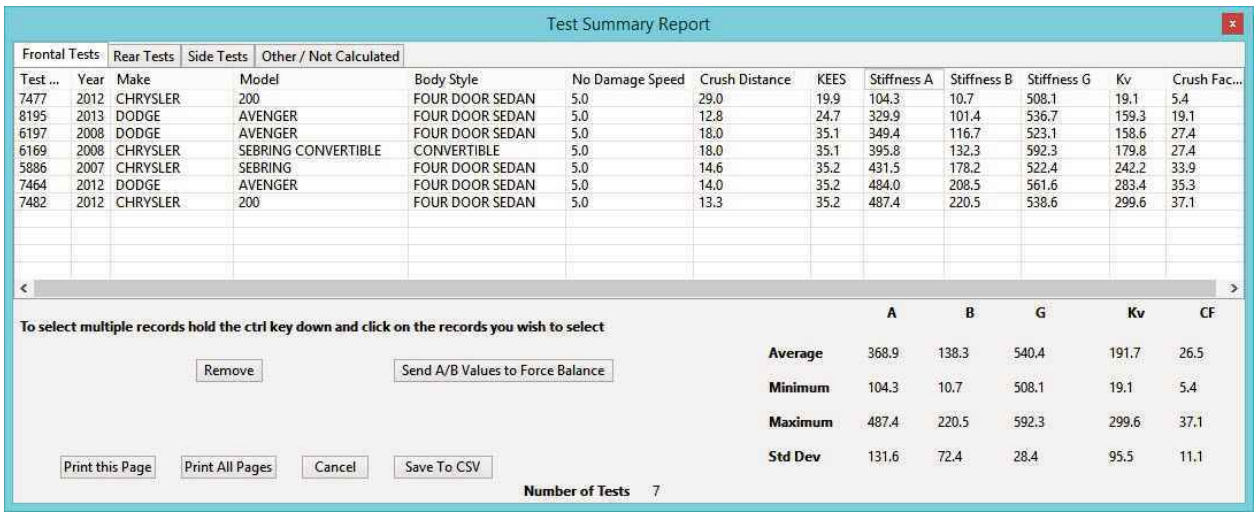
Looking at the Jaguar delta-v's on the Average line, the calculated delta-v of 21.4 mph is about 17 mph low compared to the "Full Evaluation" value, 11-13 mph below the Spin Analysis value, and ~6 mph below the ACM value.

We have preliminary results that look pretty good, especially when looking at the Dodge data.

While the Jaguar comparisons are not as good, some of this can be attributed to the greater uncertainties where the Jaguar is concerned due to the eccentric “hit” along with the uncertainty as to what the appropriate “No Damage” value would be for the Jaguar given the impact is directly over the rear axle and wheel.

Given that we have a speed solution that while not perfect, is looking pretty good, lets look to see if we have any weak spots in our analysis.

When we look at the Test Summary Stiffness Values, one of the tests (#7477 - 2012 Chrysler 200) seems to be an outlier with low values.



Test ...	Year	Make	Model	Body Style	No Damage Speed	Crush Distance	KEES	Stiffness A	Stiffness B	Stiffness G	Kv	Crush Fac...
7477	2012	CHRYSLER	200	FOUR DOOR SEDAN	5.0	29.0	19.9	104.3	10.7	508.1	19.1	5.4
8195	2013	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	12.8	24.7	329.9	101.4	536.7	159.3	19.1
6197	2008	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	18.0	35.1	349.4	116.7	523.1	158.6	27.4
6169	2008	CHRYSLER	SEBRING CONVERTIBLE	CONVERTIBLE	5.0	18.0	35.1	395.8	132.3	592.3	179.8	27.4
5886	2007	CHRYSLER	SEBRING	FOUR DOOR SEDAN	5.0	14.6	35.2	431.5	178.2	522.4	242.2	33.9
7464	2012	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	14.0	35.2	484.0	208.5	561.6	283.4	35.3
7482	2012	CHRYSLER	200	FOUR DOOR SEDAN	5.0	13.3	35.2	487.4	220.5	538.6	299.6	37.1

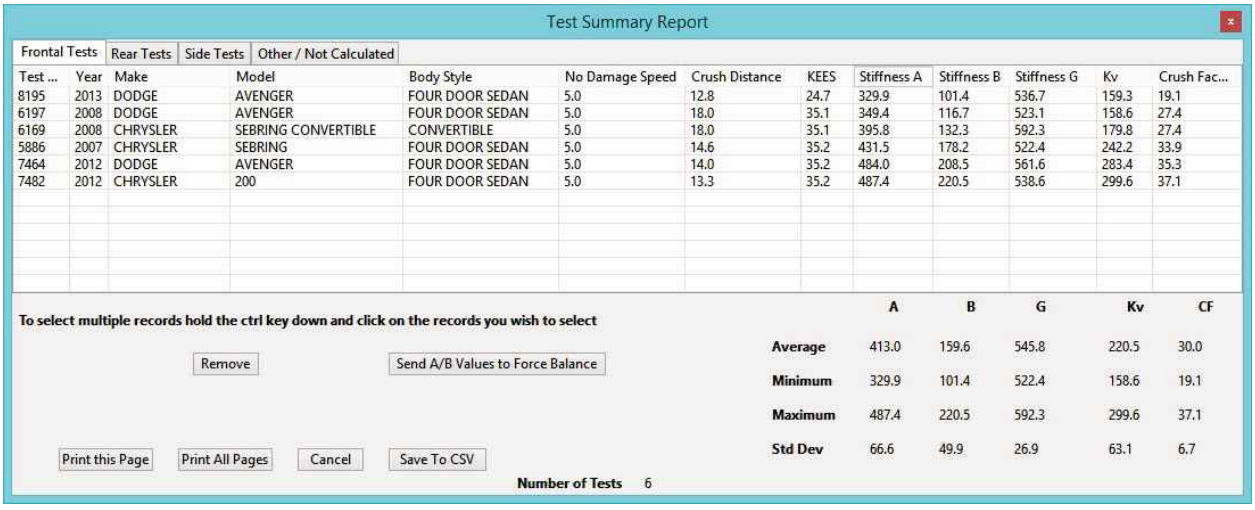
	A	B	G	Kv	CF
Average	368.9	138.3	540.4	191.7	26.5
Minimum	104.3	10.7	508.1	19.1	5.4
Maximum	487.4	220.5	592.3	299.6	37.1
Std Dev	131.6	72.4	28.4	95.5	11.1

This outlier has several effects upon the Stiffness Value data set -

A - It pulls the average values “down” which will result in lower calculated speeds, and

B - it increases the spread of the data, a result of which can be seen in the Standard Deviation which is a way to measure how “tight” the data set is.

To remedy this, and tighten the data set, we can eliminate that test which gives us a data Set and Test Summary that looks like this -

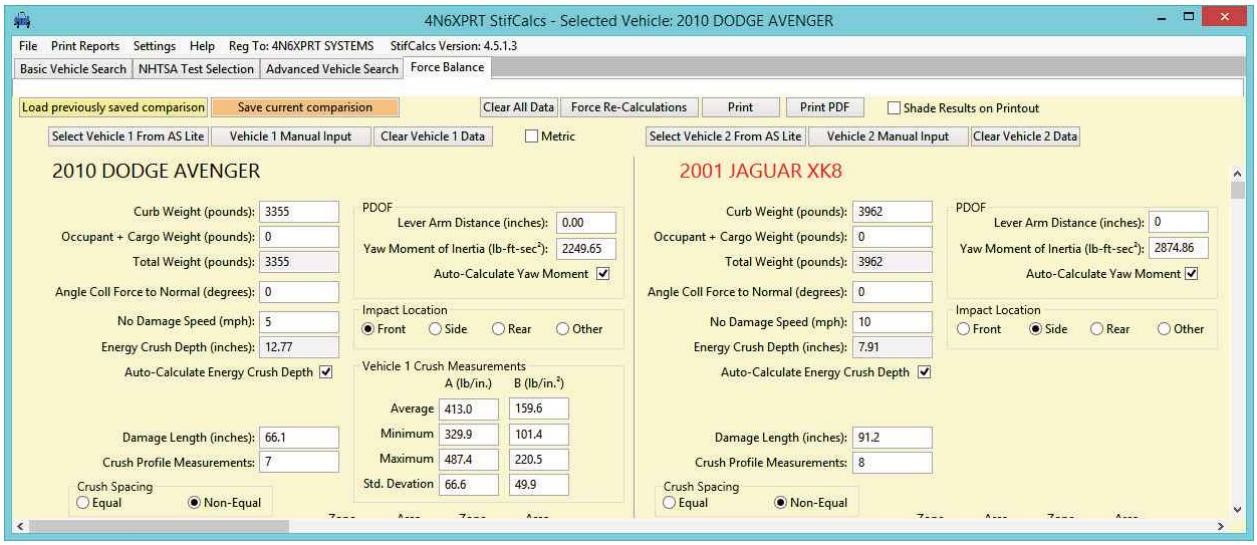


Test ...	Year	Make	Model	Body Style	No Damage Speed	Crush Distance	KEES	Stiffness A	Stiffness B	Stiffness G	Kv	Crush Fac...
8195	2013	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	12.8	24.7	329.9	101.4	536.7	159.3	19.1
6197	2008	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	18.0	35.1	349.4	116.7	523.1	158.6	27.4
6169	2008	CHRYSLER	SEBRING CONVERTIBLE	CONVERTIBLE	5.0	18.0	35.1	395.8	132.3	592.3	179.8	27.4
5886	2007	CHRYSLER	SEBRING	FOUR DOOR SEDAN	5.0	14.6	35.2	431.5	178.2	522.4	242.2	33.9
7464	2012	DODGE	AVENGER	FOUR DOOR SEDAN	5.0	14.0	35.2	484.0	208.5	561.6	283.4	35.3
7482	2012	CHRYSLER	200	FOUR DOOR SEDAN	5.0	13.3	35.2	487.4	220.5	538.6	299.6	37.1

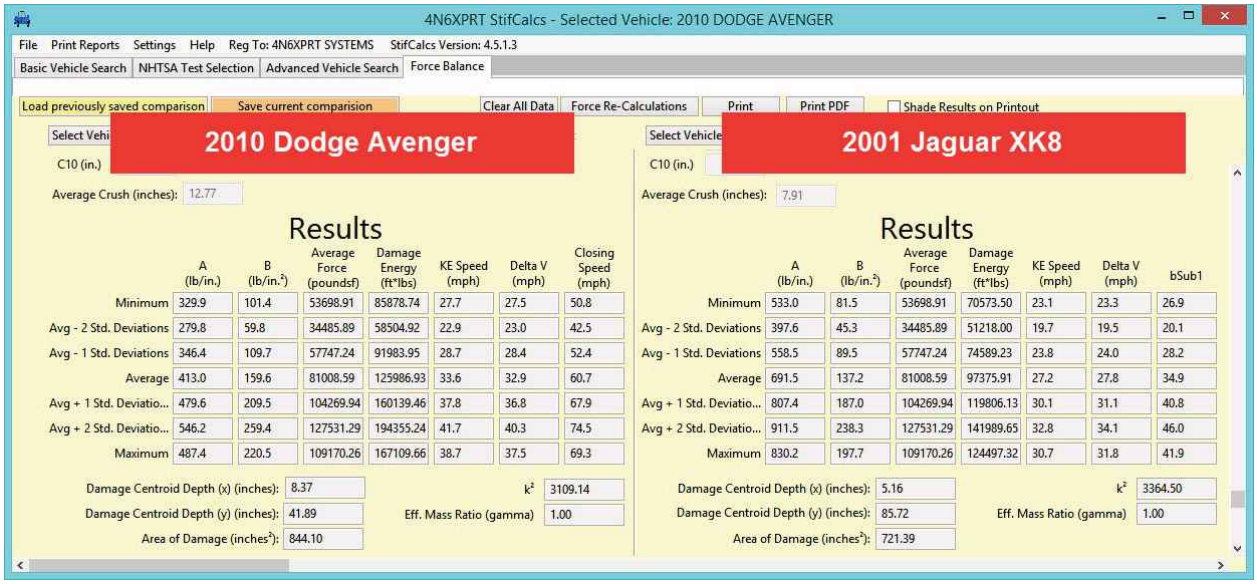
	A	B	G	Kv	CF
Average	413.0	159.6	545.8	220.5	30.0
Minimum	329.9	101.4	522.4	158.6	19.1
Maximum	487.4	220.5	592.3	299.6	37.1
Std Dev	66.6	49.9	26.9	63.1	6.7

When the two data sets are reviewed, it can be seen that the Standard Deviation of the “A” value has been reduced by half, and the “B” value by about 1/3. This indicates a tighter and thus, from certain points of view, a “better” data set to work with.

So, now we input the modified stiffness values into our Force Balance analysis and look at how our speeds might/might not be effected by the removal of the outlier test.



When the basic setup is modified by the new stiffness value set, and the Jaguar Lever Arm is returned to ‘0', the calculated Closing Speed Results are seen below.



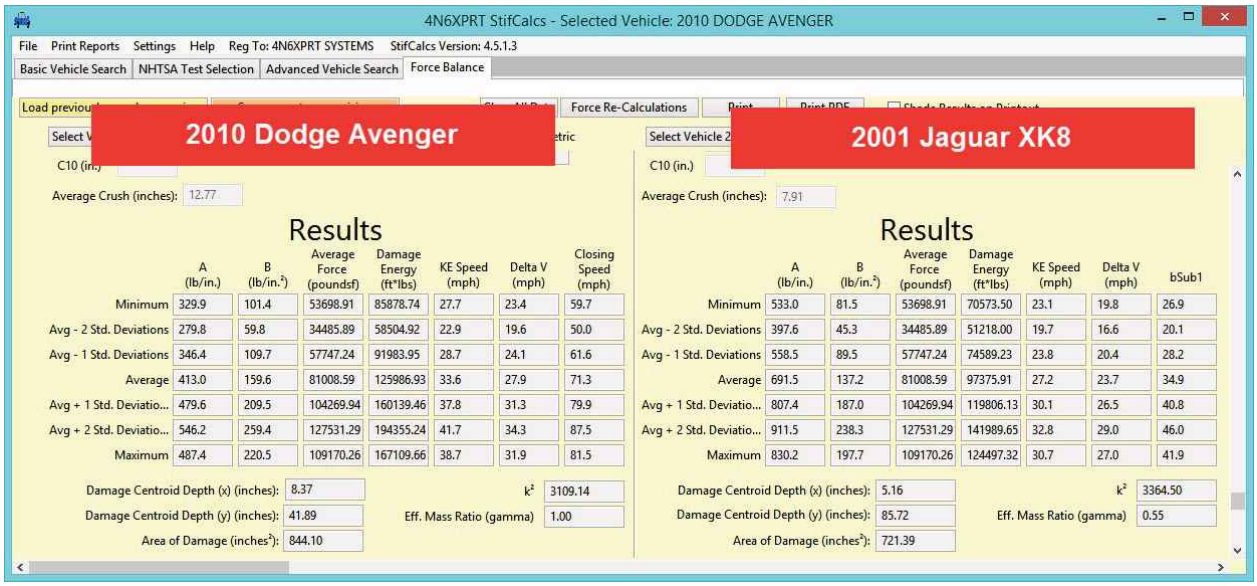
Examining the two sets of results, it can be seen that the Closing Speed based on the Average Stiffness Values from the reduced data set has increased from 57 mph, to 60.7 mph, and the +1 Standard Deviation speed has decreased from 68.4 mph down to 67.9 mph. It can also be seen that the tighter data set has resulted in a smaller speed range between -1 Standard Deviation to +1 Standard Deviation of 15.5 mph as opposed to 25.8 mph with the full data set. Again, to see if we

have some agreement between the calculated and instrumented speeds in more than one category, a comparison of the delta-v's should also be conducted.

Since the best agreement with the closing speed is at the +1 Standard Deviation line, those are the delta-v speeds to look at.

The calculated delta-v for the Dodge of 36.8 mph is ~8-10 mph greater than the instrumented speeds of 26-29. For the Jaguar, the calculated speed of 31.1 mph is ~ 7 mph below the "Full Evaluation" delta-v, but is in basic agreement with the ACM and Spin Analysis speeds

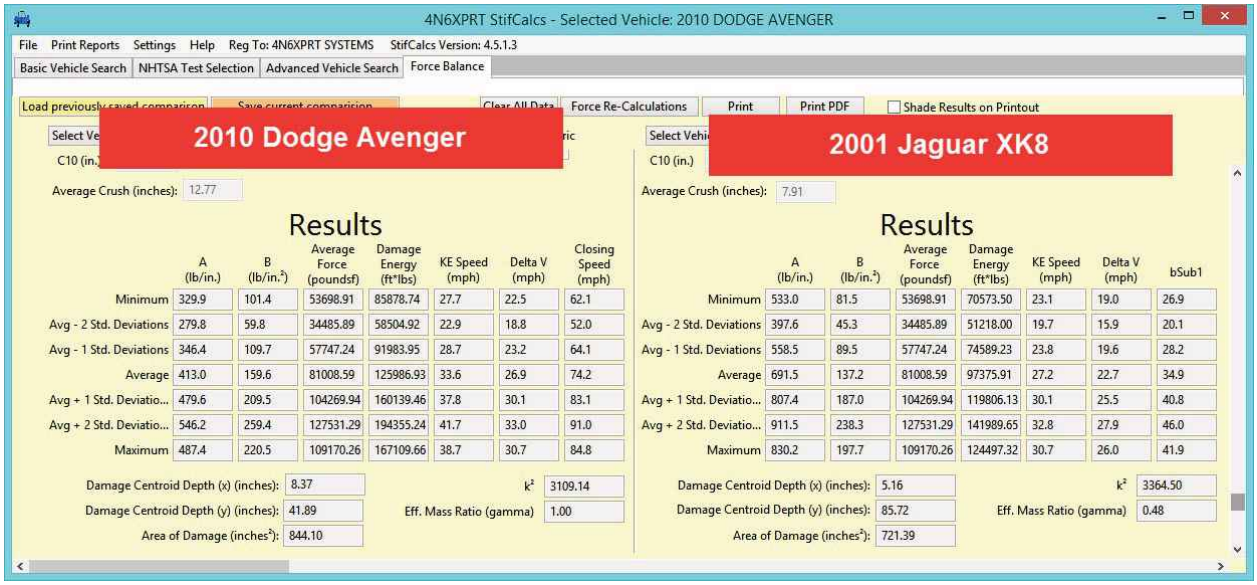
Changing the Jaguar Lever Arm to 53 inches results in the following calculated speeds -



Again, a comparison of the two result sets shows that the Closing Speed based on the Average A-B values from the reduced data set has increased from 67.1 mph up to 71.3 mph, which is slightly higher than our instrumented speed range of 66-68 mph. However, it is still well within (the +/- 1 standard deviation off of the speed calculated from the Average A-B values. Also, it can again be seen that the tighter data set has resulted in a lower overall speed range between +/- 1 Standard Deviation of 18.3 mph vs. 30.3 mph with the full data set.

Looking at the delta-v's on the -1 Standard Deviation and Average lines, the Dodge calculated delta-v is ~24-28 mph. This again compares well with the Dodge ACM delta-v of 26-29 mph. Examining the calculated delta-v for the Jaguar on those same two line, the calculated 20-24 mph is 14-19 mph below the "Full Evaluation" speed of 38.5 mph, ~12 mph below the Spin Analysis speed, and ~4-7 mph below the "ACM" speed.

Making the final Lever Arm Adjustment to the Jaguar from 53 to 60.3 inches produces these results -



This change, a longer lever arm, increases the calculated speed for the Average A-B Stiffness Values from the reduced data set from 69.7 mph to 74.2 mph. While this is ~6-8 mph above the instrumented speeds of 66-68 mph it is still within the range of -1 Standard Deviation to Average values, and so, while not hitting the desired mark of 68 mph for the Average Stiffness Values is well within the desired range of between +/- 1 Standard Deviation off of the Average Values.

Looking again at the delta-v's on the -1 Standard Deviation and Average lines, the Dodge calculated delta-v is ~23-27 mph. This again compares well with the Dodge ACM delta-v of 26-29 mph. Examining the calculated delta-v for the Jaguar on those same two line, the calculated ~19-23 mph is ~15-19 mph below the "Full Evaluation" speed of 38.5 mph, ~9-14 mph below the Spin Analysis speed, and ~4-7 mph below the "ACM" speed.

The delta-v comparisons are summarized with the following tables

<table>
<tr><td colspan="4">Full Stiffness Data Set</td></tr>
<tr><td colspan="2">Dodge Avenger delta-v</td><td colspan="2">Jaguar XK8 delta-v - Lever Arm = 0 inches</td></tr>
<tr><td rowspan="3">ACM
26-29 mph</td><td rowspan="3">calculated
~37 mph</td><td>ACM = 27 mph</td><td rowspan="3">calculated
~31.3 mph</td></tr>
<tr><td>Spin = 32-34 mph</td></tr>
<tr><td>FE* = 38.5 mph</td></tr>
</table>

FE* = *Full Evaluation*

Full Stiffness Data Set			
Dodge Avenger delta-v		Jaguar XK8 delta-v - Lever Arm = 53 inches	
ACM 26-29 mph	calculated ~26.3 mph	ACM = 27 mph Spin = 32-34 mph FE* = 38.5 mph	calculated ~22.2 mph

FE* = *Full Evaluation*

Full Stiffness Data Set			
Dodge Avenger delta-v		Jaguar XK8 delta-v - Lever Arm = 60.3 inches	
ACM 26-29 mph	calculated ~25.2 mph	ACM = 27 mph Spin = 32-34 mph FE* = 38.5 mph	calculated ~21.4 mph

FE* = *Full Evaluation*

Reduced Stiffness Data Set			
Dodge Avenger delta-v		Jaguar XK8 delta-v - Lever Arm = 0 inches	
ACM 26-29 mph	calculated ~36.8 mph	ACM = 27 mph Spin = 32-34 mph FE* = 38.5 mph	calculated ~31.1 mph

FE* = *Full Evaluation*

Reduced Stiffness Data Set			
Dodge Avenger delta-v		Jaguar XK8 delta-v - Lever Arm = 53 inches	
ACM 26-29 mph	calculated ~24.1-27.9 mph	ACM = 27 mph Spin = 32-34 mph FE* = 38.5 mph	calculated ~20.4-23.7 mph

FE* = *Full Evaluation*

Reduced Stiffness Data Set			
Dodge Avenger delta-v		Jaguar XK8 delta-v - Lever Arm = 60.3 inches	
ACM 26-29 mph	calculated ~23.2-26.9 mph	ACM = 27 mph Spin = 32-34 mph FE* = 38.5 mph	calculated ~19.6-22.7 mph

FE* = *Full Evaluation*

As with the previous Lever Arm results, the speed range between the +/- 1 Standard deviation speeds has dropped from 31.5 mph with the full data set to 19.0 mph with the reduced, "tighter" data set. This is, in general, what would be considered a "good thing".

So, which "set" do we use? Which lever arm? What is appropriate? Is any of it appropriate?

Addressing the last point first, yes, the Force Balance calculation results are appropriate to be used. There is reasonably good agreement between the calculated Closing Speeds and the delta-v's calculated for the Dodge and compared to its ACM. Further, the calculated delta-v's for the Jaguar have reasonably good agreement with the "ACM" values. Maybe not as good as would be desired, but still, reasonably good.

If this was a "real" collision, I would use both sets, and the 53 inch lever arm.

The full set will provide lower speeds, but a larger speed range. The "reduced" set gives slightly higher speeds, but is a tighter data set and thus provides a smaller overall range.

The 53 inch lever arm is fairly easy to support based on a visual examination of the damage to the Jaguar and to the Dodge. While this could perhaps be fine tuned based on the position of the tire in the Dodge's front grill, that becomes a bit more problematic if the Jaguar is travelling across the Dodge's path with any kind of speed. Because the 53 inch lever arm is a bit shorter than the 60.3 inch lever arm judged to be "the correct" lever arm, it is also a bit more conservative on the calculated speeds without "giving away the farm".

Last, point to consider. Other than the lever arm offset, there is nothing particularly unique about the crush in Crash Test 2. There was no real structural damage that weakened the stiffness of either vehicle. Even the Jaguar's loss of the Rear wheel did not weaken the structure of the Jaguar, it just was another indication of a very "stiff" hit. We were able to obtain good profiles for both vehicles. Even with the question of the outlier test on the full data set, we have a good set of stiffness values. Therefore, there is nothing to indicate that the actual speed should match the calculated speed within the +/- 1 Standard Deviation speed range .... and it does.

Analysis Summary and Wrap Up

Another way of looking at the calculated speeds as opposed to the instrumented speeds is a percentage of error analysis. If we use a instrumented speed of 68 mph, and the closing speed based on our Average Stiffness Values, the calculated closing speed is:

Error = [(Calculated - Actual) / Actual] * 100
Error = [(74.2 - 68) / 68] *100
Error = 9.1 %

Since the calculated error is positive, that means the error is higher than actual.

While any error is undesirable, a certain amount is expected given variability in (NHTSA) data sample, non-conformance of actual crash to (NHTSA) test crash criteria, and reliability of the crash data taken at the crash site, tow yard, etc. On of the commonly stated error ranges stated around me is +/- 10%. Given that the error rate of 9.1% is less than the "acceptable" error of 10%, this could be judged to be a good and usable speed determination method.

Lets look at another error rate - what is the error rate of 1 Standard Deviation based on the calculated Closing Speeds.

Another way of looking at the

Error - 1 Std Dev = | [(Calculated - Actual) / Actual] * 100 |
Error - 1 Std Dev = | [(64.1 - 74.2) / 74.2] *100 |
Error - 1 Std Dev = **13.6 %**

Which means that if the ACTUAL speed was at either -1 or +1 Standard Deviation from the calculated speed from the average Stiffness Values, you would have an error of 13.6 %. What this also means is, that within a sample size consisting of ~66% (the population range that falls within +/-1 Standard Deviation), we can expect an error rate off of the "actual" value of up to 13.6% of the Mean value, and a variability of 27.2% error between the low of -1 Standard deviation and the high of +1 Standard Deviation. Conceivably, the "actual" value could be at one end of the range, and part of the "population" at the other. This is why tighter data reducing the total spread is considered to be a "good thing". With all of that said, it needs to be understood that this is NOT a problem with the method. It is inherent to the variability from vehicle to vehicle in crash testing. It is also part and parcel with the reality of Statistics and applying measurements to data within the "Daubert Rules of Evidence".

It is also important to remember that no matter WHAT you are considering in a vehicle collision, this variability exists, be it speed from crush, speed from skid, Human Factors, PRT, and yes, even with EDR/CDR data. It is the system that we work within, variability comes with it.

What we need to answer for ourselves is, how much variance from the expected are we willing to live with before we throw up our hands and walk away?

Force Balance Calculated Speed Limitations

The Force Balance calculations are an energy based Energy-Force-Speed determination method. As such it has the same limitations that other energy methods have. If you assign a "clock position" to a vehicle where 12 is the front, 3 the right side, 6 the rear, and 9 the left side, then any collision that has both vehicles approaching each other within the respective 9-12-3 o'clock positions will have a calculated closing speed that is lower than the actual closing speed. This is best illustrated by the following example -

If you have two vehicles approaching each other head on (12 to 12) at highway speeds of 60 mph each, you have a closing speed of 120 mph. However, the energy collision speed is 84.5 mph.

$$\text{Square Root} (60^2 + 60^2) = 84.5$$

With this as a known, the Force Balance method applied without any other analysis to any "head-on" type vehicle-vehicle approach (head-on, left turn into approaching through vehicle, etc.) will establish a "floor" Closing Speed, but the actual closing speed will be some value higher than the calculated speed.

Conversely, when the bullet vehicle is approaching the target vehicle within the 3-6-9 o'clock quadrants, there is no combination of energy effects, and thus the closing speed between the two vehicles will be calculated "correctly". However, some portion of the ground speed of the target vehicle may have to be added to the closing speed in order to get the ground speed of the bullet vehicle.

Due to the Dodge Avenger approaching the Jaguar from essentially a "true" perpendicular path from the 9 o'clock side of the Jaguar, the speed of the Jaguar, whether it be 0 mph as in the test, 30 mph or 90 mph or any speed in between should have very little or no effect upon the calculated closing speed of the Dodge to the Jaguar at impact.

Wrap Up

The print outs for the Force Balance Analysis in a "2 up" for this test in the various Lever Arm positions has been included within the Appendixes. These make it somewhat easier to see the ramifications of the changes on both vehicles for each configuration. This is followed by the normal 1 page per page printout for easier reading.

For those of you present during the Data Analysis Presentation(s), the data as presented is included at the end of the Appendixes.

If anyone has any questions or wishes to discuss this further with me, please get in contact via email or by giving me a call.

Definition of Terms

ACM - Airbag ontrol Module

CDR - Crash Data Retrieval (under current terminology usage)

EDR - Event Data Recorder

EDR/CDR - this is the equipment and methodology that allows for retrieval of the data collected by the "airbag module" in the event of a collision where the airbag(s) are deployed.

same/similar vehicle - a set of vehicles that are essentially the same across a span of years. May also include models form different makes that "live" under a parent manufacturer umbrella. Specifically, in this instance, the Dodge Avenger is the "same" vehicle from 2007-2014 model years, and is similar in major body parts to the Chrysler Sebring and the Chrysler 200. Also referred to Sisters and Clones.

Stiffness Values - these values are calculated from crash tests where speed and vehicle crush depths are known and/or measured. They are a measurement as to how "stiff" or "soft" a vehicle is. They are then applied to crush measured in a crsh to help determine how fst the vehicle was going based on the amount of crush damage measured for the each of the vehicles involved in a collision.

IPTM 2026 Symposium

Crash Test 2

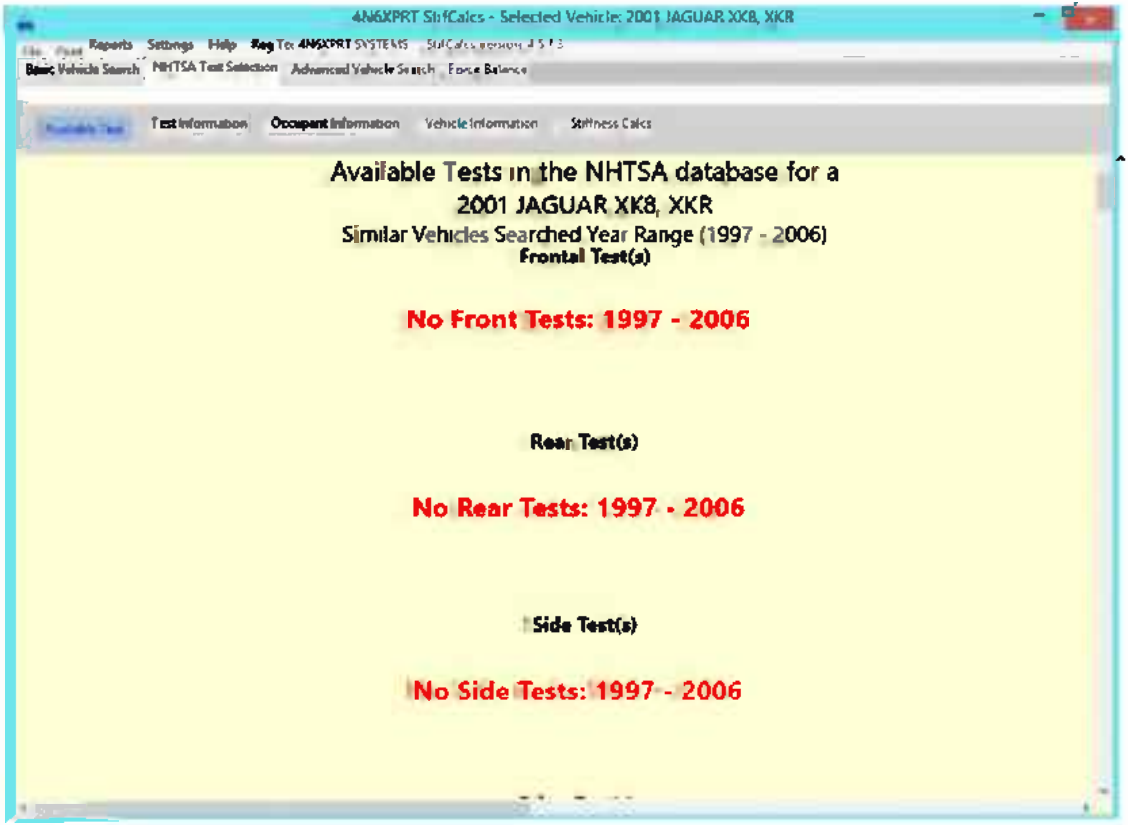
Force Balance Calculations

Crash Test 2

Available NHTSA Crash Tests on JAGUAR's

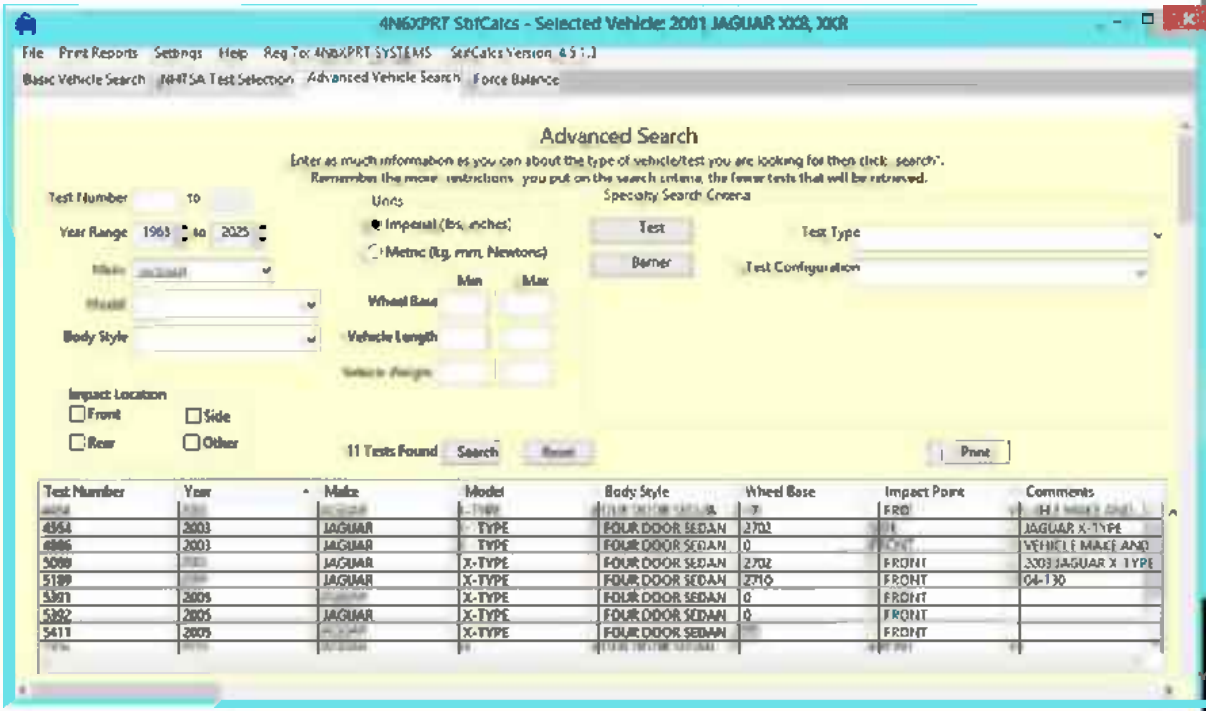
2001 Jaguar XK8

No tests in desired Year Range



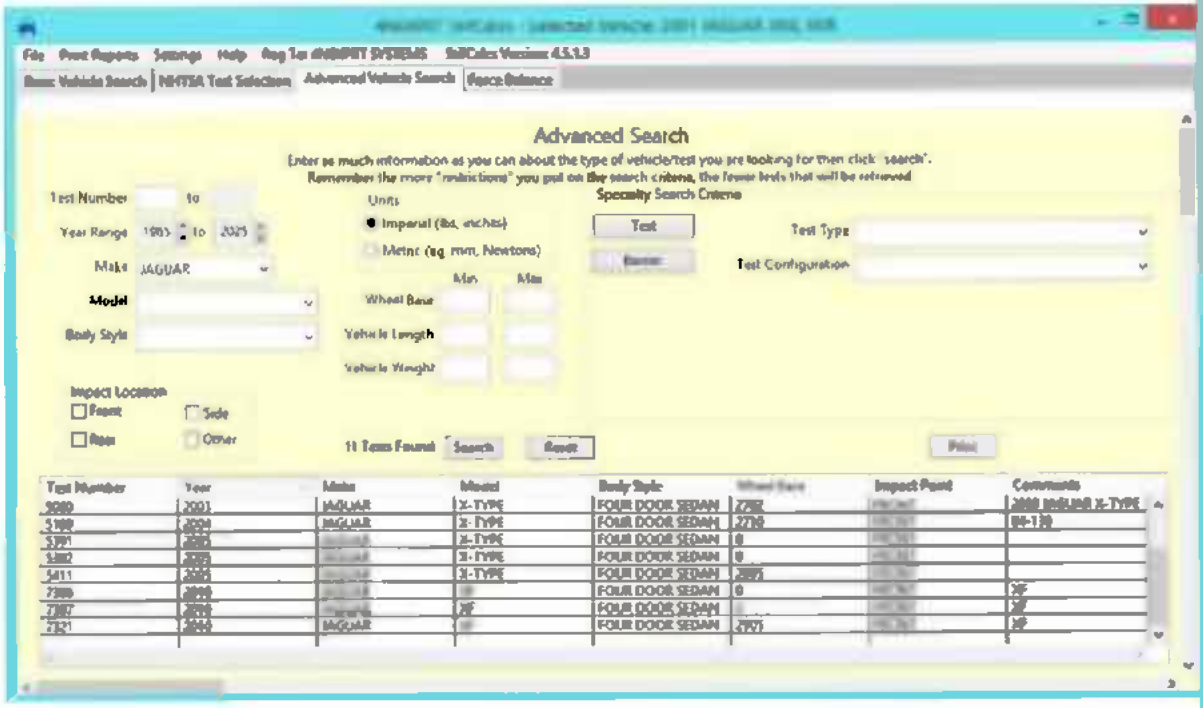
All Jaguar - X-Type

8 tests - 7 Front - 1 Side



All Jaguar - XF

3 Tests - All Front



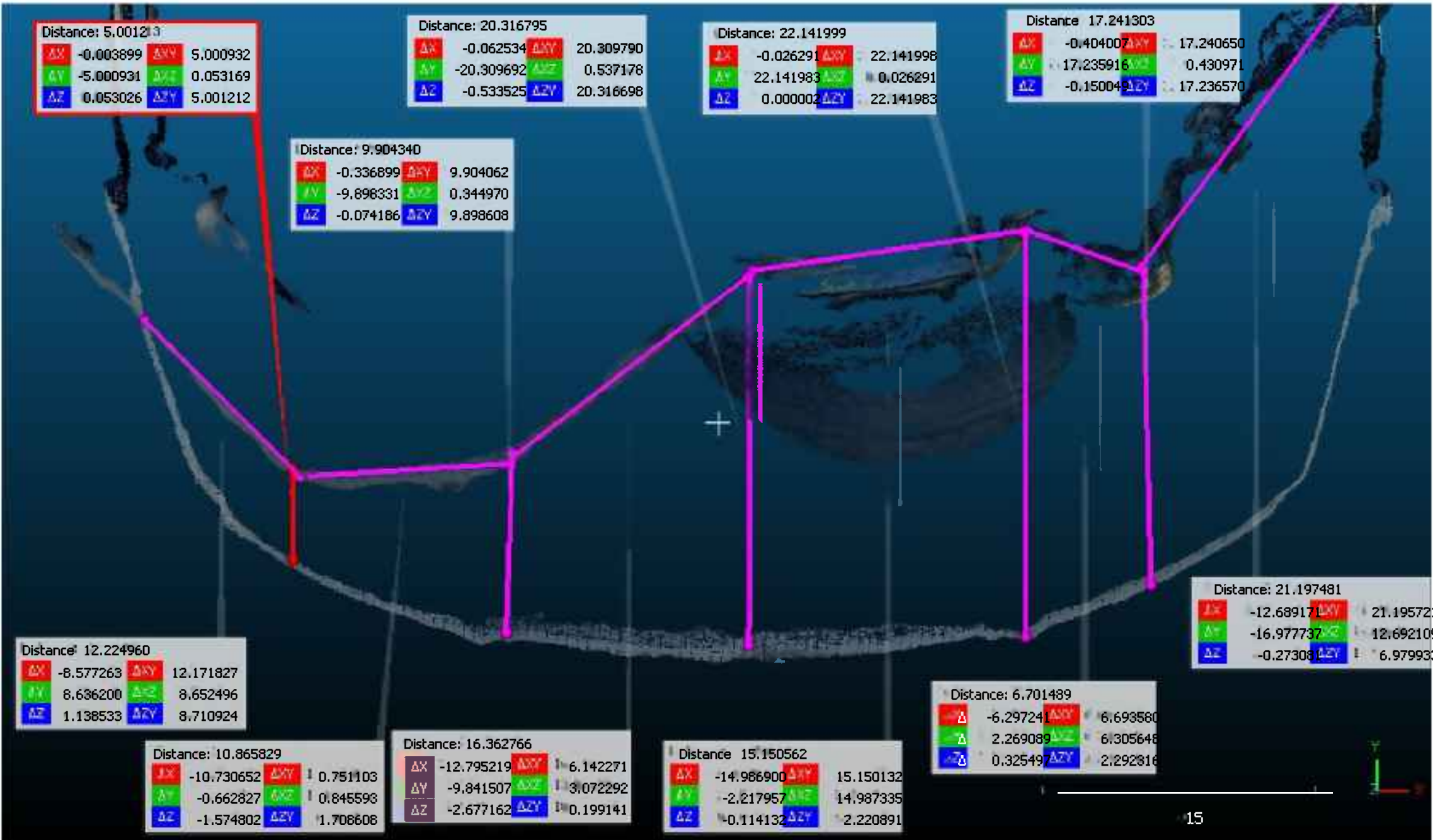
Crash Test 2

2010 Dodge Avenger Front Crush Profile

2010 Dodge Avenger Damage Profile - IPTM 2026 Symposium - CT2

Units = Inches

delta-y = crush depth delta-x = crush length



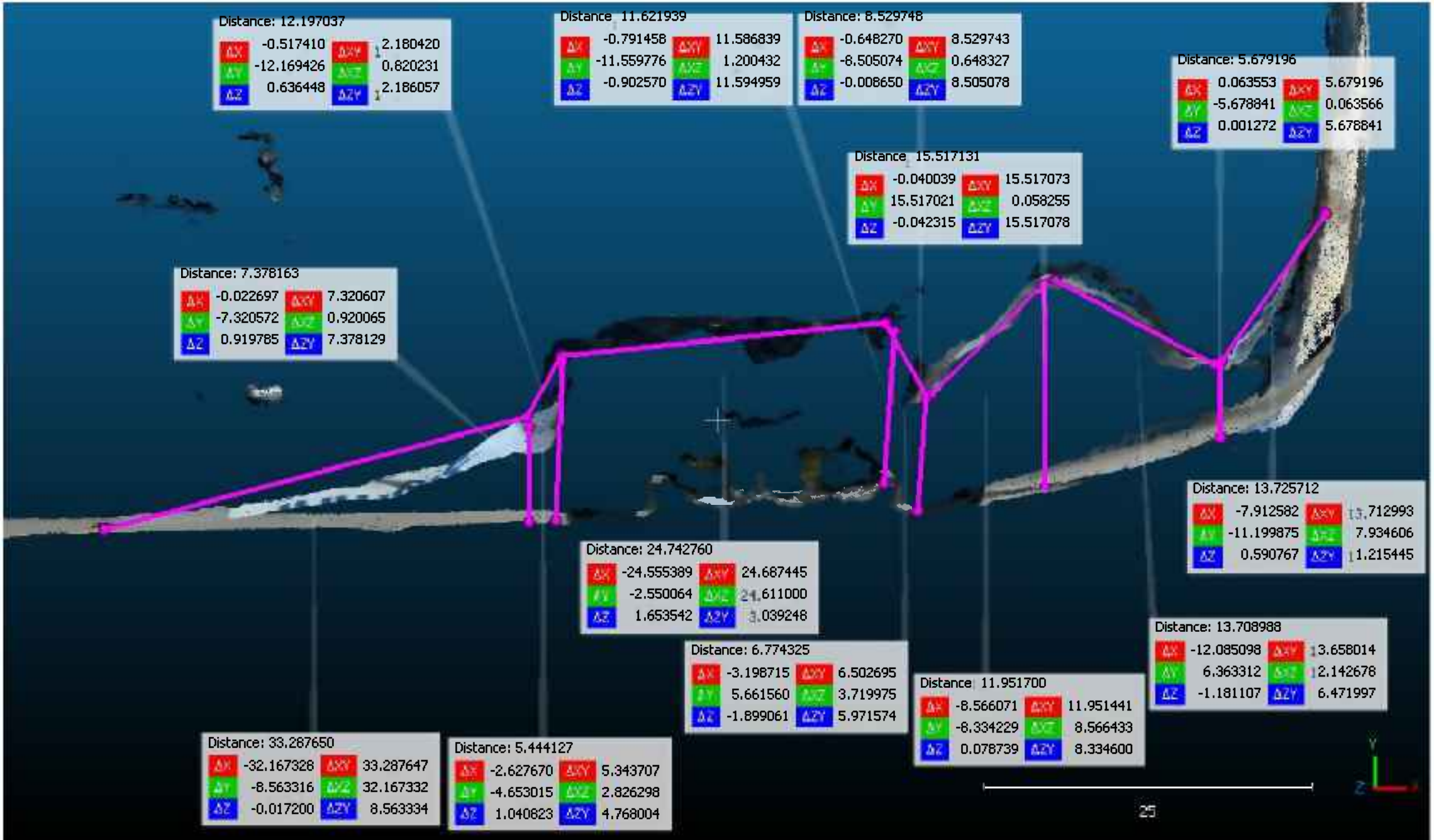
Crash Test 2

2001 Jaguar XK8 Side Crush Profile

2001 Jaguar XK8 Damage Profile - IPTM 2026 Symposium - CT2

Units = Inches

delta-y = crush depth delta-x = crush length



Crash Test 2

Dodge Avenger

Full NHTSA Data Set

Crash Test Stiffness Summary

Available Test Results
Front Impact Test Summary

Report Filter Settings

Year Range: 2007 - 2014
Make: DODGE
Model: AVENGER

Test Number	Vehicle Info	No Damage Average Speed (mph)	Crush (inch)	KEES (mph)	Vehicle Stiffness Values A	B	Width G	Kv	Crush Factor
7477	2012 CHRYSLER 200 FOUR DOOR SEDAN	5.0	29.0	19.9	104.3	10.7	508.1	19.1	5.4
8195	2013 DODGE AVENGER FOUR DOOR SEDAN	5.0	12.8	24.7	329.9	101.4	536.7	159.3	19.1
6197	2008 DODGE AVENGER FOUR DOOR SEDAN	5.0	18.0	35.1	349.4	116.7	523.1	158.6	27.4
6169	2008 CHRYSLER SEBRING CONVERTIBLE CON...	5.0	18.0	35.1	395.8	132.3	592.3	179.8	27.4
5886	2007 CHRYSLER SEBRING FOUR DOOR SEDAN	5.0	14.6	35.2	431.5	178.2	522.4	242.2	33.9
7464	2012 DODGE AVENGER FOUR DOOR SEDAN	5.0	14.0	35.2	484.0	208.5	561.6	283.4	35.3
7482	2012 CHRYSLER 200 FOUR DOOR SEDAN	5.0	13.3	35.2	487.4	220.5	538.6	299.6	37.1
	Average (AVG)				**368.9**	**138.3**	**540.4**	**191.7**	**26.5**
	Minimum (MIN)				**104.3**	**10.7**	**508.1**	**19.1**	**5.4**
	Maximum (MAX)				**487.4**	**220.5**	**592.3**	**299.6**	**37.1**
	Standard Deviation (STDev-sample)				**131.6**	**72.4**	**28.4**	**95.5**	**11.1**
	Number of Tests (n)			**7**					

Crash Test 2

Jaguar Lever Arm = 0 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	13.8	25.5
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	23.1	42.6
Average	368.9	138.3	70561.45	110107.41	31.4	30.9	57.0
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	37.0	68.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	42.2	78.0
Maximum	487.4	220.5	109170.26	167109.66	38.7	37.5	69.3

Damage Centroid Depth (x) (inches)	8.37	k²	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	11.7	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	19.5	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	26.1	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	31.3	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	35.8	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	31.8	41.9

Damage Centroid Depth (x) (inches)	5.16	k²	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	721.39		

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	13.8	25.5
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	23.1	42.6
Average	368.9	138.3	70561.45	110107.41	31.4	30.9	57.0
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	37.0	68.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	42.2	78.0
Maximum	487.4	220.5	109170.26	167109.66	38.7	37.5	69.3

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	7.90	22.52	1.90	42.78	5.27	118.58
C2 (inches)	5.70	12.10	128.26	5.68	728.20	19.08	2447.49
C3 (inches)	15.50	8.60	103.20	6.17	636.76	21.08	2175.66
C4 (inches)	8.50	3.20	32.16	5.06	162.89	11.28	362.84
C5 (inches)	11.60	24.60	292.74	5.95	1742.17	110.80	32436.58
C6 (inches)	12.20	2.60	25.35	4.98	126.18	14.19	359.74
C7 (inches)	7.30	32.20	117.53	2.43	285.99	203.93	23968.28
C8 (inches)	0.00						
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	11.7	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	19.5	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	26.1	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	31.3	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	35.8	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	31.8	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	721.39		

Crash Test 2

Jaguar Lever Arm = 53 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees).	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches).	12.77
Damage Length (inches).	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.7	29.9
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	19.6	50.1
Average	368.9	138.3	70561.45	110107.41	31.4	26.3	67.1
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	31.5	80.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	35.9	91.7
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

Damage Centroid Depth (x) (inches): 8.37
Damage Centroid Depth (y) (inches): 41.89
Area of Damage (inches²): 844.10
k²: 3109.14
Eff. Mass Ratio (gamma): 1.00

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees).	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches).	7.91
Damage Length (inches).	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches)	53.00
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	9.9	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	16.6	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	22.2	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	26.7	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	30.4	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	27.0	41.9

Damage Centroid Depth (x) (inches): 5.16
Damage Centroid Depth (y) (inches): 85.72
Area of Damage (inches²): 721.39
k²: 3364.50
Eff. Mass Ratio (gamma): 0.55

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.7	29.9
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	19.6	50.1
Average	368.9	138.3	70561.45	110107.41	31.4	26.3	67.1
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	31.5	80.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	35.9	91.7
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	53.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	7.90	22.52	1.90	42.78	5.27	118.58
C2 (inches)	5.70	12.10	128.26	5.68	728.20	19.08	2447.49
C3 (inches)	15.50	8.60	103.20	6.17	636.76	21.08	2175.66
C4 (inches)	8.50	3.20	32.16	5.06	162.89	11.28	362.84
C5 (inches)	11.60	24.60	292.74	5.95	1742.17	110.80	32436.58
C6 (inches)	12.20	2.60	25.35	4.98	126.18	14.19	359.74
C7 (inches)	7.30	32.20	117.53	2.43	285.99	203.93	23968.28
C8 (inches)	0.00						
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	9.9	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	16.6	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	22.2	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	26.7	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	30.4	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	27.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.55
Area of Damage (inches^2):	721.39		

Crash Test 2

Jaguar Lever Arm = 60.3 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.3	31.1
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	18.9	52.1
Average	368.9	138.3	70561.45	110107.41	31.4	25.2	69.7
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	30.3	83.6
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	34.5	95.4
Maximum	487.4	220.5	109170.26	167109.66	38.7	30.7	84.8

Damage Centroid Depth (x) (inches)	8.37	k²	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	60.30
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	9.5	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	16.0	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	21.4	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	25.6	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	29.2	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	26.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k²	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.48
Area of Damage (inches²):	721.39		

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	8.60	21.50	1.67	35.83	5.73	123.27
C2 (inches)	5.00	10.70	79.18	3.83	303.24	16.63	1316.64
C3 (inches)	9.80	12.80	192.64	7.83	1508.42	32.74	6307.84
C4 (inches)	20.30	15.00	318.00	10.61	3372.83	52.61	16728.75
C5 (inches)	22.10	6.30	123.80	9.88	1222.59	28.22	3493.38
C6 (inches)	17.20	12.70	109.22	5.73	626.19	67.73	7397.83
C7 (inches)	0.00						
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.3	31.1
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	18.9	52.1
Average	368.9	138.3	70561.45	110107.41	31.4	25.2	69.7
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	30.3	83.6
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	34.5	95.4
Maximum	487.4	220.5	109170.26	167109.66	38.7	30.7	84.8

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	60.30
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	133.9	5.1	7963.03	22895.37	13.2	9.5	6.8
Avg - 2 Std. Deviations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	406.7	47.4	35655.76	52414.03	19.9	16.0	20.5
Average	634.4	115.4	70561.45	87195.50	25.7	21.4	32.0
Avg + 1 Std. Deviations	813.0	189.6	105467.14	120953.21	30.3	25.6	41.0
Avg + 2 Std. Deviations	965.1	267.2	140372.84	154154.49	34.2	29.2	48.7
Maximum	830.2	197.7	109170.26	124497.32	30.7	26.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.48
Area of Damage (inches^2):	721.39		

Crash Test 2

Dodge Avenger

Reduced NHTSA Data Set

Crash Test Stiffness Summary

Available Test Results
Front Impact Test Summary

Report Filter Settings

Year Range: 2007 - 2014
Make: DODGE
Model: AVENGER

Test Number	Vehicle Info	No Damage Average Speed (mph)	Crush (inch)	KEES (mph)	Vehicle Stiffness A	B	Vehicle Width Values G	Kv	Crush Factor
8195	2013 DODGE AVENGER FOUR DOOR SEDAN	5.0	12.8	24.7	329.9	101.4	536.7	159.3	19.1
6197	2008 DODGE AVENGER FOUR DOOR SEDAN	5.0	18.0	35.1	349.4	116.7	523.1	158.6	27.4
6169	2008 CHRYSLER SEBRING CONVERTIBLE CON...	5.0	18.0	35.1	395.8	132.3	592.3	179.8	27.4
5886	2007 CHRYSLER SEBRING FOUR DOOR SEDAN	5.0	14.6	35.2	431.5	178.2	522.4	242.2	33.9
7464	2012 DODGE AVENGER FOUR DOOR SEDAN	5.0	14.0	35.2	484.0	208.5	561.6	283.4	35.3
7482	2012 CHRYSLER 200 FOUR DOOR SEDAN	5.0	13.3	35.2	487.4	220.5	538.6	299.6	37.1
	Average (AVG)				**413.0**	**159.6**	**545.8**	**220.5**	**30.0**
	Minimum (MIN)				**329.9**	**101.4**	**522.4**	**158.6**	**19.1**
	Maximum (MAX)				**487.4**	**220.5**	**592.3**	**299.6**	**37.1**
	Standard Deviation (STDev-sample)				**66.6**	**49.9**	**26.9**	**63.1**	**6.7**
	Number of Tests (n)			**6**					

Crash Test 2

Jaguar Lever Arm = 0 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches),	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	27.5	50.8
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	23.0	42.5
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	28.4	52.4
Average	413.0	159.6	81008.59	125986.93	33.6	32.9	60.7
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	36.8	67.9
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	40.3	74.5
Maximum	487.4	220.5	109170.26	167109.66	38.7	37.5	69.3

Damage Centroid Depth (x) (inches)	8.37	k²	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds),	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds),	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches).	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	23.3	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	19.5	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	24.0	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	27.8	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	31.1	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	34.1	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	31.8	41.9

Damage Centroid Depth (x) (inches)	5.16	k²	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	721.39		

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	27.5	50.8
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	23.0	42.5
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	28.4	52.4
Average	413.0	159.6	81008.59	125986.93	33.6	32.9	60.7
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	36.8	67.9
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	40.3	74.5
Maximum	487.4	220.5	109170.26	167109.66	38.7	37.5	69.3

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	7.90	22.52	1.90	42.78	5.27	118.58
C2 (inches)	5.70	12.10	128.26	5.68	728.20	19.08	2447.49
C3 (inches)	15.50	8.60	103.20	6.17	636.76	21.08	2175.66
C4 (inches)	8.50	3.20	32.16	5.06	162.89	11.28	362.84
C5 (inches)	11.60	24.60	292.74	5.95	1742.17	110.80	32436.58
C6 (inches)	12.20	2.60	25.35	4.98	126.18	14.19	359.74
C7 (inches)	7.30	32.20	117.53	2.43	285.99	203.93	23968.28
C8 (inches)	0.00						
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	23.3	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	19.5	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	24.0	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	27.8	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	31.1	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	34.1	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	31.8	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	721.39		

Crash Test 2

Jaguar Lever Arm = 53 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees).	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches).	12.77
Damage Length (inches).	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	23.4	59.7
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	19.6	50.0
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	24.1	61.6
Average	413.0	159.6	81008.59	125986.93	33.6	27.9	71.3
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	31.3	79.9
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	34.3	87.5
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees).	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches).	7.91
Damage Length (inches).	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches)	53.00
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches). 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	19.8	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	16.6	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	20.4	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	23.7	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	26.5	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	29.0	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	27.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.55
Area of Damage (inches²):	721.39		

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	23.4	59.7
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	19.6	50.0
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	24.1	61.6
Average	413.0	159.6	81008.59	125986.93	33.6	27.9	71.3
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	31.3	79.9
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	34.3	87.5
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	53.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	7.90	22.52	1.90	42.78	5.27	118.58
C2 (inches)	5.70	12.10	128.26	5.68	728.20	19.08	2447.49
C3 (inches)	15.50	8.60	103.20	6.17	636.76	21.08	2175.66
C4 (inches)	8.50	3.20	32.16	5.06	162.89	11.28	362.84
C5 (inches)	11.60	24.60	292.74	5.95	1742.17	110.80	32436.58
C6 (inches)	12.20	2.60	25.35	4.98	126.18	14.19	359.74
C7 (inches)	7.30	32.20	117.53	2.43	285.99	203.93	23968.28
C8 (inches)	0.00						
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	19.8	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	16.6	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	20.4	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	23.7	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	26.5	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	29.0	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	27.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.55
Area of Damage (inches^2):	721.39		

Crash Test 2

Jaguar Lever Arm = 60.3 inches

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec²)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							
Average Crush (inches):		12.77					

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	22.5	62.1
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	18.8	52.0
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	23.2	64.1
Average	413.0	159.6	81008.59	125986.93	33.6	26.9	74.2
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	30.1	83.1
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	33.0	91.0
Maximum	487.4	220.5	109170.26	167109.66	38.7	30.7	84.8

Damage Centroid Depth (x) (inches)	8.37	k²	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches²):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	60.30
Yaw Moment of Inertia (lb-ft-sec²)	2874.86

		Unequal Spacing (inches)	Zone Area (inches²)	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							
Average Crush (inches):		7.91					

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	19.0	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	15.9	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	19.6	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	22.7	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	25.5	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	27.9	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	26.0	41.9

Damage Centroid Depth (x) (inches)	5.16	k²	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.48
Area of Damage (inches²):	721.39		

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	413.0	159.6
Minimum	329.9	101.4
Maximum	487.4	220.5
Std. Devation	66.6	49.9

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	329.9	101.4	53698.91	85878.74	27.7	22.5	62.1
Avg - 2 Std. Deviations	279.8	59.8	34485.89	58504.92	22.9	18.8	52.0
Avg - 1 Std. Deviations	346.4	109.7	57747.24	91983.95	28.7	23.2	64.1
Average	413.0	159.6	81008.59	125986.93	33.6	26.9	74.2
Avg + 1 Std. Deviations	479.6	209.5	104269.94	160139.46	37.8	30.1	83.1
Avg + 2 Std. Deviations	546.2	259.4	127531.29	194355.24	41.7	33.0	91.0
Maximum	487.4	220.5	109170.26	167109.66	38.7	30.7	84.8

Damage Centroid Depth (x) (inches)	8.37	k^2	3109.14
Damage Centroid Depth (y) (inches)	41.89	Eff. Mass Ratio (gamma)	1.00
Area of Damage (inches^2):	844.10		

2001 JAGUAR XK8 - Side Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91
Damage Length (inches):	91.2
Crush Profile Measurements:	8

PDOF

Lever Arm Distance (inches):	60.30
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00	7.90	22.52	1.90	42.78	5.27	118.58
C2 (inches)	5.70	12.10	128.26	5.68	728.20	19.08	2447.49
C3 (inches)	15.50	8.60	103.20	6.17	636.76	21.08	2175.66
C4 (inches)	8.50	3.20	32.16	5.06	162.89	11.28	362.84
C5 (inches)	11.60	24.60	292.74	5.95	1742.17	110.80	32436.58
C6 (inches)	12.20	2.60	25.35	4.98	126.18	14.19	359.74
C7 (inches)	7.30	32.20	117.53	2.43	285.99	203.93	23968.28
C8 (inches)	0.00						
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bsub1
Minimum	533.0	81.5	53698.91	70573.50	23.1	19.0	26.9
Avg - 2 Std. Deviations	397.6	45.3	34485.89	51218.00	19.7	15.9	20.1
Avg - 1 Std. Deviations	558.5	89.5	57747.24	74589.23	23.8	19.6	28.2
Average	691.5	137.2	81008.59	97375.91	27.2	22.7	34.9
Avg + 1 Std. Deviations	807.4	187.0	104269.94	119806.13	30.1	25.5	40.8
Avg + 2 Std. Deviations	911.5	238.3	127531.29	141989.65	32.8	27.9	46.0
Maximum	830.2	197.7	109170.26	124497.32	30.7	26.0	41.9

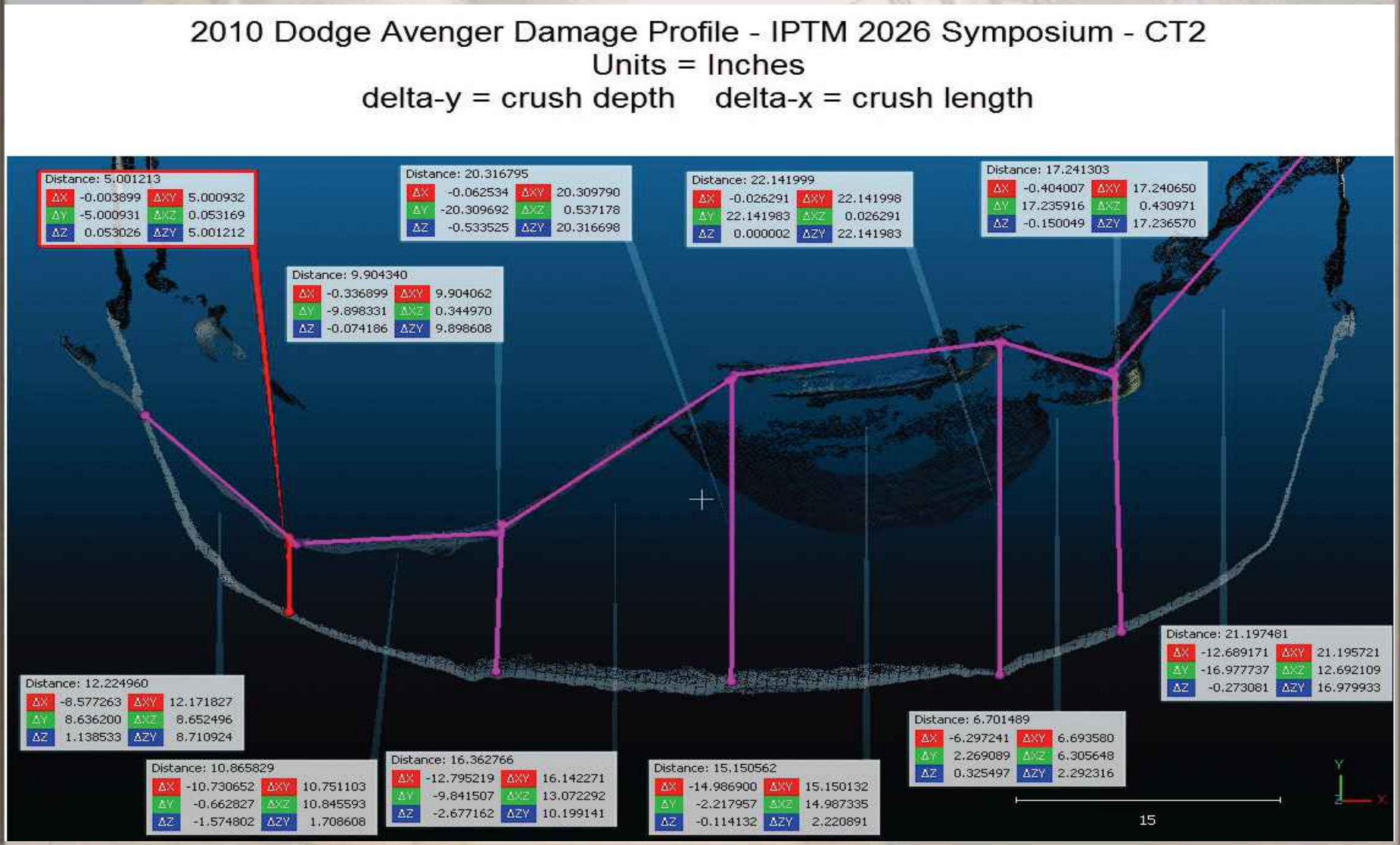
Damage Centroid Depth (x) (inches)	5.16	k^2	3364.50
Damage Centroid Depth (y) (inches)	85.72	Eff. Mass Ratio (gamma)	0.48
Area of Damage (inches^2):	721.39		

IPTM 2026

Force Balance: Crash Test 2

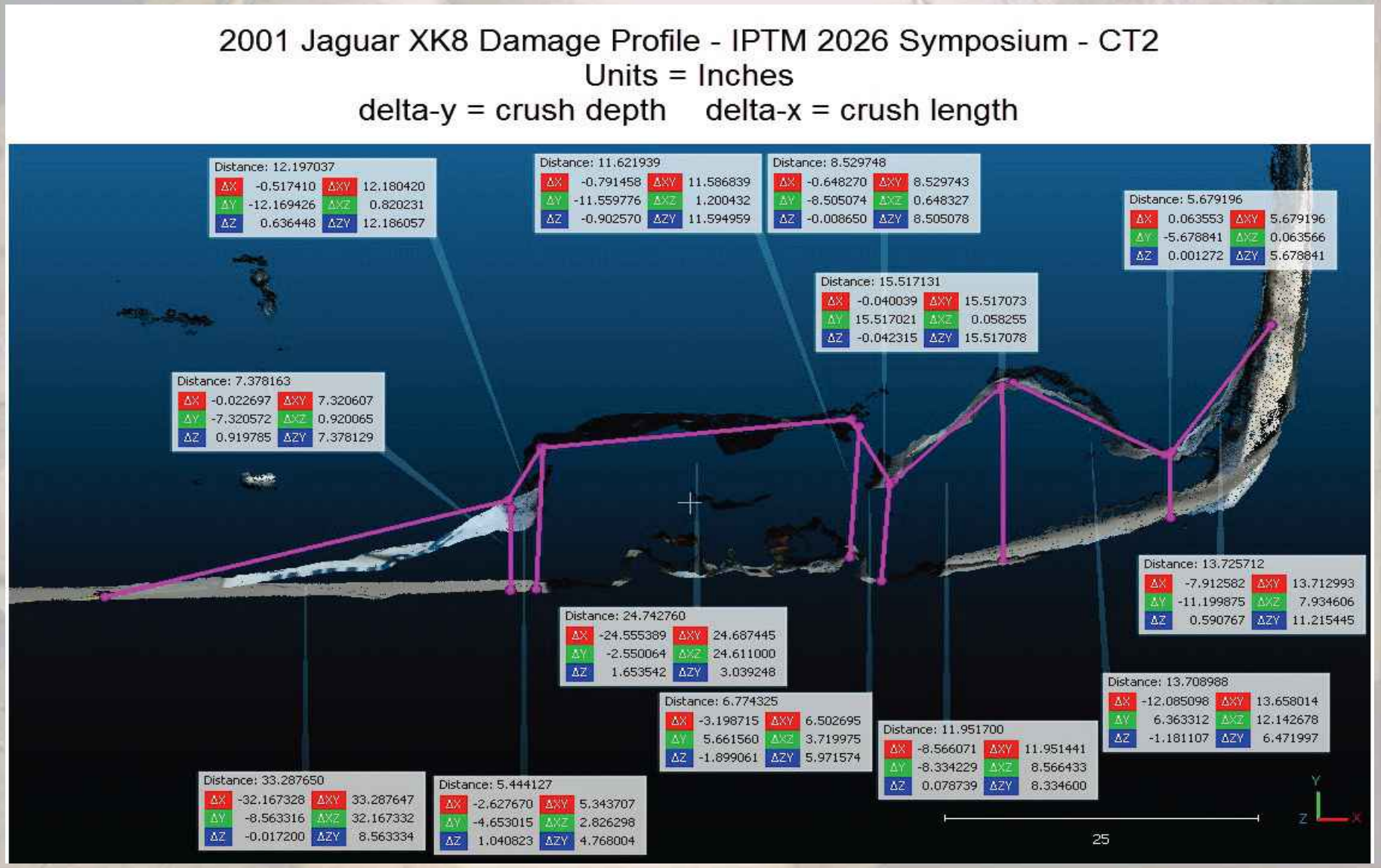
IPTM 2026

Force Balance: Crash Test 2



IPTM 2026

Force Balance: Crash Test 2



IPTM 2026

Force Balance: Crash Test 2

Year Range: 2007 - 2014
Make: DODGE
Model: AVENGER

Test Number	Vehicle Info	No Damage Speed (mph)	Average Crush (inch)	KEES (mph)	Vehicle Stiffness A	Vehicle Stiffness B	Width Values G	Width Values Kv	Crush Factor
7477	2012 CHRYSLER 200 FOUR DOOR SEDAN	5.0	29.0	19.9	104.3	10.7	508.1	19.1	5.4
8195	2013 DODGE AVENGER FOUR DOOR SEDAN	5.0	12.8	24.7	329.9	101.4	536.7	159.3	19.1
6197	2008 DODGE AVENGER FOUR DOOR SEDAN	5.0	18.0	35.1	349.4	116.7	523.1	158.6	27.4
6169	2008 CHRYSLER SEBRING CONVERTIBLE CON...	5.0	18.0	35.1	395.8	132.3	592.3	179.8	27.4
5886	2007 CHRYSLER SEBRING FOUR DOOR SEDAN	5.0	14.6	35.2	431.5	178.2	522.4	242.2	33.9
7464	2012 DODGE AVENGER FOUR DOOR SEDAN	5.0	14.0	35.2	484.0	208.5	561.6	283.4	35.3
7482	2012 CHRYSLER 200 FOUR DOOR SEDAN	5.0	13.3	35.2	487.4	220.5	538.6	299.6	37.1
	Average (AVG)				**368.9**	**138.3**	**540.4**	**191.7**	**26.5**
	Minimum (MIN)				**104.3**	**10.7**	**508.1**	**19.1**	**5.4**
	Maximum (MAX)				**487.4**	**220.5**	**592.3**	**299.6**	**37.1**
	Standard Deviation (STDev-sample)				**131.6**	**72.4**	**28.4**	**95.5**	**11.1**
	Number of Tests (n)			**7**					

IPTM 2026

Force Balance: Crash Test 2

2010 DODGE AVENGER - Front Impact

Curb Weight (pounds):	3355
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3355
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	5.0
Energy Crush Depth (inches):	12.77
Damage Length (inches):	66.1
Crush Profile Measurements:	7

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2249.65

"Known" Stiffness Values

	A	B
Average	368.9	138.3
Minimum	104.3	10.7
Maximum	487.4	220.5
Std. Devation	131.6	72.4

2001 JAGUAR XK8 - Front Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962
Angle Coll Force to Normal (degrees):	0.0
No Damage Speed (mph):	10.0
Energy Crush Depth (inches):	7.91

PDOF

Lever Arm Distance (inches):	0.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

IPTM 2026

Force Balance: Crash Test 2 - Dodge Crush

Damage Length (inches): 66.1

Crush Profile Measurements: 7

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.00	8.60	21.50	1.67	35.83	5.73	123.27
C3 (inches)	9.80	10.70	79.18	3.83	303.24	16.63	1316.64
C4 (inches)	20.30	12.80	192.64	7.83	1508.42	32.74	6307.84
C5 (inches)	22.10	15.00	318.00	10.61	3372.83	52.61	16728.75
C6 (inches)	17.20	6.30	123.80	9.88	1222.59	28.22	3493.38
C7 (inches)	0.00	12.70	109.22	5.73	626.19	67.73	7397.83
C8 (inches)							
C9 (inches)							
C10 (inches)							

Average Crush (inches): 12.77

IPTM 2026

Force Balance: Crash Test 2 - Jaguar Crush

Damage Length (inches): 91.2

Crush Profile Measurements: 8

		Unequal Spacing (inches)	Zone Area (inches^2)	Zone Depth(x) (inches)	Area Depth(x) (inches^3)	Zone Depth(y) (inches)	Area Depth(y) (inches^3)
C1 (inches)	0.00						
C2 (inches)	5.70	7.90	22.52	1.90	42.78	5.27	118.58
C3 (inches)	15.50	12.10	128.26	5.68	728.20	19.08	2447.49
C4 (inches)	8.50	8.60	103.20	6.17	636.76	21.08	2175.66
C5 (inches)	11.60	3.20	32.16	5.06	162.89	11.28	362.84
C6 (inches)	12.20	24.60	292.74	5.95	1742.17	110.80	32436.58
C7 (inches)	7.30	2.60	25.35	4.98	126.18	14.19	359.74
C8 (inches)	0.00	32.20	117.53	2.43	285.99	203.93	23968.28
C9 (inches)							
C10 (inches)							

Average Crush (inches): 7.91

IPTM 2026

Force Balance: Crash Test 2
Lever Arm on Jaguar = 0"

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	13.8	25.5
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	23.1	42.6
Average	368.9	138.3	70561.45	110107.41	31.4	30.9	57.0
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	37.0	68.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	42.2	78.0
Maximum	487.4	220.5	109170.26	167109.66	38.7	37.5	69.3

IPTM 2026

Force Balance: Crash Test 2
Lever Arm on Jaguar = 53"

2001 JAGUAR XK8 - Front Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962

PDOF

Lever Arm Distance (inches):	53.00
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.7	29.9
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	19.6	50.1
Average	368.9	138.3	70561.45	110107.41	31.4	26.3	67.1
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	31.5	80.4
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	35.9	91.7
Maximum	487.4	220.5	109170.26	167109.66	38.7	31.9	81.5

IPTM 2026

Force Balance: Crash Test 2
Lever Arm on Jaguar = 60.3 inches

2001 JAGUAR XK8 - Front Impact

Curb Weight (pounds):	3962
Occupant + Cargo Weight (pounds):	0
Total Weight (pounds):	3962

PDOF

Lever Arm Distance (inches):	60.30
Yaw Moment of Inertia (lb-ft-sec^2)	2874.86

Results

	A	B	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (MPH)
Minimum	104.3	10.7	7963.03	16438.22	12.1	11.3	31.1
Avg - 2 Std. Deviations	105.7	-6.5	N/A	N/A	N/A	N/A	N/A
Avg - 1 Std. Deviations	237.3	65.9	35655.76	57855.62	22.7	18.9	52.1
Average	368.9	138.3	70561.45	110107.41	31.4	25.2	69.7
Avg + 1 Std. Deviations	500.5	210.7	105467.14	162566.84	38.1	30.3	83.6
Avg + 2 Std. Deviations	632.1	283.1	140372.84	215074.61	43.9	34.5	95.4
Maximum	487.4	220.5	109170.26	167109.66	38.7	30.7	84.8