A Comparison between Edcrash and Ai Damage

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Abstract

This paper compares the operation and results of the relatively new AiTS computer program, Ai Damage, with the well established Engineering Dynamics Corporation (EDC) program Edcrash. Although program operation differs in certain respects, comparative results are in very good agreement.

Data entry systems are different, as too are some of the diagnostic messages. A summary of the main differences and similarities between the programs are described below.

A series of validation data sets were devised to highlight significant differences in the results generated by each program. These included comparison of computed delta-v values, calculated moment arms, handling of damage profiles, calculation of the magnitude of principle force and energy absorbed. Several minor variations were noted, mainly due to slightly different default data assumed by each of the programs.

A comparison is also provided of the Lotus Test Day[1] results for Edcrash and Ai Damage.

Introduction

Crush analysis programs are used to estimate the change in velocity (delta-v) of a vehicle from the amount of energy expended in causing crush deformation to both vehicles. To be effective a consistent system of measuring crush damage and method of comparing that damage with known data needs to be used. During the 1970's Raymond McHenry[2] developed a series of algorithms from which changes in velocity could be produced. These were originally designed to provide additional input to a vehicle simulation program, but work very well as a stand alone program. The CRASH algorithms were refined over several years and are now known as CRASH3.

Both Edcrash and Ai Damage, in common with several similar products, were developed from CRASH3. Edcrash is no longer actively marketed by EDC and the last update was in 1995 to version 4.61. It is a DOS based program and has a menu system guiding the text based data entry system. The replacement is a combination of the EDC Human Vehicle Environment (HVE) shell and Crash module, which has not been reviewed by this author. It is understood that this version works under Windows and uses updated crush coefficients.

Ai Damage is currently in Version 1.6 and was designed specifically for Microsoft Windows 95 and runs equally well under Windows NT or Windows 98. It is not however compatible with earlier versions of Windows or DOS. Data entry and amendment is through a 'Wizard' style interface with several pages of input, and graphical representation on screen as data is entered.

Both products are protected by a hardware key (dongle), which in Ai Damage also stores all the licensing information for the user.

Measuring protocols

Edcrash uses the measuring system defined by CRASH3. Data entry is restricted to either two, four or six crush measurements defining one, three or five crush zones respectively. The order of measurements is defined by reference to a plan view of a vehicle, with the first crush measurement C1 towards the left or rear of the vehicle. Edcrash requires the input of the total damage width and will accept data in metric or imperial measurements.

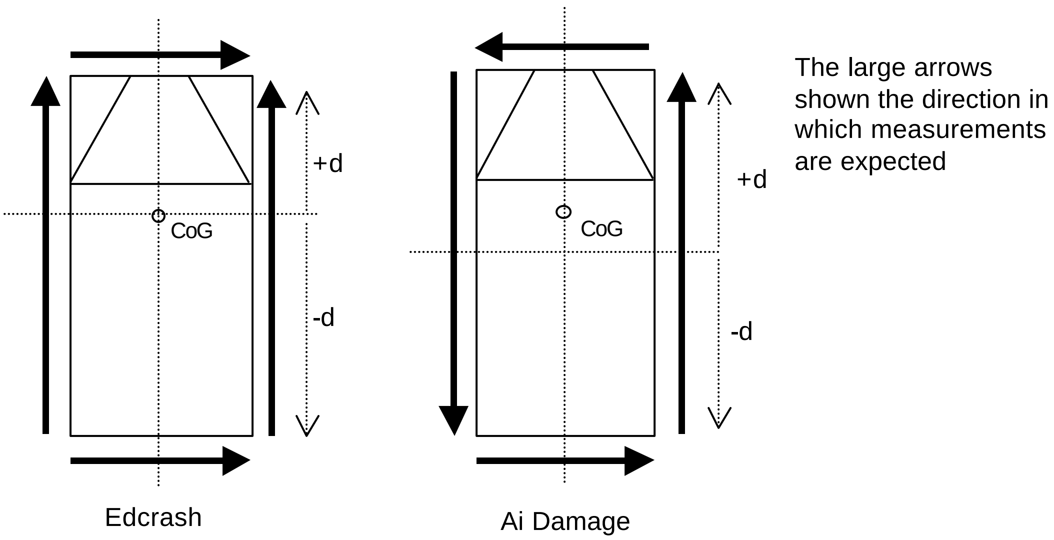
Edcrash uses fully the SAE damage measuring protocol[3] and insists on a collision deformation code (CDC) being entered for each collision. If crush damage is specified later in the data entry process, the CDC does little more than define which panel of the vehicle is being measured, and the principle direction of force. (PDOF)

With Ai Damage there is no facility to enter any CDC. Crush measurements are limited to any number between 2 and 100 and all measurements are taken from left to right with reference to the side of the vehicle being measured. Total damage width is not required, instead the width of the crush zones is entered, from which the program calculates the total width.

Offsets are measured with either a plus or minus figure relative to the centre of the crushed area. The major difference here is that Edcrash requires the offset relative to the position of the centre of gravity of the vehicle, whereas Ai Damage wants the offset relative to the geometric centre. This can introduce significant differences into results of otherwise identical data sets. For example on a base class 5 vehicle the centre of gravity is 25.5 cm forward of the centre line of the vehicle.

A summary of the measuring protocols are shown in diagram 1 below.

Diagram 1. Summary of measuring protocols



Momentum

Both programs have the ability to perform momentum calculations in addition to any crush analysis. The way that momentum is incorporated into each program differs considerably. With Edcrash the positions of the vehicles at impact, final positions and intermediate points may be entered using a co-ordinate and vehicle heading system. The program then works backwards from the point of rest, through any intermediate positions and back to the impact position to determine the post impact velocities for each vehicle. Additional information about the amount of braking at each wheel, (or average braking), steer angles and coefficient of friction are also required. The actual process and calculation procedures used for the post impact phase are detailed further in the Edcrash Training Manual[4].

Ai Damage cannot perform these post-impact calculations. Instead the user is left to determine the post-impact velocities by some other means and these are entered directly as a speed and direction of the centre of mass immediately post-impact.

Using the post-impact velocities, both programs perform a two dimensional momentum calculation to determine the pre-impact speeds. In addition, the delta-V's calculated, using the crush analysis, are subtracted from the post-impact velocities, to produce pre-impact velocities.

Program operation and results

Edcrash performs its calculations using US measurements and US coefficients. Any metric values appear to be converted prior to the calculations and then converted back into metric for final results. Ai Damage performs all its calculations in metric and uses metric crush coefficients. This difference inevitably introduces a few minor variations into any comparison tests.

Both programs produce comprehensive results, which may be viewed on screen or printed for further reference. In common with many, if not all, DOS based programs, Edcrash requires the printer to be set up before operation and is limited to several standard printers using custom drivers supplied with the program. Ai Damage will print through any printer installed under Windows, but has the limitation that output is designed to print on A4 (or larger) sized paper.

Both produce a text based summary of the main results together with a listing of any warnings or diagnostic messages produced.

Diagnostic calculations

During the calculation process it is possible to perform diagnostic calculations which give information about possible problems. The types of calculations are dependent upon whether a crush calculation, momentum calculation or both are performed.

For a crush only analysis both programs compare the magnitude of forces calculated by the program. Although the energy absorbed in the collision for each vehicle need not be equal, the forces that cause that crush should be equal, according to Newton's Third Law.

Edcrash only reports warnings when the size of the diagnostic calculations exceed internally set levels. Ai Damage always shows the results of diagnostic calculations and it is left to the user to determine whether these indicate a potential problem. For the crush analysis only calculation, Edcrash will generate a warning message only if the difference exceeds 100%.

Other warning and diagnostic messages are not discussed further in this text as these are both discussed fully in the respective program manuals and help files.[4 5]

Comparison tests

Six program runs were devised to highlight any differences between the results generated by the two programs. In all these tests a simple damage profile was used, which can allow calculations to be performed 'by-hand'. In addition, data gathered by the Lotus Crash Day tests was used to generate another series of comparisons. This provides comparisons which relate to more practical situations.

Comparisons are shown between the results produced for the total delta-V, component delta-V's, energy dissipated, magnitude of force and calculated moment arms.

In all the comparative tests, the default crush coefficients were used for Edcrash. Ai Damage is supplied with equivalent coefficients in the vehicle library "olddata.lib". This vehicle library is based on the CRASH3 generic vehicle data published by EDC[7].

The tests encompass all the five base classes of vehicle and utilise all four sides of the vehicle. An outline description of each test is shown below.

Test 1.
Head on impact between a class 1 and class 2 vehicle with no user defined offset.

Test 2.
Head on impact between a class 3 and class 4 vehicle with a 20 cm offset for each vehicle.

Test 3.
T-bone impact between a class 1 (front) and class 5 (right hand side) vehicle with a zero offset for the class 1 vehicle and for the class 5 vehicle an impact offset of 40 cm in front of the centre of mass. Principle forces varied by 15° from a perpendicular impact.

Test 4.
T-bone impact between a class 1 (rear) and class 5 (left hand side) vehicle with a zero offset for the class 1 vehicle and a 40 cm offset behind the centre of mass. 15° variation in force angle also specified.

Test 5.
This test is essentially a repeat of test 1 for Edcrash data entry, but compares the effect of varying the number of crush measurements for Ai Damage. The damage profile is designed to have the same shape and thus should generate the same results.

Test 6.
45 degree and 60 degree frontal impact between two class 2 vehicles. This test is designed to show the effect of reaching and exceeding the energy magnification limit which for both programs is set at 2. This magnification factor is reached at an angle of 45 degrees. At 60 degrees the energy magnification should remain the same.

The Lotus Results are merely provided as a comparison using the same data. No comment is made on the validity of the measuring process or indeed the results produced, as this is covered adequately elsewhere.[6]

The table in Appendix A shows a summary of the data entered for each of the tests.

Results

For easy comparison all the delta-V results are shown in kilometres per hour (km h^{-1}). The calculations were performed for each test, for Ai Damage (A) and Edcrash (E). Results are grouped together by test and vehicle and are shown in full in Appendix B.

Tests 1 and 2 show a very good correlation between the two programs. The slight differences in the calculated delta-V's are within 0.08%, which could be due solely to the fact that Ai Damage reports results to two decimals, compared with Edcrash which reports results to one decimal. The magnitudes of force and energy are within 0.15%. A close correlation between the moment arm of the principle force is also noted.

Tests 3 and 4 show a larger variation. In test 4 particularly there appears to be a significant difference between the delta-V's, a little over 6%. There are also significant differences between the calculated moment arms. This indicates that the problem may lie in the dimensions of the vehicles.

Closer examination of the default data used for each program reveals that there is a slight difference between the overall dimensions of each of the vehicles. This is less than one centimetre for most of the measurements involved, except for the length of vehicle 1. Ai Damage uses an overall body length of 367 cm whereas Edcrash uses 405.9 cm. A difference between the yaw moments of inertia used by each program was also noted.

If the Ai Damage data is amended to match the dimensional data used by Edcrash the results are recalculated as,

Test 4 - Ai Damage amended data to match Edcrash

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	52.08	48.94	17.81	112122	291191	-77.38
1 (E)	52.1	48.9	17.8	112036.3	290890	-77.4
2 (A)	34.72	8.99	33.54	110773	366840	-0.94
2 (E)	34.7	9.0	33.5	110691.3	366534.1	-0.9

A similar procedure for test 3 can also be performed to produce a similar close correlation. The value of ensuring that the dimensions used in the calculations reflect the actual collision vehicles used is also demonstrated by this.

Of note in tests 3 and 4, is the fact that Edcrash computes very slightly different force and crush energy values between the left and right hand sides. Although insignificant in themselves, it is suggested that with identical coefficients and identical crush measurements the force and crush energy should be the same.

Test 5 was designed to highlight any problems with the procedures used for generating the position of the centre of mass of the damage profile. This result is used within the programs to determine the moment arm. Ai Damage can use any number of crush measurements from 2 to 100, including both an even or odd number of measurements. This test demonstrates that with odd or even numbers of coefficients consistent results are computed.

Test 6 shows that the energy magnification is a factor of 2 at and impact angle of 45°. Identical crush measurements and damage width were used as for vehicle 2 in test 1. The calculated energy dissipated in this test was twice that calculated in test 1, for both vehicles.

Interestingly a slight variation between the two Edcrash values for energy were noted. As noted previously the two energy figures should be identical. If the impact angle for vehicle 1 is increased to 46° the two energy figures are identical. This may be due solely to rounding procedures.

The Lotus tests show very close agreement across all the results. The largest variation between the computed delta-V's was 0.23% in Lotus Test 2. A low delta-V was calculated for this particular test, exacerbating the difference. If quoted to one decimal throughout, there was no difference between the two sets of delta-V results.

Conclusions

Care should be taken when transferring data from one program to the other, as measuring protocols differ significantly. It can be very easy to transpose a series of crush measurements and produce a result which is a mirror image of the true damage profile.

Similar care must be taken with the offset measurement as this too differs between the programs. It is important to determine what offset measurement has been obtained, whether relative to the centre of mass, or the geometric centre.

The results of all the tests show that if similar data is entered into both Ai Damage and Edcrash then very similar results are produced, regardless of whether the calculation is performed in US measurements (Edcrash) or metric (Ai Damage).

Default dimensional data does vary between the programs and this can introduce significant variations between otherwise identical data sets.

Acknowledgements

The author gratefully acknowledges the assistance of the No 6 Region Police Driving School, Devizes in providing use of their copy of Edcrash, and also to Peter Jennings who provided helpful comments in the drafting of this report.

References

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6. Smith, R. Reconstructions of the Collisions Staged at the Field Day at Norwich. Impact Vol 4 No 5 1995
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Appendix A. Entry data

Entry data used for each of the comparison tests

Test & Vehicle	Base class	Force angle (degrees)	Offset* (cm)	Length (cm)	Spacing (cm)	Crush measurements** (cm)
1 (1)	1	0	0 (0)	100	20	100 90 80 70 60 50
1 (2)	2	0	0 (0)	100	20	100 90 80 70 60 50
2 (1)	3	0	20 (-20)	125	25	70 70 70 70 70 70
2 (2)	4	0	-20 (20)	125	25	70 70 70 70 70 70
3 (1)	1	15	0 (0)	150	30	70 60 50 40 30 20
3 (2)	5	75	65.5 (40)	200	40	20 30 40 50 60 70
4 (1)	1	-160	0 (0)	150	30	20 30 40 50 60 70
4 (2)	5	-105	-14.5(-40)	200	40	70 60 50 40 30 20
5 (1)	1	0	0 (0)	100	10	100 95 90 85 80 75 70 65 60 55 50***
5 (2)	2	0	0 (0)	100	50	100 75 50
6 (1)	2	45	0 (0)	100	20	100 90 80 70 60 50
6 (2)	2	60	0 (0)	100	20	100 90 80 70 60 50
Lotus 1 (1)	1	0	0 (0)	156	31.2	9 13 16 16 16 23
Lotus 1 (2)	2	180	0 (0)	156	31.2	38 44 47 46 44 53
Lotus 2 (1)	3	0	0 (0)	145	29	22 17 15 11 7 3
Lotus 2 (2)	2	90	-90 (-100)	130	130	12 12
Lotus 3 (1)	3	0	-50 (50)	50	50	25 1
Lotus 3 (2)	3	90	21 (0)	160	32	9 27 42 45 53 68

* Due to measuring differences Edcrash figures are shown in brackets.
** Order of crush measurements may be reversed for Edcrash data entry.
*** Edcrash crush measurements 100 90 80 70 60 50.

Appendix B. Results

Test 1.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	58.32	-58.32	0.00	138420	295820	5.56
1 (E)	58.3	-58.3	0.0	138398.9	295799.1	5.6
2 (A)	58.32	-58.32	0.00	124461	268940	5.56
2 (E)	58.3	-58.3	0.0	124392.1	268780	5.6

Test 2.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	51.76	-51.76	0.00	171868	407250	-20.00
1 (E)	51.8	-51.8	0.0	171657.9	406664	-20.0
2 (A)	43.00	-43.00	0.00	136340	281813	20.00
2 (E)	43.0	-43.0	0.0	136305.9	281782	20.0

Test 3.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	55.96	-54.05	-14.48	103302	308440	-30.11
1 (E)	56.0	-54.1	-14.5	103276.8	308403	-30.1
2 (A)	37.30	-9.66	-36.03	110773	366840	-37.16
2 (E)	37.3	-9.7	-36.0	110683	366520	-36.7

Test 4.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	55.40	52.06	18.95	112122	291191	-64.08
1 (E)	52.1	48.9	17.8	112036.3	290890	-77.4
2 (A)	36.93	9.56	35.68	110773	366840	-0.42
2 (E)	34.7	9.0	33.5	110691.3	366534.1	-0.9

Test 5.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	58.32	-58.32	0.00	138420	295820	5.56
1 (E)	58.3	-58.3	0.0	138398.9	295799.1	5.6
2 (A)	58.32	-58.32	0.00	124461	268940	5.56
2 (E)	58.3	-58.3	0.0	124392.1	268780	5.6

Test 6.

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	49.47	-34.98	-34.98	248922	380339	-118.48
1 (E)	49.2	-34.8	-34.8	248777.7	380107.4	-118.2
2 (A)	49.47	-24.74	-42.84	248922	537880	-147.14
2 (E)	49.2	-24.6	-42.6	248784.2	537544	-146.8

Lotus Test 1 (Triumph v Nissan)

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	45.76	-45.76	0.0	25621.3	160237	-7.97
1 (E)	45.7	-45.7	0.0	25608.2	160197.3	-7.9
2 (A)	41.83	41.83	0.0	99717.1	285806	-2.17
2 (E)	41.8	41.8	0.0	99639.7	285506.2	-2.2

Lotus Test 2 (Carlton v Alfa Romeo)

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	16.32	-16.32	0.0	21020	150583	17.44
1 (E)	16.3	-16.3	0.0	21012.4	150434.4	17.5
2 (A)	16.84	0.0	-16.84	8998.32	103740	100
2 (E)	16.8	0.0	-16.8	8993.5	103691.0	100

Lotus Test 3 (Volvo v Audi)

Vehicle and calculation	Total ΔV (km h^{-1})	Longitudinal ΔV (km h^{-1})	Lateral ΔV (km h^{-1})	Energy (J)	Magnitude of force (N)	Moment arm (cm)
1 (A)	27.80	-27.80	0.0	7710.23	52890	57.69
1 (E)	27.8	-27.8	0.0	7707.0	52837.4	57.7
2 (A)	29.67	0.0	-29.67	81965.9	307670	-16.26
2 (E)	29.7	0.0	-29.7	81900.8	307406.8	-16.3