

DARWIN 3.4 Release Notes

December 29, 2000

Southwest Research Institute

Enhancements

Risk Assessment Code

Flight_life

The surface stress intensity factor solution, SC02, has been upgraded such that it can compute stress intensity factors for a crack aspect ratio of $a/c \leq 2$. Previous versions were limited to $a/c \leq 1$. This enhancement primarily affects embedded cracks transitioning to surface cracks and is more realistic.

The corner crack solution has been speeded up significantly. It performs 7.5 times faster than the CC01 module in NASGRO. The accelerated version has been stored into a separate directory called `cc01_src`.

The crack transition criteria have been upgraded and expanded to include the effects of cyclic loadings during fatigue cycles; i.e., the effects of cyclic plastic zone sizes when crack tips approach the plate surface and the effective defect dimensions resulting from the first order cyclic plastic zone size correction.

The failure criteria have been upgraded to take into account the failure based on a first order plastic zone size correction subjected to the maximum monotonic loading.

The program structure has been changed slightly to accommodate the several upgrades in this release. The performance of the current release is equivalent to or better than the previous release depending on the extent of how the CC01 module has been invoked.

Inspection Transition

An option to transition the applied inspection schedules as the crack transitions from embedded to surface has been added. The user may specify which inspection schedules to use BEFORE and AFTER transition. In addition, the user may specify different inspection schedules to use if the defect breaks through to the bottom, left, top or right edges of the fracture mechanics plate, see the Figure 1 below.

Old Format

Inspection	1
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New Format

Inspection_before	1
Inspection_after_left	2
Inspection_after_top	3
Inspection_after_right	4
Inspection_after_bottom	5

Inspection schedule 1 will be used for inspections simulated before transition,
inspection schedule 2 will be used for inspections simulated after transition if the crack transitions to the left edge of the plate,
inspection schedule 3 will be used for inspections simulated after transition if the crack transitions to the top edge of the plate,

inspection schedule 4 will be used for inspections simulated after transition if the crack transitions to the right edge of the plate, inspection schedule 5 will be used for inspections simulated after transition if the crack transitions to the bottom edge of the plate.

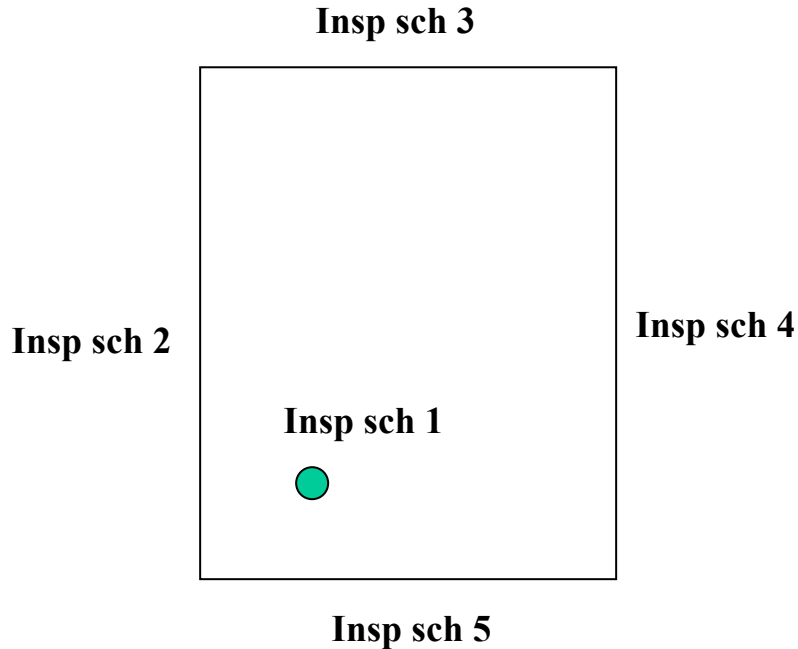


Figure 1 Example of Inspection Schedule Definition

Rainflow & Shakedown options

The DARWIN rainflow and shakedown options may be disabled.

Rainflow counting can be enabled or disabled using the following input format:

```
rainflow option
```

where `option` is either `ON` or `OFF`. The default option is `ON`. If rainflow is disabled, the load cases are assumed input in order of maximum and minimum pairs.

Shakedown analysis may be enabled or disabled using the following format:

```
shakedown option
```

where `option` is either `ON` or `OFF`. The default option is `ON`.

Updated tabular format

The format for tabular input of crack growth analysis has been updated to reflect the new capabilities in the version 3.4. In particular, the format includes the crack area, crack type and side of plate information. The new format is shown in Figure 2 below with the new information highlighted.

Z 1 o n e	}	R e f e r e n c e
N o C o f f i c i e n t s		
N o p o f f i c i e n t s		
a_1 c_1 A_{M1} r_{M1} N_{M1} $t a y_{M1}$ p_{M1} $i e d e$		
a_{M1} c_{M1} A_{M1} r_{M1} N_{M1} $t a y_{M1}$ p_{M1} $i e d e$		
L = # f e		
N o p o f f i c i e n t s		
a_1 c_1 A_{M1} r_{M1} N_{M1} $t a y_{M1}$ p_{M1} $i e d e$		
a_{M2} c_{M2} A_{M2} r_{M2} N_{M2} $t a y_{M2}$ p_{M2} $i e d e$		
L = # f e		
⋮		
R e f e r e n c e		

Figure 2 Tabular Input Format

Confidence Bounds

Failure probability predictions based on Monte Carlo simulation have an associated sampling error that can be approximated as a normal distribution. Upper and lower bounds for failure probability predictions (based on 95% confidence level) are now provided for zone and disk failure probabilities in the risk assessment code output file. For example, in Figure 3, Zone 1 has a mean unconditional failure probability of 3.57E-10. The lower and upper bounds reported for Zone 1 are 7.22E-12 and 7.08E-10, respectively (i.e., there is 95% confidence that the failure probability will fall within these bounds). These bounds are dependent on the number of Monte Carlo samples used (i.e., as the number of samples is increased, the bounds become narrower). Confidence bounds are also reported for the disk on a per-flight-cycle basis, as shown in Figure 4. For further details on zone and disk confidence bounds, see Appendix A of the Darwin Users Guide.

95% Confidence Bounds at 20000 cycles
0.00 % of disks not inspected
(unconditional results)

Zone	pf without inspection			pf with inspection		
	lower bound	mean	upper bound	lower bound	mean	upper bound
1	7.22E-12	3.57E-10	7.08E-10	0.00E+00	8.94E-11	2.65E-10
2	1.81E-10	8.97E-09	1.78E-08	1.81E-10	8.97E-09	1.78E-08
3	6.01E-09	3.00E-08	5.40E-08	4.04E-10	2.00E-08	3.96E-08
4	5.55E-08	9.70E-08	1.38E-07	3.08E-08	6.47E-08	9.85E-08
5	3.02E-07	3.73E-07	4.44E-07	2.25E-07	2.88E-07	3.50E-07
6	7.58E-07	8.59E-07	9.60E-07	6.31E-07	7.25E-07	8.18E-07
7	3.15E-08	3.43E-08	3.71E-08	2.79E-08	3.06E-08	3.32E-08
8	0.00E+00	1.74E-08	4.16E-08	0.00E+00	8.71E-09	2.58E-08
9	0.00E+00	2.19E-07	6.47E-07	0.00E+00	2.19E-07	6.47E-07
10	0.00E+00	1.46E-06	3.12E-06	0.00E+00	0.00E+00	0.00E+00
11	0.00E+00	9.01E-07	2.15E-06	0.00E+00	0.00E+00	0.00E+00
12	8.52E-07	2.77E-06	4.69E-06	2.14E-07	1.73E-06	3.25E-06
13	1.05E-05	1.46E-05	1.88E-05	7.03E-06	1.06E-05	1.41E-05
14	2.06E-06	2.29E-06	2.52E-06	1.82E-06	2.03E-06	2.25E-06
disk	1.86E-05	2.37E-05	2.88E-05	1.18E-05	1.57E-05	1.96E-05

Figure 3. Zone Confidence Bounds

Unconditional probability results for disk
(95% Confidence Bounds)

- Probability-of-Fracture Per Flight-Cycle Without Inspection (20000 Cycles)			
lower bound	mean	upper bound	
-----	-----	-----	
9.31543E-10	1.18478E-09	1.43801E-09	
- Probability-of-Fracture Per Flight-Cycle With Inspection (20000 Cycles)			
lower bound	mean	upper bound	
-----	-----	-----	
5.90937E-10	7.85627E-10	9.80317E-10	
- Probability-of-Removal by Inspection			
lower bound	mean	upper bound	
-----	-----	-----	
1.23050E-05	1.72931E-05	2.22811E-05	
- Prob-of-Fracture Reduction Per Flight-Cycle due to Inspection(20000 Cycles)			
lower bound	mean	upper bound	
-----	-----	-----	
2.36945E-10	3.99151E-10	5.61358E-10	

Figure 4. Disk Confidence Bounds

Graphical User Interface

Save Option

A prompt to save a .dat file before closing was added.

Inspection Transition

The zone editor panel was updated to facilitate the selection of inspection schedules ‘before’ and ‘after’ transition. Embedded cracks have a Pre & Post Transition option – see Figure 5. The procedure to specify inspection schedules is as follows. First, the user selects the icon, e.g., Pre-Transition, then selects the inspection schedule(s) to use from the available list. This process is repeated to specify the inspection schedules for Post-Transition. Note, the Pre option is only available for embedded cracks.

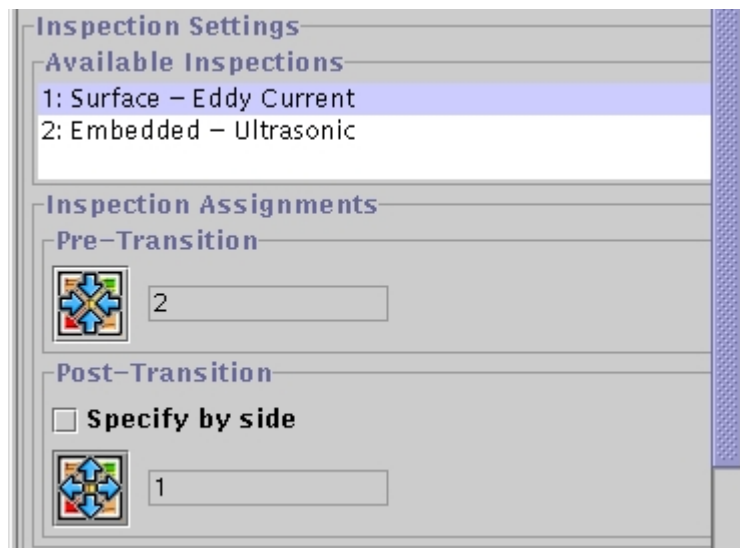


Figure 5 Embedded Crack - all post-transition sides same

The user may elect to specify inspection schedules by individual side as shown in Figure 6.

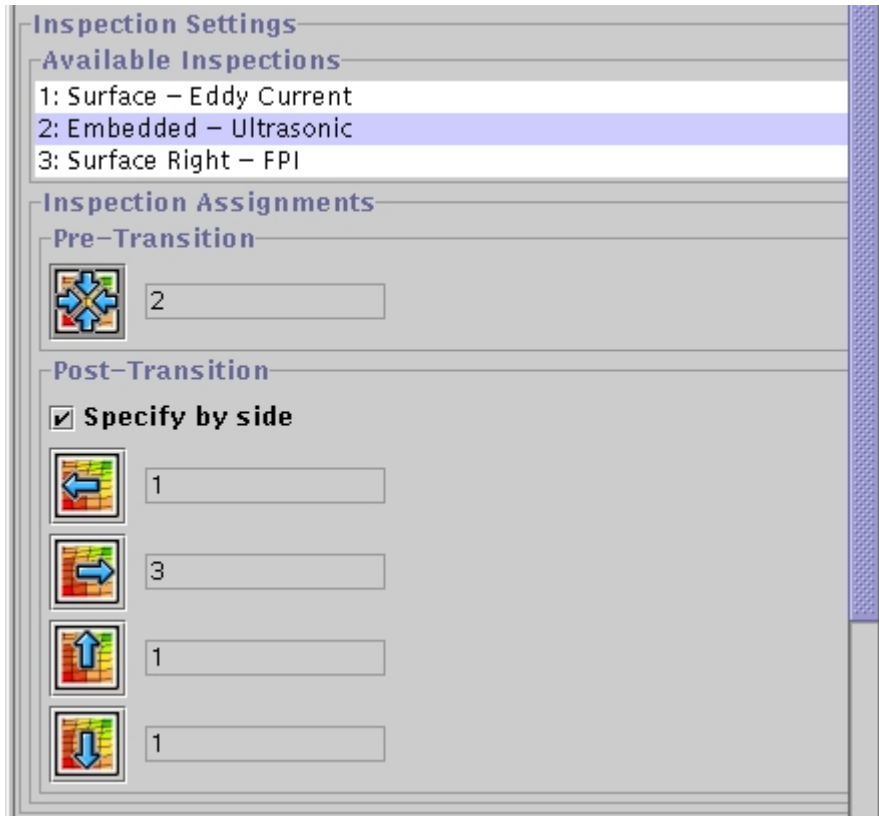


Figure 6 Embedded Crack post-transition sides different

For surface & corner cracks, by definition the crack has already transitioned and the crack must be placed on the bottom side. Therefore, only this option is available (Figure 7).

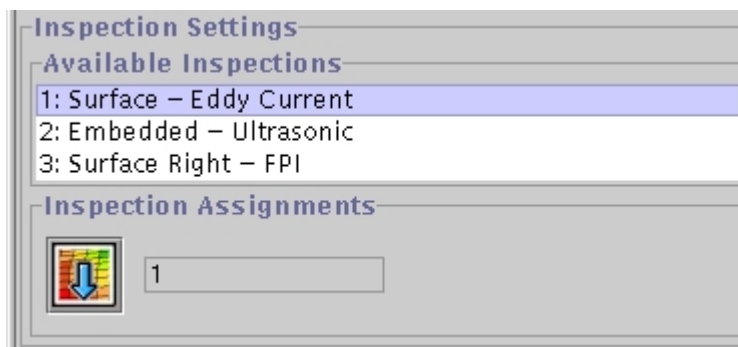


Figure 7 Surface/Corner crack, only Bottom Inspection

Bug Fixes

Graphical User Interface

Inspection Plot

For table format, pdf plot, the probability axis scale was not being rescaled to fit the data. This has been corrected.

Inspection Screen

When a previously saved .dat file with an inspection defined with normal distribution was opened and the inspection format modified from normal to table, the file could not be saved. This has been corrected.

Inspection schedule titles that were too long prevented selection or displayed incorrectly. The titles are now truncated according to the window dimensions.

Validation

The situation where a material, defect distribution or inspection is removed or replaced after a number of zones have been defined, previously generated a value of 0 in the .dat file. This situation is now detected in the GUI during validation. No information on the offending keyword is written to the .dat file. Note, the error must be fixed by reediting each zone. A method to quickly update each zone will be considered for a future release.

Validate warns if zero samples are specified for any zone.

Plots

Labels were updated on the inspection and material fatigue crack growth plots.

Evaluate Results/Risk Assessment/Zone Assessments Plot

Symbols for 'without' and 'with' inspection were reversed and have been fixed.

Known Bugs

Writing of inspection schedules for surface cracks using new format

A minor bug was discovered after the verification problems were executed. If 'inspection_after' or 'inspection_after_bottom' is used in the zone definition to define inspection schedules, no information is summarized on the output file. Note, this bug does not affect the calculations.