DARWIN® 8.1 Release Notes

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Southwest Research Institute®

Summary of New Capabilities

DARWIN 8.1 includes the following new features:

- Autozoning with inspection
- Random FE residual stress
- Anomaly orientation
- Hot corrosion
- 3D univariant residual stress
- 3D surface & line zoning
- Updated SIF solutions for surface cracks
- Component replacement for fleet assessments

Autozoning with Inspection

In previous versions of DARWIN, users specified inspections for zones by manually assigning inspection schedules to the interior and edges of manually created rectangular plate fracture mechanics models. This approach was not supported by autozoning because it required that the fracture mechanics model be available prior to execution of DARWIN, but autozoning does not create fracture models until the actual execution of DARWIN. DARWIN 8.1 provides a new approach for assignment of inspections that includes support for autozoning. As shown in
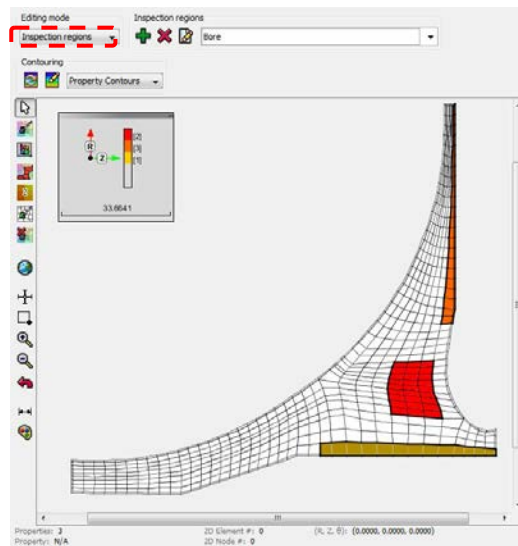

Figure 1. The new inspection capability in DARWIN 8.1 enables the user to assign inspection regions directly on the finite element model geometry.

Figure 1, the user can now assign inspection regions directly on the finite element model geometry rather than assigning inspection schedules to the fracture mechanics model. Definition of inspections has been consolidated to a single Inspection Events menu (Figure 2) in which the user can specify inspection methods (POD curves), timetables (schedules) and regions (geometry). The menu is automatically hidden from view when inspections are not in use. This new capability is used to define inspections for zones that are created both manually and via autozoning.
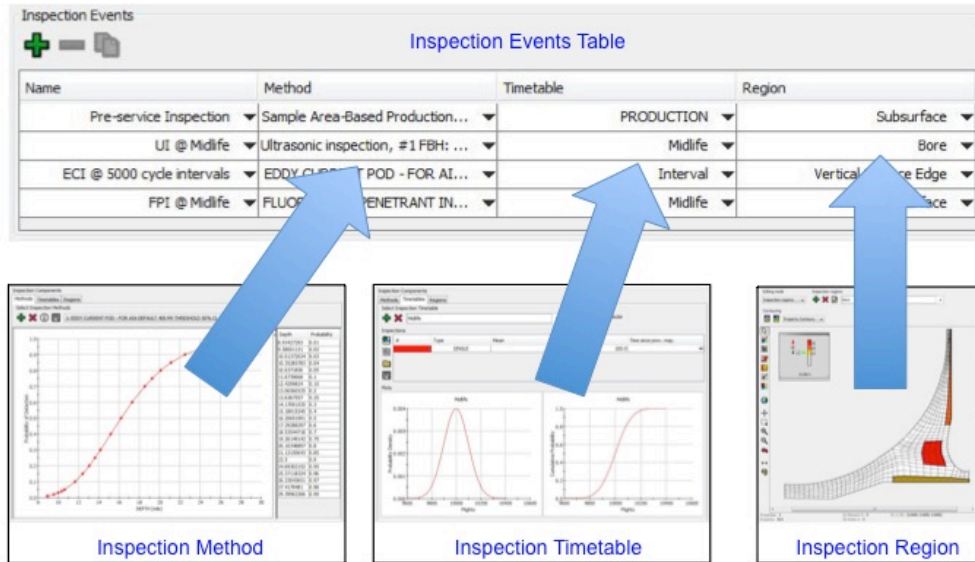

Figure 2. Definition of inspections in DARWIN 8.1 has been consolidated to a single menu for selection of inspection methods, timetables, and regions.

Random FE Residual Stress

Previous versions of DARWIN provided support for residual stresses associated with surface treatments. This enabled the user to manually specify a stress gradient that could be superimposed with service stresses associated with 2D finite element (FE) model results. In DARWIN 8.1, a new capability has been introduced that provides treatment for residual stresses associated with manufacturing process operations such as forging and heat treatment. This new capability enables the user to import 2D FE residual stress results (such as those generated by the DEFORM™ software), to model them as either deterministic or random residual stresses, and to superimpose them with 2D FE service stress results for application to crack growth life and risk assessments.

New capabilities have been introduced to define, process, and visualize the multiple residual stress results associated with modeling random residual stresses in DARWIN. The user provides residual stress files containing one or more sets of residual stress results. Each result set or "data sample" is based on a unique combination of manufacturing process variables. DARWIN
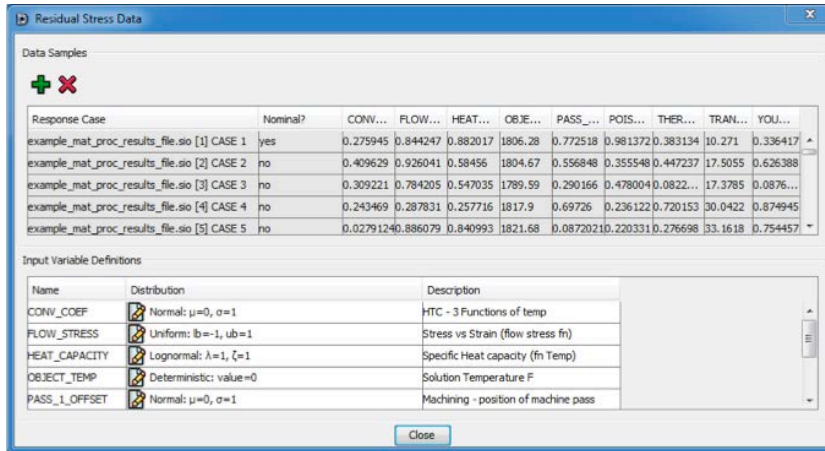
Figure 3. The new FE Residual Stress capability enables users to select multiple residual stress results files and to define the random parameters associated with the manufacturing process input variables.
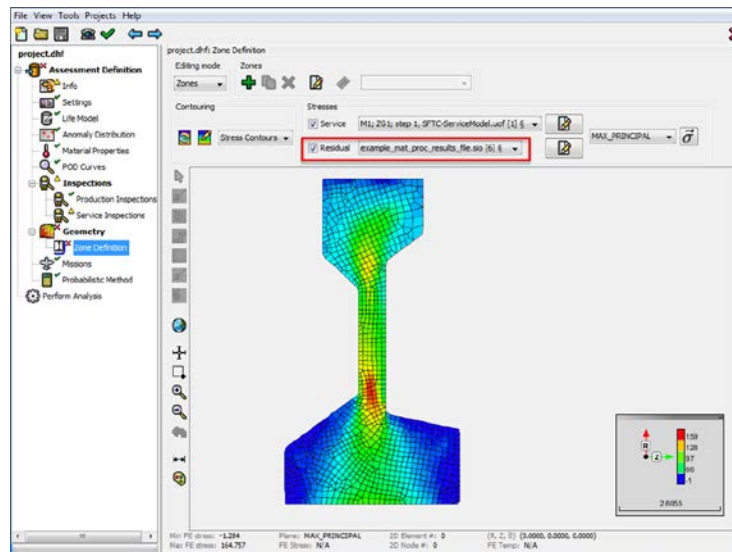

Figure 4. DARWIN 8.1 enables users to view stress contours associated with multiple FE residual stress results either individually or superimposed with applied service stresses.

enables users to select multiple residual stress results files and to define the random parameters associated with the manufacturing process input variables (Figure 3). The user can view stress contours associated with each residual stress result set individually or superimposed with the applied service stresses (Figure 4).

During probabilistic life assessments, a residual stress response surface is created based on the user-provided residual stress results files. Random values associated with the manufacturing process variables are propagated through the response surface to obtain random residual stresses at each finite element node and along the crack propagation path for each zone.

DARWIN provides 2D contour plots of the computed random residual stresses at selected probability distribution percentile values as shown in Figure 5.
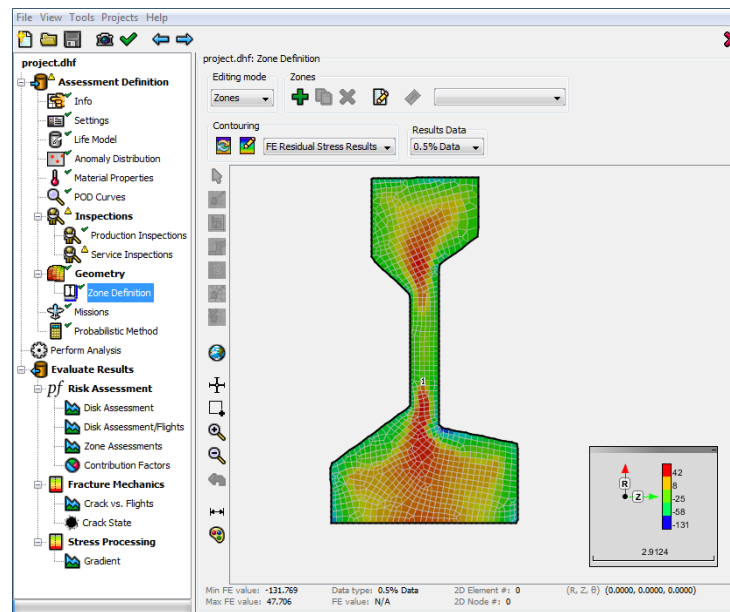

Figure 5. DARWIN 8.1 provides 2D contour plots of computed random residual stresses at selected probability distribution percentile values.

Anomaly Orientation

Previous versions of DARWIN include a six degree of freedom (6DOF) anomaly model that enables users to define the dimensions and orientation of an anomaly in the form of a three dimensional ellipsoid. Recent studies suggest that residual strains associated with manufacturing processing may influence the orientation of inherent material anomalies. A new capability was introduced in DARWIN 8.1 that enables the user to import 2D FE residual strain results (such as those generated by the DEFORM software) for use in anomaly orientation computations. DARWIN enables users to select residual strain results files and to view strain values as 2D contour plots on the component (Figure 6).

A separate anomaly orientation module is provided that enables the user to specify the relationship among residual strain and anomaly orientation. By default, the module aligns the longest dimension of an anomaly with the direction of maximum principal residual strain at the selected location. The DARWIN GUI provides visualization of 6DOF anomaly orientation in the crack growth plane based on residual strain values (Figure 7).
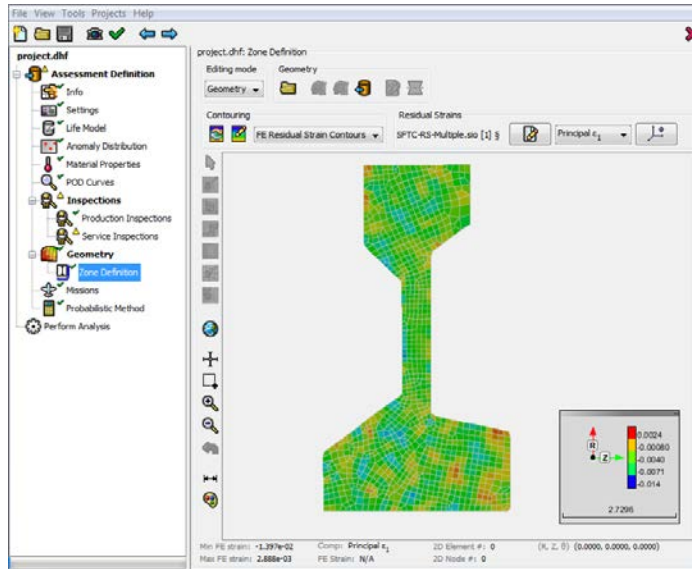
Figure 6. DARWIN 8.1 provides visualization of FE residual strain values from DEFORM.
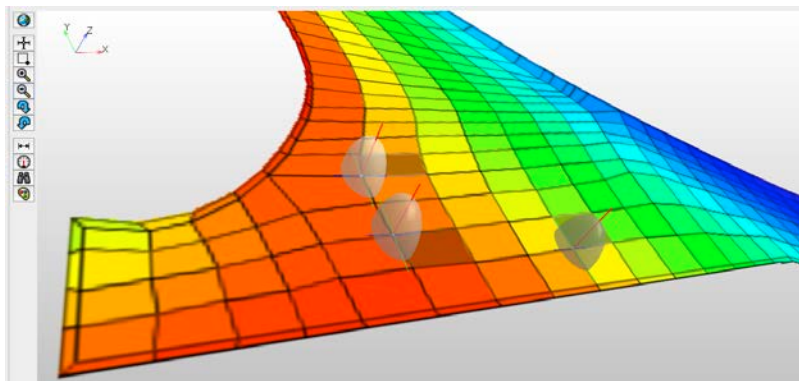

Figure 7. DARWIN 8.1 provides visualization of 6DOF anomaly orientation in the crack growth plane based on FE residual strain values from DEFORM.

Hot Corrosion

Previous versions of DARWIN have provided support for anomalies that are introduced during manufacturing. In DARWIN 8.1, a new Corrosion Pit anomaly type was introduced to provide treatment for corrosion pits that may form during the service life of a component (Figure 8). The user provides an anomaly distribution file containing random initial pit sizes and growth rates associated with various temperature and stress conditions. The DARWIN GUI provides visualization of pit size versus time associated with user-provided corrosion pit anomaly distribution files for the mean and selected confidence intervals (Figure 9). During run time, corrosion pits form and grow at user-specified rates until they form growing cracks (i.e., when the maximum stress intensity factor exceeds the large crack threshold value). Thereafter, fatigue crack growth is based on cyclic and time-dependent parameters specified in user-provided

material properties files. The DARWIN GUI provides visualization of both the pit growth and fatigue crack growth portions of life (Figure 10).
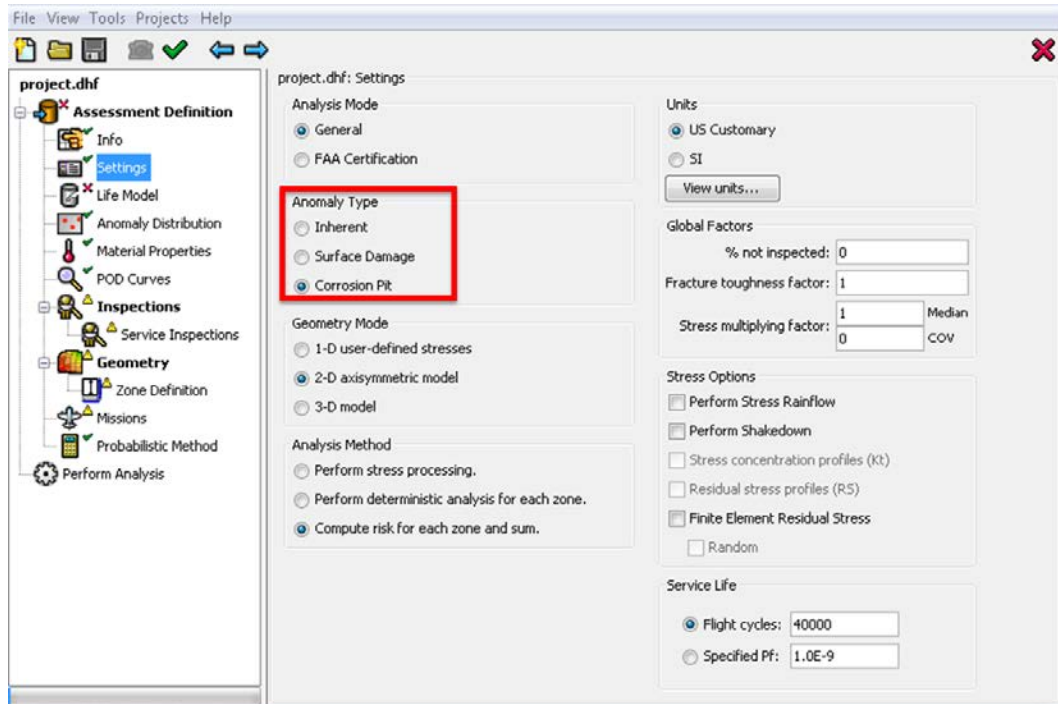

Figure 8. DARWIN 8.1 includes a new corrosion pit anomaly type that provides treatment for hot corrosion.
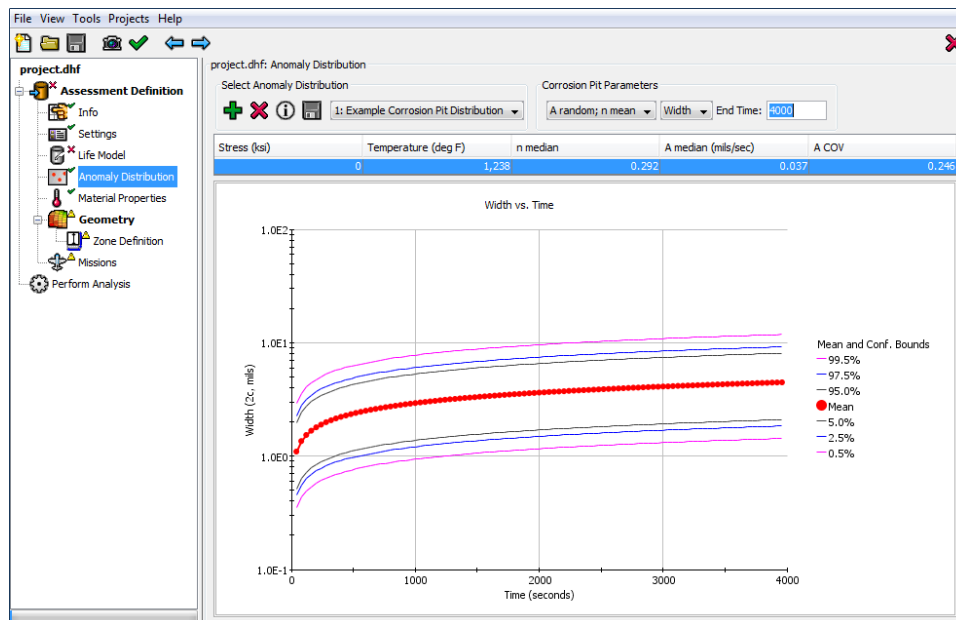

Figure 9. The DARWIN GUI provides visualization of pit size versus time associated with user-provided corrosion pit anomaly distribution files.
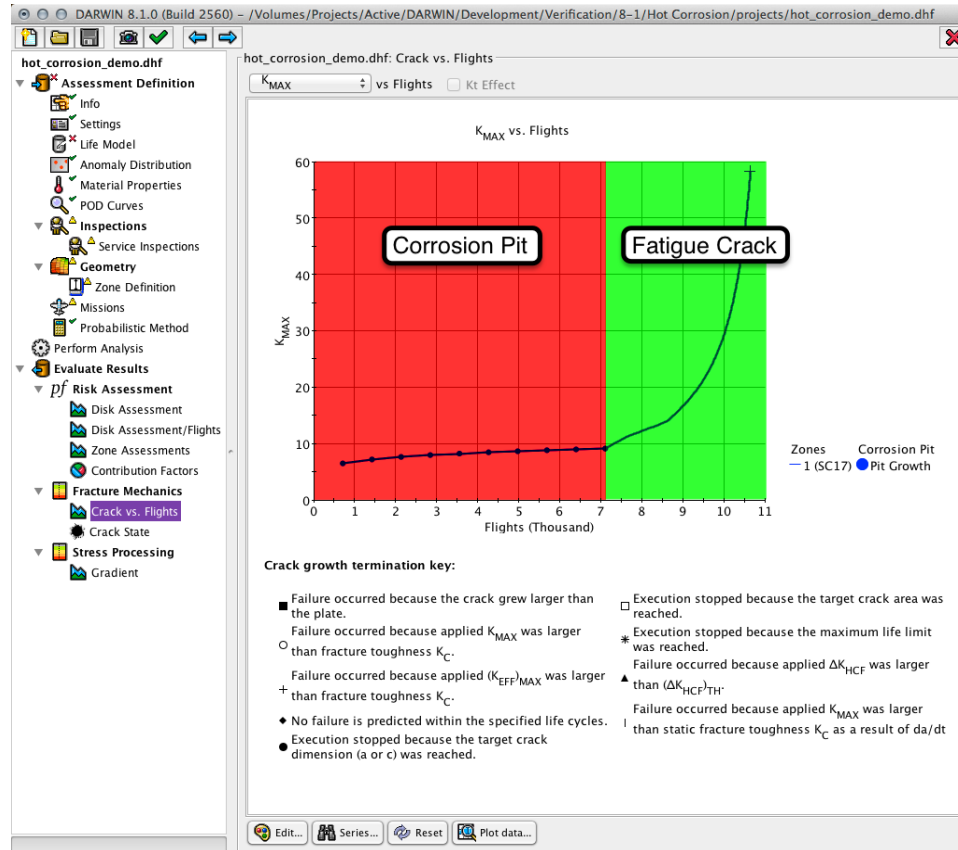
Figure 10. DARWIN 8.1 provides visualization of both pit growth and fatigue crack growth portions of life for components under hot corrosion.

3D Univariant Residual Stress

Surface treatment methods such as shot peening are commonly used to introduce compressive residual stresses on the surfaces of a component for life extension purposes. Previous versions of DARWIN included a capability to simulate residual stress fields on the exterior surfaces of 2D FE models based on univariant residual gradients provided by the user. In DARWIN 8.1, this capability was enhanced to support 3D FE models. It enables users to define univariant residual stress gradients and assign them to selected surface nodes in 3D FE model geometries. The surface nodes associated with the residual stress field are represented as red dots (see Figure 11). The orientation of the residual stress gradient applied to a node is set to the average orientation of the surface normal vectors associated with the faces of the finite elements adjacent to the node. When the user places the crack center at one of these nodes, the residual stress gradient associated with the node is projected onto the crack plane and superimposed with service stresses for use in fatigue crack growth life computations. This capability is available in the 3D General Surface Damage mode for univariant crack types.
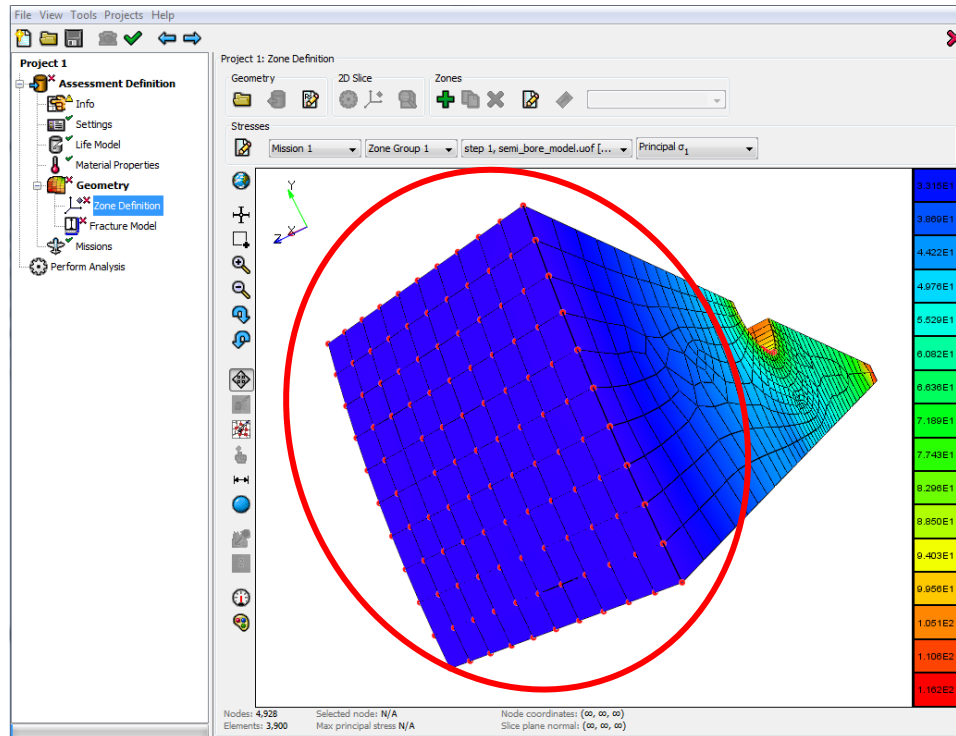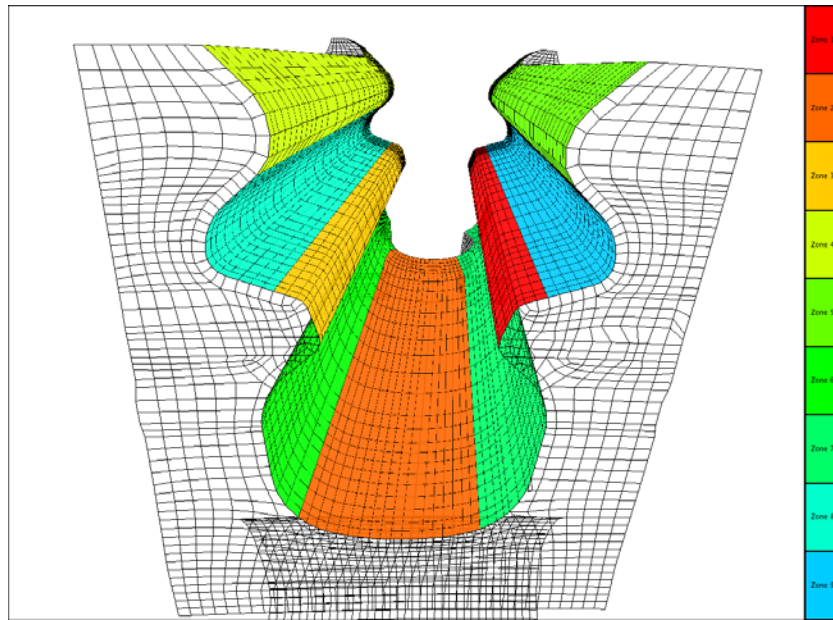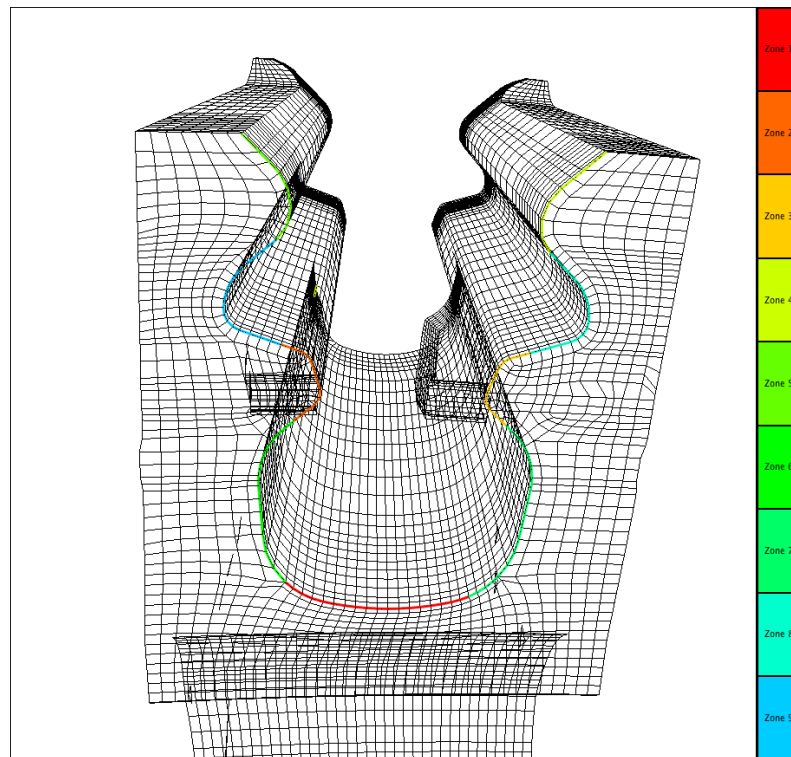
Figure 11. The DARWIN 8.1 3D residual stress enhancement enables users to assign residual stress gradients (represented by red dots) directly to 3D FE nodes.

3D Surface & Line Zoning

DARWIN supports the use of 3D FE models to perform risk assessment of components containing surface damage anomalies. In previous versions of DARWIN, a single zone was used to represent individual features such as holes and blade slots. Previous versions did not provide a display of the surface elements associated with a zone, and the user had to calculate and enter the surface area. In Version 8.1, DARWIN was enhanced to enable the user to define zones in 3D FE models by selecting element faces (surface-based zones, Figure 12a) or edges (line-based zones, Figure 13b). During zone creation, the faces or edges associated with a zone are highlighted and the cumulative surface area or line length is automatically computed and displayed for the zone. DARWIN was also enhanced to support anomaly distributions for line-based zones that are based on the number of anomalies per unit length. This new capability enables users to assign multiple zones to individual features for improved risk estimates.

(a)

(b)

Figure 12. DARWIN 8.1 was enhanced to enable the user to define zones in 3D FE models based on (a) element faces (surface-based zones), or (b) element edges (line-based zones).

Updated SIF Solutions for Surface Cracks

Previous versions of DARWIN included univariant (SC17) and bivariant (SC19) stress intensity factor (SIF) solutions for surface cracks. In DARWIN 8.1, these solutions were updated to provide more accurate values, particularly for crack size aspect ratios (a/c) less than 1. The updated univariant and bivariant solutions are named SC30 and SC31, respectively. The legacy SC17 and SC19 solutions are still provided in DARWIN 8.1 for comparison purposes and will be eventually phased out.

Component Replacement for Fleet Assessments

DARWIN includes a Fleet Assessment Module that can be used to assess the risk of a fleet of aircraft based on probability of fracture results from DARWIN. The fleet assessment computation is based on a fleet of aircraft in which engine components may be replaced during the service life. In previous versions of DARWIN, the risk computation was based on a population of components (i.e., disks) rather than aircraft. Components containing cracks that were detected during non-destructive inspection simulations were removed from the population before failure and were not replaced. DARWIN 8.1 includes a new option to replace a component following a simulated inspection event. This enables computation of the additional risk associated with replaced components for use in fleet assessment computations. This new capability is available as an optional feature (see DARWIN User's Guide for activation of this feature).
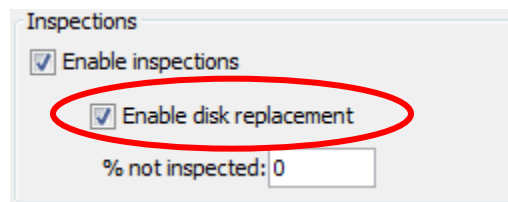

Figure 13. DARWIN 8.1 was enhanced to enable replacement of components that are removed during inspection events for application to the DARWIN Fleet Assessment Module.