DARWIN® 9.1 Release Notes

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Southwest Research Institute®

Summary of New Capabilities

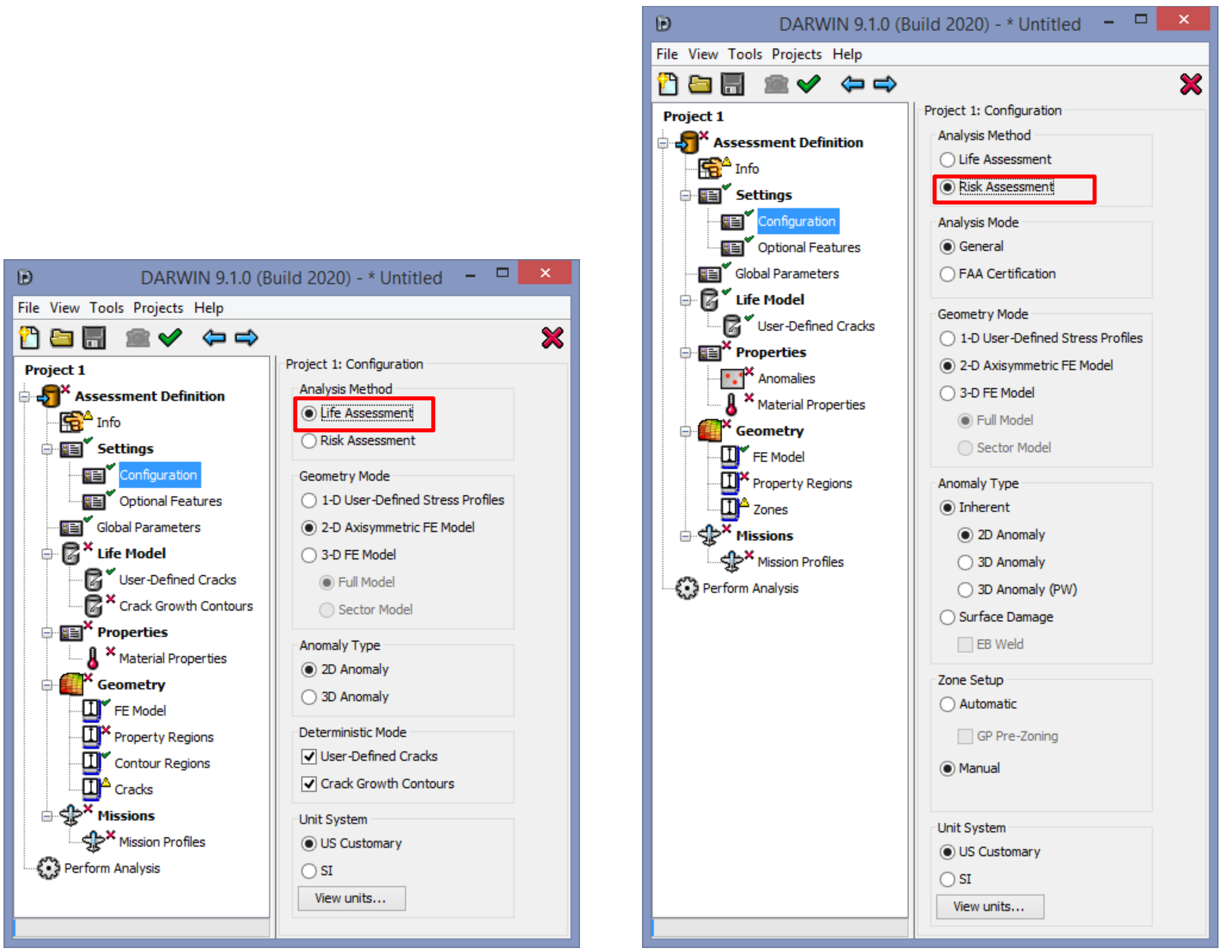
DARWIN 9.1 includes the following new features:
- Zoneless Deterministic Analysis
- Autoplate for 3D Finite Element Models
- Improved Support for Large Finite Element Models
- Enhanced Monte Carlo with GP Response Surface
- Critical Initial Crack Size Contours

Zoneless Deterministic Analysis

DARWIN was originally designed to assess the fracture risk of components containing rare material anomalies. The original DARWIN GUI workflow (i.e., content and sequence of GUI menus and features) was intended to support the zone-based risk assessment methodology described in FAA Advisory Circulars 33.14-1 and 33.70-2. However, many analysts also use DARWIN to assess deterministic fatigue crack growth (FCG) life as described in AC 33.70-1. Previous versions of DARWIN enabled users to perform deterministic fatigue crack growth analysis, but the risk assessment-based GUI workflow required additional input that was not required for deterministic analysis. For example, users had to define a zone for each initial crack location in a deterministic FCG life analysis, but much of the zone information was not used in the analysis.

DARWIN 9.1 enables users to perform deterministic life assessments without zones. A new GUI workflow was developed specifically for deterministic assessments in which a new "life assessment" mode is defined in the first (configuration) GUI menu. This enables the GUI to display the analysis configuration settings that apply only to deterministic life assessment. When performing a deterministic life assessment, the user no longer needs to specify the analysis mode and the zone information. The new configuration settings displays for the life assessment and risk assessment analysis methods are shown in Figures 1a and 1b, respectively. The GUI Optional Features menu was enhanced as well to display only the information that is applicable to deterministic life or probabilistic risk assessments.

A new "deterministic mode" option was added to the configuration menu that is available only for deterministic life assessments. It enables users to perform individual FCG analyses at user-specified locations (User-Defined Cracks option) and/or to construct a series of FCG life contours (Crack Growth Contours option). Users may select one or both deterministic mode options. The User-Defined Cracks option enables users to place cracks at multiple locations in an FE model and to perform a deterministic FCG life analysis at these locations. Users provide the crack location, crack type, crack growth plane, and fracture mechanics plate (via the Autoplate algorithm). The crack growth contours option enables users to define one or more crack growth contour models via a new "Crack Growth Contours" preprocessing screen shown in Figure 2. When this option is selected, a deterministic life assessment is performed for every node within the crack growth contour regions specified by the user. This option enables users to view fatigue crack growth life contours associated with specified initial crack sizes. It also provides contours for other fatigue crack growth properties such as K_{max}, crack depth, and crack length at the critical crack state.



(a) (b)

Figure 1: DARWIN 9.1 provides separate streamlined GUI workflows for deterministic FCG life and probabilistic fracture risk assessments: (a) life assessment analysis method, and (b) risk assessment analysis method.

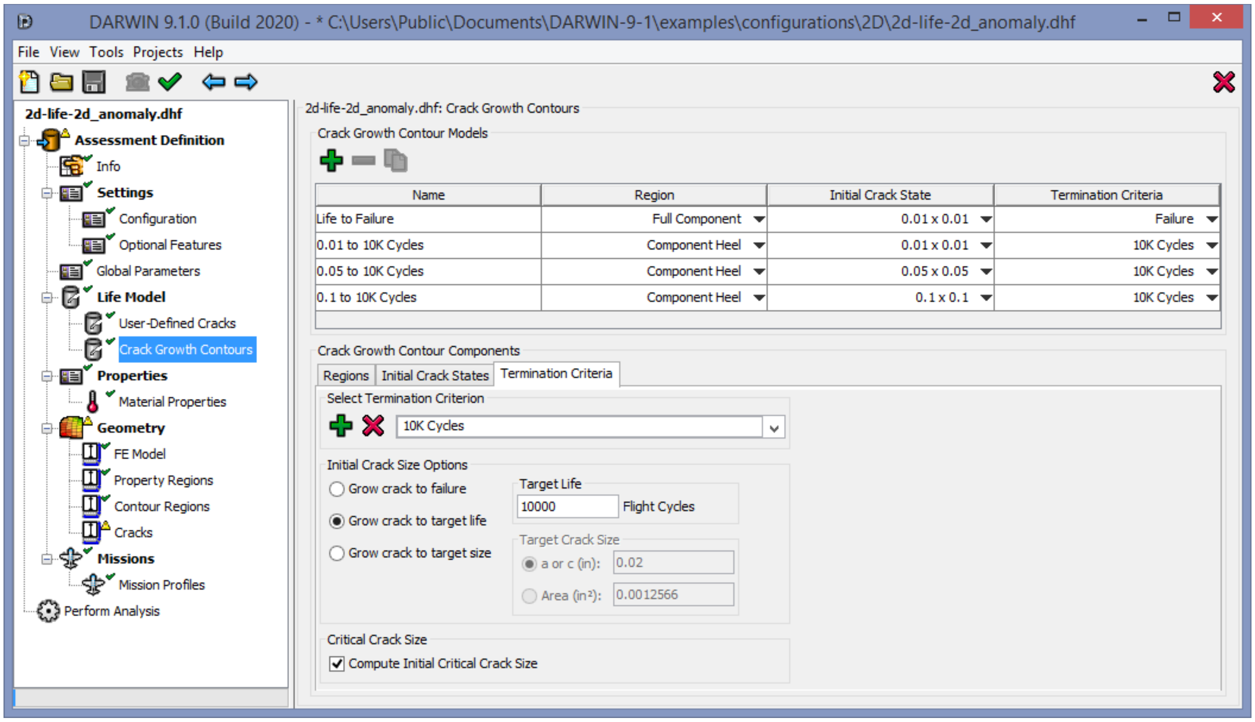


Figure 2: DARWIN 9.1 features a new screen to define crack growth contour settings. Users have control over the regions, initial crack states, and termination criteria.

Autoplate for 3D Finite Element Models

The DARWIN Autoplate algorithm identifies the size and orientation of fracture mechanics models (i.e., rectangular plates) based on the geometry, temperature, and stresses at specified locations in a finite element (FE) model. The DARWIN autozoning algorithms use the Autoplate algorithm to create zones. In previous versions of DARWIN, users could also invoke the Autoplate algorithm when manually creating zones via the DARWIN GUI, but this capability was limited to 2D FE models. For manual zone creation using 3D FE models, users were required to determine the size and orientation of fracture mechanics models using engineering judgment. Furthermore, for 3D models the initial crack locations were limited to nodes on the surfaces of FE models.

DARWIN 9.1 now enables users to create zones manually for 3D FE models using the Autoplate algorithm. When the user selects an initial crack location on the 3D FE model, the slice plane and fracture model are created simultaneously using a single mouse click based on the Autoplate algorithm. The GUI also enables users to specify the initial crack location anywhere on the surface of a 3D FE model as shown in Figure 3. These enhancements have resulted in a common interface for manually creating zones in both 2D and 3D FE model geometries.

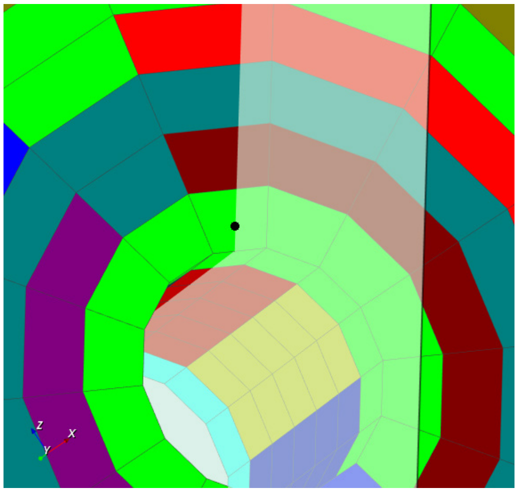


Figure 3: DARWIN 9.1 enables users to place an initial crack anywhere on the surfaces of 3D finite element models and use Autoplate to define the plate.

The Autoplate algorithm supports fracture models for surface, embedded, and corner crack types (SC30, EC05, and CC11, respectively). For all other crack types, the user must provide the fracture model parameters (i.e., fracture model dimensions and orientation). In previous versions of DARWIN, it was often difficult for users to determine whether a fracture model had been created by a user or via the Autoplate algorithm. This information was only provided in a table. In DARWIN 9.1, the GUI was enhanced as shown in Figure 4 to enable users to distinguish among models created by users and via Autoplate. Autoplate-defined plates are represented with a green border, and user-defined plates are represented with a white border.

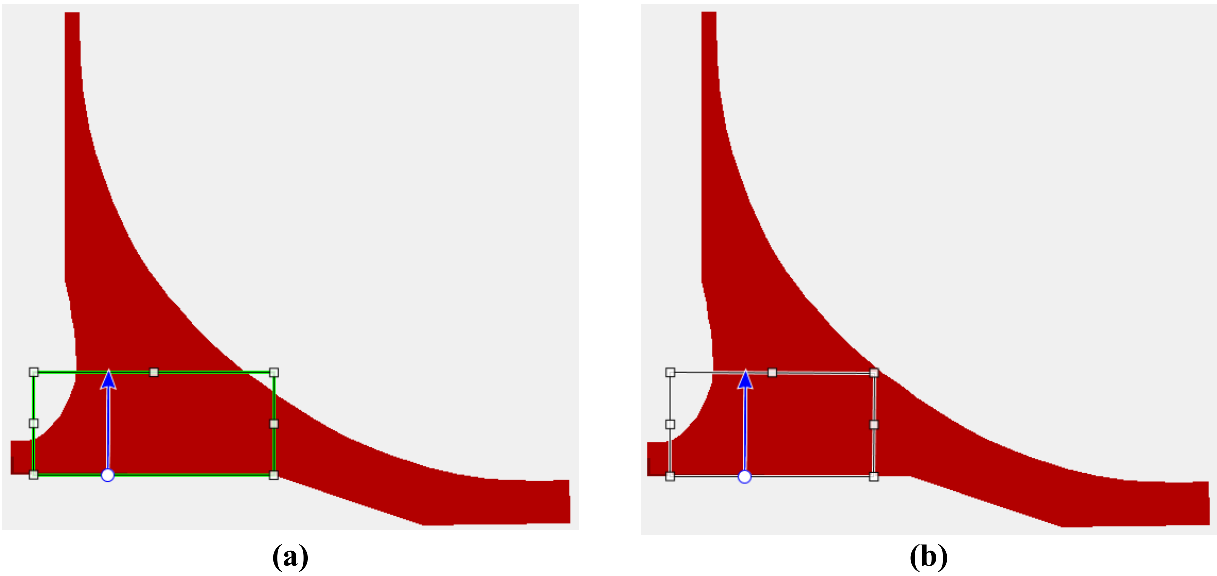


Figure 4: The GUI fracture model display was enhanced to enable user to distinguish among models created by users and via Autoplate: (a) Autoplate-defined plates are represented with a green border, and (b) user-defined plates are represented with a white border.

Improved Support for Large Finite Element Models

Previous versions of DARWIN did not provide adequate support for large FE models with large numbers of load steps. The time required to import and display large FE models in the GUI could be measured in double digit minutes or even hours. The time required to process these FE models in the risk assessment code (RAC) was extensive, and often terminated because the memory required to process the analysis exceeded available computer random access memory. The memory limitation was due to the use of a text-based file format for FE models. DARWIN 9.1 introduces a new binary file format called HSIESTA to store finite element results data. HSIESTA replaces an earlier file format (SIESTA) used by DARWIN to store the same information. HSIESTA stores information in a binary format that is more easily accessible to DARWIN.

DARWIN 9.1 now reads, displays, and utilizes data from HSIESTA. These enhancements have significantly reduced the time required to read and display the stresses and temperatures associated with large FE models. For example, consider a finite element model with approximately 100,000 nodes and 1,000 load cases. In the previous version of DARWIN (Version 9.0), the GUI required nearly ten minutes to import and display the stresses and temperatures associated with a single load case. The time required to display the stresses and temperatures associated with another load case in the same model exceeded ten minutes and eventually timed out. Using the HSIESTA capability implemented DARWIN 9.1, the same FE model was imported and displayed in approximately ten seconds, or roughly 60 times faster than the previous DARWIN version that used SIESTA files. The GUI was also able to display the stresses and temperatures associated with other load cases in the file in roughly 8 seconds for each load case.

FE2NEU (DARWIN FE results file translator) was enhanced to translate FE models from commercial FE software (e.g., ANSYS, ABAQUS) to the HSIESTA format. It was further enhanced to convert legacy SIESTA-formatted files to the HSIESTA format. This will enable users to convert FE results from legacy files to the new HSIESTA format for use in DARWIN 9.1.

The DARWIN computational engine was also enhanced to read and process data from HSIESTA. The RAC was enhanced with new random access API functions that enable it to read data from specific regions of the HSIESTA file rather than importing the entire file into memory. Preliminary results indicate reduced memory usage for large finite element models when the number of zones is much smaller than the number of elements/nodes.

Enhanced Monte Carlo with GP Response Surface

Previous versions of DARWIN include a probabilistic method called GP (Gaussian Process) Importance Sampling. During run time, this method creates a Gaussian Process response surface model relating fatigue crack growth lives to initial crack size, stress scatter, and life scatter values. Fracture risk is then predicted by applying Monte Carlo simulation to the GP response surface.

DARWIN 9.1 enhances this probabilistic method to provide support for additional random variables: six degree-of-freedom anomalies (3 orthogonal dimension random variables and 3 orthogonal orientation random variables) and formation life scatter (including shop visit time). Note that it does not currently support random mission mixing. The enhanced method has been renamed "Monte Carlo w/ GPM" (Figure 5). It provides computational efficiency that is comparable to the Importance Sampling probabilistic method.

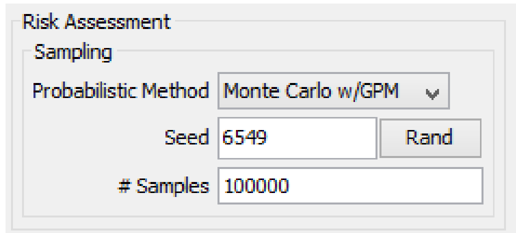


Figure 5: In DARWIN 9.1, the Gaussian Process response surface probabilistic method has been enhanced to support additional random variables for fracture risk assessments.

Critical Initial Crack Size Contours

For inspection purposes, it is often useful to estimate the size of an initial crack in a component that will grow to failure at the design life. This is called the critical initial crack size (CICS). DARWIN 9.1 has been enhanced to compute CICS values at each node in a finite element model. This new capability enables users to compute and view contours of CICS values associated with user-specified fatigue crack growth life values, as illustrated in Figure 6.

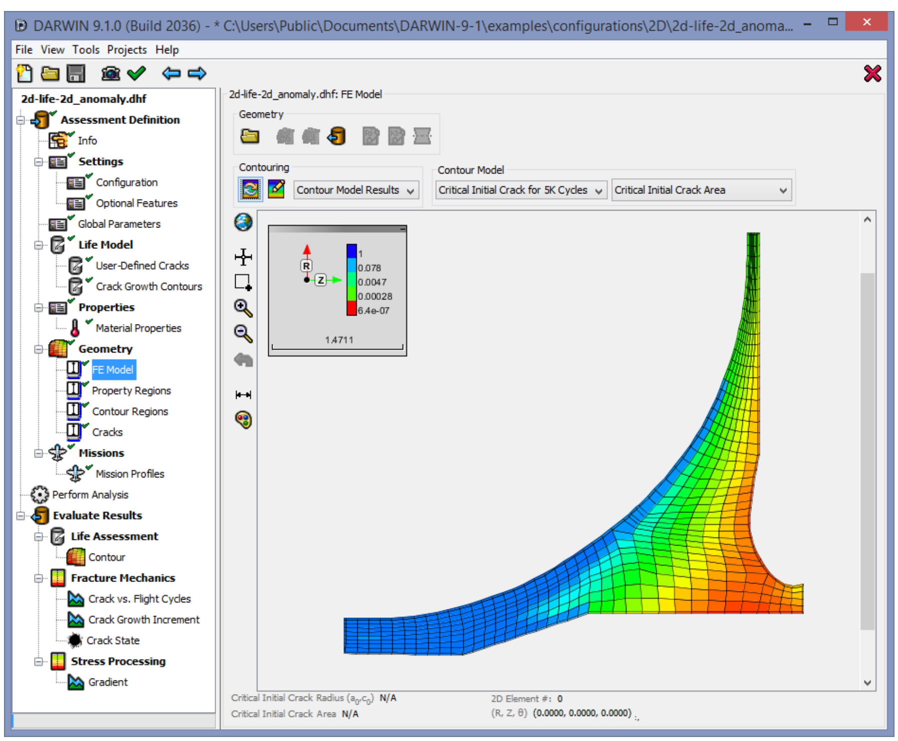


Figure 6: DARWIN 9.1 includes a capability to compute and display critical initial crack sizes.