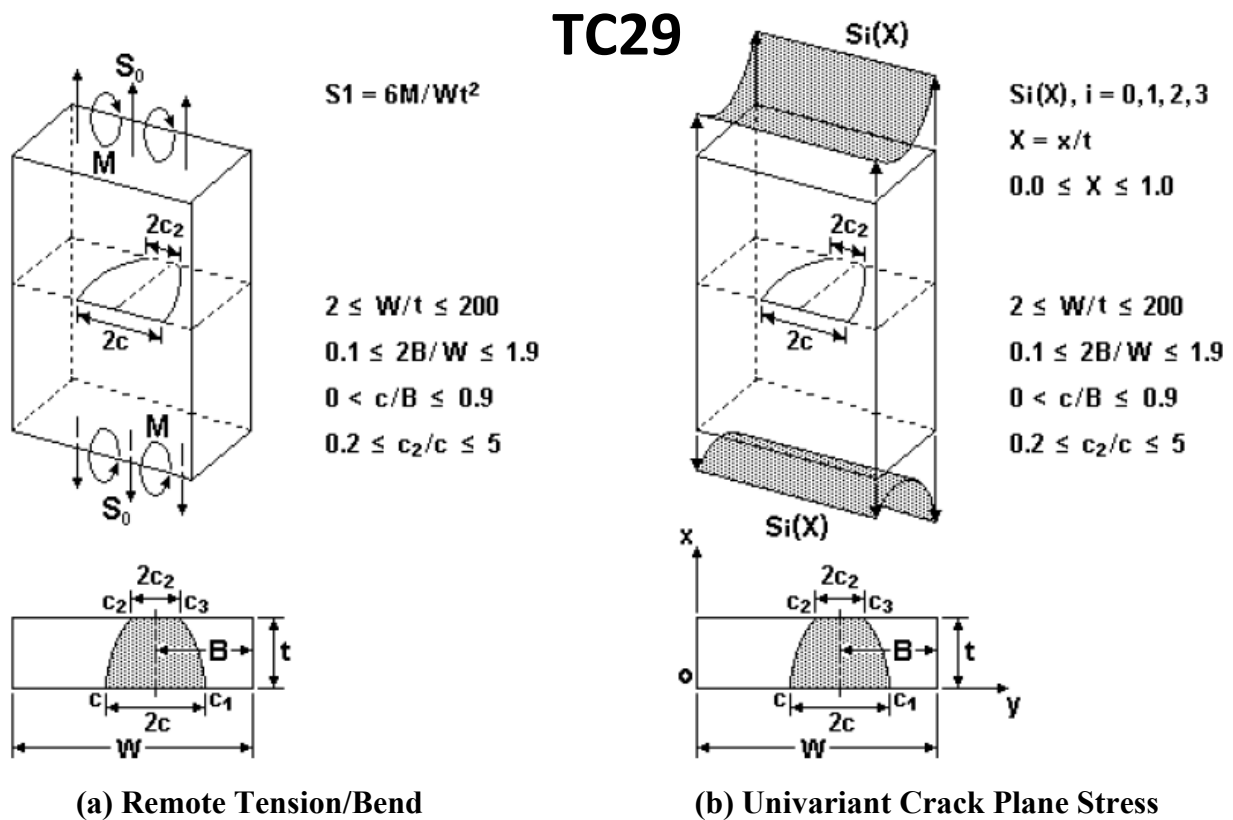


NASGRO v10.1 Release Notes

New and Improved Stress Intensity Factor (SIF) Models

- **New Model for a Curved Through Crack in a Finite Width Plate (TC29):**

Crack case TC29 is a new solution for a curved offset through crack in a finite width plate. It is analogous to the straight crack front in TC11, with additional capabilities for out-of-plane bending, though without the incorporation of in-plane bending. The part-elliptical crack front allows for two separate surface crack tips: “c” on the front face and “c₂” on the back face of the plate. The plate can be loaded by remote tension/bending stress or by univariant stress gradient along the plate thickness on the crack plane. TC29 supports curved crack fronts that model the physical shape of cracks under out-of-plane bending. Additional detail on the development of this new model is contained in Appendix C of the Reference Manual.



- **New Weight Function Solutions for Surface and Through Cracks at Holes (SC37, SC38, and TC43):**

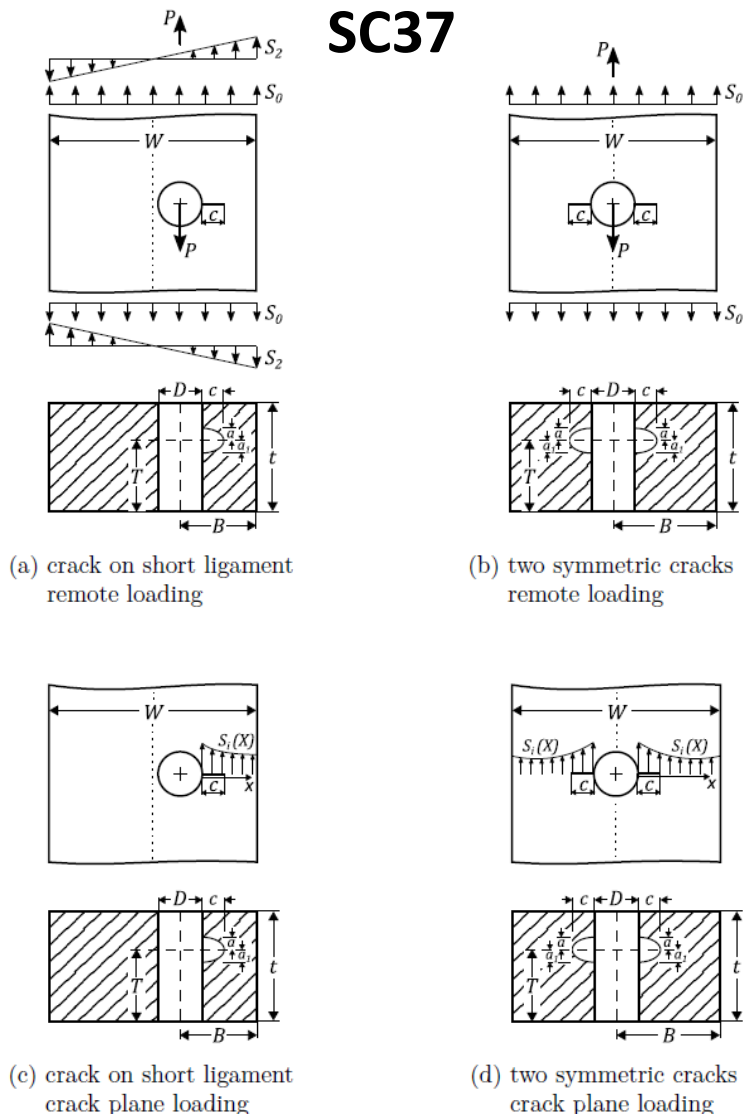
Three new crack cases (SC37, SC38, and TC43) have been developed as improvements over previous cracked hole models (SC18, SC29 and TC13), with improved accuracy and larger calibration matrices. We recommend that users employ them as their default SIF solutions for these geometries in all new analyses. NASGRO continues to support the older SIF solutions for legacy purposes. Additional detail on the development of these new models is contained in Appendix C of the Reference Manual.

Crack case SC37 is a univariant weight function solution for a semi-elliptical surface crack growing from a hole surface of a finite width plate. *SC37 is an improved version of SC18 with better accuracy relative to SIF solutions extracted from high-fidelity FEAs.* SC37 supports univariant stresses as service loadings and as residual stresses. SC37 also supports remote loadings S_0 , S_2 , and S_3 as shown to the right. The following two sub-configurations are available for use:

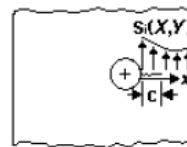
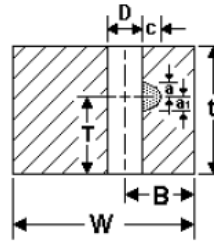
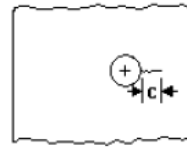
1. A single crack growing on the short ligament side of the offset hole
2. Twin cracks growing symmetrically from the opposite sides of the centered hole under symmetric loading

The geometry limits for this case vary depending on the crack configuration selected and are displayed in the GUI and summarized in Appendix C. These limits match the earlier limits for SC37.

SC37



Crack case SC38 is a bivariant weight function solution for a single semi-elliptical surface crack growing at a hole surface of a finite width plate. The crack is located on the short ligament side of the hole. The crack model shares the same geometric configuration as SC37 with a single crack option. However, this model provides a capability to define bivariant stress variation across the crack plane. *SC38 is an improved version of SC29 with better accuracy relative to SIF solutions extracted from high-fidelity FEAs.* SC38 has the same geometric limits as SC29.



SC38

$$0.25 \leq D/t \leq 2$$

$$0.5 \leq a/c \leq 5$$

$$0.1 \leq B/W \leq 0.5$$

$$0 \leq c/(B-D/2) \leq 0.8$$

$$0.05 \leq 2T/t \leq 1.95$$

$$a/\min(T, t-T) \leq 0.95$$

$$X = x/(B-D/2)$$

$$Y = y/t$$

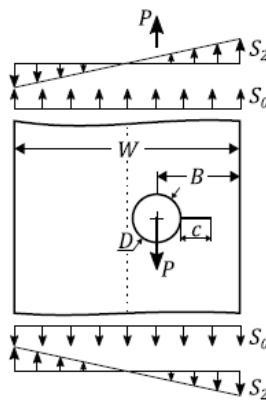
$$0.0 \leq X \leq 1.0$$

$$0.0 \leq Y \leq 1.0$$

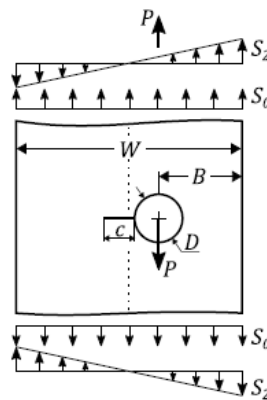
$$i = 0, 1, 2, 3$$

Crack case TC43 is a weight function solution for one or two through cracks at an off-center hole in a finite width plate with a general nonlinear stress distribution. *TC43 is an improved version of TC13 with better accuracy relative to SIF solutions extracted from high-fidelity FEAs.* One of the following subconfigurations can be selected:

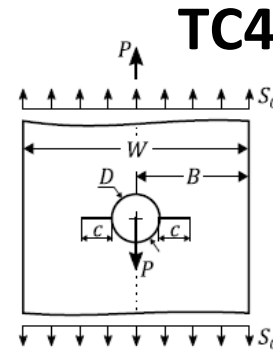
1. The crack on the short ligament side of an offset hole, 2. The crack on the long ligament side of an offset hole, or 3. Two symmetric cracks from a centered hole. The geometry limits for this case vary depending on the crack configuration selected and are displayed in the GUI and summarized in Appendix C. These geometry limits match the geometry limits for TC13. TC43 supports remote loadings, user-defined stresses, and residual stresses.



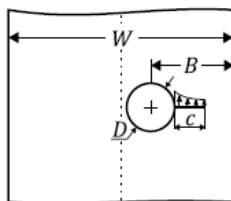
(a) crack on short ligament remote loading



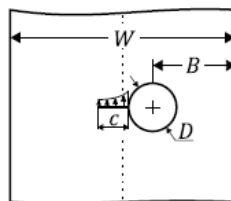
(b) crack on long ligament remote loading



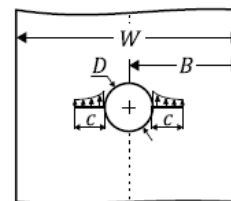
(c) two symmetric cracks remote loading



(d) crack on short ligament crack plane loading



(e) crack on long ligament crack plane loading

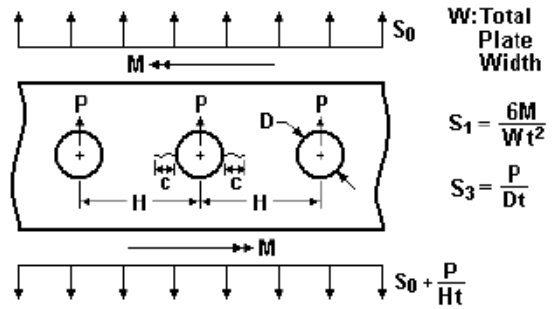


(f) two symmetric cracks crack plane loading

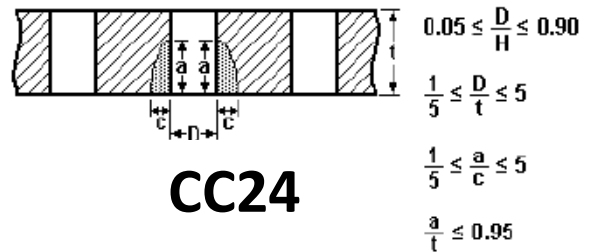
TC43

- **Expansion of Corner Cracks in Row of Holes Model for Two Cracks at One Hole (CC24):**

Previously, crack case CC24 only supported two identical quarter-elliptical corner cracks located at all holes in a row of holes. In NASGRO v10.1, we have expanded CC24 to support two equal corner cracks located at a single hole in a row of holes. There a toggle in CC24 to switch between the different geometric configurations. The original solution remains the default.

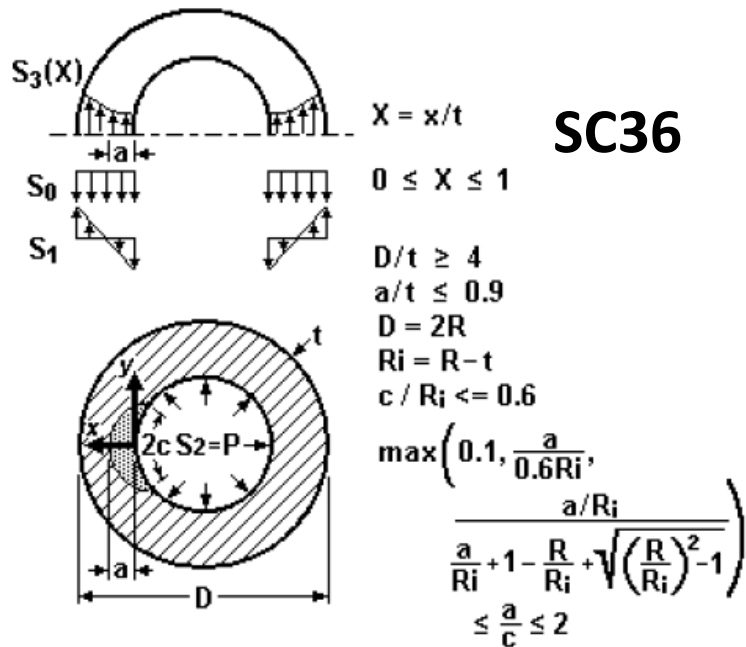


The geometric limits are largely consistent in both crack case configurations, though the crack length may be larger if only one hole is cracked. CC24 continues to support S0, S1, and S3 loading remotely, and it transitions to TC05 if the crack tip breaks through the thickness.



- **Addition of Surface Crack in Hollow Sphere Model for Internal Crack (SC36):**

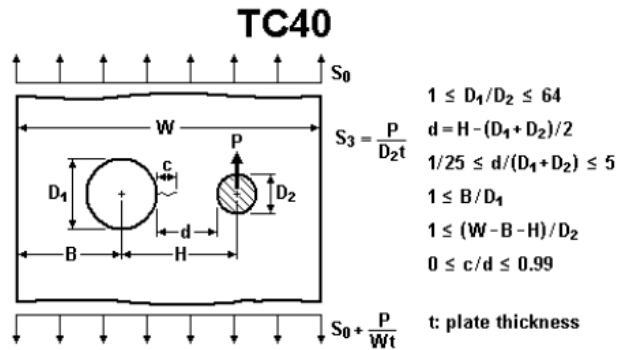
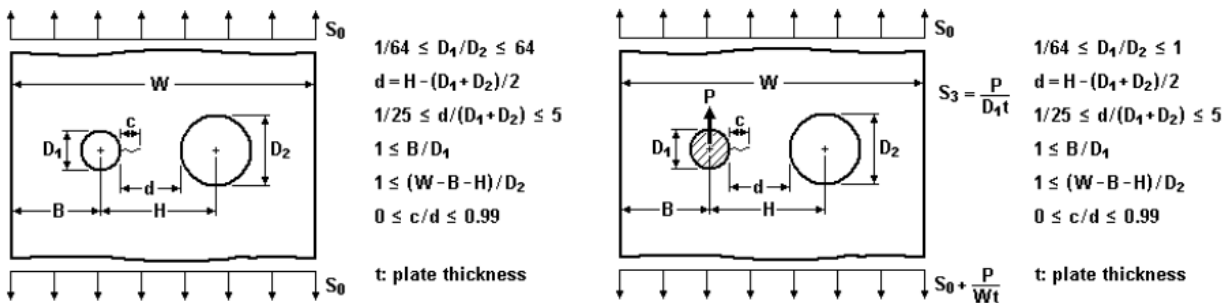
Crack case SC36 is a weight function solution for a surface crack in a hollow sphere. Previously, the crack could only be located on the external surface. A new solution has now been added to SC36 that supports a surface crack on the internal spherical surface. The user can select an internal or external crack location via a radio button on the SC36 GUI. The internal crack is now the default option. SC36 supports the loadings and geometries shown on the right. It also supports axisymmetric stresses in the sphere as service loadings and residual stresses.



Additional detail on the development of this new model is contained in Appendix C of the Reference Manual.

- **Expansion of TC40 for a Through Crack Between Two Unequal Holes in Wide Plate to Include Finite Width and Hole Offset:**

TC40 features a straight through crack located between two unequal diameter holes in a plate. NASGRO v10.0 introduced this solution for infinite width plates. In NASGRO v10.1, TC40 now supports finite width plates and hole offset. There are three geometric options available shown below that support different pinned configurations. For the pin-loaded cases (b) and (c), the pin is always in the smaller diameter hole. TC40 always supports remote uniform loading. TC40 also continues to support infinite width plates. To activate the infinite plate solution, the user should set $W > 100*(D_1+D_2+d)$ and center the two-hole system in the plate. The resulting SIF will match the SIF from v10.0 for an infinite width plate.



- **Expanded Solution Limits and Other SIF Model Improvements:**

- *Expansion of TC28 for thinner plates with end bending restraint*

TC28 is a part-elliptical through-crack model in a finite width plate, with the option of either restrained or unrestrained in-plane bending. The geometric limits of TC28 have been extended to support thinner plates and smaller cracks for models with restrained bending. The maximum width-to-thickness ratio has increased from 20 to 100, making the geometric limits identical for restrained and unrestrained bending.

- *Expansion of TC35 solution limits when bending is restrained*

The crack case TC35 represents an edge through-thickness crack in a plate with a single symmetric step change in thickness. Bending can be either restrained or unrestrained. Previously, there were different geometric limits for the restrained and unrestrained cases, with the unrestrained case allowing wider variation in both relative widths and thickness. The restrained configuration has now been updated to allow for the same limits as the unrestrained configuration, as shown below.

$$\begin{array}{ll} 1 \leq t_2/t_1 \leq 10 & 0.05 \leq W_2/W_1 \leq 10 \\ 0 \leq c/W \leq 0.9 & 0.005 \leq t_1/W_1 \leq 1 \end{array}$$

- *Revision of TC08 geometry limits*

TC08 represents a planar circumferential through crack in a thin walled hollow cylinder. Previously, the GUI showed the minimum cylinder length for solution validity, but did not verify that requirement was met prior to running the solution. The program has been updated to verify the length. A check for the minimum radius/thickness ratio has also been implemented to prevent potentially nonconservative results with $R/t < 10$. In both cases, the analysis allows the user to proceed with the warning, if desired for comparison to legacy analyses.

- *Updated transition route for CC26*

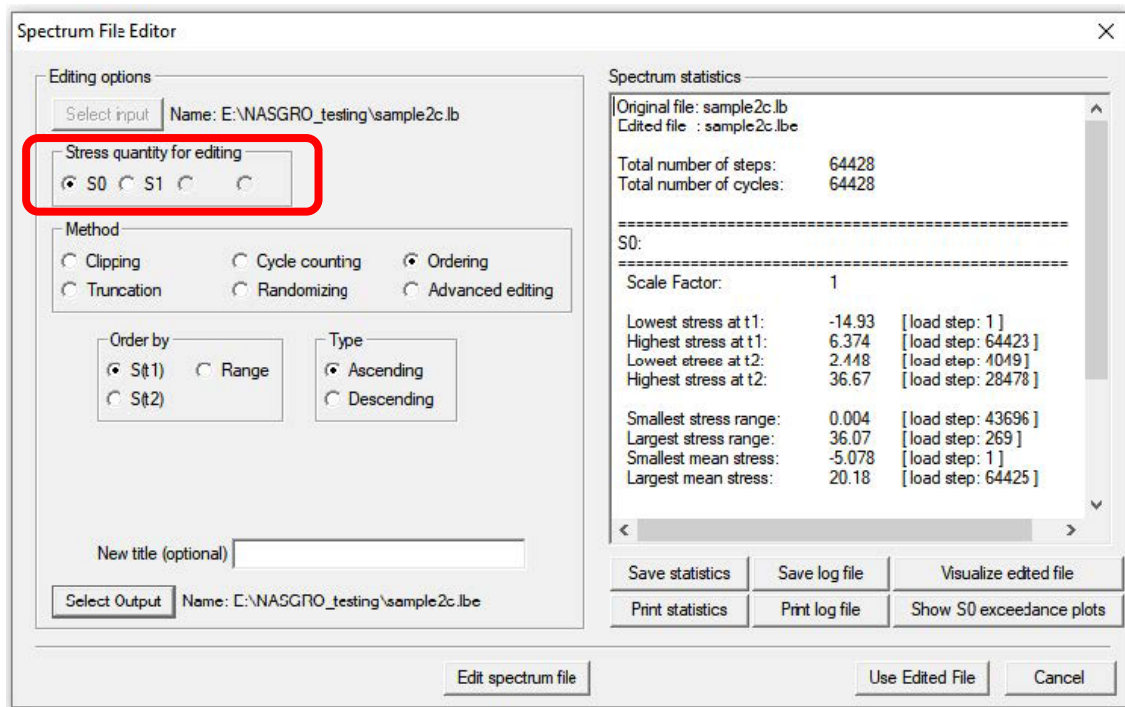
CC26 is a bivariate weight function solution for a quarter-elliptical corner crack at hole offset in a plate. It is analogous to CC10, and it was introduced in NASGRO v10.0 as a more accurate solution than CC10. Previously, it transitioned from CC26 to TC13 if the crack depth broke through the thickness. In NASGRO v10.1, it has been modified to transition to TC43 to take advantage of the increased solution accuracy of TC43 vs. TC13. Note that for legacy purposes, CC10 still transitions to TC13.

- *Option for SC30 to transition to a curved through crack*

NASFLA v10.1 introduces a new capability for SC30 (an offset semi-elliptical surface crack in a plate) to transition to a straight through crack (TC11 or TC12) or to a curved through crack (TC28 or TC29). Users may toggle between these transition routes on the Geometry tab of NASFLA. By default, NASFLA sets the toggle to the straight through crack fronts that have historically been the only option.

Expansion of Spectrum Editing Capability

In previous NASGRO versions, spectrum editing (for example, clipping or truncation) could only be performed using the S0 value in the load spectrum. Starting with NASGRO 10.1, users can select which one of the stress quantities (as available based on the selected crack case) they wish to use for editing. This is especially helpful for crack cases such as lug geometries, for which only S3 loading is available. Selection of the stress quantity is done in the pop-up Spectrum Editing window.



Graphical User Interface and Output File Improvements

- The graphical user interfaces (GUIs) for a number of the NASGRO modules have been upgraded to be more flexible and dynamic. Previous work in recent versions included converting GUIs to be fully dynamic layouts, adjusting controls for different screen resolutions, enabling scrolling of the entire GUI pane, and retaining the proper layout when changing the GUI size. This update continued that progress by updating many of the various pop-up dialogs to accommodate different screen and/or font sizes. Implementation of additional dynamic dialogs is planned for future releases.
- Previous NASFLA versions printed an advisory message in the OUT1 file and the GUI output window whenever $R < -2$. However, the advisory message provided little useful information, and users had no real alternatives. The message sometimes prompted unnecessary concern among novice users and was probably ignored by veteran users. Therefore, beginning with NASGRO 10.1, this advisory message will no longer be printed. We have revised Section 2.1.2 of the NASGRO Reference Manual to provide additional

explanation of the analysis approach used for $R < -2$. We have reviewed this approach and confirmed that it is reasonable and sufficient.

- At the end of the “Final Results” section of the NASFLA output and the OUT1 file, a line has been added to show both the “Initial crack model” and the “Final crack model.” The crack model descriptions have also been updated for consistency with those in Appendix C of the manual. This additional output provides a convenient indication if transition occurred during the analysis or not.

Material Nomenclature Updates

- P3EA13AB1: The ID and the product form/orientation/environment description for this material indicate that the fit is based on both L-T and T-L data. However, in actuality it is based only on L-T data. The description has been corrected, and the ID has been changed to P3EA11AB1 to comply with NASGRO ID naming conventions (where “11” indicates L-T data only, and “13” indicates both L-T and T-L data).
 - The NASFLA GUI will intercept ID P3EA13AB1 when loaded from an input file and instead load the replacement ID P3EA11AB1. The GUI will automatically resave the input file with the replacement ID, and the option to save the original input file under a different name is presented to the user.
- M7QC22AD1 and M7QC25AD1: Some time ago the industry group maintaining aluminum alloy temper designations changed the T736xx temper designation to T74xx for alloys 7050 and 7175. This was already reflected in NASGRO for alloy 7050 but not for 7175. This is now corrected by showing both T74 and T736 in the alloy and heat treatment descriptions for all M7QC entries, as well as in the specific material descriptions shown in the material parameter value section for entries M7QC22AD1 and M7QC25AD1. This is consistent with how 7050 is displayed in NASGRO.

Documentation Improvements

The Reference Manual has undergone significant improvements in recent years, and those improvements continue. In addition to adding or updating the Appendix C sections for each of the crack cases described above to reflect new features and capabilities, the following changes were made for this version:

- Section 2.2.3 (Choosing the Crack Geometry) was revised and reorganized to provide up-to-date description of the crack geometries that are currently available in NASGRO.
- Section 2.2.7.4 (Setting the Limit Stress Checks) was revised to clarify differences between input of limit stresses and scale factors for each of the stress quantities, depending on the crack case in use. GUI labels were modified accordingly.

- Sections 2.2.10 and 2.2.11 (NASFLA Outputs and Computations) were expanded. These sections now provide a detailed summary of the different features and options that are currently available in Output Options and Computations tabs of NASFLA.
- Section 6 of the Main Reference Manual documenting the use of NASMAT has been fully rewritten. It now contains significantly more detail on the various features, step-by-step instructions for viewing, entering, and fitting new data, and descriptions of each of the library, user, and program files used by the module. The new Section 6.4 provides guidelines for obtaining fracture toughness and fatigue crack growth rate data in order to fully characterize a material for inclusion in the NASMAT database and fitting of the NASGRO equation.
- Appendix B has been expanded to include new sections for TC29, CC24, and SC36. TC40 net section stress formulations were also updated for the finite width plate solutions.
- Appendix C has been expanded to include descriptions for the new crack cases TC29, TC43, SC36, SC37, and SC38. Also, the descriptions for TC08, TC28, TC29, TC35, TC40, and CC24 were updated to include additional details and solution verifications.
- Appendix D was overhauled and ported over to the new LaTeX documentation system. The new document is reorganized into a case-by-case structure. Each section starts with a summary of overall transition capabilities of the crack case. The summary page includes a case-specific transition diagram designed to give a quick visual of the downstream transition paths and show what other cases can transition into the current crack geometry. The remainder of the crack section provides all forward transition capabilities that it supports. This new document implements hyperlinked TOC and text, wherever possible, so the reader can conveniently navigate through the sections of interest. The new pdf bookmarks can be used to quickly jump to a crack section of interest. Finally, while the document was being overhauled, a number of new crack cases were added to the document, including TC24, TC29, TC33, TC34, TC37, TC39, CC18, CC24, CC26, CC29, CC30, SC30, SC31, SC37, and SC38. Additional details were also added for CC01, CC08, and CC11.
- Appendix N is a completely new appendix that provides the detailed mathematical background and algorithms used by NASMAT in fitting the NASGRO and Walker equations to fatigue crack growth rate data. In addition, the mathematics of the fitting process used to model the dependence of ΔK_{th} on R, and to convert the fanning parameters (C_{th} and F_{th}) are described. Details are also provided on the equations used to calculate the parameters (A_k and B_k) used to model the thickness dependence on toughness.
- Appendix Q was updated with the material nomenclature changes detailed above.

