



# ***GENESIS***

Structural Analysis and Optimization

**New Features and Enhancements**

**Version 15.0**

January 2016

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# 1 Executive Summary

This document describes the new and enhanced features added to *GENESIS* in version 15.0. Key enhancements include the following:

**Bolt Pretension Analysis:** The new solution control command BOLTSUB facilitates nonlinear contact analysis using bolt preloading. A new interpolation element named BOLT is used to connect separated top and bottom portions of a bolt model with a bolt control grid. The bolt pretension analysis is conducted using two loadcases, with one containing the entries that define the preloading. The second loadcase contains the non-pretension loads of the problem and references to the first loadcase using the BOLTSUB command.

**Lua Scripts:** GENESIS now has the ability to load and run custom program instructions called scripts. The program contains a built-in Lua scripting engine to interpret and execute the script lines. Scripts are loaded using the new executive control command named SCRIPT. This capability gives powerful controls to the user, with the possibility of changing the behavior of the program and/or changing values of internal parameters and/or arrays as the program runs.

**External Eigensolvers:** External eigensolvers can now be coupled with GENESIS.

**Glue Connection Improvements:** Two new entries: CGLUE1 and BPOINTG are now available to define a glue connection between a surface and a set of grids. CGLUE connections now conduct heat in heat transfer analysis. In previous versions, they only worked in structural loadcases.

**NSM by Element:** Nonstructural mass can now be added by element. In previous versions, NSM could only be added by properties.

**Automatic Dependent DOF Selection:** A new PARAMeter, AUTOMSET, automatically re-arranges degrees of freedom dependencies on MPC and rigid elements to avoid creating repeated dependent degrees of freedom.

**Performance Improvements:** Identical MPC sets are automatically detected to reduce the number of boundary conditions. This can significantly reduce the analysis solution time for some problems. Analysis results for selected sets of grids/elements are printed faster than before.

**Cloned Regions for Topology:** A new entry, TPROPC, allows forcing the final topology design of one region to be a scaled copy of the final topology design of a master region.

**New Fabrication Constraints for Topology:** New periodic fabrication constraints can be used to enforce designs to have repeated patterns with a user predefined pitch: PX, PY and PZ. New fabrication constraints can be used to force material to fill symmetrically and periodically with respect to a specified symmetry plane: P0X, P0Y and P0Z.

**Updated DOT Optimizer:** GENESIS now uses DOT 7.0 which is the latest version of the DOT optimizer.

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## 2 Analysis Enhancements

1. Bolt Pretension Analysis: The new solution control command BOLTSUB facilitates nonlinear contact analysis using bolt preloading. A new interpolation element named BOLT is used to connect separated top and bottom portions of a bolt model with a bolt control grid. The bolt pretension analysis is conducted using two loadcases, with the first containing the entries that define the preloading. The second loadcase contains the externally applied loading of the problem and references the first loadcase using the BOLTSUB command.

Solution Control Command - BOLTSUB

Bulk Data Statement - BOLT

2. New Point to Surface Connections: Two new entries: CGLUE1 and BPOINTG are now available for connecting a set of points to a surface.

Bulk Data Statements - CGLUE1, BPOINTG

3. Glue Connection: CGLUE connections now conduct heat in heat transfer analysis. In previous versions, they only worked on the structural loadcases. CGLUE connecting surfaces from CQUAD4/CQUAD8/CTRIA3/CTRIA6 now consider both the element normal for the top surface and its opposite for the bottom surface and take into account the element thickness to locate these in space when applying the normal search distance parameter.

Bulk Data Statement - CGLUE

4. Enhanced Weld Element: The CWELD element can now be used to connect composite elements to other composite or shell elements. The PARTPAT option can now reference PCOMP/PCOMPG properties. The ELPAT and ELEMID options can now reference elements that point to PCOMP/PCOMPG. Previously, CWELD could only connect PSHELL properties/elements.

Bulk Data Statements - CWELD

5. Tube Element: A new data entry, CTUBE, generates a rod element connecting two grids, and can be used for any type of analysis. This new entry is equivalent to CROD, added to support input data generated for other programs. The companion PTUBE data entry specifies tubular rod properties by a diameter and a thickness.

Bulk Data Statements - CTUBE, PTUBE

6. External Eigensolver: An API infrastructure to use externally calculated eigenvalues and eigenvectors has been added. External eigensolvers can now be coupled with GENESIS.

Executive Control Command - EIGMETHOD

Bulk Data Statements - EIGR

7. NSM by Element: Nonstructural mass can now be added by element. In previous versions, nonstructural mass could only be added by property.

Bulk Data Statements - NSM, NSM1, NSML, NSML1

8. Automatic Dependent DOF Selection: A new parameter, AUTOMSET, can enable automatically selecting which degrees of freedom from MPC and rigid elements should be set as dependent. This can simplify resolution of input data errors caused when the same dof is specified as dependent on multiple entries.

Bulk Data Statement - PARAM: AUTOMSET

9. MPC Improvement: Now, identical MPC sets are automatically detected to reduce the number of boundary conditions. This can significantly reduce solution time for some problems.

Bulk Data Statement - MPC

10. Modal Dynamic Analysis Enhancement: Now the eigenmodes used to form the basis for modal dynamic frequency response analysis can be selected. The MODESELECT solution control command adds the ability to specify modes using inclusion or exclusion rules based on mode numbers and/or frequency ranges. New analysis parameters LFREQ and HFREQ can be used to set a default inclusion frequency range.

Solution Control Command - MODESELECT

Bulk Data Statement - PARAM: HFREQ, LFREQ

11. Glue Connections Enhancement: CGLUE/BCPAIR now have individual penalty adjustment factors. A weak CGLUE connection combined with the CDISP response can be used to measure penetration/separation of surfaces, without truly enforcing the glue.

Bulk Data Statements - CGLUE, BCPAIR

12. One Dimensional Bush Element: To facilitate the use of input data generated for other codes, CBUSH1D entries will be read and converted to equivalent CBUSH entries. Likewise, static analysis properties on PBUSH1D entries will be converted to equivalent PBUSH entries.

Bulk Data Statements - CBUSH1D, PBUSH1D

13. Anisotropic Composite Analysis: Now composite property PCOMP can reference general anisotropic (MAT2) materials.

Bulk Data Statements - PCOMP

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### 3 Structural Optimization Enhancements

1. **Lua Scripts:** GENESIS now has the ability to load and run custom program instructions called scripts. The program contains a built-in Lua scripting engine to interpret and execute the script lines. Scripts are loaded using the new executive control command, `SCRIPT`. This capability gives powerful controls to the user to change the behavior of the program and/or change values of internal parameters and/or arrays as the program runs.

Executive Control Command - `SCRIPT`

2. **SPC Force Response:** Reaction forces, reaction moments and magnitude of reaction forces from static loadcases are now available as static responses for optimization.

Bulk Data Statements - `DRESP1, TRESP1, RTYPE=SPCF`

3. **Strain Energy by Property:** The existing `SENERGY` response from static loadcases has been enhanced to offer strain energy of individual properties. In previous versions, `SENERGY` was only available as the total strain energy. When multiple properties are listed in a single `DRESP1` or `TRESP1`, the program will sum the strain energies of all associated elements to create a combined response.

Bulk Data Statements - `DRESP1, TRESP1, RTYPE=SENERGY`

4. **Updated DOT:** The latest version of the DOT optimizer, 7.0, is now available with GENESIS.

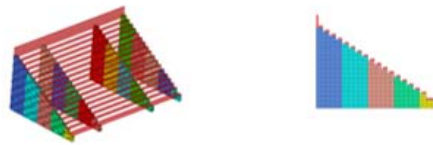
5. **Lumped Nonstructural Mass Improvements:** The total mass added by `NSML` and/or `NSML1` will now remain constant even if the areas/lengths of the affected elements are changed by shape optimization. Previously, `NSML/NSML1` were converted to `NSM/NSM1` at the start of the program using the initial element dimensions, and therefore the total nonstructural mass could change if the areas/lengths of the affected elements changed.

Bulk Data Statements - `NSML, NSML1`

## 4 Topology Optimization Enhancements

1. Cloned Topology Regions: A new entry, TPROPC, allows the user to impose that the final topology design of parts of their structure be identical or be scaled copies of the final topology design of a master part.

Bulk Data Statement - TPROPC



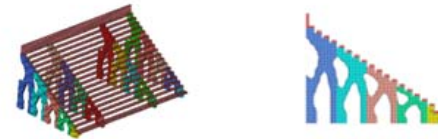
Design Space: 20 regions



Alternative Design 1: Reference Answer



Alternative Design 2: Cloning without Scaling Design



Alternative Design 3: Cloning with Scaling Design

Note 1: In the alternative Design 2, one master topology region is cloned into 19 additional topology regions. Notice that the master region is repeated 20 times where four clones are complete repetitions while the other 16 copies are partial repetitions (as 16 design regions are shorter than the master).

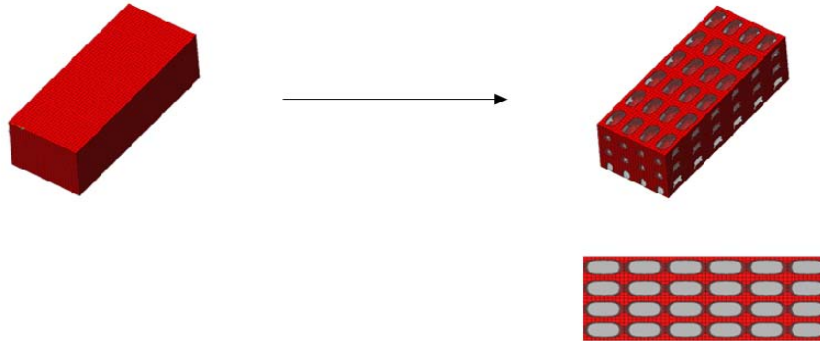
Note 2: In the alternative Design 3, one master topology region is used to clone into the other 19 topology regions. In this case scaling is used so that regions on the right are scaled versions of the regions on the left. Notice that the design on the left is repeated four times un-scaled and it is repeated 16 times scaled down.

## New Features

2. Periodic Fabrication Constraints: New periodic fabrication constraints can be used to force topology results to have an optimal pattern repeated in a specified pitch.

Bulk Data Statement - TSYM1, TSYM2, TSYM3

Types - PX, PY and PZ

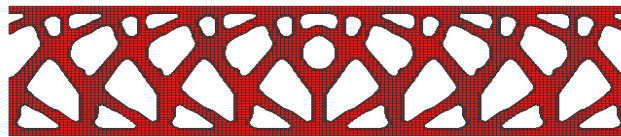


Note: Triple periodic symmetry is used (PX, PY & PZ) simultaneously in one design region. The 3 selected pitch distances produce a pattern that is repeated 6x4x3 (72) times. In the figure above the solid structure on the left is the initial design, the figures on the right are two views of the topology results.

3. Symmetric Periodic Fabrication Constraints: New fabrication constraints can be used to force material to fill symmetrically and periodically with respect to a specified plane.

Bulk Data Statement - TSYM1, TSYM2, TSYM3

Types -P0X, P0Y and P0Z



Note: The topology result above was obtained using the new fabrication constraint (P0X) that forces periodic with mirror symmetry. The selected pitch distance (DISTAX) produces a pattern that is repeated 4 times on the left and 4 times of the right of a plate that passes perpendicularly and vertically to the center. The coordinates system used in this problem has the x axis parallel to a horizontal line.



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## 5 Output Enhancements

1. **Reduced Output Size:** By default, OUTPUT2 post processing files are now compressed using the standard `gzip` format to save disk space. The compressed files are named with a `*.op2.gz` extension. These compressed files may be imported directly into Design Studio, or may be uncompressed using numerous third-party utilities. Using analysis parameters, `OP2ZIP` and `ZIPLVL`, the compression can be turned off or the size of the files can be further reduced by truncating results and/or expending more CPU time. For non-compressed post-processing files, an option to reduce file size by excluding grids for which all displacement/eigenvector result components are zero has been added. `PARAM,IPRM21,0` activates this option.  
Bulk Data Statement - `PARAM: OP2ZIP, ZIPLVL, IPRM21`
2. **Performance Improvement:** Analysis results for selected sets of grids/elements are printed faster than before.
3. **Scratch File Cleanup:** When the GENESIS executable finishes abnormally, numerous scratch files may be left on the system. Now, on Linux systems, the run script, `genesis`, will automatically delete any remaining scratch files. A list of any deleted files will be appended to the `*.log` file.

## **6 New Input Data**

### **6.1 Executive Control**

EIGMETHOD	Defines the name of an external shared object (DLL) that will solve a general eigenvalue problem.
SCRIPT	Defines a customization script to alter normal program behavior.

### **6.2 Solution Control**

BOLTSUB	Solution control command that references an existing static loadcase for preload bolt analysis.
MODESELECT	Selects a subset of the calculated modes to become the basis for modal dynamic frequency response analysis.

### **6.3 Bulk Data**

BOLT	Bolt Interpolation Element.
BPOINTG	Point Collection Definition by Grid.
CGLUE1	Defines a glue connection between a surface and a collection of points.
CTUBE	Connectivity information for truss elements.
PTUBE	Properties of tube elements.
TPROPC	Topology designable region with cloning definition.

### **6.4 DRESP1/TRESP1- New RTYPE**

SPCF	Reaction forces can now be specified in TRESP1 or DRESP1.
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## 6.5 New Analysis PARAMETERS

AUTOMSET	If AUTOMSET = YES, then the degrees of freedom made dependent by MPC and/or RBAR, RBE1, RBE2, RBE3, RROD, RSPLINE and BOLT elements will be determined automatically. In this case, the dependent d.o.f. specifications on the corresponding bulk data entries will be discarded, and consequently it is allowed to specify the same d.o.f. as dependent on multiple entries. AUTOMPC is an alias for this parameter.
HFREQ	Upper frequency cutoff for modes to include in the modal basis for modal dynamic frequency response analysis. If a loadcase has a MODESELECT solution control command, then this parameter will be ignored. This parameter can remove modes from the modal basis, and reduce the accuracy of the modal frequency response solution. If this parameter is used, the results should be carefully reviewed for adequacy.
IPRM21	Set to 0 to omit from displacement/eigenvector post-processing results all grids for which the 6 components are zero.
LFREQ	Lower frequency cutoff for modes to include in the modal basis for modal dynamic frequency response analysis. If a loadcase has a MODESELECT solution control command, then this parameter will be ignored. This parameter can remove modes from the modal basis, and reduce the accuracy of the modal frequency response solution. If this parameter is used, the results should be carefully reviewed for adequacy.
OP2ZIP	Compression control for OUTPUT2 postprocessing files.
SHL2SKN	PSHELL properties with a thickness less than or equal to this value will be automatically converted to PSKIN properties. This is intended to avoid numerical ill-conditioning that can result from using small thicknesses.
ZIPLVL	Controls the aggressiveness of the compressor engine when writing compressed OUTPUT2 files. Using a higher level will typically result in smaller file sizes at the expense of increased CPU time. This parameter is only effective when parameter OP2ZIP > 0.

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## 7 Enhanced Input Data

### 7.1 Executive Control

**CEND** The CEND delimiter is now optional. If it is not present, the first detected solution control command will mark the end of executive control and the start of solution control.

**INCLUDE** Files can be included in the executive control section. In previous versions, INCLUDE was only allowed in the solution control and bulk data sections.

### 7.2 Solution Control

**CDISP** Contact clearance results are now output for grids on surfaces used by CGLUE.

**CPRESS** Contact pressure results are now output for grids on surfaces used by CGLUE.

### 7.3 Bulk Data

**BCPAIR** Field 7 is now the penalty adjustment parameter.

**BSURFE** Can now be referenced by new CGLUE1 data entry.

**BSURFM** Can now be referenced by new CGLUE1 data entry.

**BSURFP** Can now be referenced by new CGLUE1 data entry.

**CGLUE** Now works with heat transfer problems. Field 7 is now the penalty adjustment parameter.

**CWELD** PARTPAT option can now reference PCOMP/PCOMPG properties. ELPAT and ELEMID options can now reference CQUAD4/CQUAD8/CTRIA3/CTRIA6 elements that point to PCOMP/PCOMPG properties.

**EIGR** Now can reference an external eigenvalue solver. This requires the use of the EIGMETHOD executive control command.

**NSM** Can now reference elements.

**NSM1** Can now reference elements.

**NSML** Can now reference elements.

**NSML1** Can now reference elements.




PCOMP	Can now reference MAT2.
TSYM1	Now accepts new fabrication constraints: Periodic: PX, PY and PZ Periodic and Symmetric from symmetry plane: P0X, P0Y and P0Z
TSYM2	Now accepts new fabrication constraints: Periodic: PX, PY and PZ Periodic and Symmetric from symmetry plane: P0X, P0Y and P0Z
TSYM3	Now accepts new fabrication constraints: Periodic: PX, PY and PZ Periodic and Symmetric from symmetry plane: P0X, P0Y and P0Z

#### 7.4 DRESP1/TRESP1- RTYPE Enhancements

CDISP	Contact clearance is now available for CGLUE connections.
CPRESS	Contact pressure is now available for CGLUE connections. Note that glue can also transmit tension, which is returned as a negative “pressure”.
SENERGY	Strain energies can now be selected by one or more properties.

## 8 New Example Problems

The following table describes new examples and their corresponding input file names. The listed files are provided with the installation:

Name	Problem	Special Features	Figure
T031.dat	Topology Optimization with Cloning and no Scaling	Use of TPROPC	
T032.dat	Topology Optimization with Cloning and Scaling	Use of TPROC with SCALEZ option	
T033.dat	Topology Optimization with Periodic and Symmetry Constraints	Uses Periodic fabrication constraint	

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## 9 GENESIS Manual Updates

All *GENESIS* manuals have been updated to reflect the new features, as well as the new and modified data entries.

<b>Manual Title</b>	<b>Filename</b>	<b>Status</b>
GENESIS: Analysis Manual	volume1.pdf	Updated to reflect all enhanced and new features.
GENESIS: Design Manual	volume2.pdf	Updated to reflect all enhanced and new features.
GENESIS: Analysis Examples	volume3.pdf	Updated.
GENESIS: Design Examples	volume4.pdf	Updated.
GENESIS: Quick Reference Manual	quickref.pdf	Updated to reflect all changes and new data entries
GENESIS: New Features and Enhancements	newfeat.pdf	This document which describes the changes between GENESIS versions 15.0 and 14.0

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## 10 Changes in Version 15.0 with Respect to Version 14.0

*GENESIS* 15.0 should run any problem that was successfully running in version 14.0 with no changes, except for the following:

The CGLUE connections now conduct heat in heat transfer analysis. In previous versions, CGLUE entries were ignored in heat transfer analysis.

CGLUE connections to surfaces from CQUAD4/CQUAD8/CTRIA3/CTRIA6 elements may behave differently if the SRCHDIS field is non-blank due to changes in the search algorithm. These elements now effectively generate two surfaces, one from the top and one from the bottom of the elements, and these are located in space taking the element thickness into account. Only one of the top or bottom will have an appropriately directed normal, and the normal distance to that surface must be less than SRCHDIS to connect a glue point. Previously, only the normal indicated by the BSURFx was considered, and the surface was located by passing it through the grids.

The total mass added by NSML and/or NSML1 entries will now be constant, even if the affected elements are changed by shape optimization. This may result in a different optimized design.