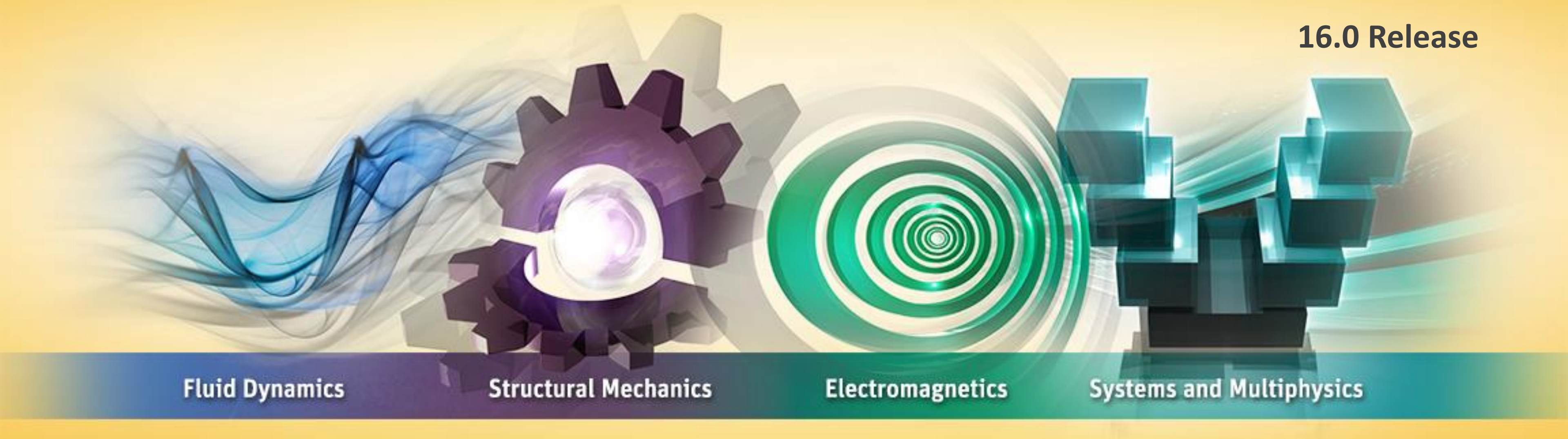
Appendix A
Eigenvalue Buckling Analysis

16.0 Release



Introduction to ANSYS Mechanical

Chapter Overview

In this Appendix, performing an eigenvalue buckling analysis in Mechanical will be covered.

Mechanical enables you to link the Eigenvalue Buckling analysis to a *nonlinear* Static Structural analysis that can include all types of nonlinearities. This will not be covered in this section. We will focused on Linear buckling.

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A. Background On Buckling

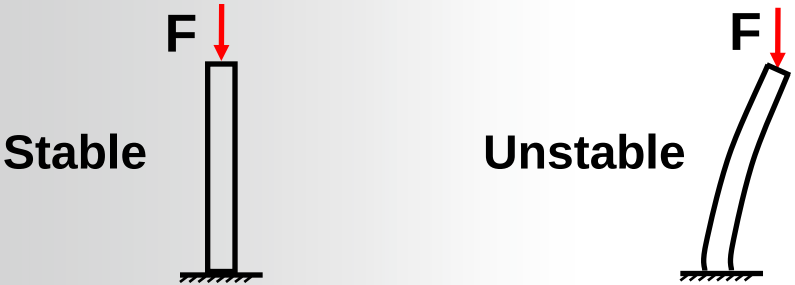
B. Buckling Analysis Procedure

C. Workshop AppA-1

A. Background on Buckling

Many structures require an evaluation of their structural stability. Thin columns, compression members, and vacuum tanks are all examples of structures where stability considerations are important.

At the onset of instability (buckling) a structure will have a very large change in displacement {Δx} under essentially no change in the load (beyond a small load perturbation).



… Background on Buckling

Eigenvalue or linear buckling analysis predicts the theoretical buckling strength of an *ideal linear elastic* structure.

This method corresponds to the textbook approach of linear elastic buckling analysis.

- The eigenvalue buckling solution of a Euler column will match the classical Euler solution.

Imperfections and nonlinear behaviors prevent most real world structures from achieving their theoretical elastic buckling strength.

Linear buckling generally yields *unconservative* results by not accounting for these effects.

Although *unconservative*, linear buckling has the advantage of being computationally cheap compared to nonlinear buckling solutions.

... Basics of Linear Buckling

For a *linear buckling analysis*, the eigenvalue problem below is solved to get the buckling load multiplier λ_i and buckling modes ψ_i:

$$([K]+\lambda_i[S])\{\psi_i\}=0$$

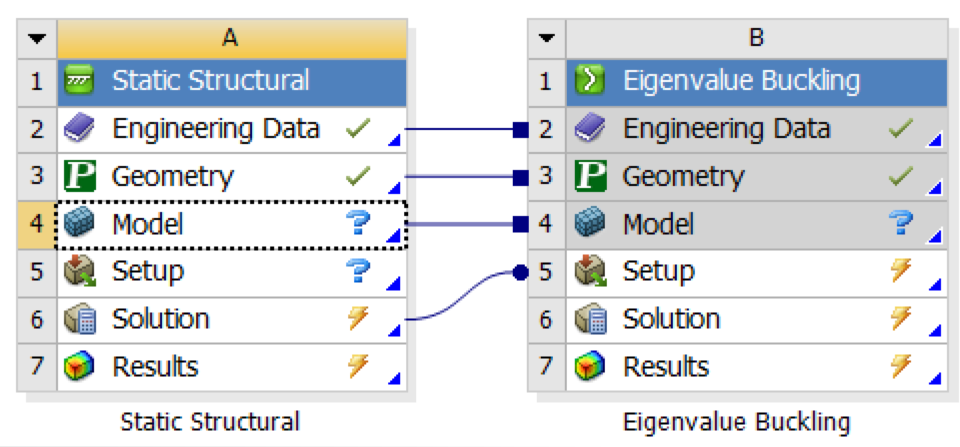
Assumptions:

- [K] and [S] are constant:
  - Linear elastic material behavior is assumed
  - Small deflection theory is used, and *no* nonlinearities included

It is important to remember these assumptions related to performing *linear buckling analyses* in Mechanical.

B. Buckling Analysis Procedure

A Static Structural analysis will need to be performed prior to (or in conjunction with) a buckling analysis.



… Geometry and Material Properties

Any type of geometry supported by Mechanical may be used in buckling analyses:

- **Solid bodies**
- **Surface bodies (with appropriate thickness defined)**
- **Line bodies (with appropriate cross-sections defined)**
  - **Only buckling modes and displacement results are available for line bodies.**
- **Although Point Masses may be included in the model, only inertial loads affect point masses, so the applicability of this feature may be limited in buckling analyses**

For material properties, *Young's Modulus* and *Poisson's Ratio* are required as a minimum

… Contact Regions

Contact regions are available in free vibration analyses, however, contact behavior will differ for the *nonlinear* contact types exactly as with modal analyses.

(see chapter 8 of the Mechanical Introduction course for further details).

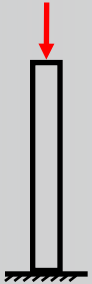
Contact Type	Linear Buckling Analysis		
	Initially Touching	Inside Pinball Region	Outside Pinball Region
Bonded	Bonded	Bonded	Free
No Separation	No Separation	No Separation	Free
Rough	Bonded	Free	Free
Frictionless	No Separation	Free	Free

… Loads and Supports

At least one structural load, which causes buckling, should be applied to the model:

- ***All* structural loads will be multiplied by the load multiplier (λ) to determine the buckling load (see below).**
- **Compression-only supports are not recommended.**
- **The structure should be fully constrained to prevent rigid-body motion.**

F x λ = Buckling Load

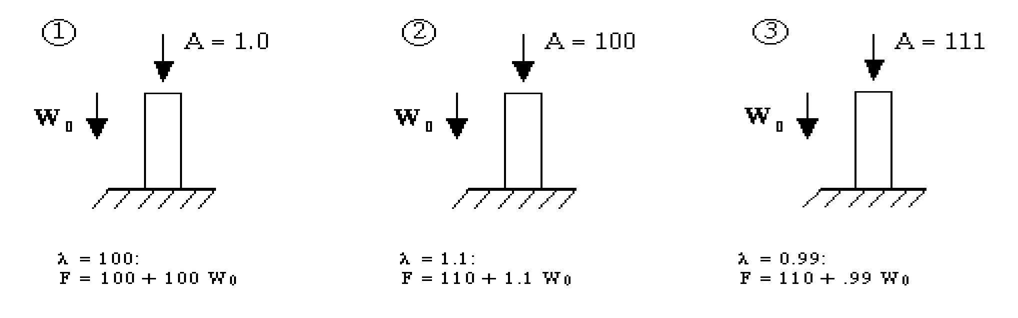


In a buckling analysis all applied loads (F) are scaled by a multiplication factor (λ) until the critical (buckling) load is reached

... Loads and Supports

Special considerations must be given if constant *and* proportional loads are present.

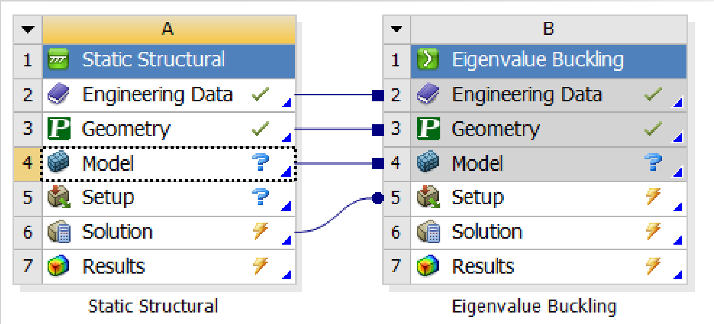
- **The user may iterate on the buckling solution, adjusting the variable loads until the load multiplier becomes 1.0 or nearly 1.0.**
- **Consider the example of a column with self weight W_o and an externally applied force *A*.**
- **A solution can be reached by iterating while adjusting the value of *A* until λ = 1.0. This insures the self weight = actual weight or $W_o * \lambda = W_o$.**

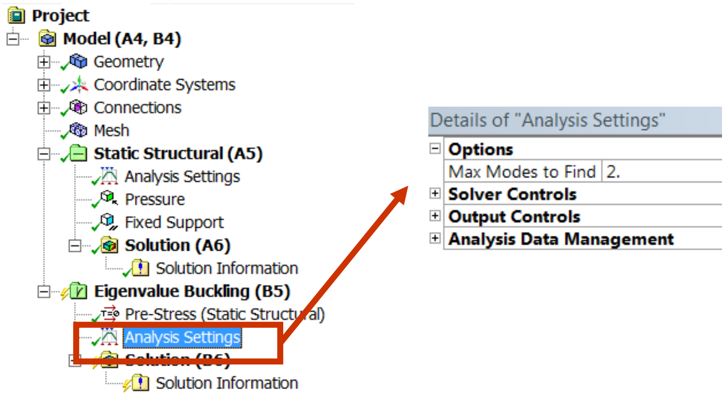


... Buckling Setup

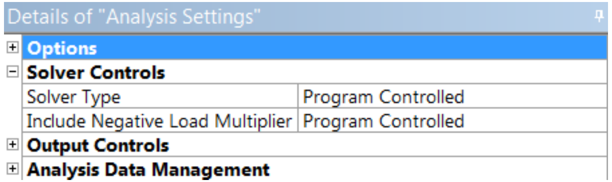
Buckling analyses are always coupled to a structural analysis within the project schematic.

- **The "Pre-Stress" object in the tree contains the results from a structural analysis.**
- **The Details view of the "Analysis Settings" under the Linear Buckling branch allows the user to specify the number of buckling modes to find.**





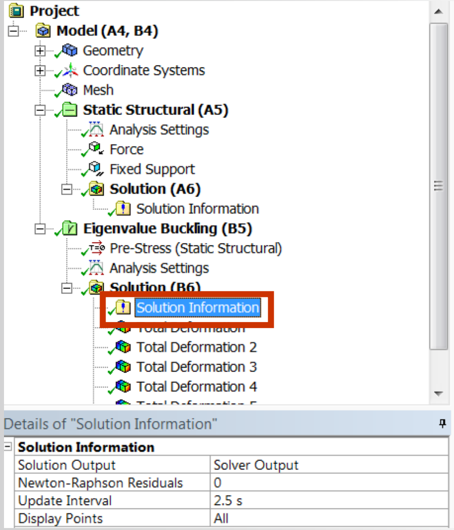
In the details view, under solver controls, user can include negative load multiplier.

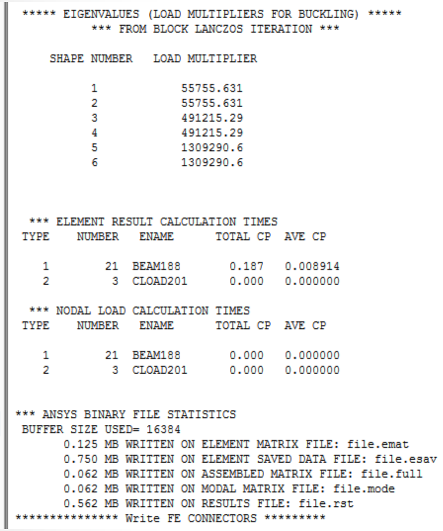


… Solving the Model

After setting up the model the buckling analysis can be solved along with the static structural analysis.

- **A linear buckling analysis is *more computationally expensive* than a static analysis on the same model.**
- **The "Solution Information" branch provides detailed solution output.**



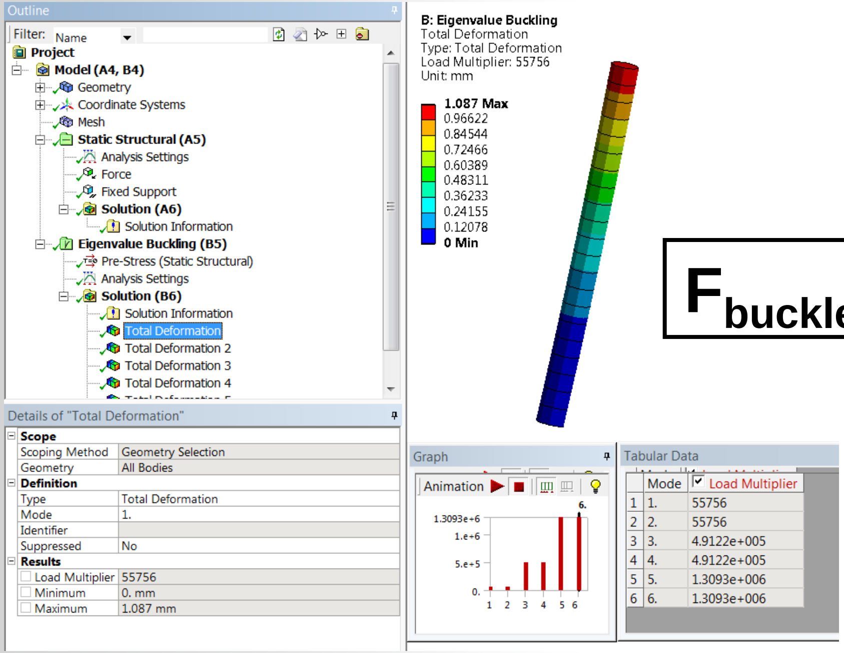


```
***** EIGENVALUES (LOAD MULTIPLIERS FOR BUCKLING) *****
          *** FROM BLOCK LANCZOS ITERATION ***

    SHAPE NUMBER   LOAD MULTIPLIER

          1           55755.631
          2           55755.631
          3           491215.29
          4           491215.29
          5           1309290.6
          6           1309290.6


 *** ELEMENT RESULT CALCULATION TIMES
TYPE    NUMBER   ENAME      TOTAL CP  AVE CP

   1       21  BEAM188       0.187   0.008914
   2        3  CLOAD201      0.000   0.000000

 *** NODAL LOAD CALCULATION TIMES
TYPE    NUMBER   ENAME      TOTAL CP  AVE CP

   1       21  BEAM188       0.000   0.000000
   2        3  CLOAD201      0.000   0.000000


*** ANSYS BINARY FILE STATISTICS
 BUFFER SIZE USED= 16384
       0.125 MB WRITTEN ON ELEMENT MATRIX FILE: file.emat
       0.750 MB WRITTEN ON ELEMENT SAVED DATA FILE: file.esav
       0.062 MB WRITTEN ON ASSEMBLED MATRIX FILE: file.full
       0.062 MB WRITTEN ON MODAL MATRIX FILE: file.mode
       0.562 MB WRITTEN ON RESULTS FILE: file.rst
*************** Write FE CONNECTORS *********
```

… Reviewing Results

After the solution is complete, the buckling modes can be reviewed:

- **The Load Multiplier for each buckling mode is shown in the Details view as well as the graph and chart areas. The load multiplier times the applied loads represent the predicted *buckling load*.**

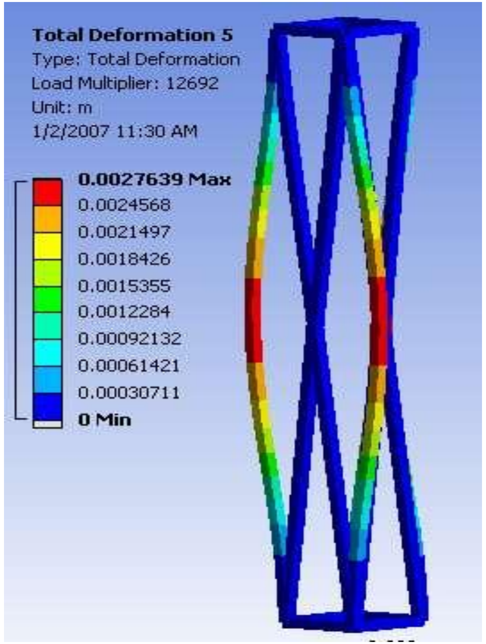


$$F_{buckle} = (F_{applied} \times \lambda)$$

… Reviewing Results

Interpreting the Load Multiplier (λ):

- **The tower model below has been solved twice. In the first case a unit load is applied. In the second an expected load applied (see next page)**



… Reviewing Results

Interpreting the Load Multiplier (λ):

Details of "1st Buckling Mode"	
Scope	
Geometry	All Bodies
Results	
Load Multiplier	29008

$$BucklingLoad = \lambda * Unit\_Load$$

$$\Rightarrow BucklingLoad = \lambda$$

Details of "1st Buckling Mode"	
Scope	
Geometry	All Bodies
Results	
Load Multiplier	1.0003

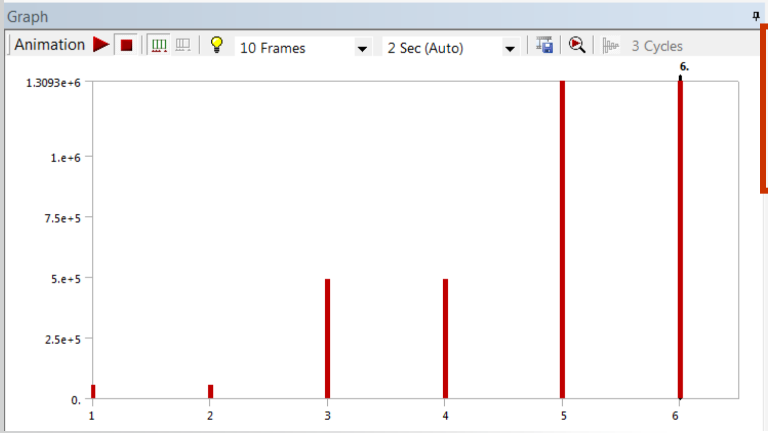
$$BucklingLoad = \lambda * Actual\_Load$$

$$\Rightarrow \frac{BucklingLoad}{Actual\_Load} = \lambda = Safety\_Factor$$

… Reviewing Results

The buckling load multipliers can be reviewed in the "Timeline" section of the results under the "Linear Buckling" analysis branch

- It is good practice to request more than one buckling mode to see if the structure may be able to buckle in more than one way under a given applied load.



Tabular Data

	Mode	Load Multiplier
1	1.	55756
2	2.	55756
3	3.	4.9122e+005
4	4.	4.9122e+005
5	5.	1.3093e+006
6	6.	1.3093e+006

Workshop Appendix A

- **Workshop Appendix A - Buckling**