Verification Example

Program: RFEM 5, RSTAB 8

Category: Post-Critical Analysis, Isotropic Linear Elasticity, Member

Verification Example: 0201 – Eight-Member Symmetric Shallow Truss Snap-Through

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Description

A symmetrical shallow structure is made of eight equal truss members, which are embedded into hinge supports according to the **Figure 1**, [1]. The structure is loaded by the concentrated force F and alternatively by the imposed nodal deformation u_z over the critical limit point when the snap-through occurs. Imposed nodal deformation is used in RFEM 5 and RSTAB 8 to obtain full equilibrium path of the snap-through. The self-weight is neglected in this example. Determine the relationship between the actual loading force F_a and the deflection u_z considering large deformation analysis. Evaluate the load factor f at given deflections u_z. The problem is described by the following set of parameters.

Material		Modulus of Elasticity	E	98100.000	psi
		Poisson's Ratio	ν	0.300	—
Geometry	Structure	Arm Length	b	500.000	in
		Height	h	40.000	in
	Cross-Section	Area	A	10.000	in^2
Load		Force	F	9810.000	lbf
		Imposed Nodal Deformation	u_z	120.000	in

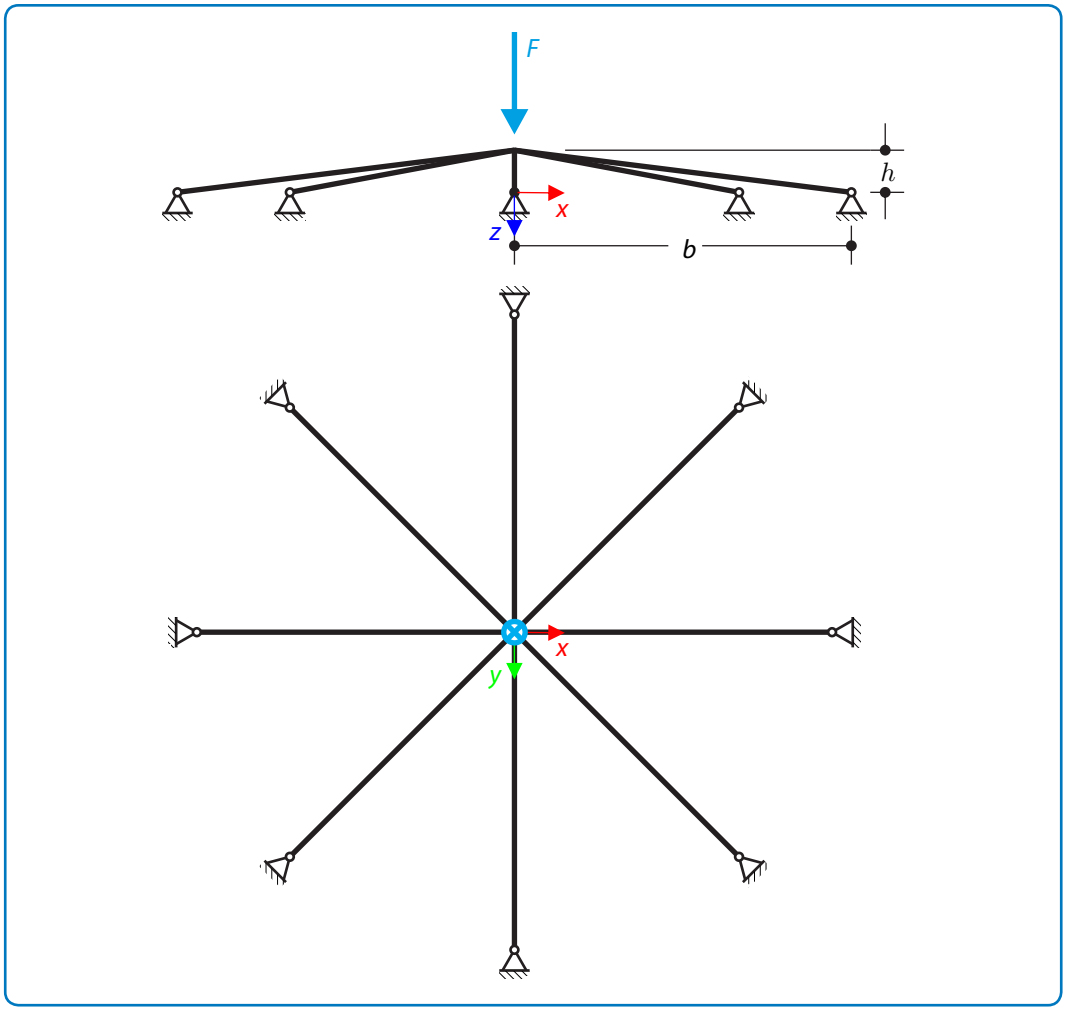

Figure 1: Problem sketch

Analytical Solution

Analytical solution is based on Verification Example 0045, where a two-truss structure is solved , for more details see [2]. Considering large deformations, the axial force N in each of four trusses can be determined from the force equilibrium

$$N = F\frac{\sqrt{(h-u_z)^2+b^2}}{8(h-u_z)}. \qquad (201-1)$$

Considering the large deformation analysis, the logarithmic form of the axial strain ε should be used

$$\varepsilon = \ln\left(1-\frac{\Delta L}{L_0}\right). \qquad (201-2)$$

The general relationship between the actual loading force F_a and the deflection u_z then results

$$F_a = \frac{8EA(h-u_z)\ln\left(1-\dfrac{\sqrt{(h-u_z)^2+b^2}-L_0}{L_0}\right)}{\sqrt{(h-u_z)^2+b^2}}, \qquad (201-3)$$

where L_0 is the initial lenght of the truss $L_0 = \sqrt{b^2 + h^2}$. For further results evaluation the load factor f is used. It is defined as a ratio of the maximum loading force F and actual loading force F_a

$$f = \frac{F}{F_a}. \qquad (201 - 4)$$

RFEM 5 and RSTAB 8 Settings

- Modeled in RFEM 5.16.01 / RSTAB 8.16.01
- The number of elements is 8
- The number of increments is 100
- The structure is modeled using members (Truss - only N)
- Isotropic linear elastic material model is used
- Postcritical analysis and modified Newton-Raphson method is used

Results

Structure Files	Program	Loading
0201.01	RFEM 5	Concentrated Force
0201.02	RFEM 5	Imposed Nodal Deformation
0201.03	RSTAB 8	Concentrated Force
0201.04	RSTAB 8	Imposed Nodal Deformation

The load factor is calculated according the deflections given in [1]. The corresponding results are listed in the table bellow and the overall course can be seen in **Figure 3**.

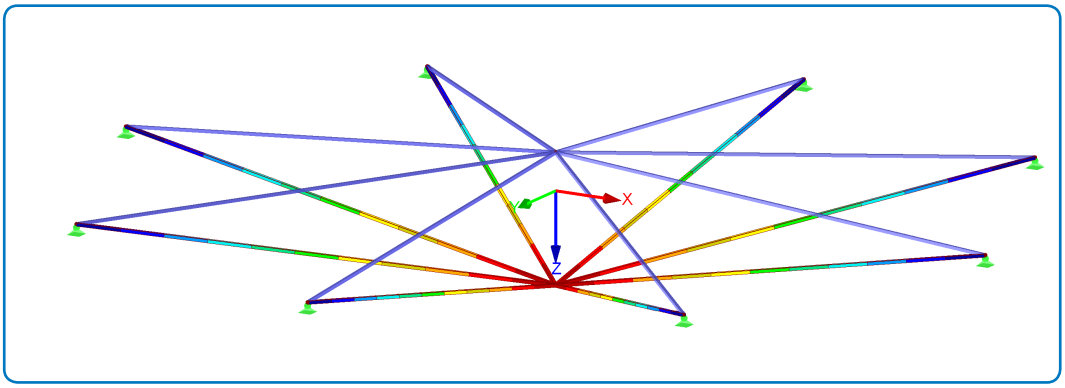

Figure 2: Result shape after snap-through in RFEM 5 / RSTAB 8

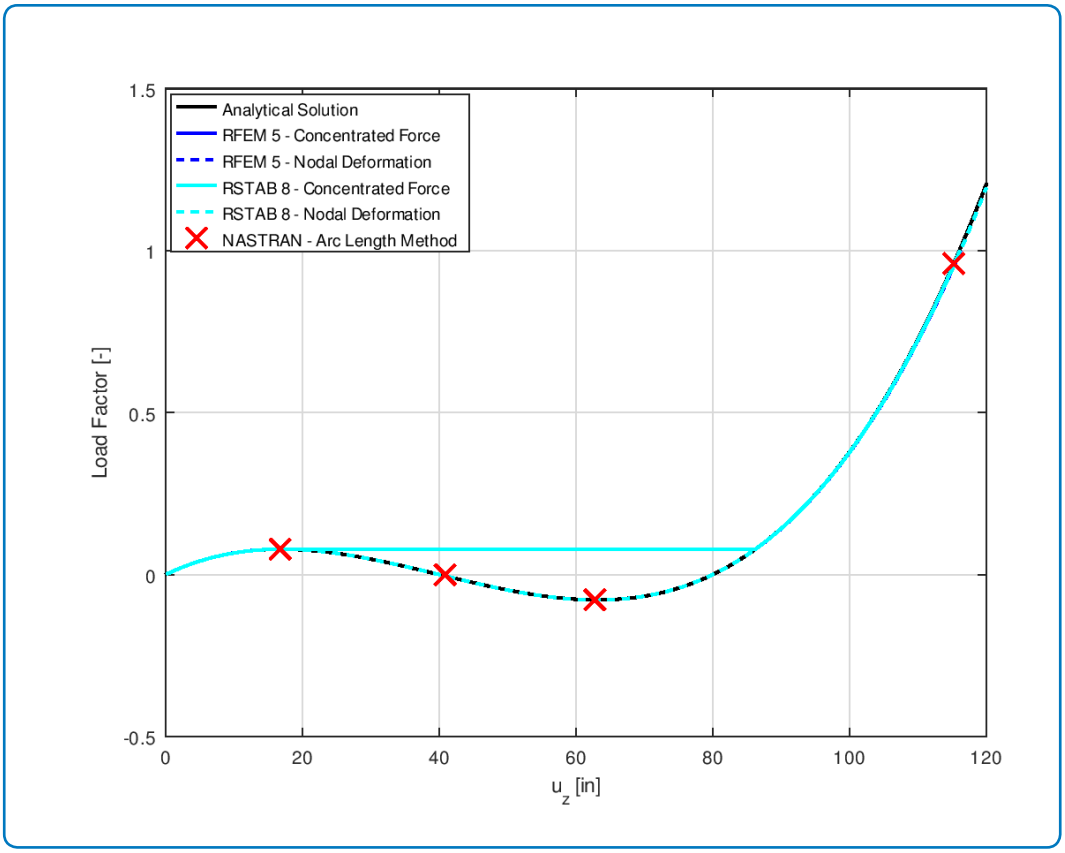

Figure 3: Results comparison – analytical solution, RFEM 5, RSTAB 8 and NASTRAN

Results evaluation in case of imposed nodal deformation loading:

Load Factor [-]	Deflection u_z [in]	Analytical solution	NASTRAN - Arc Length Method	RFEM 5	Ratio [-]	RSTAB 8	Ratio [-]
$f(u_z)$	16.750	0.0782	0.0783	0.0784	1.003	0.0784	1.003
	40.850	0.000	-0.004	-0.004	-	-0.004	-
	62.760	-0.0782	-0.0783	-0.0783	1.001	-0.0783	1.001
	115.24	0.961	0.960	0.953	0.992	0.953	0.992

Results evaluation in case of concentrated force loading:

Load Factor [-]	Deflection u_z [in]	Analytical solution	NASTRAN - Arc Length Method	RFEM 5	Ratio [-]	RSTAB 8	Ratio [-]
$f(u_z)$	16.75	0.0782	0.0783	0.0780	0.997	0.0780	0.997
	115.24	0.961	0.960	0.953	0.992	0.957	00996

Remark: RFEM 5 and RSTAB 8 results are compared with the analytical solution.

References

[1] HINDRA, G. A.. Snap-through instability patterns in truss structures. *American Institute of Aeronautics and Astronautics*, 2010.

[2] DLUBAL SOFTWARE GMBH, *Verification Example 0045 – Snap-Through*. 2015b.