Division of Strength of Materials and Structures
Faculty of Power and Aeronautical Engineering

Finite element method (FEM1)

Wykład 11B. One-dimensional structural & MPC elements in Ansys

05.2025

Structural Link element

Figure 180.1: LINK180 Geometry

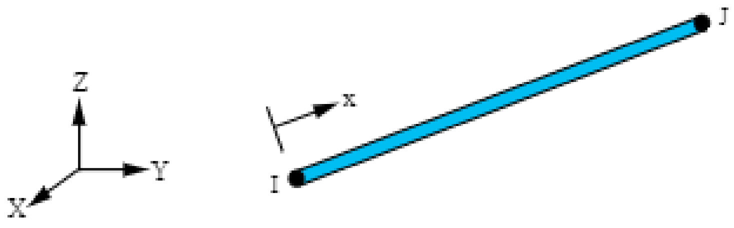


Figure 180.2: LINK180 Stress Output

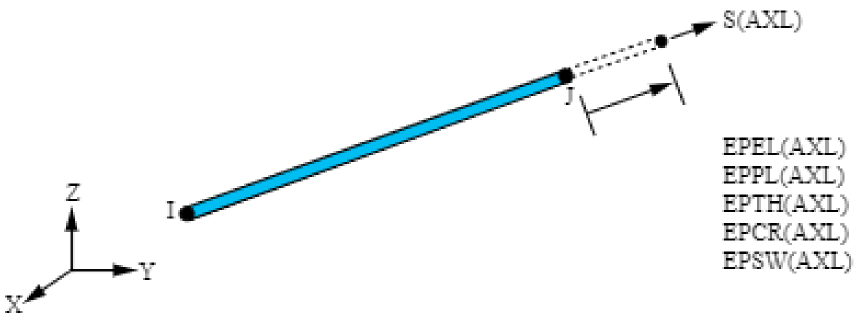
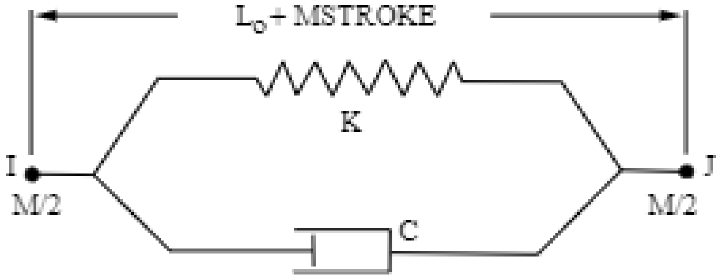


Figure 11.1: LINK11 Geometry



LINK11 may be used to model hydraulic cylinders and other applications undergoing large rotations. The element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y, and z directions. No bending or twist loads are considered.

Structural Mass element

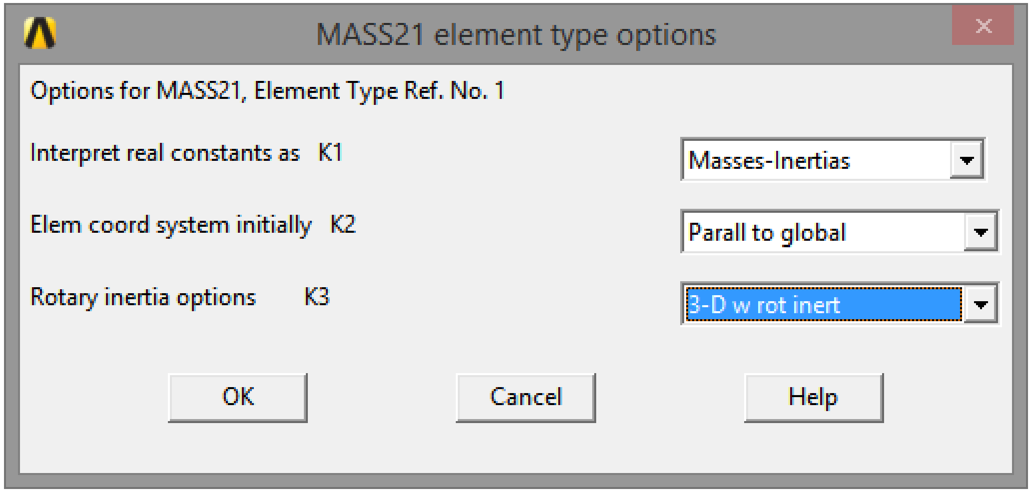
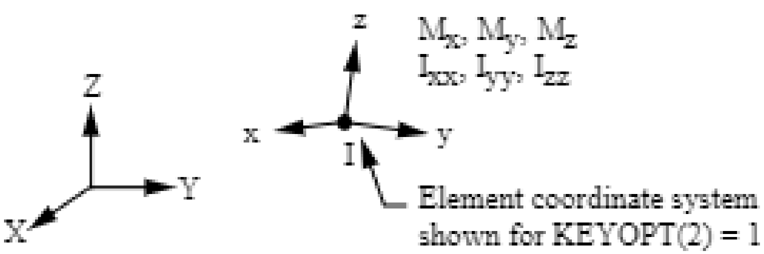


Figure 21.1: MASS21 Geometry



MASS21 is a point element having up to six degrees of freedom: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. A different mass and rotary inertia may be assigned to each coordinate direction.

Structural Beam elements

Figure 188.1: BEAM188 Geometry

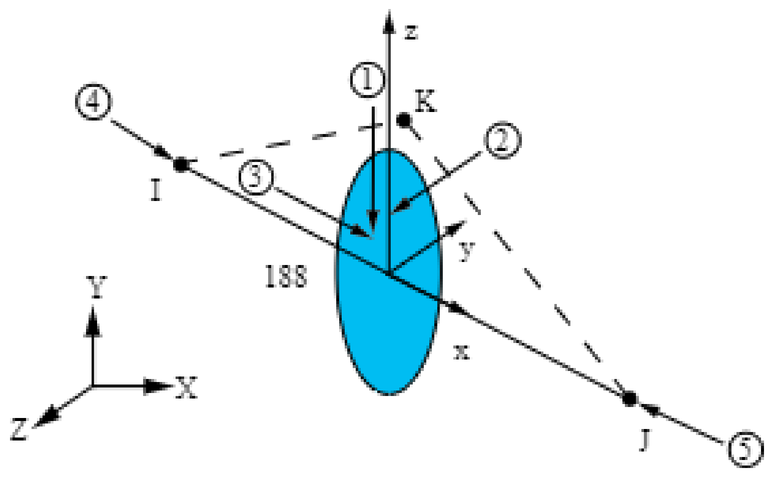
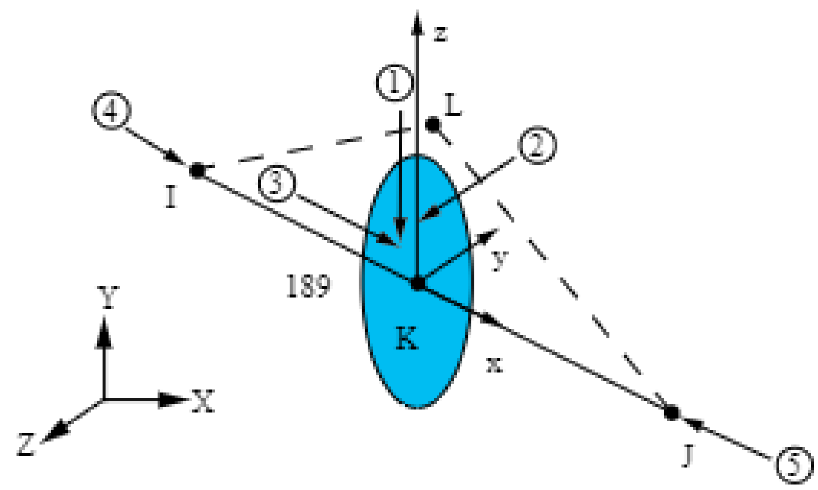
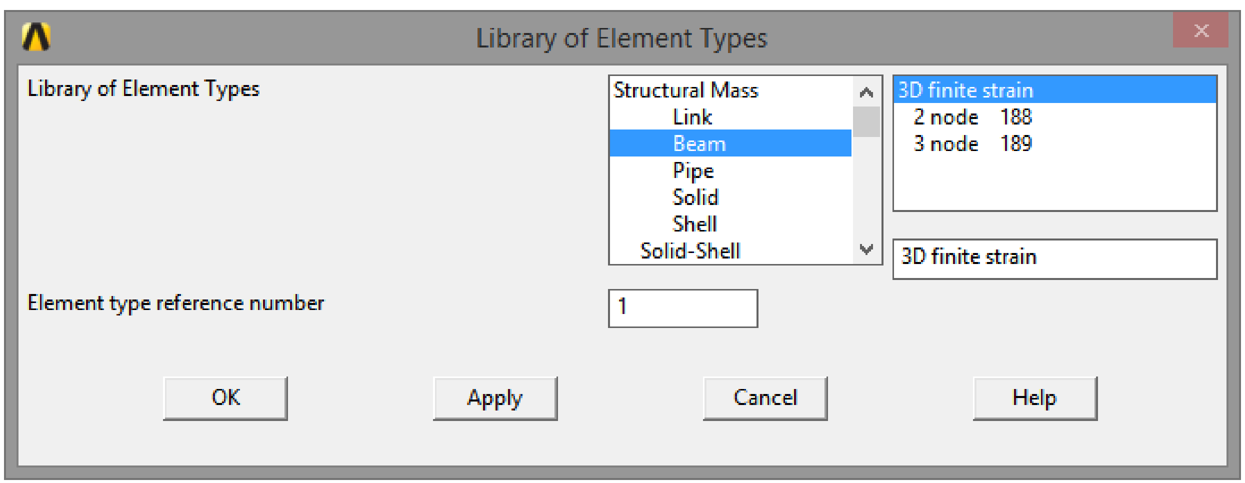


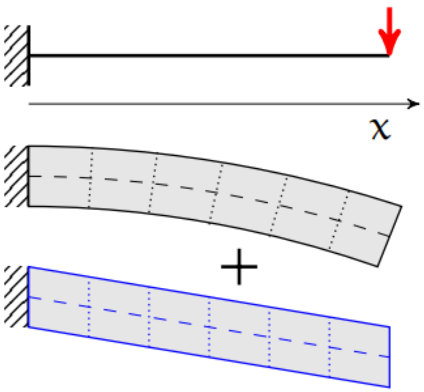
Figure 189.1: BEAM189 Geometry





Beam Theories

In engineering practice, the problem of bending bars is considered on the basis of the simple **Euler-Bernoulli theory**. The basic assumption of this theory is that a section straight and perpendicular to the axis of a rod before deformation remains straight and perpendicular after the deformation occurs. This is a consequence of <u>neglecting the influence of shear stresses</u> in the cross-section.



Deflection according to Euler-Bernoulli theory:

$$u_{EB} \sim x^3$$

Supplement according to Timoshenko theory:

$$u_T \sim x$$

$$u_{max} = \frac{FL^3}{3EJ} + \frac{FL}{kAG}$$

works for $1/5 \leq h/b \leq 5$,
$L/\max(h, b) > 10$

Source: http://www.tu.kielce.pl/~rokach/instr/mes1_wyklad_11.pdf
https://chodor-projekt.net/encyclopedia/belka-timoshenko-sprezyste-podloze/

Timoshenko theory

The plane cross-section remains plane, but is no longer perpendicular to the deformed neutral axis of the beam.
All FEM programs have beam elements based on Timoshenko theory.

Structural Beam elements

Figure 188.1: BEAM188 Geometry

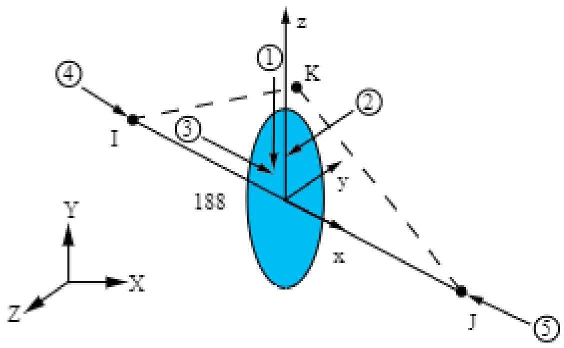


Figure 189.1: BEAM189 Geometry

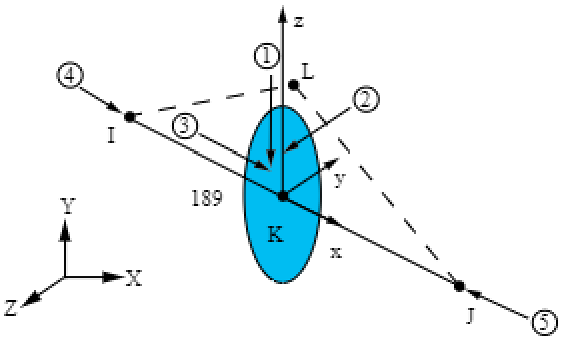
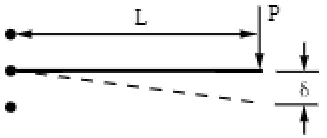


Figure 188.2: Transverse-Shear Deformation Estimation

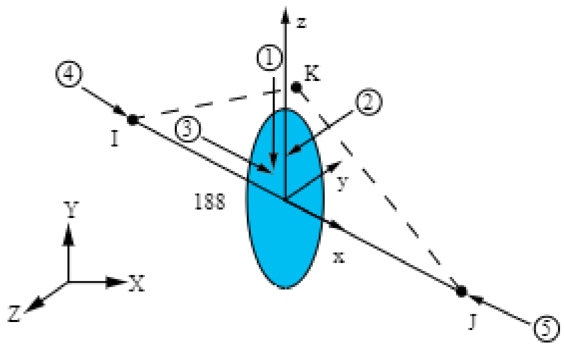


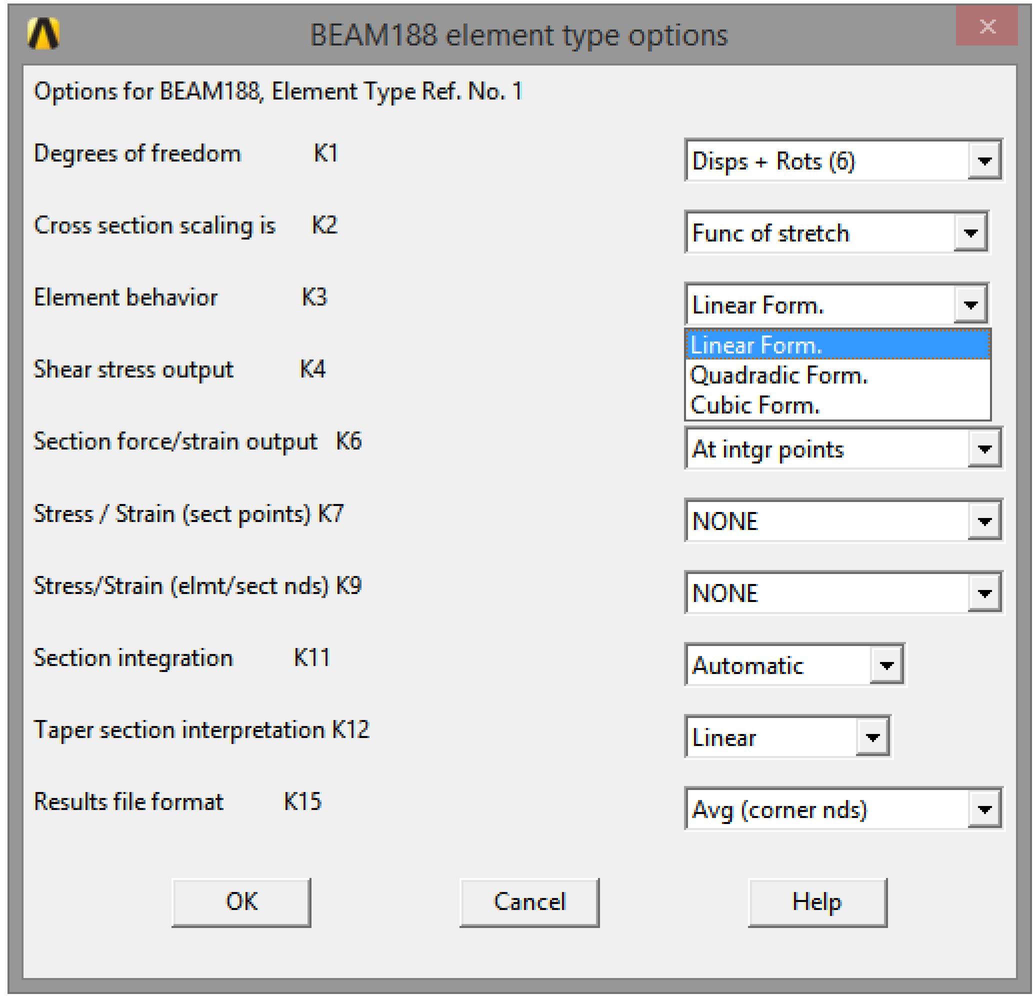
Slenderness Ratio ($GAL^2/(EI)$)	δ Timoshenko / δ Euler-Bernoulli
25	1.120
50	1.060
100	1.030
1000	1.003

Calculate the ratio using some global distance measures, rather than basing it upon individual element dimensions. The following illustration shows an estimate of transverse-shear deformation in a cantilever beam subjected to a tip load. Although the results cannot be extrapolated to any other application, the example serves well as a general guideline. A slenderness ratio greater than 30 is recommended.

BEAM 188 Structural Beam element options

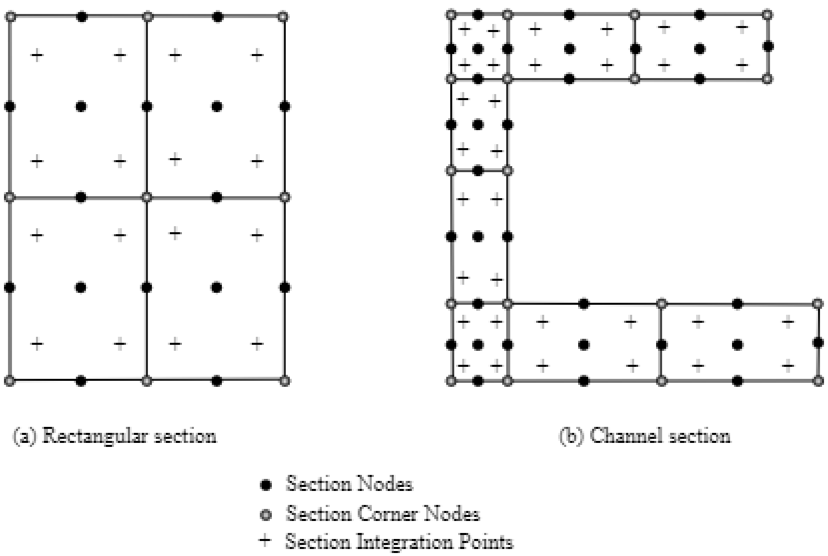
Figure 188.1: BEAM188 Geometry

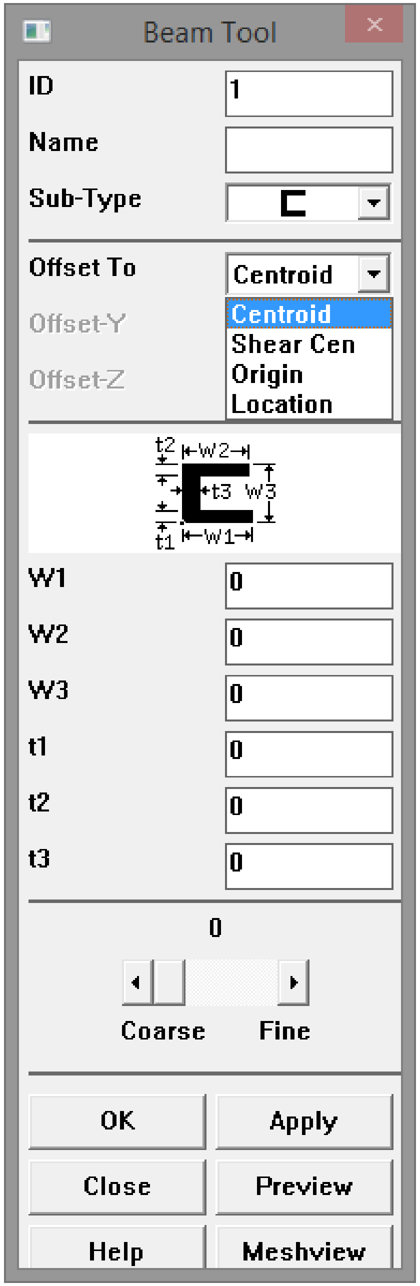


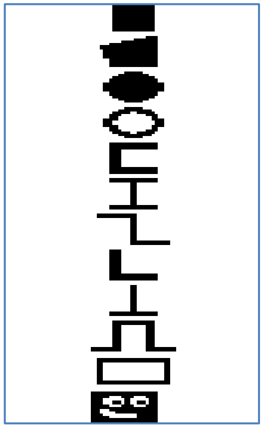


Cross-section characteristics of Beam elements

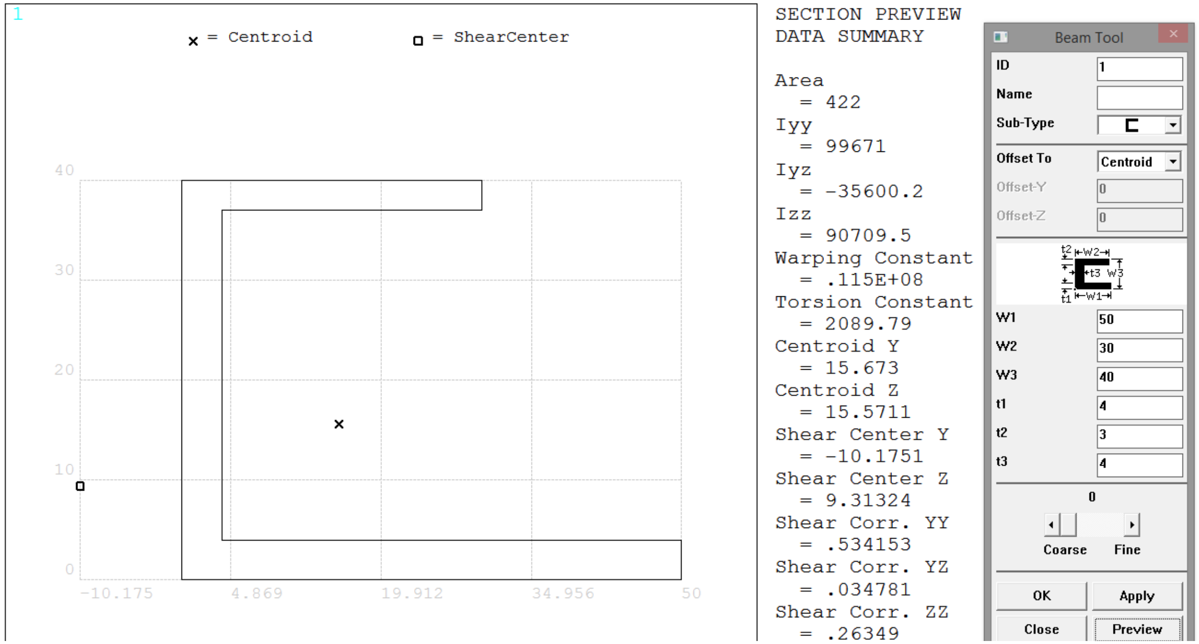
Figure 188.3: Cross-Section Cells

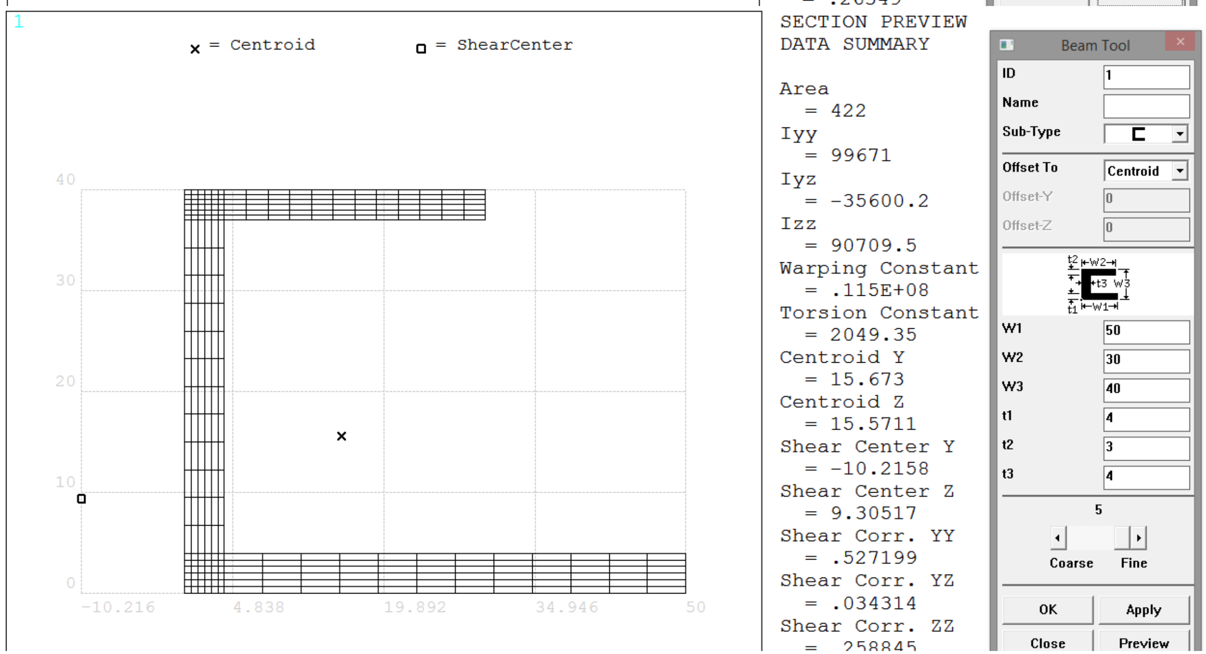




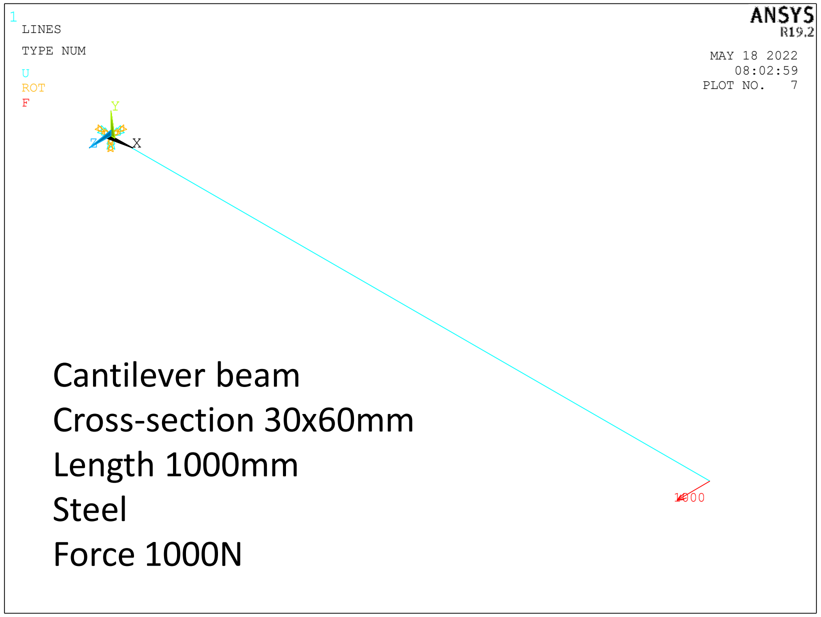


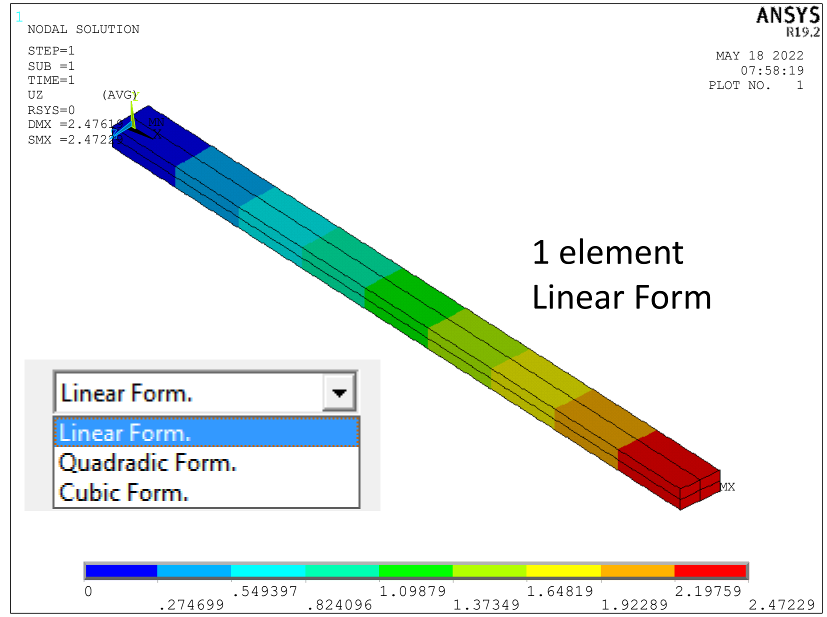
Example of calculating the characteristics of a cross-section of a Beam element

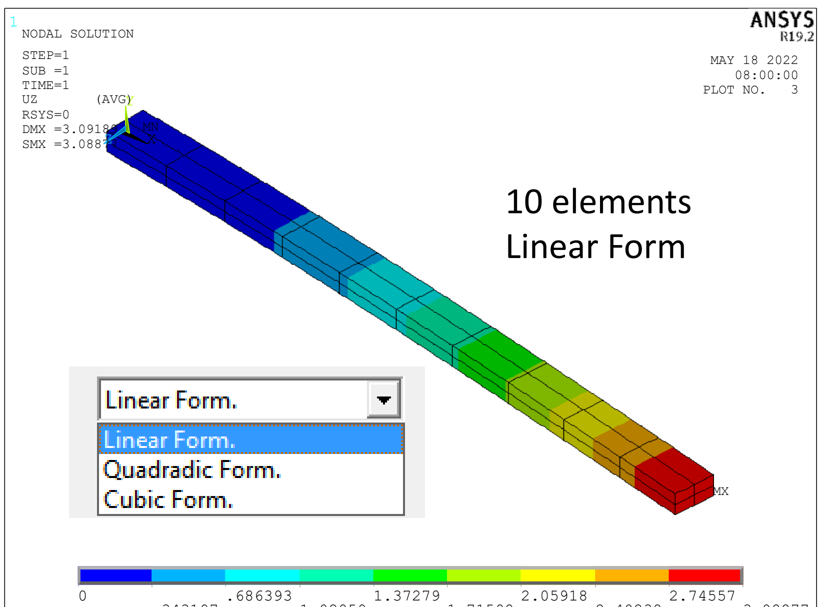


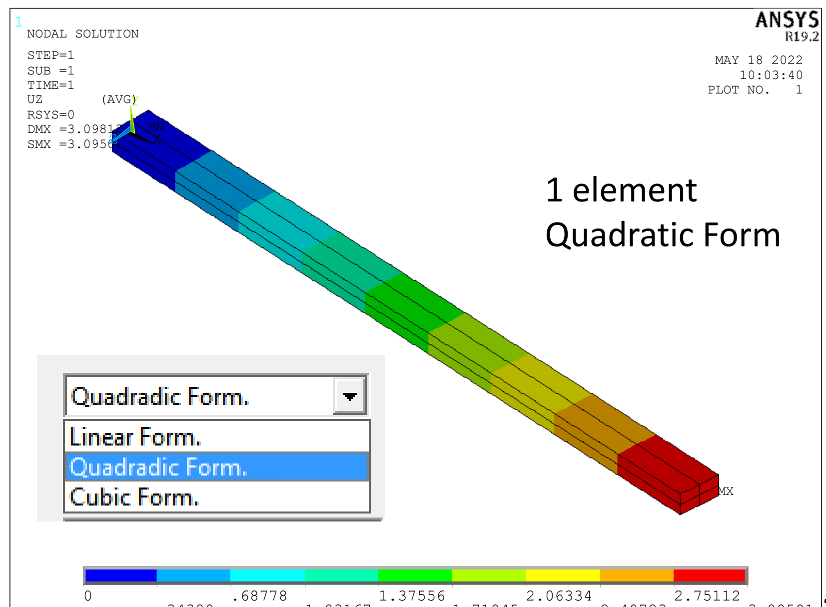


Example of how mesh and element options affect displacements

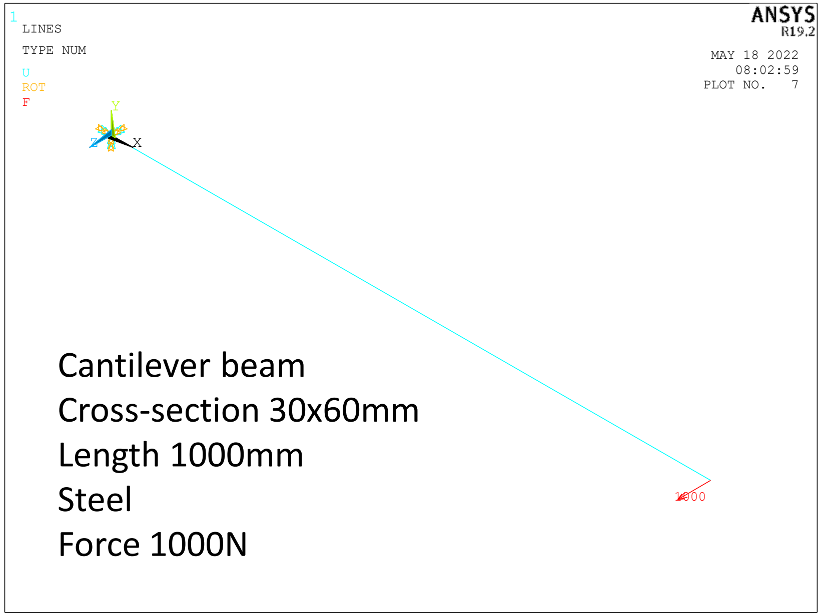


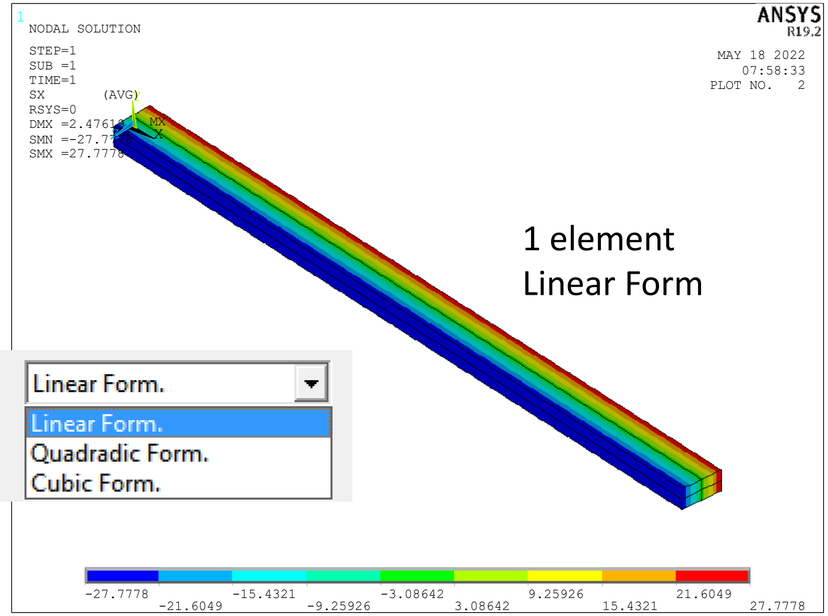


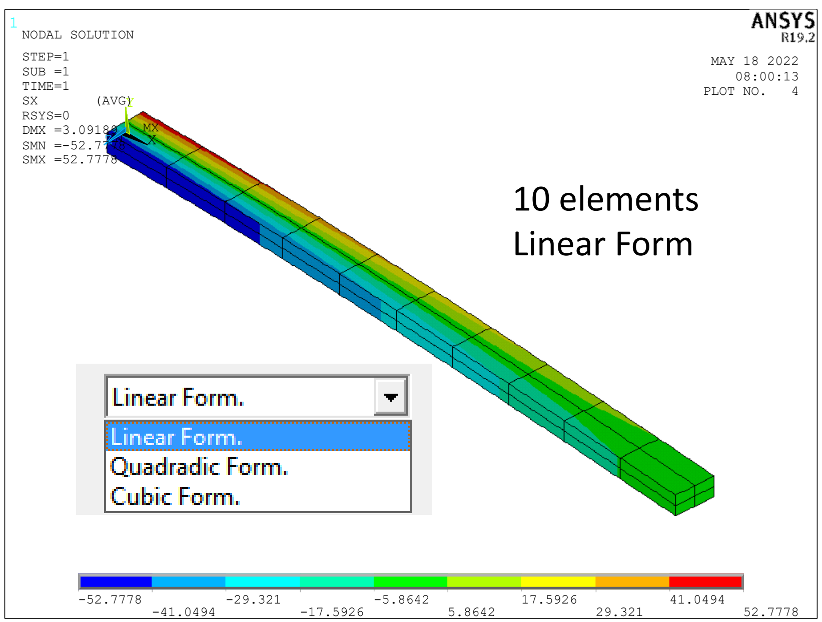


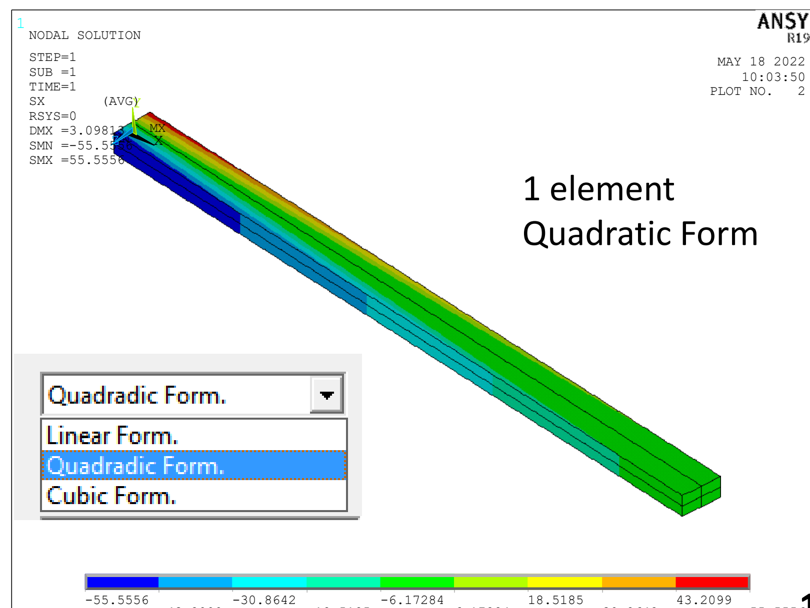


Example of how mesh and element options affect stress









Structural Pipe elements

Figure 288.1: PIPE288 Geometry

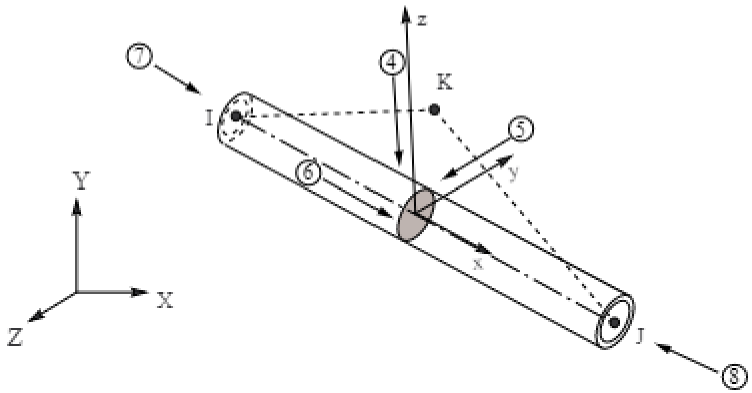


Figure 289.1: PIPE289 Geometry

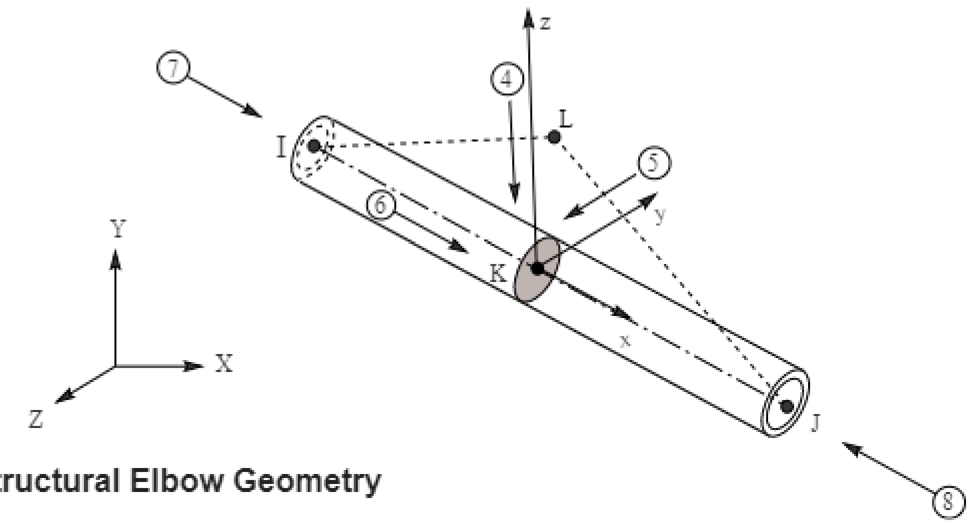
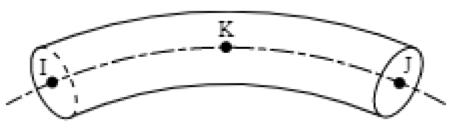
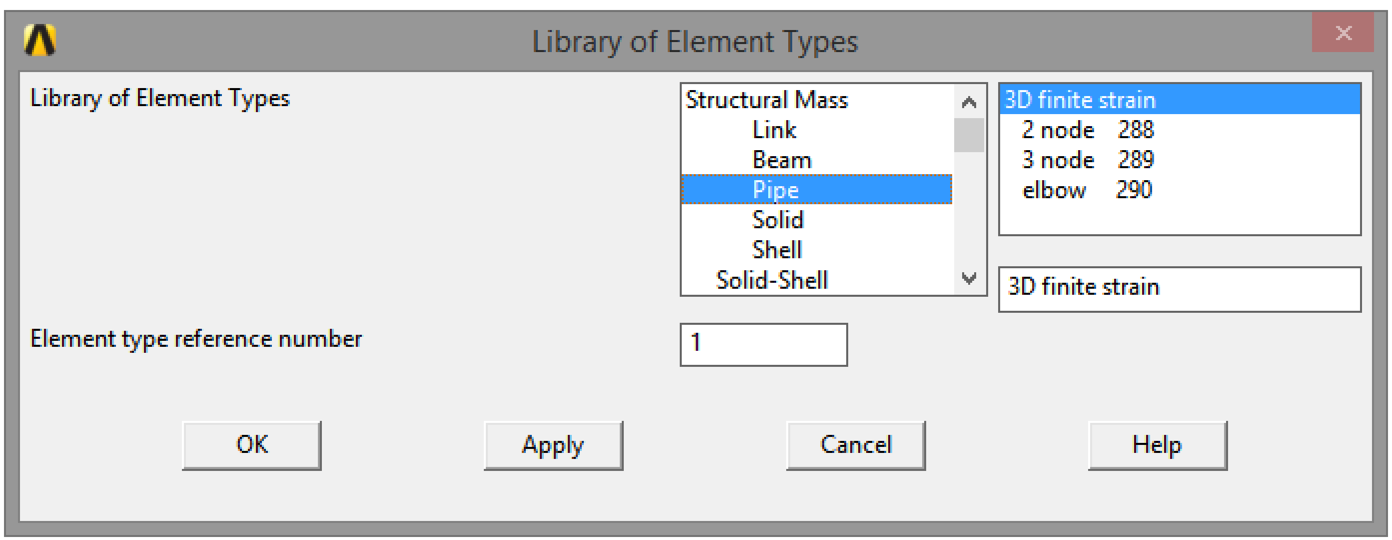


Figure 290.1: ELBOW290 Structural Elbow Geometry





Cross-sections of a Structural Pipe element

Figure 288.1: PIPE288 Geometry

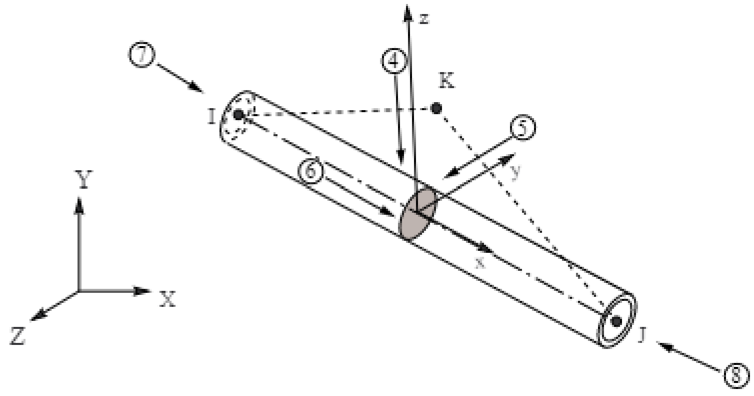
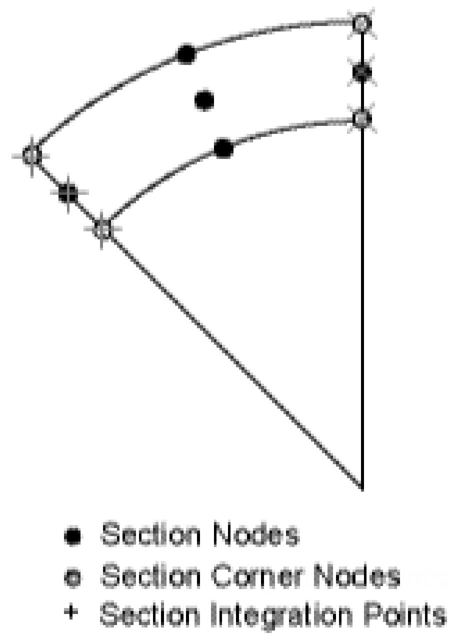
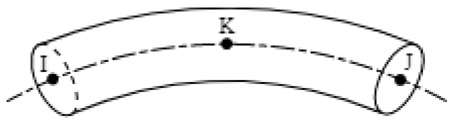


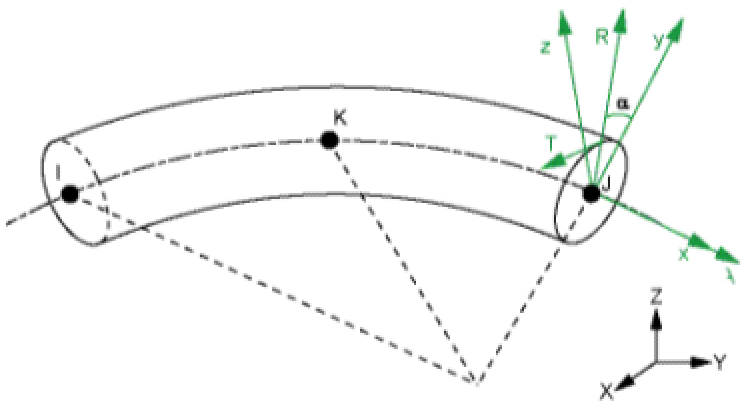
Figure 288.3: Typical Cross-Section Cell

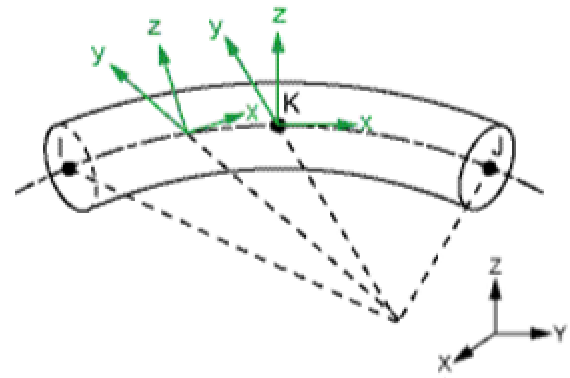


Structural Elbow element

Figure 290.1: ELBOW290 Structural Elbow Geometry





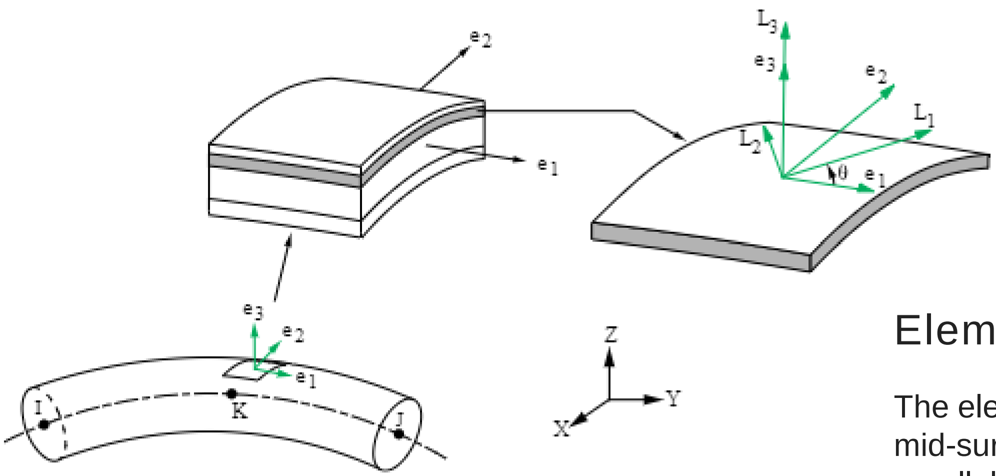


No orientation node (default)

Local Cylindrical Coordinate Systems

The cylindrical coordinate systems (A-R-T) are used for defining internal section motions (that is, axial-A, radial-R, and hoop-T displacements and rotations).

Layers in the structure of a Structural Elbow element



Element and Layer Coordinate Systems

The element coordinate systems (e1-e2-e3) are defined at the mid-surfaces of the pipe wall. The e1, e2, and e3 axes are parallel respectively to cylindrical axes A, T, and R in the undeformed configuration. Each element coordinate system is updated independently to account for large material rotation during a geometrically nonlinear analysis. Support is not available for user-defined element coordinate systems.

The layer coordinate systems (L1-L2-L3) are identical to the element coordinate system if no layer orientation angles are specified; otherwise, the layer coordinate system can be generated by rotating the corresponding element coordinate system about the shell normal (axis e3). Material properties are defined in the layer systems; therefore, the layer system is also called the material coordinate system.

Support conditions in Structural Elbow element

Cross-Section Constraints

The constraints on the elbow cross-section can be applied at the element nodes I, J, and K with the following section degrees of freedom labels:

SE – section radial motion (as occurs during expansion or ovalization, for example)

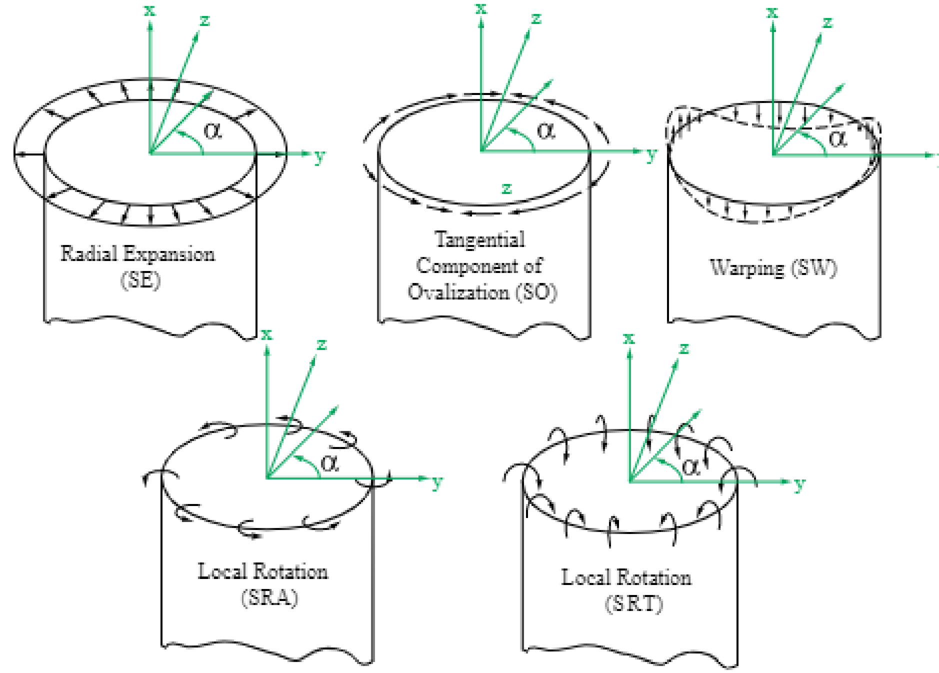
SO – section tangential motion (as occurs during ovalization, for example)

SW – section axial motion (as occurs during warping, for example)

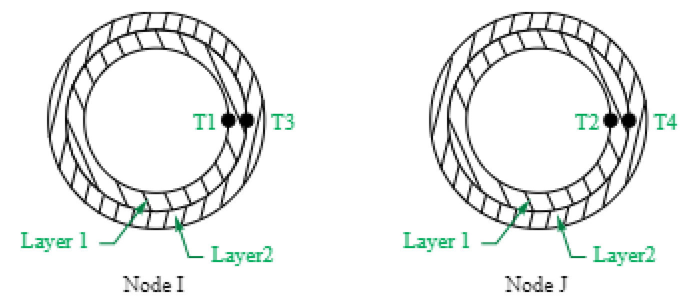
SRA – local shell normal rotation about cylindrical axis A

SRT – local shell normal rotation about cylindrical axis T

SECT – all section deformation



Only fixed cross-section constraints are allowed via the **D** command. Delete section constraints via the **DDELE** command. For example, to constrain the warping and ovalization of the cross-section at node n, issue this command:
To allow only the radial expansion of the cross-section, use the following commands:
It is not practical to maintain the continuity of cross-section deformation between two adjacent elements joined at a sharp angle. For such cases, ANSYS, Inc. recommends coupling the nodal displacements and rotations but leaving the cross-section deformation uncoupled. The **ELBOW** command can automate the process by uncoupling the cross-section deformation for any adjacent elements with cross-sections intersecting at an angle greater than 20 degrees



Structural Constraints element

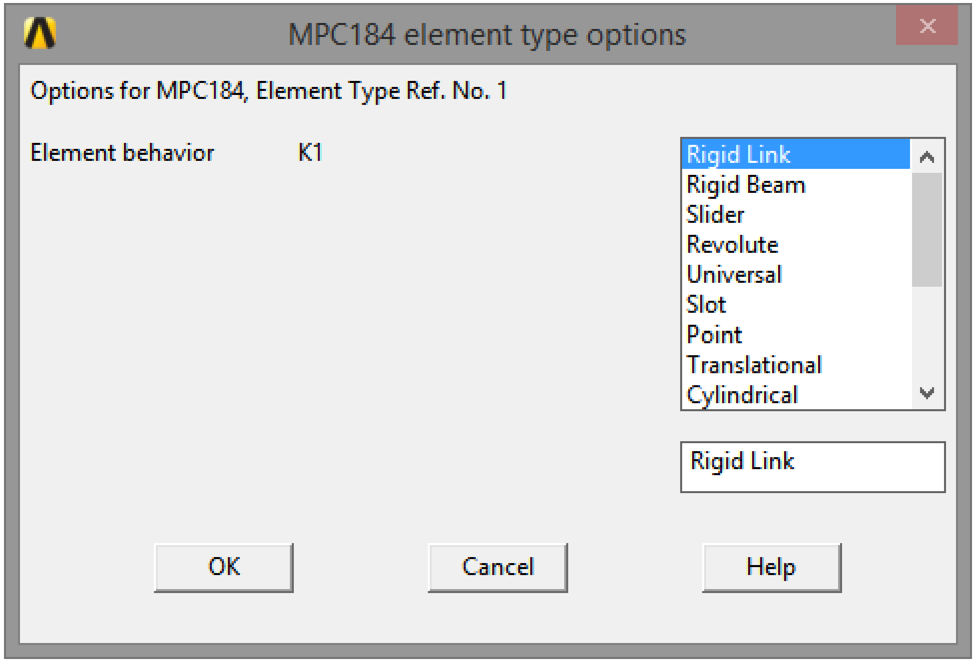
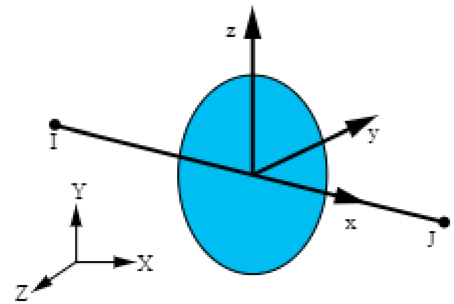


Figure 184link.1: MPC184 Rigid Link/Beam Geometry



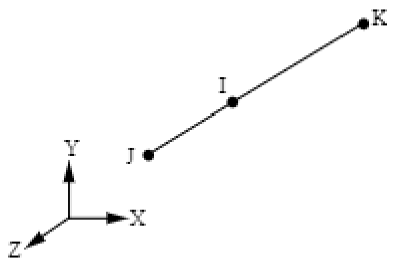
Structural Constraints element

Joint Elements

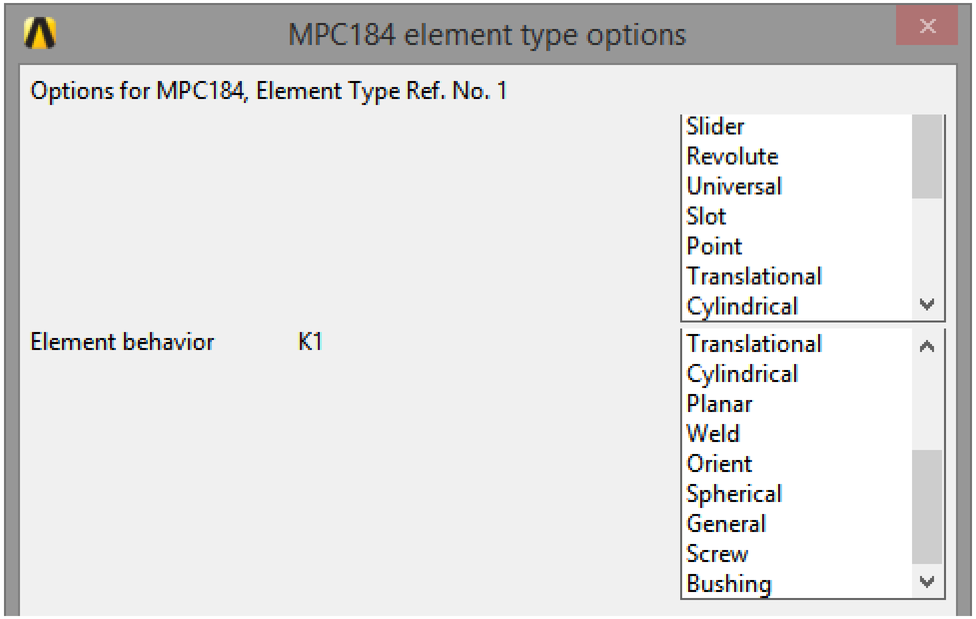
Numerical simulations often involve modeling of joints between two parts. These joints or connections may need simple kinematic constraints such as identical displacements between the two parts at the junction or more complicated kinematic constraints that allow for transmission of motion between two flexible bodies. These complex joints may also include some sort of control mechanism like limits or stops, and locks on the components of relative motion between the two bodies. In many instances, these joints may also have stiffness, damping, or friction forces based on the unconstrained components of relative motion between the two bodies. For detailed information on how to use joint elements, see Connecting Multibody Components with Joint Elements in the *Multibody Analysis Guide*.

The following types of joint elements are available:

Figure 184slid.1: MPC184 Slider Geometry



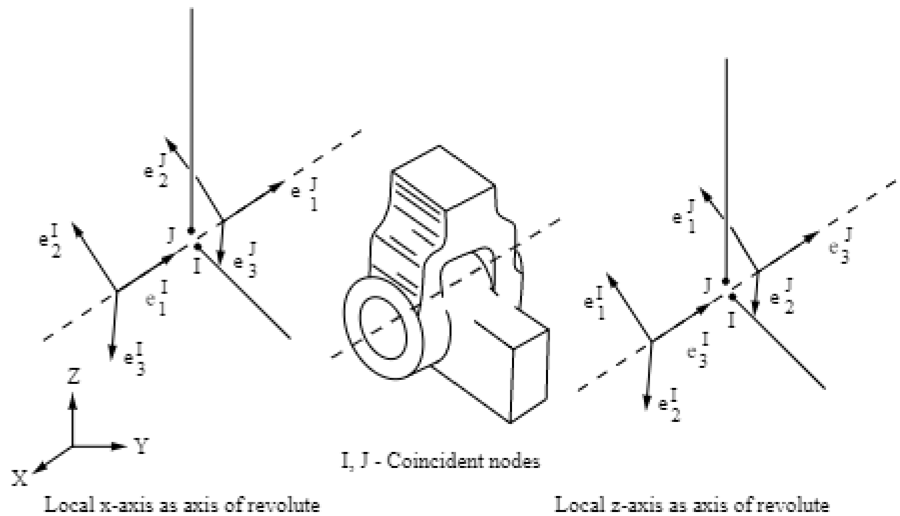
- x-axis Revolute joint
- z-axis Revolute joint
- Universal joint
- Slot joint
- Point-in-plane joint
- Translational joint
- x-axis Cylindrical joint
- z-axis Cylindrical joint
- x-axis Planar joint
- z-axis Planar joint
- Weld joint
- Orient joint
- Spherical joint
- General joint
- Screw joint



Structural Constraints element

- x-axis Revolute joint
- z-axis Revolute joint
- Universal joint
- Slot joint
- Point-in-plane joint
- Translational joint
- x-axis Cylindrical joint
- z-axis Cylindrical joint
- x-axis Planar joint
- z-axis Planar joint
- Weld joint
- Orient joint
- Spherical joint
- General joint
- Screw joint

Figure 184revo.1: MPC184 Revolute Joint Geometry



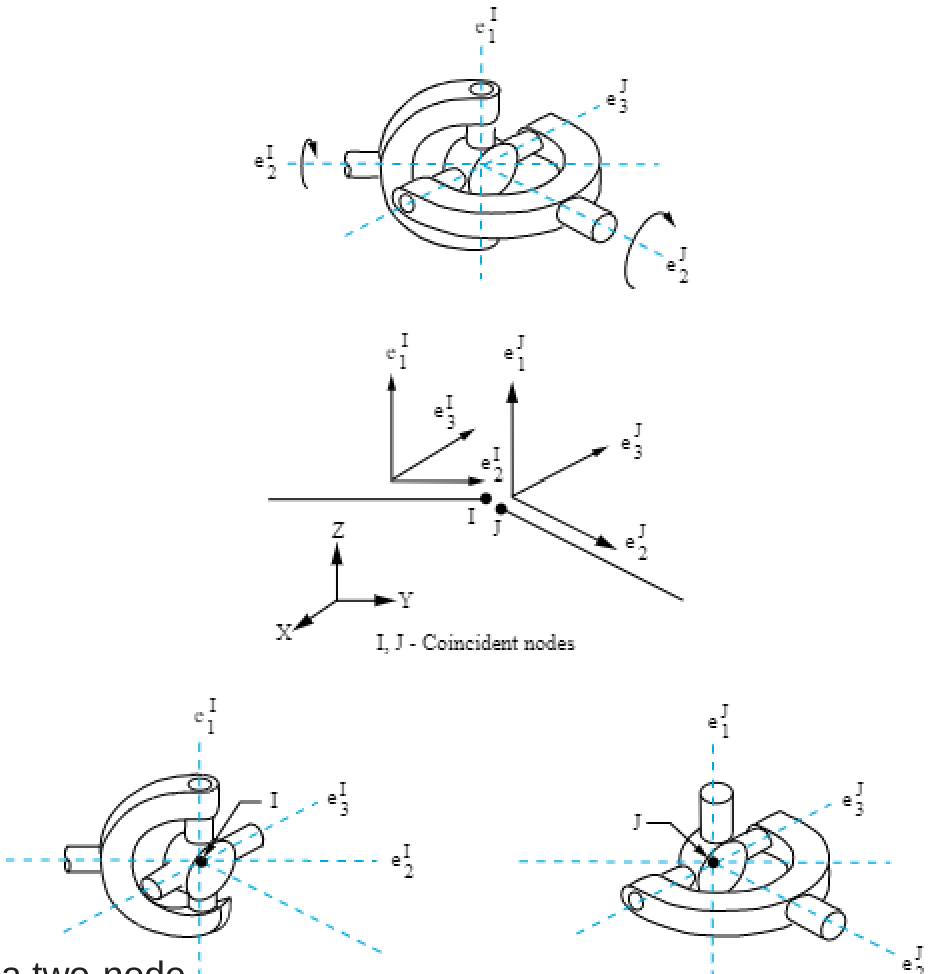
The MPC184 revolute joint is a two-node element that has only one primary degree of freedom, the relative rotation about the revolute (or hinge) axis. This element imposes kinematic constraints such that the nodes forming the element have the same displacements. Additionally, only a relative rotation is allowed about the revolute axis, while the rotations about the other two directions are fixed.

The MPC184 revolute joint is a two-node element that has only one primary degree of freedom, the relative rotation about the revolute (or hinge) axis. This element imposes kinematic constraints such that the nodes forming the element have the same displacements. Additionally, only a relative rotation is allowed about the revolute axis, while the rotations about the other two directions are fixed.

Structural Constraints element

- x-axis Revolute joint
- z-axis Revolute joint
- Universal joint
- Slot joint
- Point-in-plane joint
- Translational joint
- x-axis Cylindrical joint
- z-axis Cylindrical joint
- x-axis Planar joint
- z-axis Planar joint
- Weld joint
- Orient joint
- Spherical joint
- General joint
- Screw joint

Figure 184univ.1: MPC184 Universal Joint Geometry

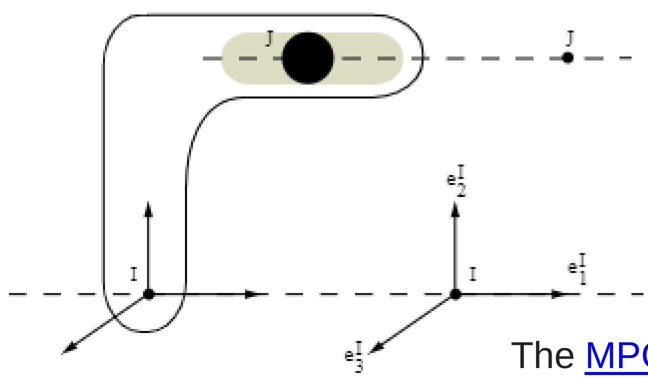


The MPC184 universal joint element is a two-node element that has two free relative rotational degrees of freedom. The two nodes forming the element must have identical spatial coordinates.

Structural Constraints element

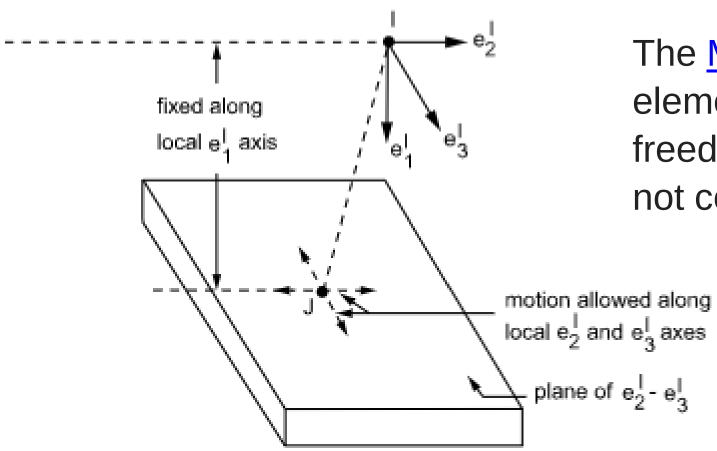
- x-axis Revolute joint
- z-axis Revolute joint
- Universal joint
- Slot joint
- Point-in-plane joint
- Translational joint
- x-axis Cylindrical joint
- z-axis Cylindrical joint
- x-axis Planar joint
- z-axis Planar joint
- Weld joint
- Orient joint
- Spherical joint
- General joint
- Screw joint

Figure 184slot.1: MPC184 Slot Joint Geometry



The MPC184 slot joint element is a two-node element that has one relative displacement degree of freedom. The rotational degrees of freedom at nodes I and J are left free.

Figure 184poin.1: MPC184 Point-in-plane Joint Geometry

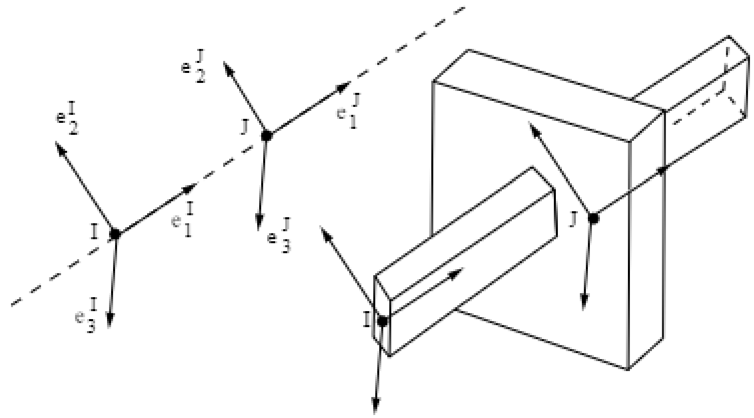


The MPC184 point-in-plane joint element is a two-node element that has two relative displacement degrees of freedom. The relative rotational degrees of freedom are not considered and cannot be controlled.

Structural Constraints element

- [x-axis Revolute joint]
- [z-axis Revolute joint]
- [Universal joint]
- [Slot joint]
- [Point-in-plane joint]
- [Translational joint]
- [x-axis Cylindrical joint]
- [z-axis Cylindrical joint]
- [x-axis Planar joint]
- [z-axis Planar joint]
- [Weld joint]
- [Orient joint]
- [Spherical joint]
- [General joint]
- [Screw joint]

Figure 184tran.1: MPC184 Translational Joint Geometry



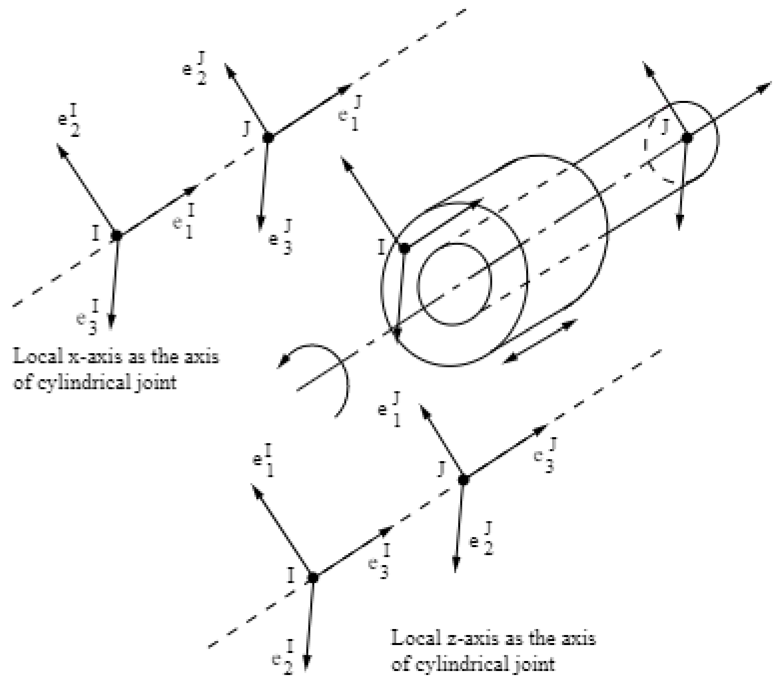
The MPC184 translational joint element is a two-node element that has one relative displacement degree of freedom. All other relative degrees of freedom are fixed.

Structural Constraints element

- [x-axis Revolute joint]
- [z-axis Revolute joint]
- [Universal joint]
- [Slot joint]
- [Point-in-plane joint]
- [Translational joint]
- [x-axis Cylindrical joint]
- [z-axis Cylindrical joint]
- [x-axis Planar joint]
- [z-axis Planar joint]
- [Weld joint]
- [Orient joint]
- [Spherical joint]
- [General joint]
- [Screw joint]

The MPC184 cylindrical joint element is a two-node element that has one free relative displacement degree of freedom and one free relative rotational degree of freedom (around the cylindrical or revolute axis). All other relative degrees of freedom are fixed.

Figure 184cyl.1: MPC184 Cylindrical Joint Geometry

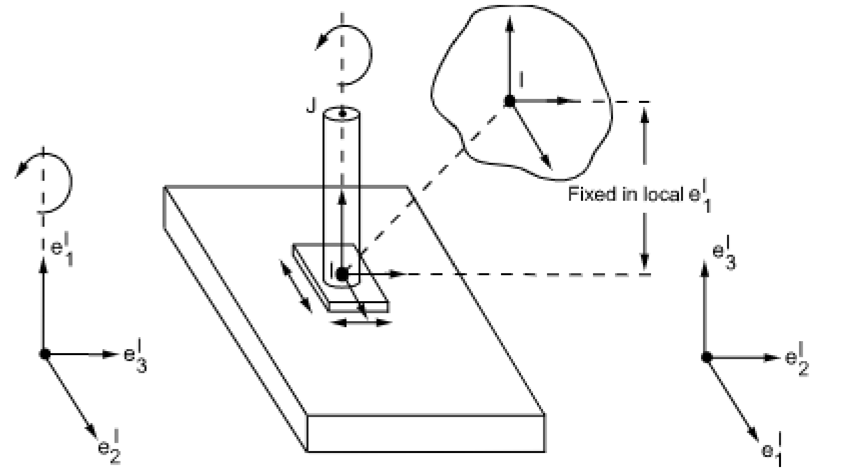


The MPC184 revolute joint is a two-node element that has only one primary degree of freedom, the relative rotation about the revolute (or hinge) axis. This element imposes kinematic constraints such that the nodes forming the element have the same displacements. Additionally, only a relative rotation is allowed about the revolute axis, while the rotations about the other two directions are fixed.

Structural Constraints element

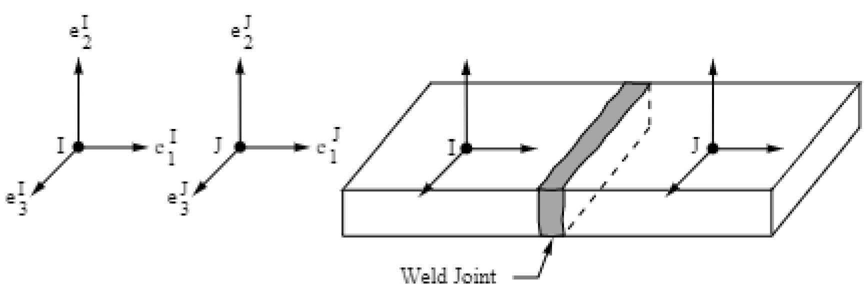
- [x-axis Revolute joint]
- [z-axis Revolute joint]
- [Universal joint]
- [Slot joint]
- [Point-in-plane joint]
- [Translational joint]
- [x-axis Cylindrical joint]
- [z-axis Cylindrical joint]
- [x-axis Planar joint]
- [z-axis Planar joint]
- [Weld joint]
- [Orient joint]
- [Spherical joint]
- [General joint]
- [Screw joint]

Figure 184plan.1: MPC184 Planar Joint Geometry



The MPC184 planar joint element is a two-node element that has two relative displacement degrees of freedom and one relative rotational degree of freedom. All other relative degrees of freedom are fixed.

Figure 184weld.1: MPC184 Weld Joint Geometry

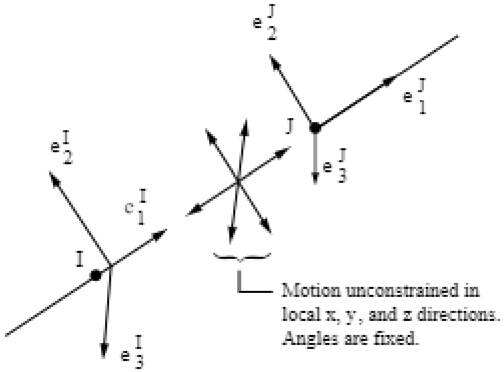


The MPC184 weld joint element is a two-node element that has all relative degrees of freedom fixed.

Structural Constraints element

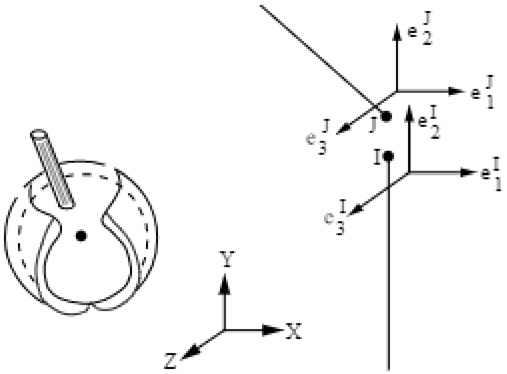
- [x-axis Revolute joint]
- [z-axis Revolute joint]
- [Universal joint]
- [Slot joint]
- [Point-in-plane joint]
- [Translational joint]
- [x-axis Cylindrical joint]
- [z-axis Cylindrical joint]
- [x-axis Planar joint]
- [z-axis Planar joint]
- [Weld joint]
- [Orient joint]
- [Spherical joint]
- [General joint]
- [Screw joint]

Figure 184orie.1: MPC184 Orient Joint Geometry



The MPC184 orient joint is a two-node element. In this joint, the relative rotational degrees of freedom are fixed while the displacement degrees of freedom are left free.

Figure 184sphe.1: MPC184 Spherical Joint Geometry

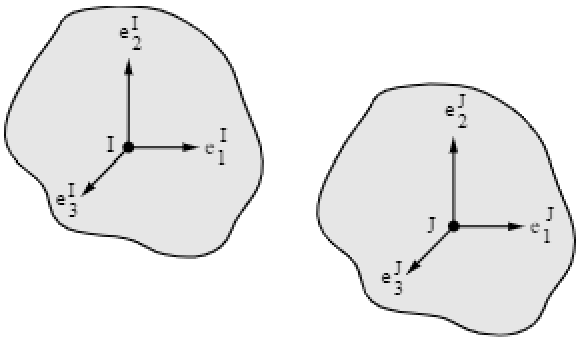


The MPC184 spherical joint element is a two-node element with the relative displacement degrees of freedom constrained. The relative rotational degrees of freedom are left unconstrained. These rotations cannot be controlled. The kinematic constraints are imposed using the Lagrange multiplier method.

Structural Constraints element

- x-axis Revolute joint
- z-axis Revolute joint
- Universal joint
- Slot joint
- Point-in-plane joint
- Translational joint
- x-axis Cylindrical joint
- z-axis Cylindrical joint
- x-axis Planar joint
- z-axis Planar joint
- Weld joint
- Orient joint
- Spherical joint
- General joint
- Screw joint

Figure 184gen.1: MPC184 General Joint Geometry

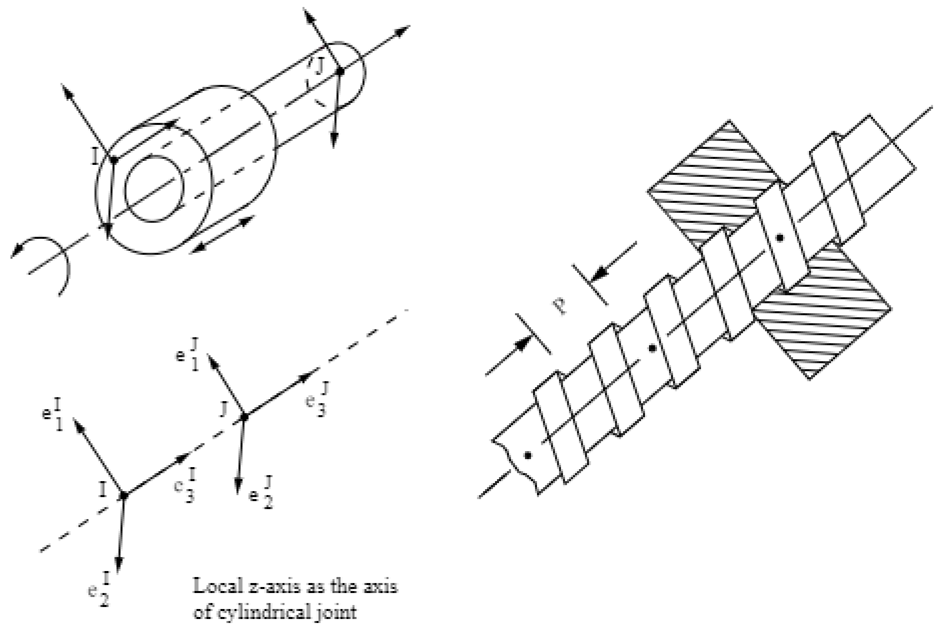


The MPC184 general joint is a two-node element. By default, no relative degrees of freedom are fixed. However, you can specify which relative degrees of freedom need to be constrained. By specifying as many relative degrees of freedom to be constrained as needed, you can simulate different joint elements.

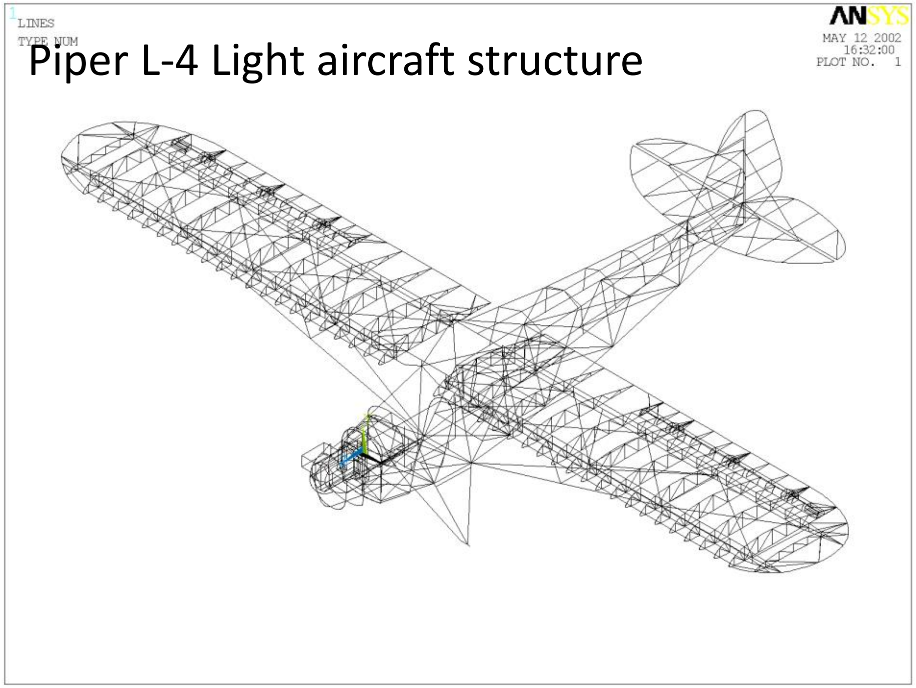
Structural Constraints element

- [x-axis Revolute joint]
- [z-axis Revolute joint]
- [Universal joint]
- [Slot joint]
- [Point-in-plane joint]
- [Translational joint]
- [x-axis Cylindrical joint]
- [z-axis Cylindrical joint]
- [x-axis Planar joint]
- [z-axis Planar joint]
- [Weld joint]
- [Orient joint]
- [Spherical joint]
- [General joint]
- [Screw joint]

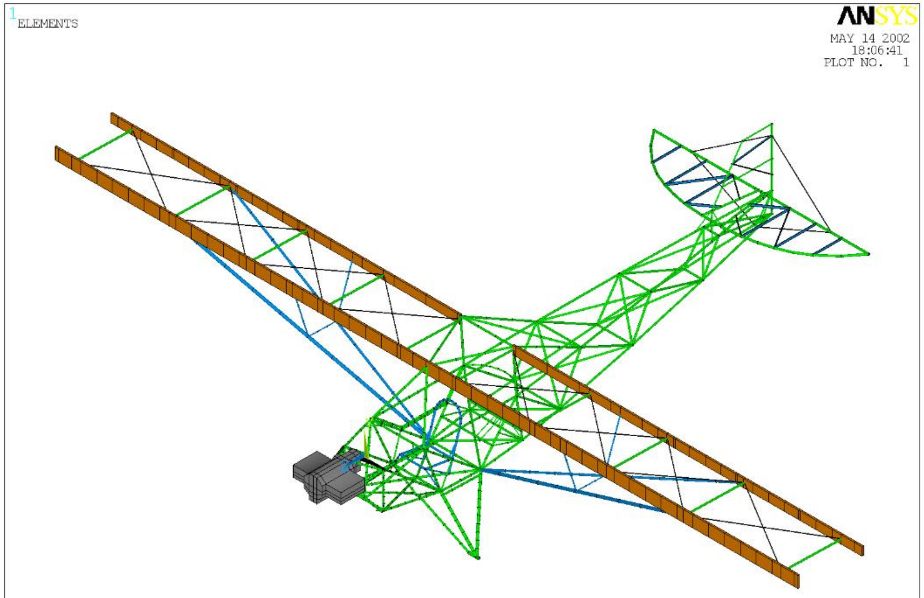
Figure 184scr.1: MPC184 Screw Joint Geometry



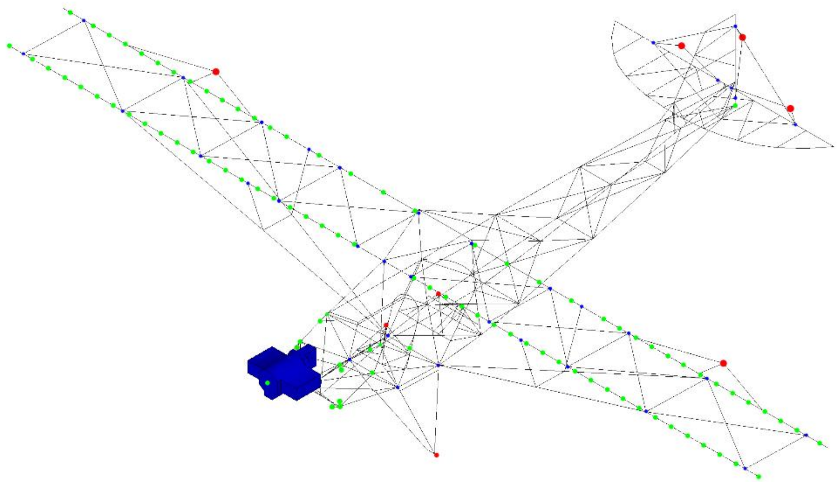
The MPC184 screw joint element is a two-node element which is very similar to the cylindrical joint element in construction. Whereas the cylindrical Joint element has two free relative degrees of freedom, the screw Joint has only one. In a screw joint, the “pitch” of the screw relates the relative rotation angle (around the cylindrical or screw axis) to the relative translational displacement along the axis of the screw. All other relative degrees of freedom are fixed



Piper L-4 Light aircraft structure

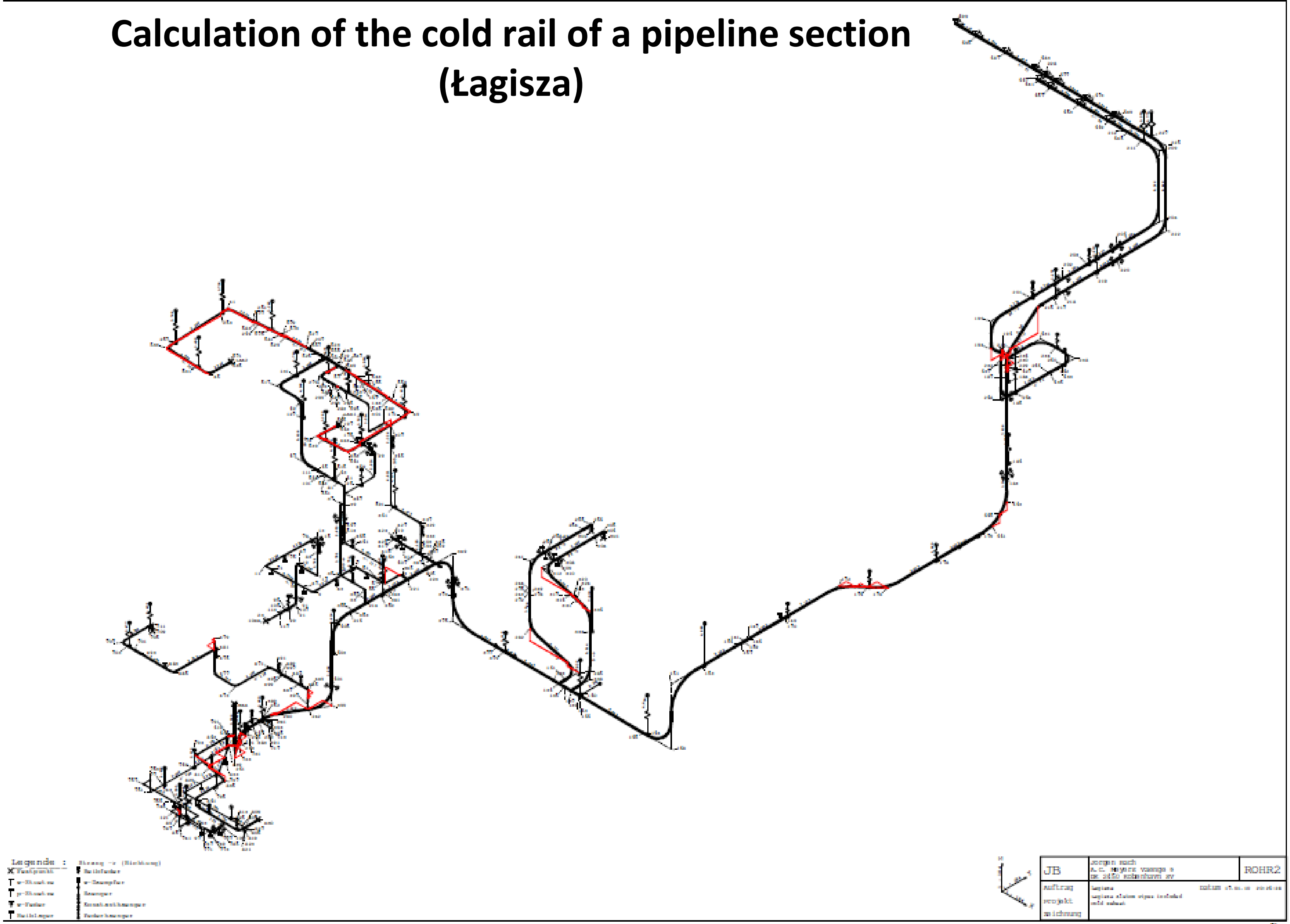


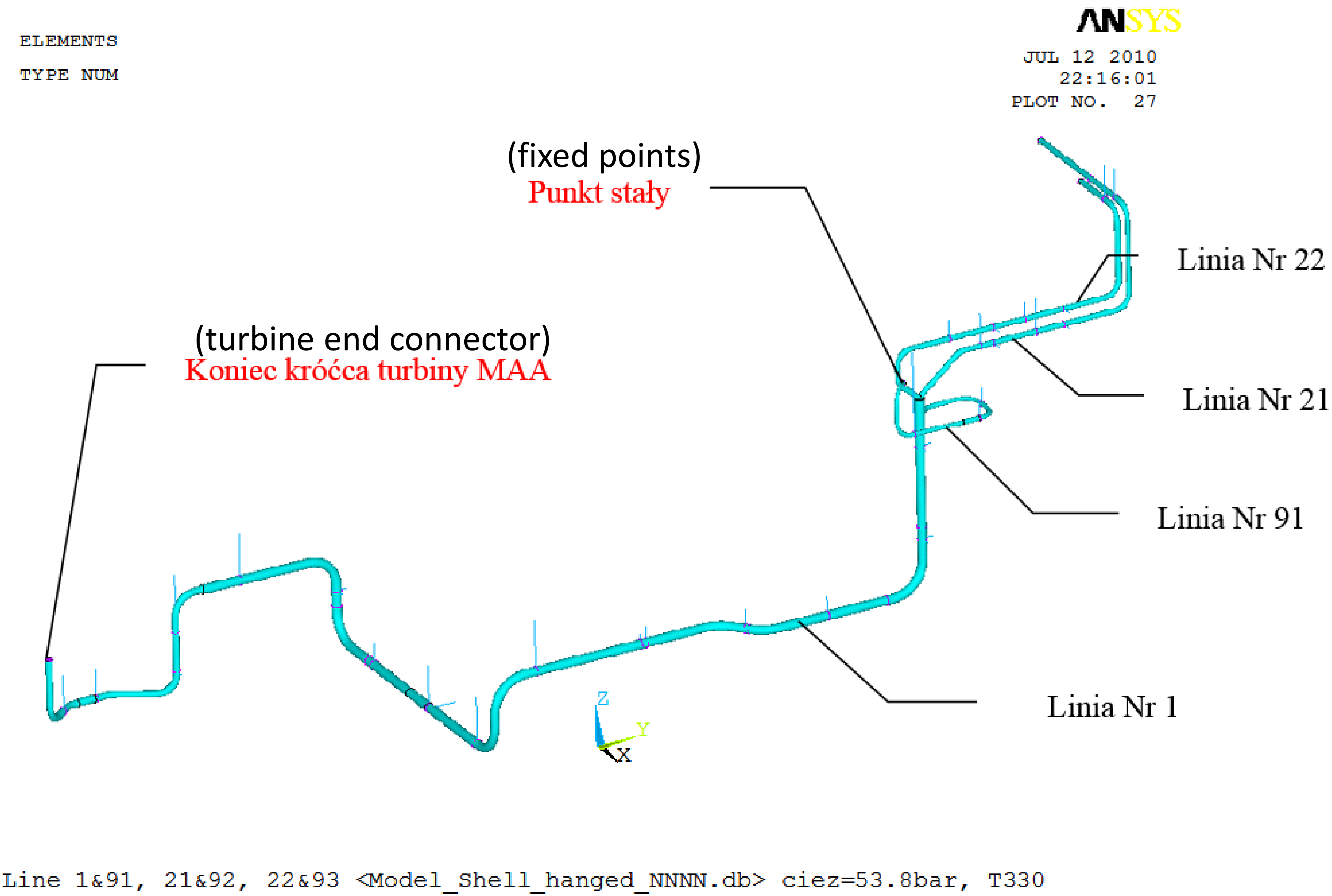
FEM beam model

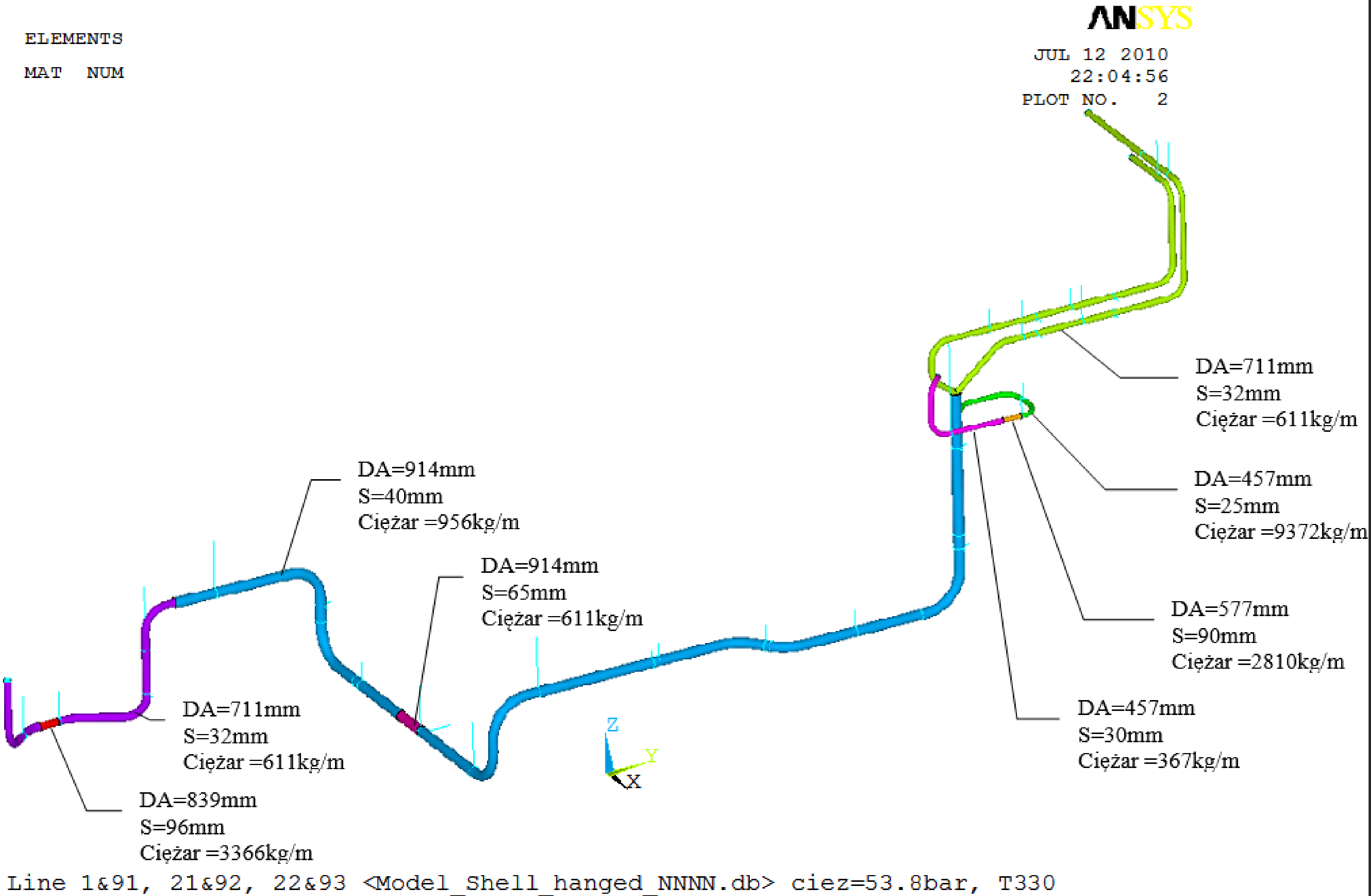


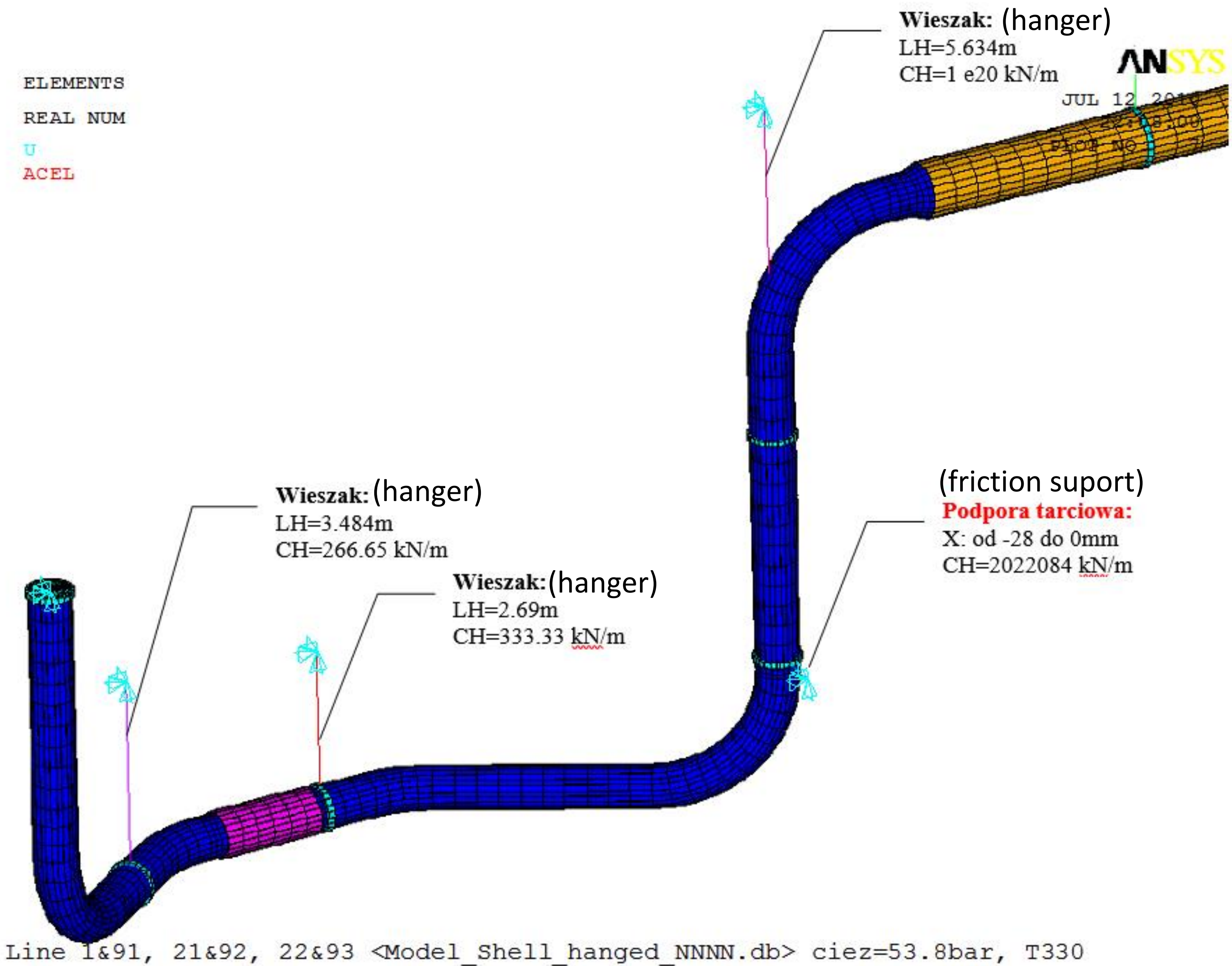
Distribution of concentrated masses in the substitute model

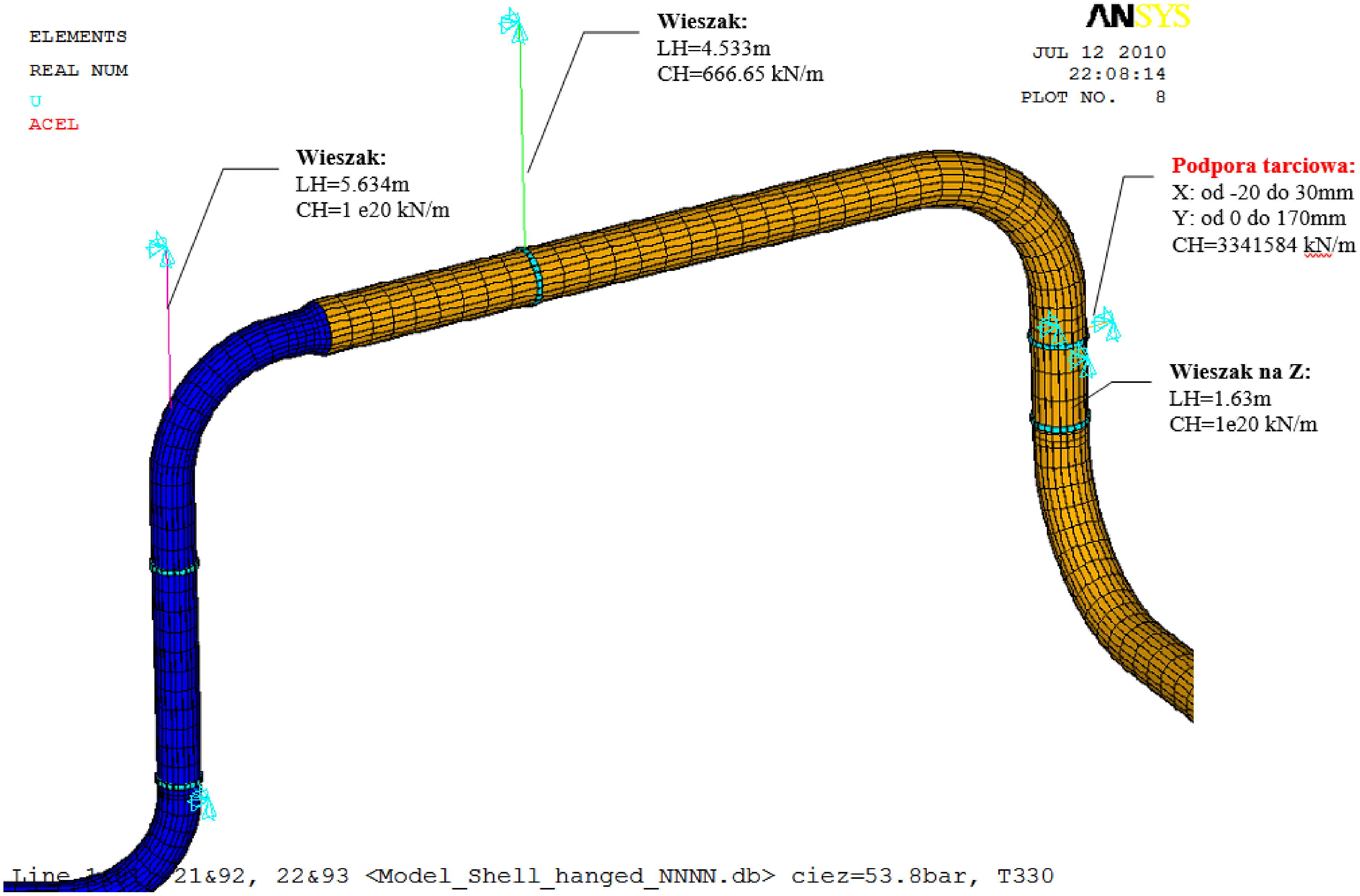
Calculation of the cold rail of a pipeline section (Łagisza)

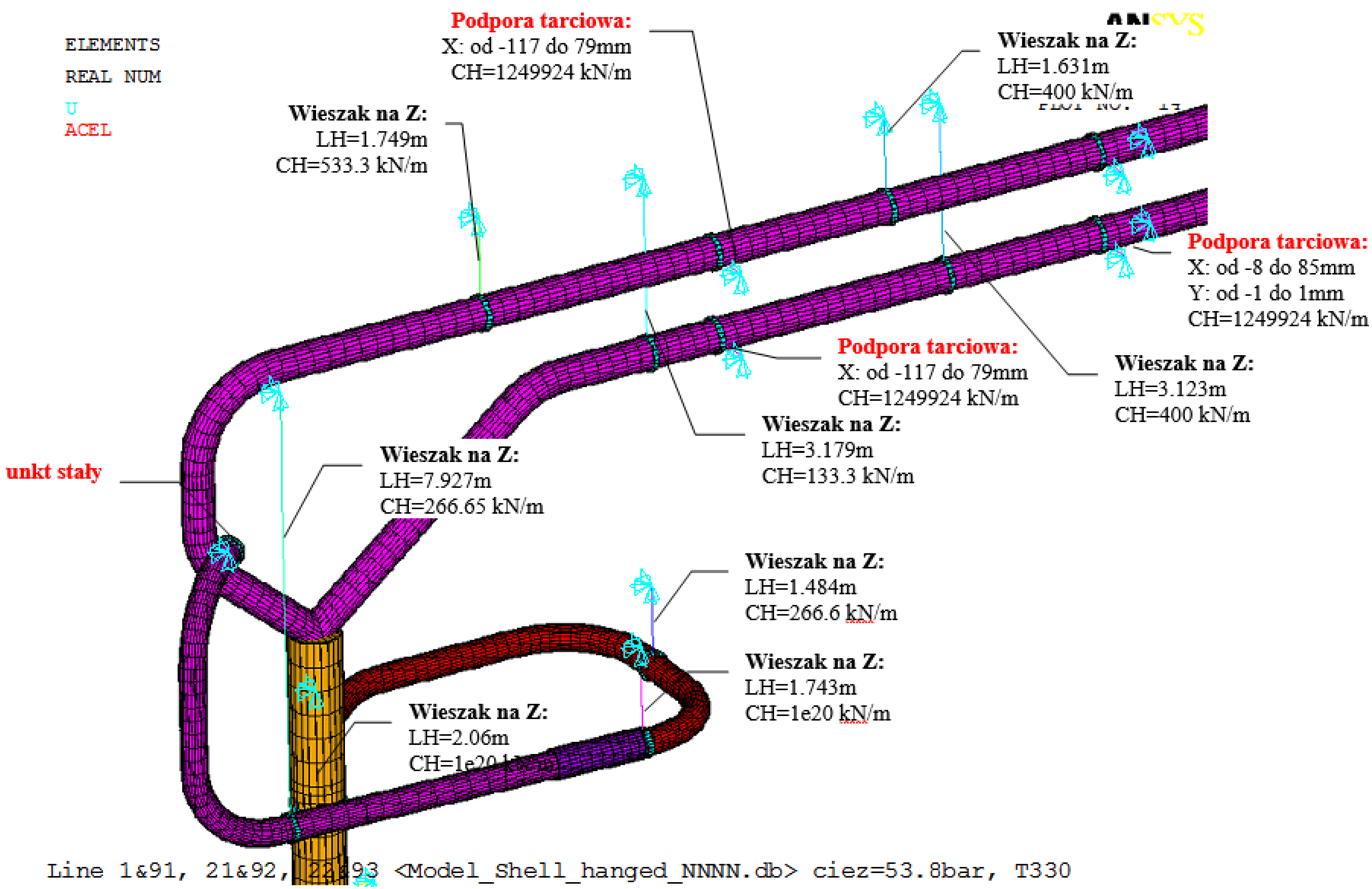



ELEMENTS
TYPE NUM
ANSYS
JUL 12 2010
22:16:01
PLOT NO. 27
(fixed points)
Punkt stały
Linia Nr 22
Linia Nr 21
Linia Nr 91
Linia Nr 1
(turbine end connector)
Koniec króćca turbiny MAA
Z
Y
X
Line 1&91, 21&92, 22&93 <Model_Shell_hanged_NNNN.db> ciez=53.8bar, T330

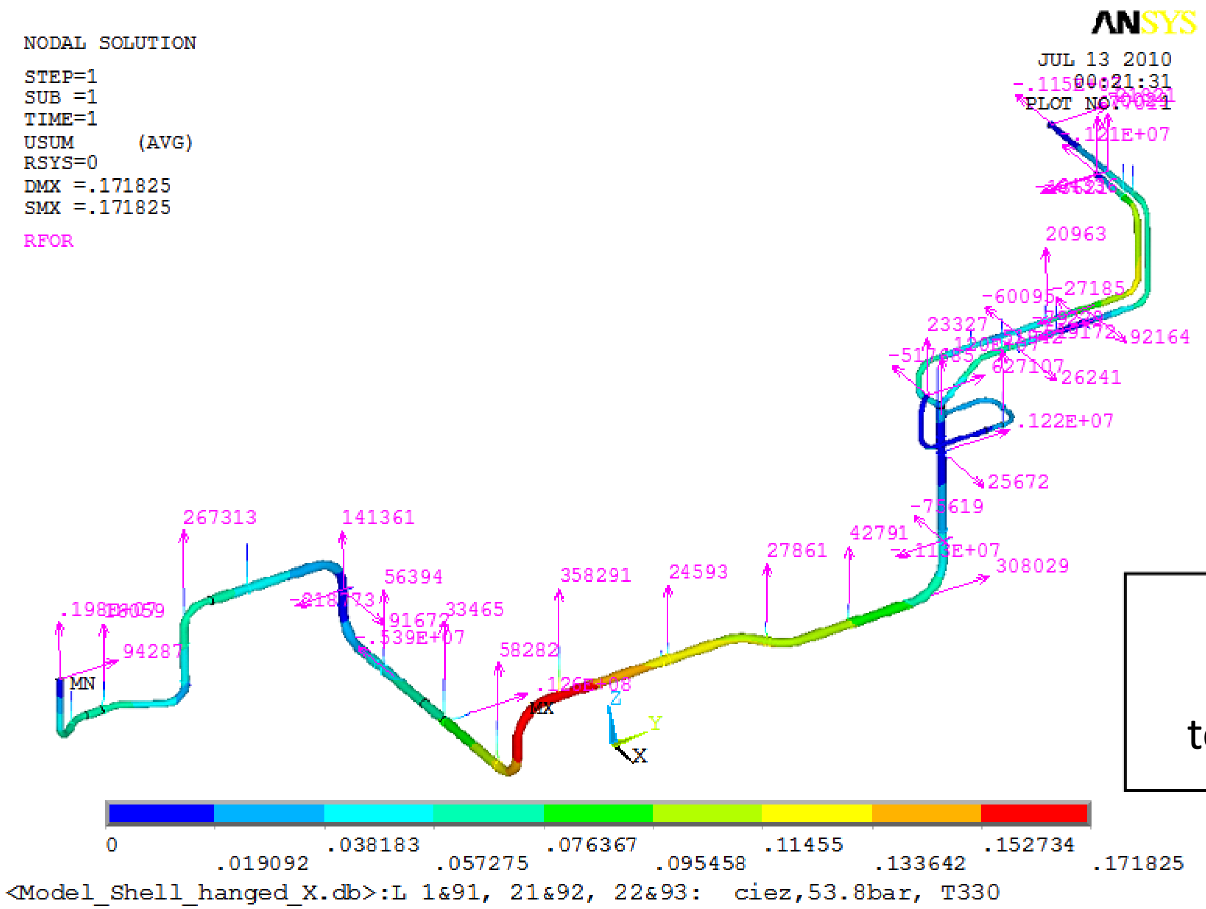

ELEMENTS
MAT NUM
ANSYS
JUL 12 2010
22:04:56
PLOT NO. 2
DA=711mm
S=32mm
Ciężar =611kg/m
DA=457mm
S=25mm
Ciężar =9372kg/m
DA=914mm
S=40mm
Ciężar =956kg/m
DA=914mm
S=65mm
Ciężar =611kg/m
DA=577mm
S=90mm
Ciężar =2810kg/m
DA=711mm
S=32mm
Ciężar =611kg/m
DA=457mm
S=30mm
Ciężar =367kg/m
DA=839mm
S=96mm
Ciężar =3366kg/m
Z
Y
X
Line 1&91, 21&92, 22&93 <Model_Shell_hanged_NNNN.db> ciez=53.8bar, T330


ELEMENTS
REAL NUM
U
ACEL
ANSYS
Wieszak: (hanger)
LH=5.634m
CH=1 e20 kN/m
Wieszak: (hanger)
LH=3.484m
CH=266.65 kN/m
Wieszak: (hanger)
LH=2.69m
CH=333.33 kN/m
(friction suport)
Podpora tarciowa:
X: od -28 do 0mm
CH=2022084 kN/m
Line 1&91, 21&92, 22&93 <Model_Shell_hanged_NNNN.db> ciez=53.8bar, T330


ELEMENTS
REAL NUM
U
ACEL
ANSYS
JUL 12 2010
22:08:14
PLOT NO. 8
Wieszak:
LH=4.533m
CH=666.65 kN/m
Wieszak:
LH=5.634m
CH=1 e20 kN/m
Podpora tarciowa:
X: od -20 do 30mm
Y: od 0 do 170mm
CH=3341584 kN/m
Wieszak na Z:
LH=1.63m
CH=1e20 kN/m
21&92, 22&93 <Model_Shell_hanged_NNNN.db> ciez=53.8bar, T330



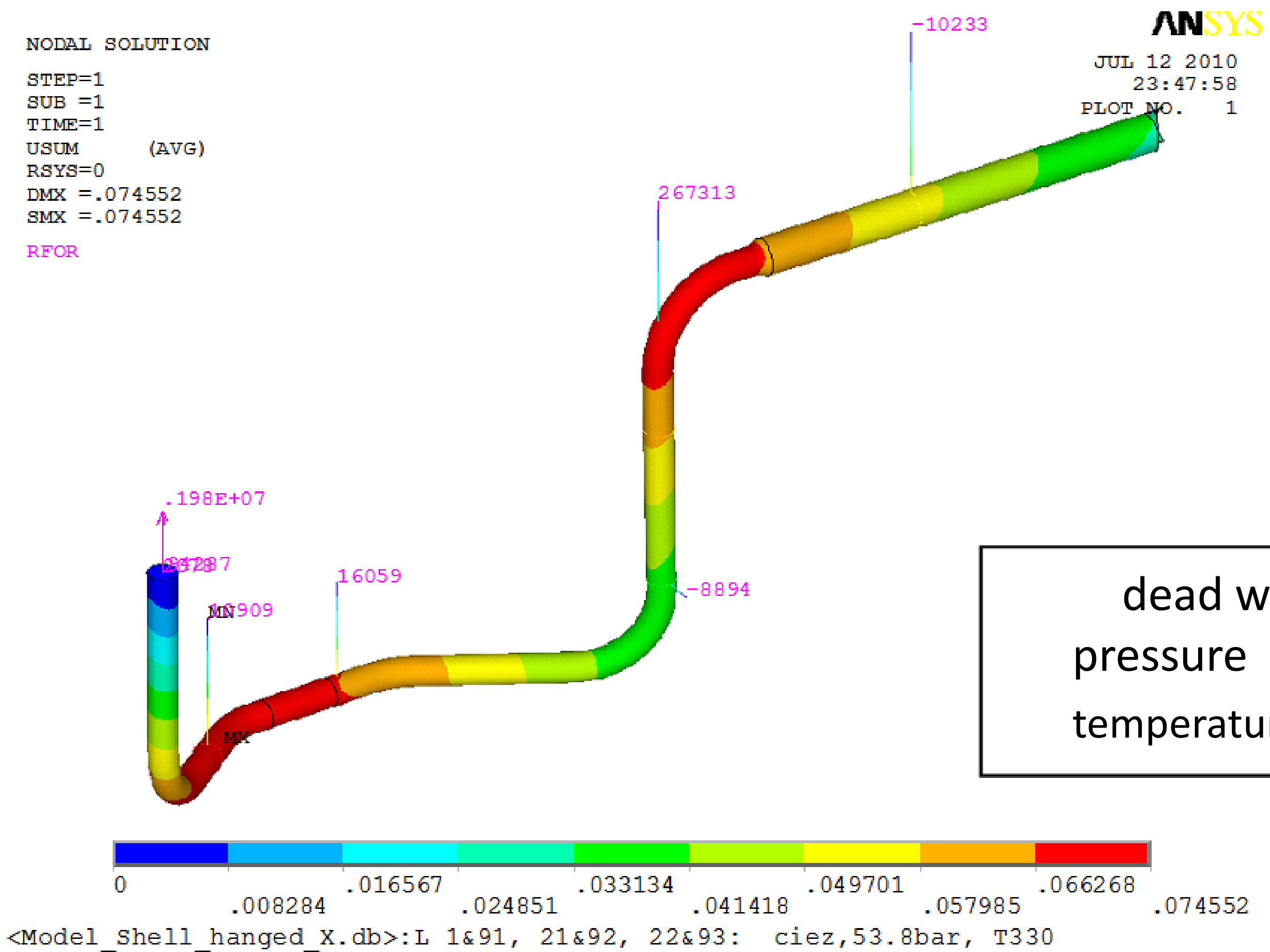
ELEMENTS
REAL NUM
U
ACEL
Podpora tarciowa:
X: od -117 do 79mm
CH=1249924 kN/m
Wieszak na Z:
LH=1.631m
CH=400 kN/m
Wieszak na Z:
LH=1.749m
CH=533.3 kN/m
Podpora tarciowa:
X: od -8 do 85mm
Y: od -1 do 1mm
CH=1249924 kN/m
Podpora tarciowa:
X: od -117 do 79mm
CH=1249924 kN/m
Wieszak na Z:
LH=3.123m
CH=400 kN/m
Wieszak na Z:
LH=3.179m
CH=133.3 kN/m
unkt stały
Wieszak na Z:
LH=7.927m
CH=266.65 kN/m
Wieszak na Z:
LH=1.484m
CH=266.6 kN/m
Wieszak na Z:
LH=1.743m
CH=1e20 kN/m
Wieszak na Z:
LH=2.06m
Line 1&91, 21&92, 22&93 <Model_Shell_hanged_NNNN.db> ciez=53.8bar, T330



dead weight

pressure 53.8bara

temperature 330°C



dead weight

pressure 53.8bara

temperature 330°C