Program: RFEM 5, RSTAB 8, RF-STEEL, STEEL

Category: Geometrically Linear Analysis, Isotropic Linear Elasticity, Member

Verification Example: 0089 – Bourdon Effect

0089 – Bourdon Effect

Description

A pipe with the tubular cross-section is loaded by means of internal pressure, see **Figure 1**. The internal pressure causes axial deformation of the pipe, what is called Bourdon effect. Determine the axial deformation u_x of the pipe endpoint. The problem is described by the following parameters.

Material	Steel	Modulus of Elasticity	E	210000.000	MPa
		Poisson's Ratio	ν	0.300	–
Geometry	Pipe	Length	L	10.000	m
		Outer Diameter	D_e	200.000	mm
		Inner Diameter	D_i	196.000	mm
Load		Pipe Internal Pressure	p	1.000	MPa

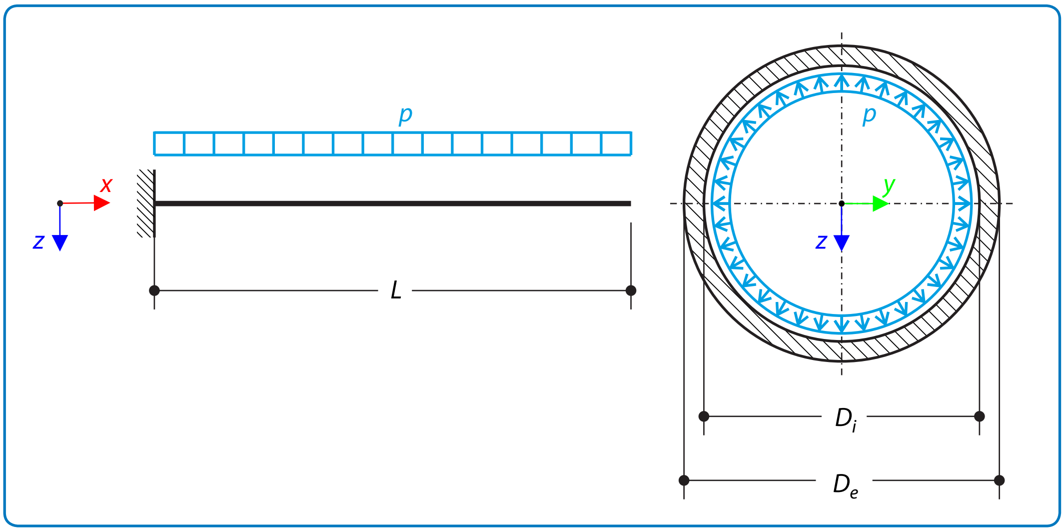

Figure 1: Problem Sketch

Analytical Solution

The pipe is considered to be a thick-walled close-ended vessel. Detailed decription of the thick-walled vessel calculation can be found in Verification example 0064, [1]. The stress state of the pipe is generally spatial due to the radial stress σ_r, tangential stress σ_t and axial stress σ_x. The axial deformation u_x of the pipe endpoint is defined by means of Hooke´s law

$$u_x = \frac{L}{E}\left(\sigma_x - \nu(\sigma_r + \sigma_t)\right). \qquad (89 – 1)$$

The axial stress σ_x when considering zero outer pressure is

$$\sigma_x = \frac{pr_i^2}{r_e^2 - r_i^2}, \tag{89 – 2}$$

where r_e and r_i is the outer and inner radius respectively. The radial and tangential stresses are defined as follows

$$\sigma_r = \sigma_x - \frac{C}{r^2}, \tag{89 – 3}$$

$$\sigma_t = \sigma_x + \frac{C}{r^2}, \tag{89 – 4}$$

where r is the radial coordinate and C is the real constant, in this case it is equal to

$$C = p\frac{r_i^2 r_e^2}{r_e^2 - r_i^2}. \tag{89 – 5}$$

Due to the agreement with RFEM 5 / RSTAB 8 analysis, further calculations are carried out for the middle radius $r_m = \frac{r_e + r_i}{2}$. Using **(89 – 1)**, the axial deformation u_x of the pipe endpoint results

$$u_x \approx 0.462 \text{ mm}. \tag{89 – 6}$$

RFEM 5 and RSTAB 8 Settings

- Modeled in RFEM 5.16.01 and RSTAB 8.16.01
- Element size is $l_{\text{FE}} = 0.500$ m
- Isotropic linear elastic material is used
- Member load 'Pipe internal pressure' is used
- Displacements due to the member loads of type 'Pipe internal pressure' (Bourdon effect) are enabled
- To obtain the values of the stresses including reduced Von Mises stress it is necessary to use add-on module RF-STEEL or STEEL with appropriate standard

Results

Structure File	Program
0089.01	RFEM 5
0089.02	RSTAB 8

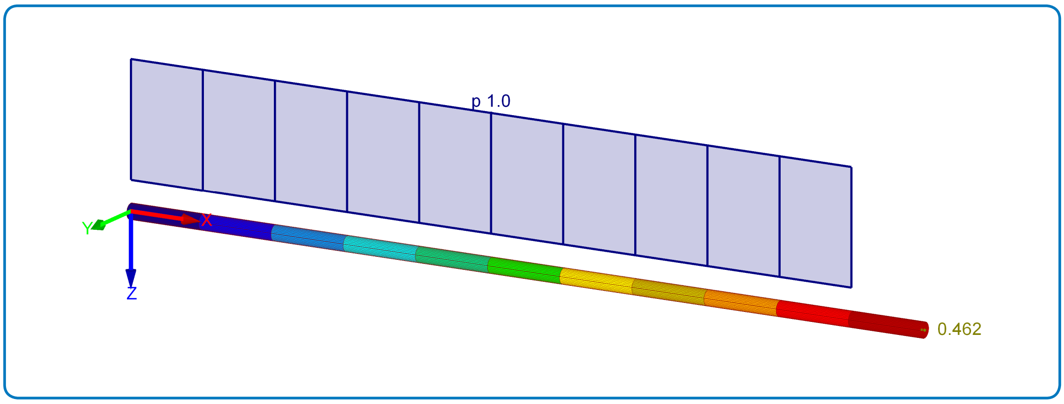

Figure 2: Results

Quantity	Analytical Solution	RFEM 5	Ratio	RSTAB 8	Ratio
u_x [mm]	0.462	0.462	1.000	0.462	1.000

References

[1] DLUBAL SOFTWARE GMBH, *Verification Example 0064 – Thick-Walled Vessel*. 2016.