Program: RFEM 5, RSTAB 8, RF-DYNAM Pro, DYNAM Pro

Category: Large Deformation Analysis, Dynamics, Member

Verification Example: 0119 – Spring with Clearance

0119 – Spring with Clearance

Description

A single-mass system with clearance δ, mass m and two springs k_1, k_2 is initially deflected by u_{x0}. Determine the natural oscillations of the system – deflection, velocity and acceleration time course. The problem sketch is in **Figure 1** and it is described by the following set of parameters.

System Properties	Mass	m	10.000	kg
	Spring Stiffness	k_1	100.000	N/mm
		k_2	10.000	N/mm
	Clearance	δ	5.000	mm
	Initial Deflection	u_{x0}	10.000	mm

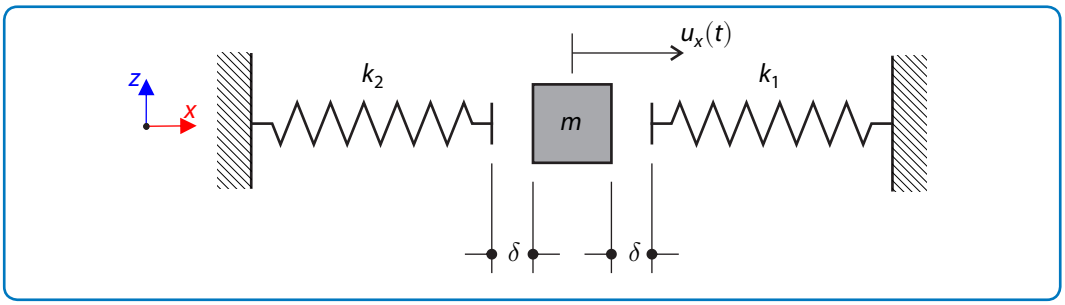

Figure 1: Problem Sketch

Analytical Solution

This is a nonlinear problem due to the clearance and different sping stiffnesses. It can be described by means of three differential equations in three intervals

$$m\ddot{u}_x + k_1(u_x - \delta) = 0, \qquad u_x \geq \delta, \tag{119 – 1}$$

$$m\ddot{u}_x = 0, \qquad u_x \in (-\delta, \delta), \tag{119 – 2}$$

$$m\ddot{u}_x + k_2(u_x + \delta) = 0, \qquad u_x \leq -\delta, \tag{119 – 3}$$

completed with the following initial conditions

$$u_x(0) = u_{x0} = 10.000 \text{ mm}, \tag{119 – 4}$$

$$\dot{u}_x(0) = 0.000 \text{ m/s}. \tag{119 – 5}$$

The problem can be solved analytically in each interval. This solution is relatively complex, therefore a numeric solution (Runge–Kutta method) of the above mentioned differential equations is used. For the time course of the deflection, velocity and acceleration see **Figure 4**. The specific values at test time 0.25 s are listed below

$$u_x(0.25) = -20.434\ [\text{mm}], \tag{119 – 6}$$

$$\dot{u}_x(0.25) = -0.098\ [\text{m/s}], \tag{119 – 7}$$

$$\ddot{u}_x(0.25) = 15.434\ [\text{m/s}^2]. \tag{119 – 8}$$

RFEM 5 and RSTAB 8 Settings

- Modeled in RFEM 5.17.01 and RSTAB 8.17.01
- Spring member with diagram is used, see **Figure 2** and **Figure 3**

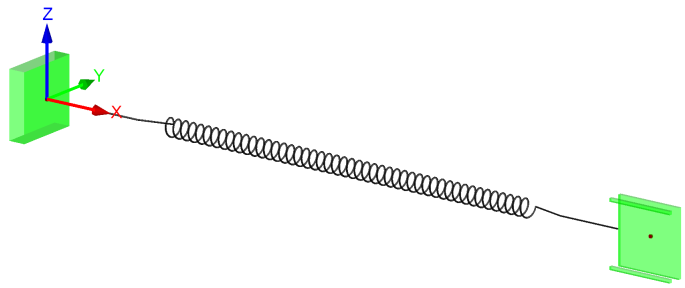

Figure 2: RFEM 5 / RSTAB 8 model

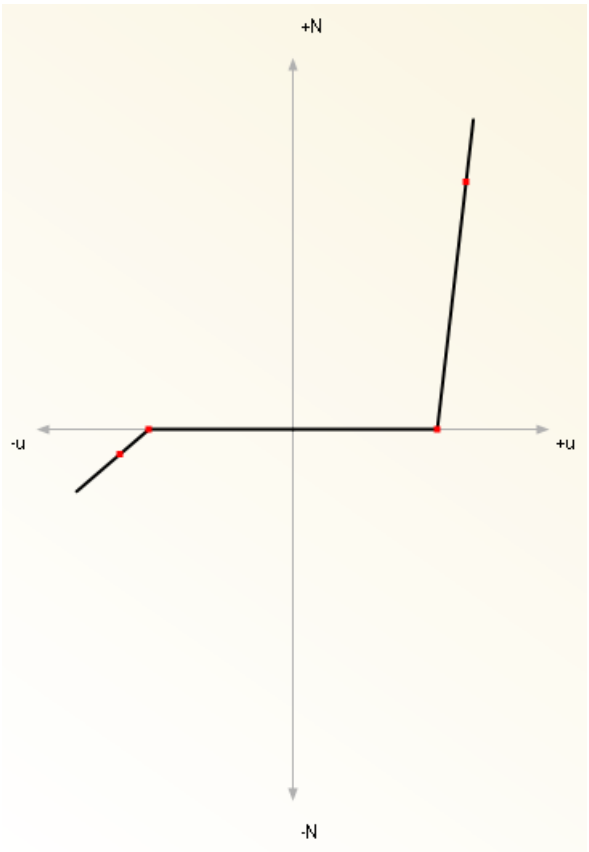

Figure 3: Diagram of the spring member in RFEM 5 / RSTAB 8

Results

Structure Files	Program	Solution Method
0119.01	RFEM 5 – RF-DYNAM Pro	Explicit analysis
0119.02	RFEM 5 – RF-DYNAM Pro	Nonlinear implicit Newmark analysis
0119.03	RSTAB 8 – DYNAM Pro	Explicit analysis

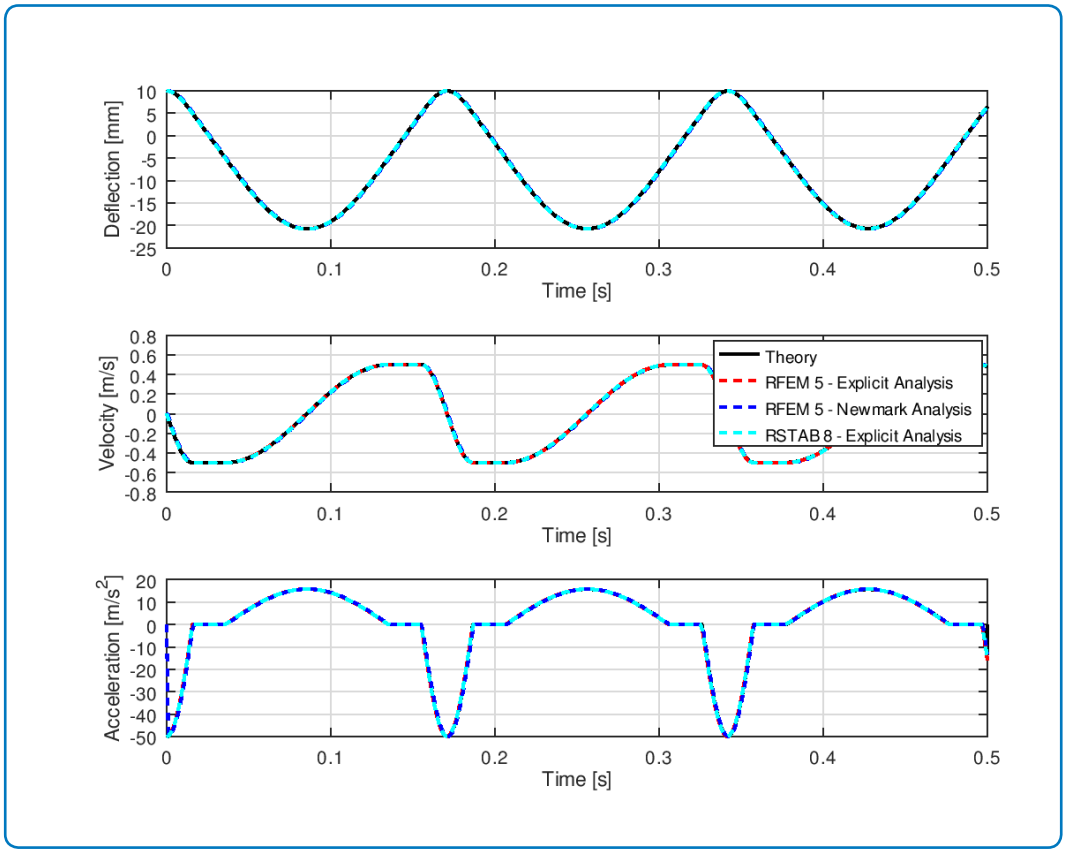

Figure 4: Results comparison

Model	Reference Solution	RFEM 5 / RSTAB 8	
	u_x [mm]	u_x [mm]	Ratio [-]
RFEM 5, Explicit Analysis	-20.434	−20.486	1.003
RFEM 5, Nonlinear Newmark Analysis		−20.432	1.000
RSTAB 8, Explicit Analysis		−20.474	1.002

Model	Reference Solution	RFEM 5 / RSTAB 8	
	$\dot{u}_x$ [m/s]	$\dot{u}_x$ [m/s]	Ratio [-]
RFEM 5, Explicit Analysis	-0.098	−0.097	0.990
RFEM 5, Nonlinear Newmark Analysis		−0.106	1.082
RSTAB 8, Explicit Analysis		−0.097	0.990

Model	Reference Solution	RFEM 5 / RSTAB 8	
	$\ddot{u}_x$ [mm/s^2]	$\ddot{u}_x$ [mm/s^2]	Ratio [-]
RFEM 5, Explicit Analysis	15.434	15.485	1.003
RFEM 5, Nonlinear Newmark Analysis		15.432	1.000
RSTAB 8, Explicit Analysis		15.473	1.003