

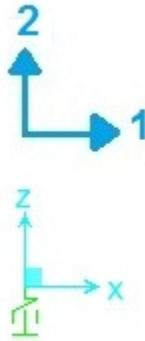
>> IN THE NAME OF GOD <<

Plastic kinematic link analysis in MATLAB and SAP2000

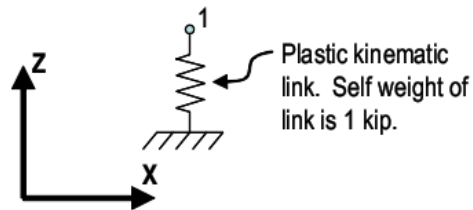
The MATLAB Program is Verified by SAP2000 v.15.1.0 – SAP2000 Verification Report – Example : Problem 6-009

This MATLAB program is written by Salar Delavar Ghashghaei - Date of Publication: April/21/2016

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GEOMETRY, PROPERTIES AND LOADING



Loading

Self weight is applied as a gravity load

Active Degrees of Freedom

U_z only

Link Properties (U_1 DOF)

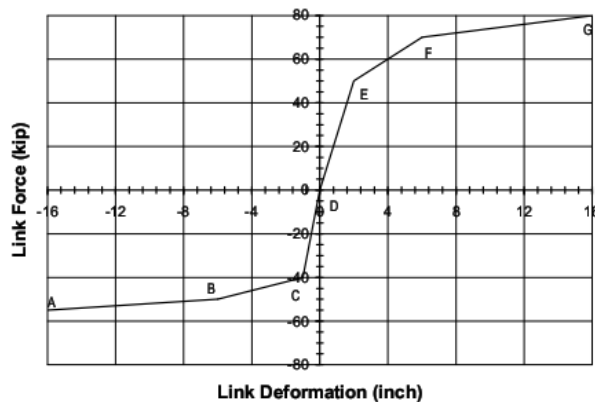
Linear Properties

Not used

Shear Distance

Not used for zero length link

Nonlinear Properties



Point	Deformation (in)	Force (kip)
A	-16	-55
B	-6	-50
C	-1	-40
D	0	0
E	2	50
F	6	70
G	16	80

See force-deformation chart to left

Plastic kinematic link model in SAP2000 (verification example: Problem 6-009)

Define Parameters:

```
% Define Parameters in unit: [mm,kN]
P1 = 0.0; % [kN]
P2 = 0.5; % [kN] Incremental loading [DOF (2)]
lanX = 0.0; lanY = 1.0;
```

Dmax = 304.8; % [mm] Max displacement

Plastic kinematic Link Properties:

d1=50.8; % [mm] Yield displacement
F1=222.4111; % [kN] Yield force
d2=152.4; % [mm]
F2=311.3755; % [kN]
d3=406.4; % [mm] Ultimate displacement
F3=355.8578; % [kN] Ultimate force
 $Rk1 = (F1 - 0) / (d1 - 0);$
 $Rk2 = (F2 - F1) / (d2 - d1);$
 $Rk3 = (F3 - F2) / (d3 - d2);$

Analysis Report:

```
#####  
# Plastic Kinematic Link Analysis #  
#####  
(+)Increment 1 : It is converged in 2 iterations  
(+)Increment 2 : It is converged in 2 iterations  
(+)Increment 3 : It is converged in 2 iterations  
(+)Increment 4 : It is converged in 2 iterations  
(+)Increment 5 : It is converged in 2 iterations  
(+)Increment 6 : It is converged in 2 iterations  
(+)Increment 7 : It is converged in 2 iterations  
(+)Increment 8 : It is converged in 2 iterations  
(+)Increment 9 : It is converged in 2 iterations  
(+)Increment 10 : It is converged in 2 iterations  
(+)Increment 11 : It is converged in 2 iterations.  
.  
.  
(+)Increment 664 : It is converged in 177 iterations  
(+)Increment 665 : It is converged in 175 iterations  
(+)Increment 666 : It is converged in 174 iterations  
(+)Increment 667 : It is converged in 172 iterations  
(+)Increment 668 : It is converged in 171 iterations  
(+)Increment 669 : It is converged in 169 iterations  
(+)Increment 670 : It is converged in 168 iterations  
(+)Increment 671 : It is converged in 166 iterations  
(+)Increment 672 : It is converged in 165 iterations  
(+)Increment 673 : It is converged in 163 iterations  
(+)Increment 674 : It is converged in 162 iterations  
(+)Increment 675 : It is converged in 161 iterations  
(+)Increment 676 : It is converged in 159 iterations  
(+)Increment 677 : It is converged in 158 iterations  
## Link reached to ultimate displacement ##
```

SAP2000 Analysis Report:

B E G I N A N A L Y S I S

2016/04/21 22:24:54

RUNNING ANALYSIS WITHIN THE GUI PROCESS
USING THE ADVANCED SOLVER (PROVIDES LIMITED INSTABILITY INFORMATION)

NUMBER OF JOINTS	=	1
WITH MASS	=	1
NUMBER OF LINK/SUPPORT ELEMENTS	=	1
NUMBER OF LOAD PATTERNS	=	1
NUMBER OF ACCELERATION LOADS	=	6
NUMBER OF LOAD CASES	=	2

N O N L I N E A R S T A T I C A N A L Y S I S

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CASE: NLSTAT1
STARTING FROM ZERO (UNSTRESSED) INITIAL CONDITIONS
LOAD CONTROL TYPE = CONJUGATE DISPLACEMENT

NUMBER OF STAGES	=	0
TYPE OF GEOMETRIC NONLINEARITY	=	NONE
INCLUDE ELASTIC MATERIAL NONLINEARITY	=	NO
INCLUDE INELASTIC MATERIAL NONLINEARITY	=	NO
METHOD TO USE WHEN HINGES DROP LOAD	=	UNLOAD ENTIRE STRUCTURE
SAVE POSITIVE INCREMENTS ONLY	=	YES
RELATIVE FORCE CONVERGENCE TOLERANCE	=	0.000100
RELATIVE EVENT TOLERANCE	=	0.010000

ELEMENT FORMATION

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Saved Steps (200	Null Steps 50	Total Steps 200	Iteration this Step 10/10	Relative Unbalance 1.000000	Curr Step Size 0.010000	Curr Sum of Steps 1.000000	Max Sum of Steps 1.000000)
0	0	1	1	37.500000	0.010000	.000000	.000000
1	0	1	Conv 2	.000000	0.010000	0.010000	0.010000
2	0	2	Conv 1	.000000	0.010000	0.020000	0.020000
3	0	3	Conv 1	.000000	0.010000	0.030000	0.030000
4	0	4	Conv 1	.000000	0.010000	0.040000	0.040000
5	0	5	Conv 1	.000000	0.010000	0.050000	0.050000
6	0	6	Conv 1	.000000	0.010000	0.060000	0.060000
7	0	7	Conv 1	7.40E-14	0.010000	0.070000	0.070000
8	0	8	Conv 1	.000000	0.010000	0.080000	0.080000
9	0	9	Conv 1	.000000	0.010000	0.090000	0.090000
10	0	10	Conv 1	7.40E-14	0.010000	0.100000	0.100000
11	0	11	Conv 1	1.48E-13	0.010000	0.110000	0.110000
12	0	12	Conv 1	2.96E-13	0.010000	0.120000	0.120000
13	0	13	Conv 1	2.96E-13	0.010000	0.130000	0.130000
14	0	14	Conv 1	2.96E-13	0.010000	0.140000	0.140000
15	0	15	Conv 1	2.96E-13	0.010000	0.150000	0.150000
16	0	16	Conv 1	4.44E-13	0.010000	0.160000	0.160000
16	0	17	1	16.666667	0.010000	0.160000	0.160000
17	0	17	Conv 2	.000000	0.010000	0.170000	0.170000
18	0	18	Conv 1	1.48E-13	0.010000	0.180000	0.180000
19	0	19	Conv 1	1.48E-13	0.010000	0.190000	0.190000
20	0	20	Conv 1	1.48E-13	0.010000	0.200000	0.200000
21	0	21	Conv 1	1.48E-13	0.010000	0.210000	0.210000
22	0	22	Conv 1	1.48E-13	0.010000	0.220000	0.220000
23	0	23	Conv 1	1.48E-13	0.010000	0.230000	0.230000
24	0	24	Conv 1	1.48E-13	0.010000	0.240000	0.240000
25	0	25	Conv 1	1.48E-13	0.010000	0.250000	0.250000
26	0	26	Conv 1	1.48E-13	0.010000	0.260000	0.260000
27	0	27	Conv 1	1.48E-13	0.010000	0.270000	0.270000
28	0	28	Conv 1	1.48E-13	0.010000	0.280000	0.280000
29	0	29	Conv 1	1.48E-13	0.010000	0.290000	0.290000
30	0	30	Conv 1	1.48E-13	0.010000	0.300000	0.300000
31	0	31	Conv 1	1.48E-13	0.010000	0.310000	0.310000
32	0	32	Conv 1	1.48E-13	0.010000	0.320000	0.320000
33	0	33	Conv 1	1.48E-13	0.010000	0.330000	0.330000
34	0	34	Conv 1	1.48E-13	0.010000	0.340000	0.340000
35	0	35	Conv 1	1.48E-13	0.010000	0.350000	0.350000
36	0	36	Conv 1	1.48E-13	0.010000	0.360000	0.360000
37	0	37	Conv 1	1.48E-13	0.010000	0.370000	0.370000
38	0	38	Conv 1	1.48E-13	0.010000	0.380000	0.380000
39	0	39	Conv 1	1.48E-13	0.010000	0.390000	0.390000
40	0	40	Conv 1	.000000	0.010000	0.400000	0.400000
41	0	41	Conv 1	.000000	0.010000	0.410000	0.410000
42	0	42	Conv 1	.000000	0.010000	0.420000	0.420000
43	0	43	Conv 1	.000000	0.010000	0.430000	0.430000
44	0	44	Conv 1	.000000	0.010000	0.440000	0.440000
45	0	45	Conv 1	2.96E-13	0.010000	0.450000	0.450000
46	0	46	Conv 1	2.96E-13	0.010000	0.460000	0.460000
47	0	47	Conv 1	2.96E-13	0.010000	0.470000	0.470000
48	0	48	Conv 1	5.92E-13	0.010000	0.480000	0.480000
49	0	49	Conv 1	5.92E-13	0.010000	0.490000	0.490000
50	0	50	Conv 1	2.96E-13	0.010000	0.500000	0.500000
51	0	51	Conv 1	2.96E-13	0.010000	0.510000	0.510000
52	0	52	Conv 1	2.96E-13	0.010000	0.520000	0.520000

53	0	53	Conv	1	2.96E-13	0.010000	0.530000	0.530000
54	0	54	Conv	1	2.96E-13	0.010000	0.540000	0.540000
55	0	55	Conv	1	2.96E-13	0.010000	0.550000	0.550000
56	0	56	Conv	1	2.96E-13	0.010000	0.560000	0.560000
57	0	57	Conv	1	2.96E-13	0.010000	0.570000	0.570000
58	0	58	Conv	1	2.96E-13	0.010000	0.580000	0.580000
59	0	59	Conv	1	2.96E-13	0.010000	0.590000	0.590000
60	0	60	Conv	1	2.96E-13	0.010000	0.600000	0.600000
61	0	61	Conv	1	2.96E-13	0.010000	0.610000	0.610000
62	0	62	Conv	1	2.96E-13	0.010000	0.620000	0.620000
63	0	63	Conv	1	2.96E-13	0.010000	0.630000	0.630000
64	0	64	Conv	1	2.96E-13	0.010000	0.640000	0.640000
65	0	65	Conv	1	2.96E-13	0.010000	0.650000	0.650000
66	0	66	Conv	1	2.96E-13	0.010000	0.660000	0.660000
67	0	67	Conv	1	2.96E-13	0.010000	0.670000	0.670000
68	0	68	Conv	1	2.96E-13	0.010000	0.680000	0.680000
69	0	69	Conv	1	2.96E-13	0.010000	0.690000	0.690000
70	0	70	Conv	1	2.96E-13	0.010000	0.700000	0.700000
71	0	71	Conv	1	2.96E-13	0.010000	0.710000	0.710000
72	0	72	Conv	1	2.96E-13	0.010000	0.720000	0.720000
73	0	73	Conv	1	2.96E-13	0.010000	0.730000	0.730000
74	0	74	Conv	1	2.96E-13	0.010000	0.740000	0.740000
75	0	75	Conv	1	2.96E-13	0.010000	0.750000	0.750000
76	0	76	Conv	1	2.96E-13	0.010000	0.760000	0.760000
77	0	77	Conv	1	2.96E-13	0.010000	0.770000	0.770000
78	0	78	Conv	1	2.96E-13	0.010000	0.780000	0.780000
79	0	79	Conv	1	.000000	0.010000	0.790000	0.790000
80	0	80	Conv	1	2.96E-13	0.010000	0.800000	0.800000
81	0	81	Conv	1	5.92E-13	0.010000	0.810000	0.810000
82	0	82	Conv	1	8.88E-13	0.010000	0.820000	0.820000
83	0	83	Conv	1	8.88E-13	0.010000	0.830000	0.830000
84	0	84	Conv	1	8.88E-13	0.010000	0.840000	0.840000
85	0	85	Conv	1	1.18E-12	0.010000	0.850000	0.850000
86	0	86	Conv	1	1.48E-12	0.010000	0.860000	0.860000
87	0	87	Conv	1	1.48E-12	0.010000	0.870000	0.870000
88	0	88	Conv	1	1.48E-12	0.010000	0.880000	0.880000
89	0	89	Conv	1	1.48E-12	0.010000	0.890000	0.890000
90	0	90	Conv	1	1.78E-12	0.010000	0.900000	0.900000
91	0	91	Conv	1	2.07E-12	0.010000	0.910000	0.910000
92	0	92	Conv	1	2.07E-12	0.010000	0.920000	0.920000
93	0	93	Conv	1	2.07E-12	0.010000	0.930000	0.930000
94	0	94	Conv	1	2.07E-12	0.010000	0.940000	0.940000
95	0	95	Conv	1	2.37E-12	0.010000	0.950000	0.950000
96	0	96	Conv	1	2.37E-12	0.010000	0.960000	0.960000
97	0	97	Conv	1	2.37E-12	0.010000	0.970000	0.970000
98	0	98	Conv	1	2.66E-12	0.010000	0.980000	0.980000
99	0	99	Conv	1	2.96E-12	0.010000	0.990000	0.990000
100	0	100	Conv	1	2.96E-12	0.010000	1.000000	1.000000

TIME FOR INITIALIZING ANALYSIS	=	0.25
TIME FOR CONTROLLING ANALYSIS	=	0.14
TIME FOR UPDATING LOADS AND STATE	=	0.06
TIME FOR FORMING STIFFNESS MATRIX	=	0.34
TIME FOR SOLVING STIFFNESS MATRIX	=	3.20
TIME FOR CALCULATING DISPLACEMENTS	=	0.62
TIME FOR DETERMINING EVENTS	=	0.00
TIME FOR SAVING RESULTS	=	0.69

TOTAL TIME FOR THIS ANALYSIS	=	5.30

A N A L Y S I S C O M P L E T E

2016/04/21 22:25:04

Plot :

Link/Support Property Data

Link/Support Type: **MultiLinear Plastic**

Property Name: **PLAK1** Set Default Name

Property Notes: Modify/Show...

Total Mass and Weight

Mass: **0.** Rotational Inertia 1: **0.**

Weight: **4.4482** Rotational Inertia 2: **0.**

Rotational Inertia 3: **0.**

Factors For Line, Area and Solid Springs

Property is Defined for This Length In a Line Spring: **25.4**

Property is Defined for This Area In Area and Solid Springs: **645.16**

Directional Properties

Direction	Fixed	NonLinear	Properties
<input checked="" type="checkbox"/> U1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Modify/Show for U1...
<input type="checkbox"/> U2	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for U2...
<input type="checkbox"/> U3	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for U3...
<input type="checkbox"/> R1	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R1...
<input type="checkbox"/> R2	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R2...
<input type="checkbox"/> R3	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R3...

Fix All Clear All

P-Delta Parameters

Advanced...

OK Cancel

Link/Support Directional Properties

Edit

Identification

Property Name: **PLAK1**

Direction: **U1**

Type: **MultiLinear Plastic**

NonLinear: **Yes**

Hysteresis Type And Parameters

Hysteresis Type: **Kinematic**

No Parameters Are Required For This Hysteresis Type

Properties Used For Linear Analysis Cases

Effective Stiffness: **0.**

Effective Damping: **0.**

Multi-Linear Force-Deformation Definition

	Displ	Force
4	0.	0.
5	50.8	222.4111
6	152.4	311.3755
7	406.4	355.8578

Order Rows Delete Row Add Row 8

Hysteresis Definition Sketch

Multilinear Plastic - Kinematic

OK Cancel

Plastic kinematic link properties in SAP2000

Define Load Patterns

Load Patterns

Load Pattern Name	Type	Self Weight Multiplier	Auto Lateral Load Pattern
1	OTHER	0	
1	OTHER	0	

Click To:

Add New Load Pattern

Modify Load Pattern

Modify Lateral Load Pattern...

Delete Load Pattern

Show Load Pattern Notes...

OK

Cancel

Define Load Cases

Load Cases

Load Case Name	Load Case Type
NLSTAT1	Nonlinear Static

Click to:

Add New Load Case...

Add Copy of Load Case...

Modify/Show Load Case...

Delete Load Case

Display Load Cases

Show Load Case Tree...

OK

Cancel

Load Case Data - Nonlinear Static

Load Case Name: NLSTAT1 [Set Def Name](#)

Notes: [Modify/Show...](#)

Load Case Type: Static [Design...](#)

Initial Conditions:

☒ Zero Initial Conditions - Start from Unstressed State

☐ Continue from State at End of Nonlinear Case [...](#)

Important Note: Loads from this previous case are included in the current case

Modal Load Case:

All Modal Loads Applied Use Modes from Case [...](#)

Loads Applied:

Load Type	Load Name	Scale Factor
Load Pattern	1	1.
Load Pattern	1	1.

Add

Modify

Delete

Other Parameters:

Load Application: [Displ Control](#) [Modify/Show...](#)

Results Saved: [Multiple States](#) [Modify/Show...](#)

Nonlinear Parameters: [User Defined](#) [Modify/Show...](#)

Analysis Type:

☐ Linear

☒ Nonlinear

☐ Nonlinear Staged Construction

Geometric Nonlinearity Parameters:

☒ None

☐ P-Delta

☐ P-Delta plus Large Displacements

OK

Cancel

load patterns and load cases in SAP2000

Load Application Control for Nonlinear Static Analysis

Load Application Control

- ☐ Full Load
☒ Displacement Control

Control Displacement

- ☒ Use Conjugate Displacement
☐ Use Monitored Displacement

Load to a Monitored Displacement Magnitude of

Monitored Displacement

- ☒ DOF at Joint
☐ Generalized Displacement

OK

Cancel

Pushover Curve

File

Static Nonlinear Case

NLSTAT1

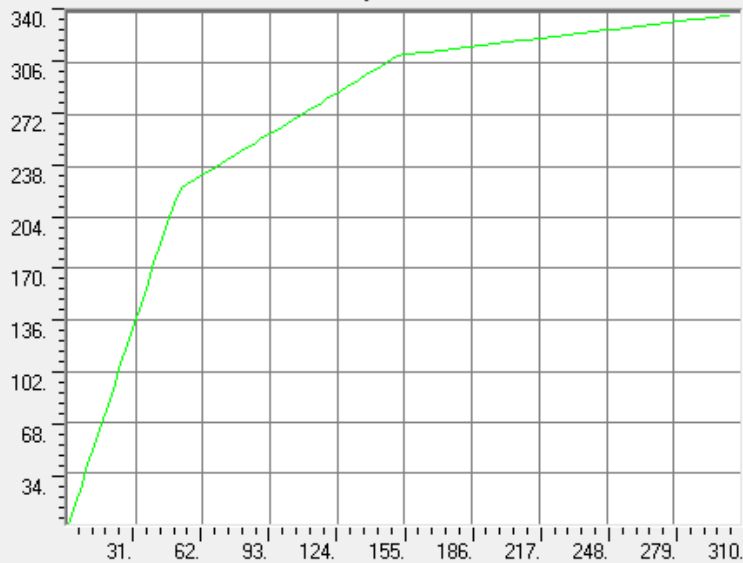
Plot Type

Resultant Base Shear vs Monitored Displacement

Units

KN, mm, C

Displacement



Current Plot Parameters

VDP01

Add New Parameters...

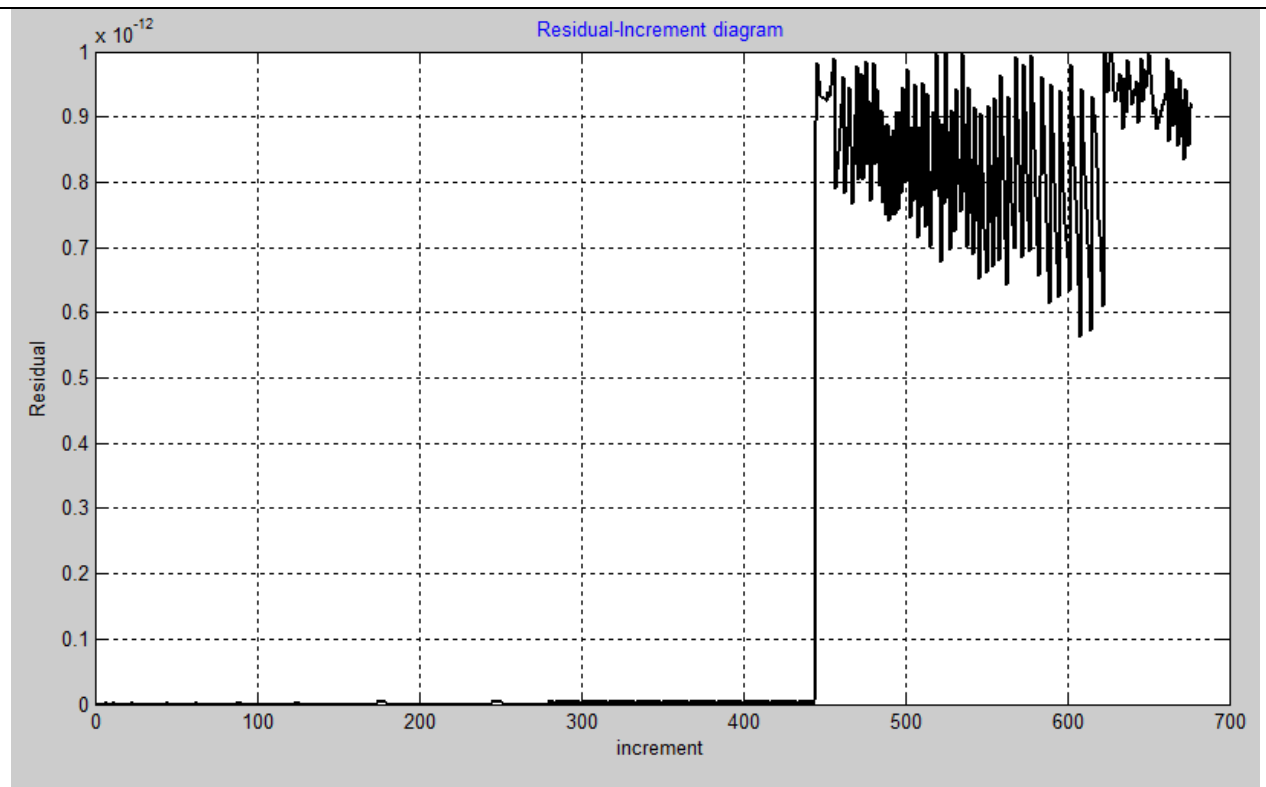
Add Copy of Parameters...

Modify/Show Parameters...

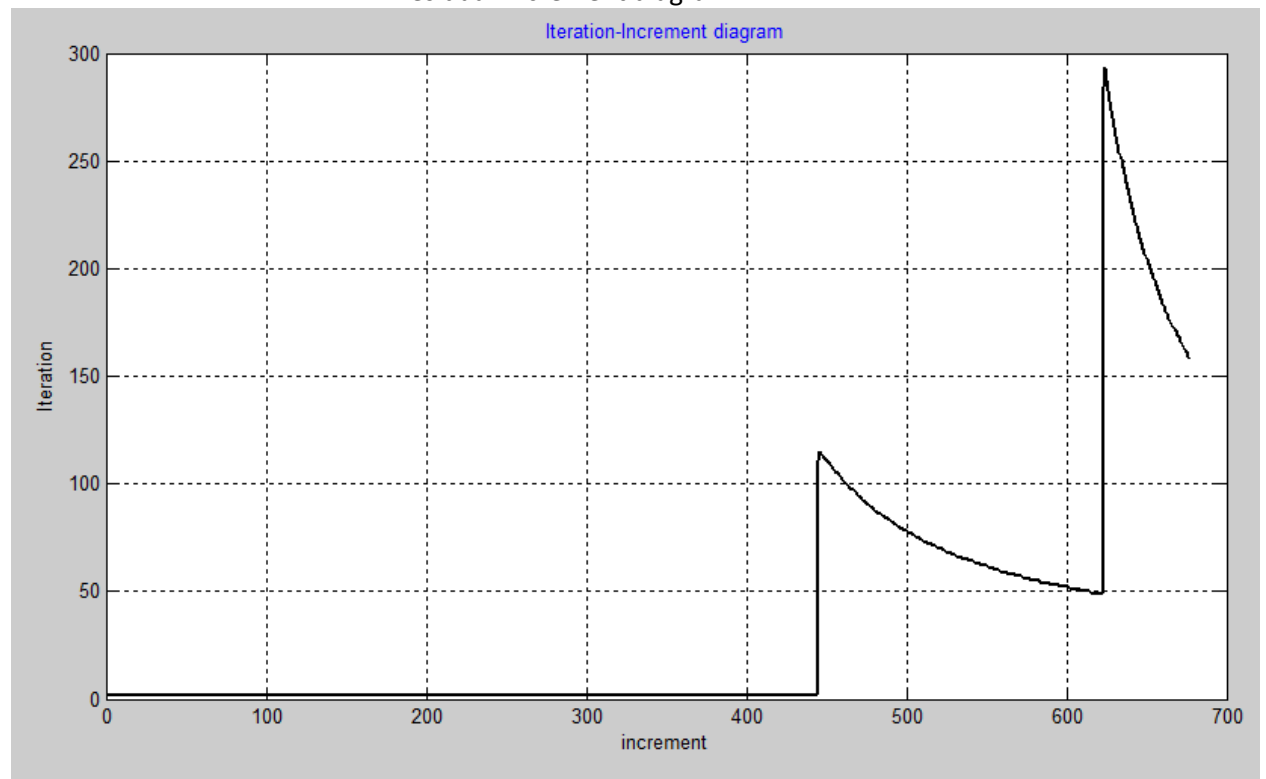
OK

Cancel

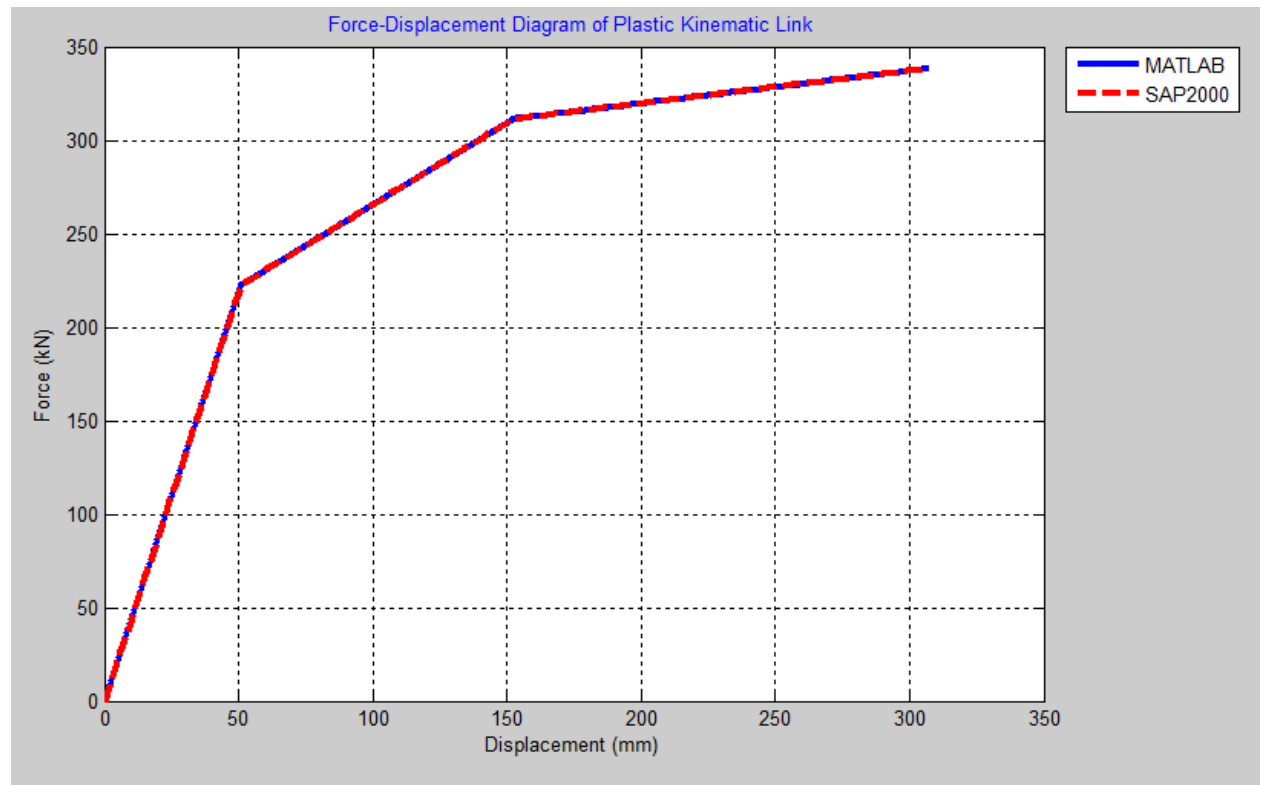
Force-Displacement diagram in SAP2000



Residual-Increment diagram in MATLAB



Iteration-Increment diagram in MATLAB



Force-displacement diagram of kinematic link in SAP2000 and MATLAB