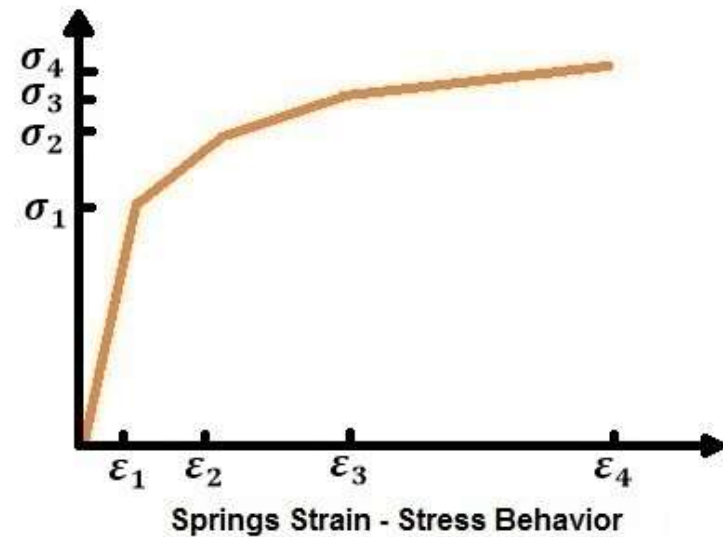
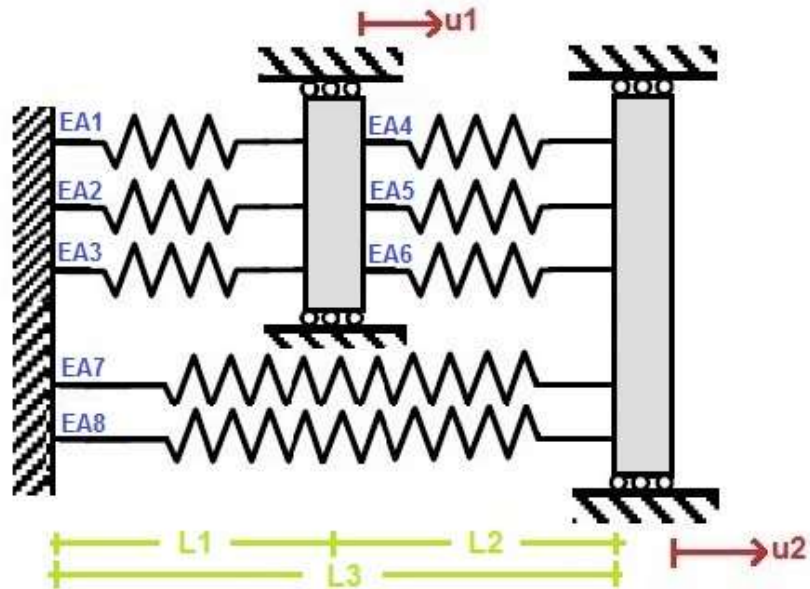


>> IN THE NAME OF GOD <<

Analysis of Linear and Nonlinear Springs with Displacement Control in MATLAB and C++



MATLAB and C++ program is written by Salar Delavar Ghashghaei – Publication Date: 14/June/2017

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Define Parameters:

```
% Define Parameters in Free Unit
P1 = 0; % External force [DOF(1)]
P2 = 0; % External force [DOF(2)]
D2 = 0.1; % Initial Incremental Displacement [DOF(2)]
itermax = 500; % maximum number of iterations
tolerance = 1e-12; % specified tolerance for convergence
u = 0; % initial guess value
```

Spring Properties:

```
% Strain Stress
DATA = [.0012 200 .005 300 .01 320 .05 350 10;
        .0013 210 .006 310 .011 330 .05 360 10;
        .0014 220 .007 320 .012 340 .05 370 10;
        .0015 230 .008 330 .013 350 .05 380 10;
        .0016 240 .009 340 .014 360 .05 390 10;
```

```

        .0017 250 .01 350 .015 370 .05 400 10;
        .0018 260 .011 360 .016 380 .05 410 20;
        .0019 270 .012 370 .017 390 .05 420 20];
L1 = 1000; % Length of spring 1
L2 = 1000; % Length of spring 2
L3 = 2000; % Length of spring 3
D2max=L1*max(DATA(:,7)); % Maximum displacement [DOF(2)]
for i=1:8
A(i)= DATA(i,9);
E1(i)=(DATA(i,2)-0)/(DATA(i,1)-0);
E2(i)=(DATA(i,4)-DATA(i,2))/(DATA(i,3)-DATA(i,1));
E3(i)=(DATA(i,6)-DATA(i,4))/(DATA(i,5)-DATA(i,3));
E4(i)=(DATA(i,8)-DATA(i,6))/(DATA(i,7)-DATA(i,5));
end
m = D2max/D2 +1; % Number of steps increment

```

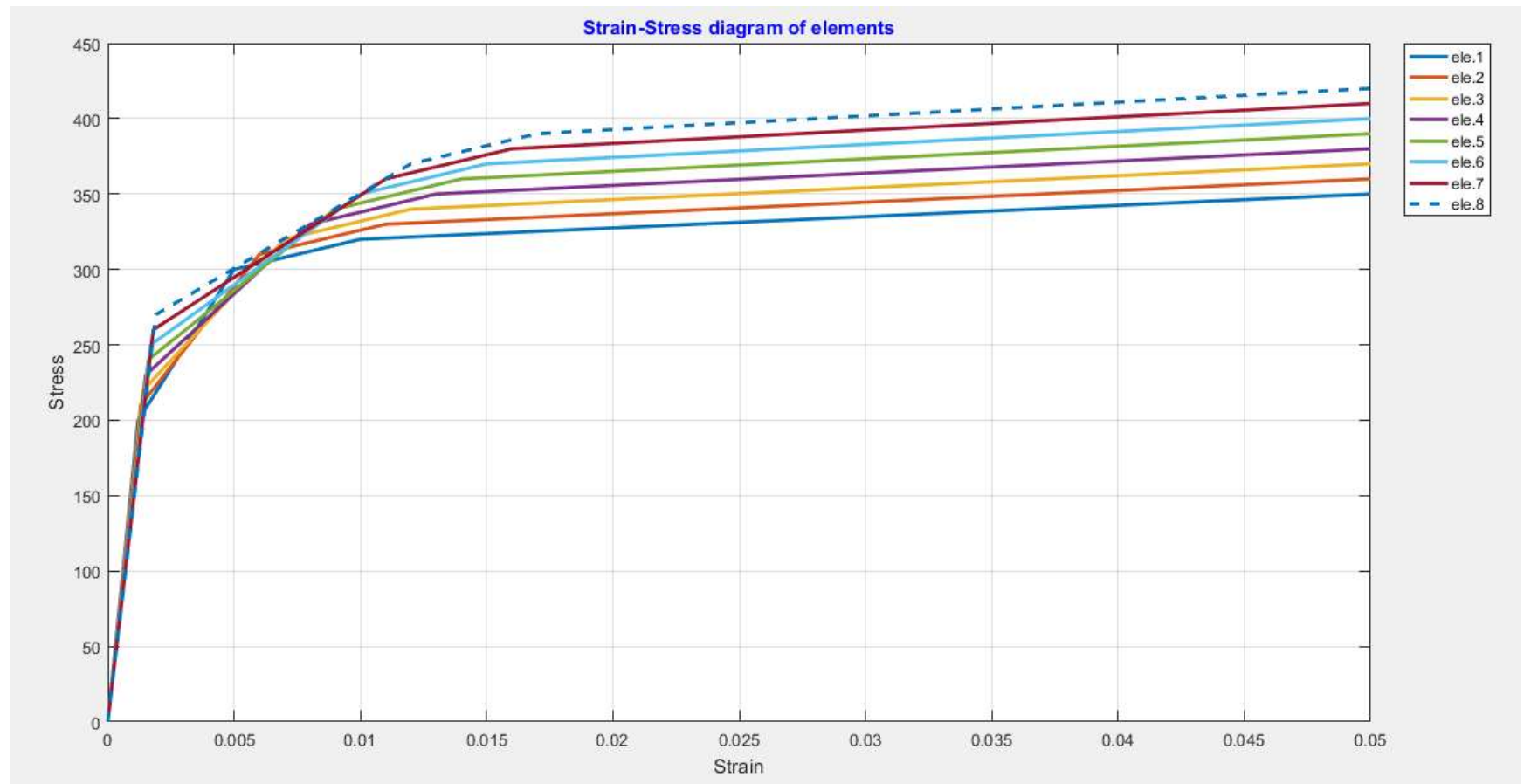
```

#####
# Pushover Analysis of Nonlinear Springs #
#####
(+)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 490 : It is converged in 11 iterations
(+)Increment 491 : It is converged in 11 iterations
(+)Increment 492 : It is converged in 11 iterations
(+)Increment 493 : It is converged in 11 iterations
(+)Increment 494 : It is converged in 11 iterations
(+)Increment 495 : It is converged in 11 iterations
(+)Increment 496 : It is converged in 11 iterations
(+)Increment 497 : It is converged in 11 iterations
(+)Increment 498 : It is converged in 11 iterations
(+)Increment 499 : It is converged in 11 iterations
(+)Increment 500 : It is converged in 11 iterations
## Displacement reached to ultimate displacement ##

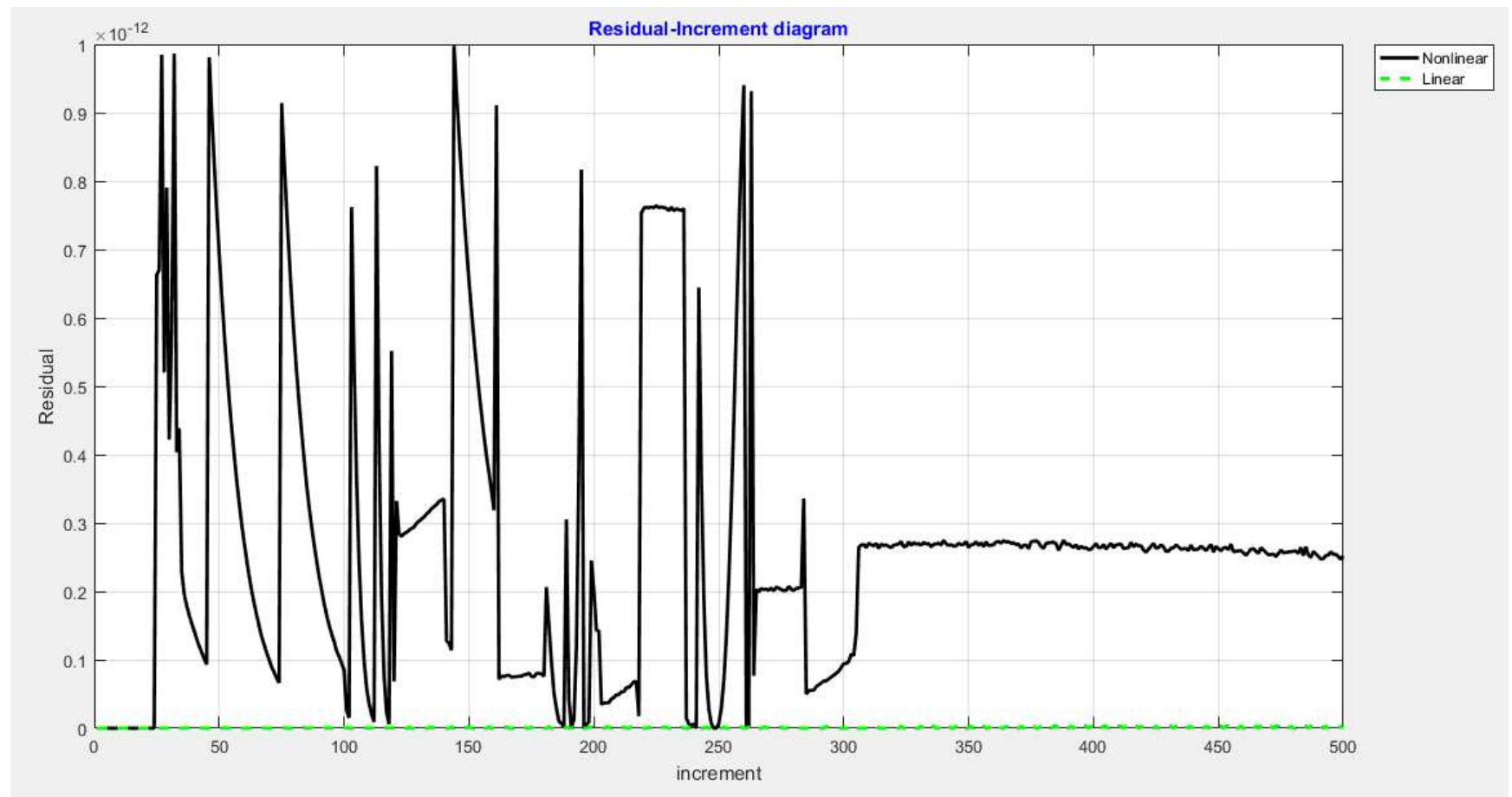
```

```
#####  
#   Pushover Analysis of Linear Springs   #  
#####  
(+)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 490 : It is converged in 2 iterations  
(+)Increment 491 : It is converged in 2 iterations  
(+)Increment 492 : It is converged in 2 iterations  
(+)Increment 493 : It is converged in 2 iterations  
(+)Increment 494 : It is converged in 2 iterations  
(+)Increment 495 : It is converged in 2 iterations  
(+)Increment 496 : It is converged in 2 iterations  
(+)Increment 497 : It is converged in 2 iterations  
(+)Increment 498 : It is converged in 2 iterations  
(+)Increment 499 : It is converged in 2 iterations  
(+)Increment 500 : It is converged in 2 iterations
```

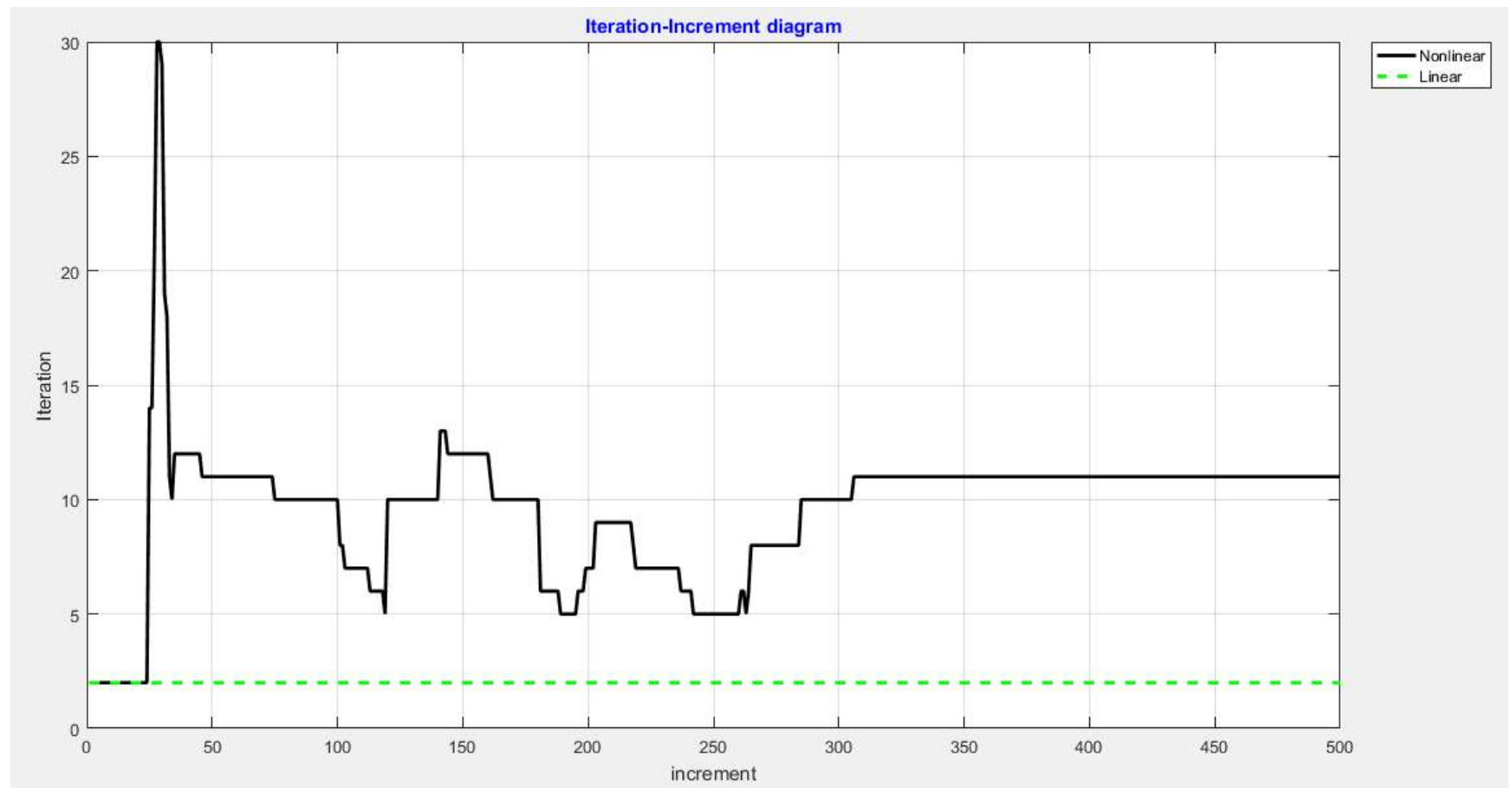
Plot :



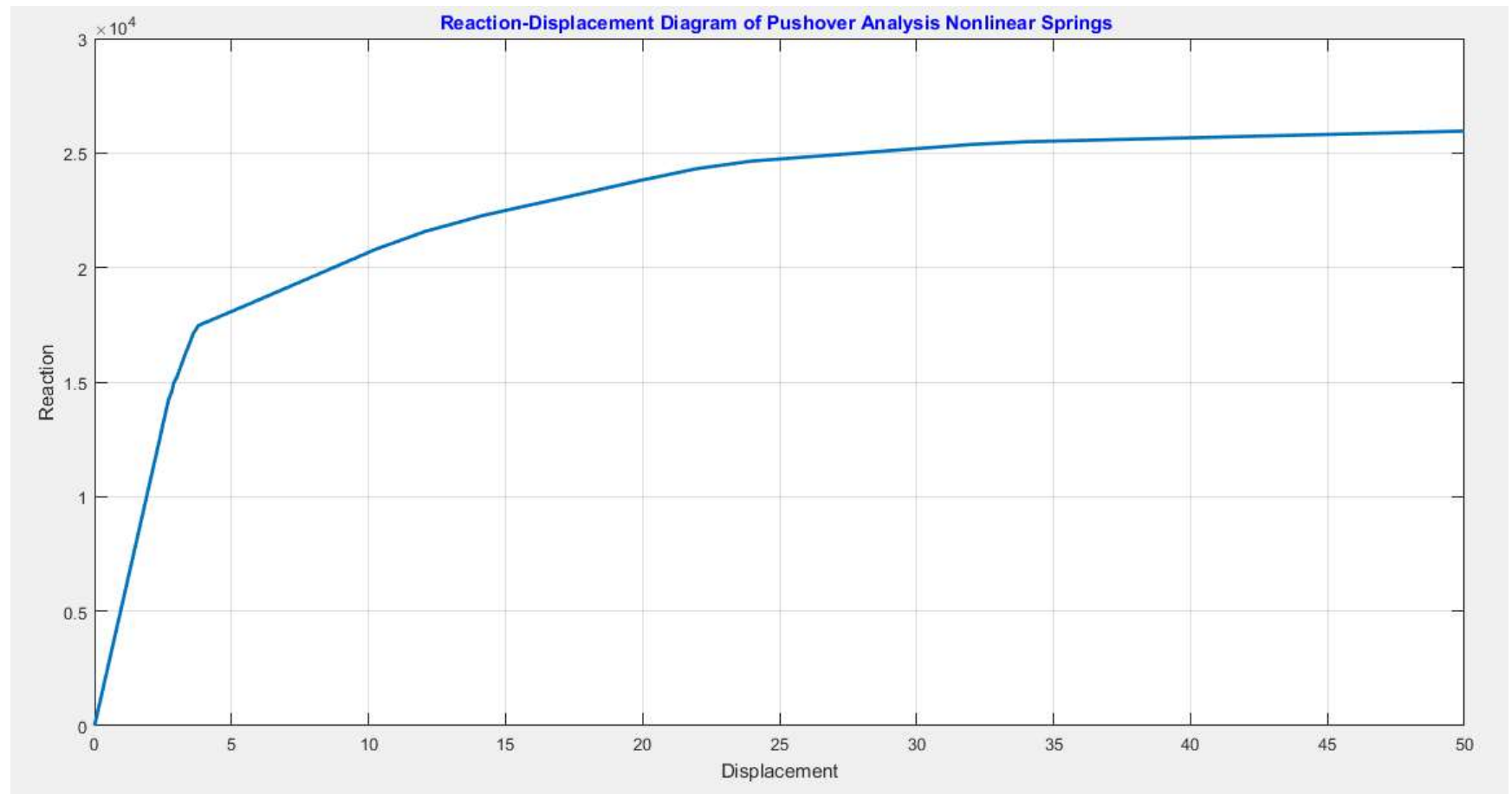
Figure(1) Strain-Stress diagram of elements in MATLAB



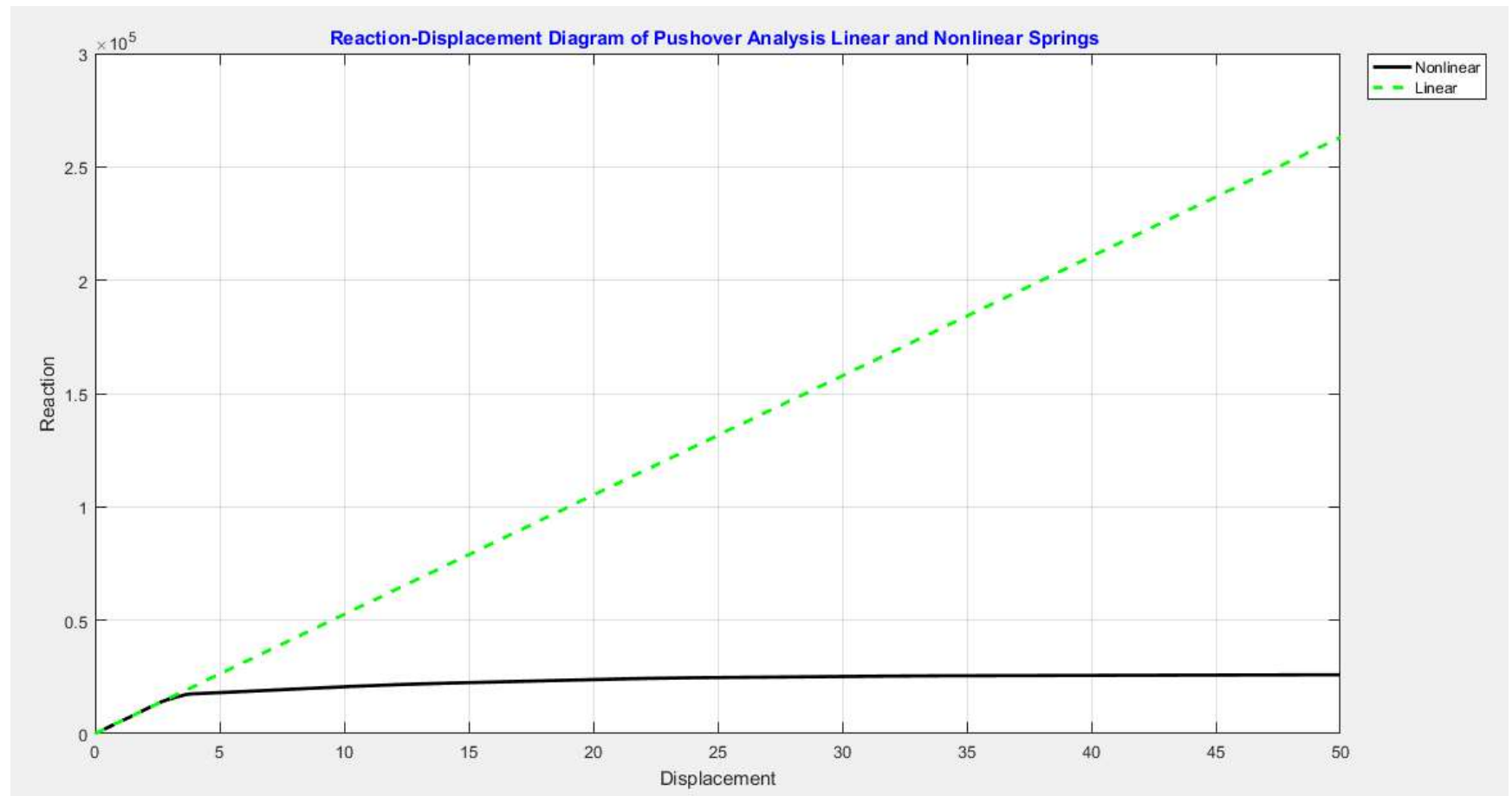
Figure(2) Residual-Increment diagram in MATLAB



Figure(3) Iteration-Increment diagram in MATLAB



Figure(4) Reaction-Displacement diagram of Nonlinear Springs in MATLAB



Figure(4) Reaction-Displacement diagram of Linear and Nonlinear Springs in MATLAB


```
E:\C++\examples\PushoverAnalysisNonlinear8SpringsDC2dofStrain.exe
*****
* >> IN THE NAME OF GOD << *
* Pushover Analysis of Nonlinear Springs with Displacement Control *
* UNIT: [ Free Unit] *
*-----*
* Program is written by Salar Delavar Ghashghaei *
* E-mail:salar.d.ghashghaei@gmail.com *
*****
===== Input Data =====

External force [DOF(1)]: 0
External force [DOF(2)]: 0
Initial External Incremental Displacement [DOF (2)]: 0.1
Maximum Displacement (Min spring Length * Max Ultimate Strain)[DOF (2)]: 50
Maximum number of iterations: 500
Specified tolerance for convergence: 1e-012
Number of calculation: 501

===== Analysis Report =====
-----
Increment Iteration Reaction Disp.[DOF(1)] Disp.[DOF(2)]
-----
1 2 526.14 0.049 0.100
2 2 1052.29 0.099 0.200
3 2 1578.43 0.148 0.300
4 2 2104.57 0.197 0.400
5 2 2630.72 0.247 0.500
6 2 3156.86 0.296 0.600
7 2 3683.00 0.346 0.700
8 2 4209.14 0.395 0.800
9 2 4735.29 0.444 0.900
10 2 5261.43 0.494 1.000
11 2 5787.57 0.543 1.100
12 2 6313.72 0.592 1.200
13 2 6839.86 0.642 1.300
14 2 7366.00 0.691 1.400
15 2 7892.15 0.740 1.500
16 2 8418.29 0.790 1.600
17 2 8944.43 0.839 1.700
18 2 9470.57 0.889 1.800
19 2 9996.72 0.938 1.900
20 2 10522.86 0.987 2.000
21 2 11049.00 1.037 2.100
22 2 11575.15 1.086 2.200
```

Figure(5) Pushover analysis of Nonlinear springs with Displacement control in C++

```
E:\C++\examples\PushoverAnalysisNonlinear8SpringsDC2dofStrain.exe

477      11      25889.68      24.285      47.700
478      11      25892.60      24.336      47.800
479      11      25895.53      24.387      47.900
480      11      25898.45      24.438      48.000
481      11      25901.38      24.489      48.100
482      11      25904.30      24.540      48.200
483      11      25907.23      24.591      48.300
484      11      25910.16      24.642      48.400
485      11      25913.08      24.693      48.500
486      11      25916.01      24.744      48.600
487      11      25918.93      24.795      48.700
488      11      25921.86      24.846      48.800
489      11      25924.79      24.897      48.900
490      11      25927.72      24.948      49.000
491      11      25930.64      24.998      49.100
492      11      25933.57      25.049      49.200
493      11      25936.50      25.100      49.300
494      11      25939.43      25.151      49.400
495      11      25942.35      25.202      49.500
496      11      25945.28      25.253      49.600
497      11      25948.21      25.304      49.700
498      11      25951.14      25.355      49.800
499      11      25954.07      25.406      49.900
500      11      25957.00      25.457      50.000

## Displacement reached to ultimate displacement ##

Section ductility ratio: 12.103 - Over strength factor: 1.194

=====
= Bilinear curve fitted =
= Disp.[DOF(2)] Reaction =
=====
      0      0
      4.1312      21735.917
      50.0000      25956.998
=====

CPU time : 0.507 seconds
Date and Time : Wed Jun 14 13:22:59 2017
```

Figure(6) Pushover analysis of Nonlinear springs with Displacement control in C++