A Benchmarch for Nonlinear Structural Identification

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THE STRUCTURE

The considered structure consists of two facing clamped steel beams connected by a non identified flexible element, see Figure 1. The two beams lay on two parallel planes, so that the connecting element is inclined. The length of each beam is 300 mm, the width 20 mm, and the thicknesses of the two members are 6 mm and 5.5 mm, respectively. The linear, elastic material adopted for the beams is characterized by a Young modulus $E = 210$ GPa, a Poisson ratio $\nu = 0.33$, and a density $\rho = 7800$ Kg/m^3. Eight sensors can be placed along the beams, in the locations specified in Figure 1 (point A, B, C, D, E, F, G and H). There, displacements, velocities and accelerations in direction z can be measured. A time dependent force in z direction can be applied at one sensor point per time.

HOW TO RUN THE BENCHMARK

The benchmark function, provided in the form of an encrypted Matlab p-file, is called as follows:

```
[time,d,v,a,load]=BeNSI2014v2(LoadPoint,LoadType,LoadPar,Tmax,dtmax)
```

The inputs arguments are:

- `LoadPoint`: the sensor where the load is applied. 1=A, 2=B, 3=C, 4=D, 5=E, 6=F, 7=G, 8=H.
- `LoadType`: the load type, `1` for harmonic function, `2` tabular time history, and `3` for a slow ramp load (static experiment).
- `LoadPar`: matrix containing the quantities to define the load history.
  - If `LoadType=1`, then `LoadPar`=$[A\ \omega\ \phi\ B]$, according to the formula: $F = A\sin(\omega t + \phi) + B$
  - If `LoadType=2`, then `LoadPar` is a matrix containing the time-load amplitude pairs: `LoadPar`=$[t_1\ L_1; t_2\ L_2; ...; t_n\ L_n]$
  - if `LoadType=3`, then `LoadPar` contains the maximum load value.

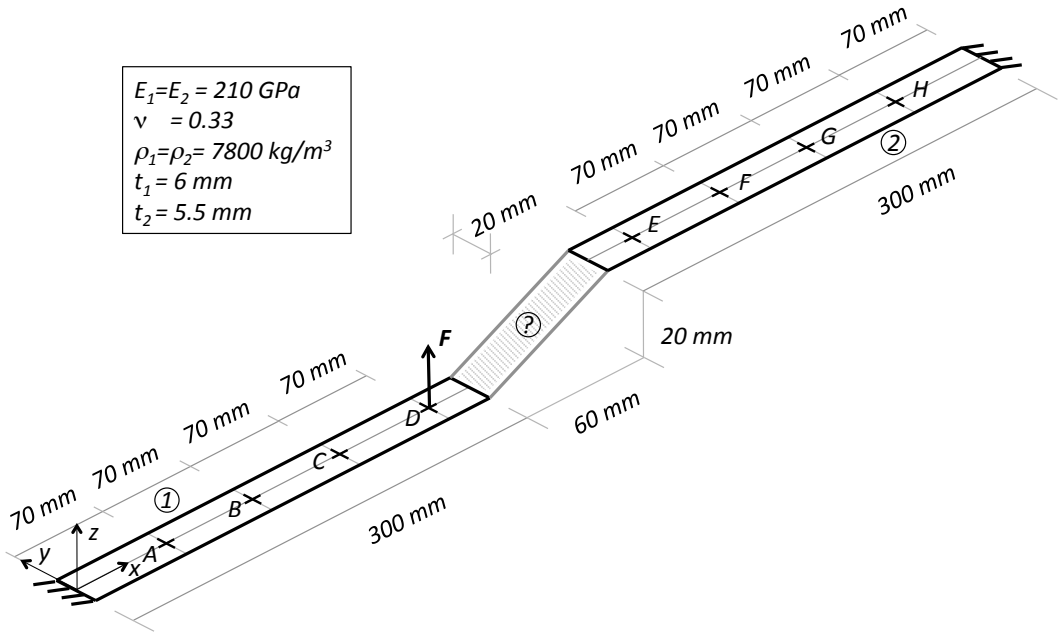

Figure 1: benchmark structure. The two clamped beams are connected by a non identified element. A force in the positive direction on sensor D is indicated.

- `Tmax`: maximum simulation time.
- `dtmax`: maximum allowable time step. It is recommended to experiment different values of this parameter to check for good accuracy of the obtained solution. In general, the smallest `dtmax`, the better the accuracy, at the expense of increased computational time.

The outputs are respectively:

- `time`: time vector.
- `d`: displacement signal from the eight sensors. The first row is from sensor A, the second from sensor B, etc.
- `v`: velocity signal from the eight sensors. In case of static load (`LoadType=3`) this vector is empty.
- `a`: acceleration signal from the eight sensors. In case of static load (`LoadType=3`) this vector is empty.
- `load`: load amplitude at each computed time step.

The system has an operational limit that cannot be exceeded. The limit is currently set at 40 mm: if the displacement any point of the structure exceeds this value, a message is issued and the time integration stops. The sensors signal is in any case available up to the the failure time.

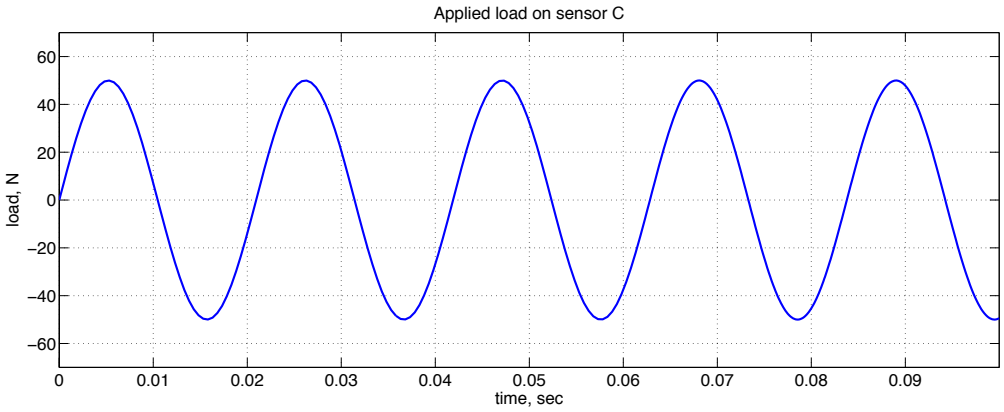

Figure 2: Harmonic load $F = 50\sin(300t)$ applied at sensor C.

Since the time integration scheme adopts a variable time step, it is possible to specify a maximum time step `dtmax` that the time marching scheme will not exceed. This can be useful if a certain sampling rate is desired.

Please note that, in case of tabular load, the last load amplitude provided is propagated constant till the maximum desired time `Tmax`. In other words,

```
[time,d,v,a,load]=BeNSI2014v2(3,2,[0 0; 0.1 10],0.2,2e-4)
```

is equivalent to:

```
[time,d,v,a,load]=BeNSI2014v2(3,2,[0 0; 0.1 10; 0.2 10],0.2,2e-4)
```

The code provides a figure with the time signal from all the sensors, and a figure with the applied load as a function of time.

EXAMPLES

Harmonic load

We want to apply a harmonic load::

$$F = 50\sin(300t)$$

on sensor C (as shown in Figure 2), and let the simulation run for 0.1 seconds. We desire a maximum time step of 5e-4 seconds. The function call will be:

```
[time,d,v,a,load]=BeNSI2014v3(3,1,[50 300 0 0],0.1,5e-4)
```

We obtain the response from the 8 sensors shown in Figure 3.

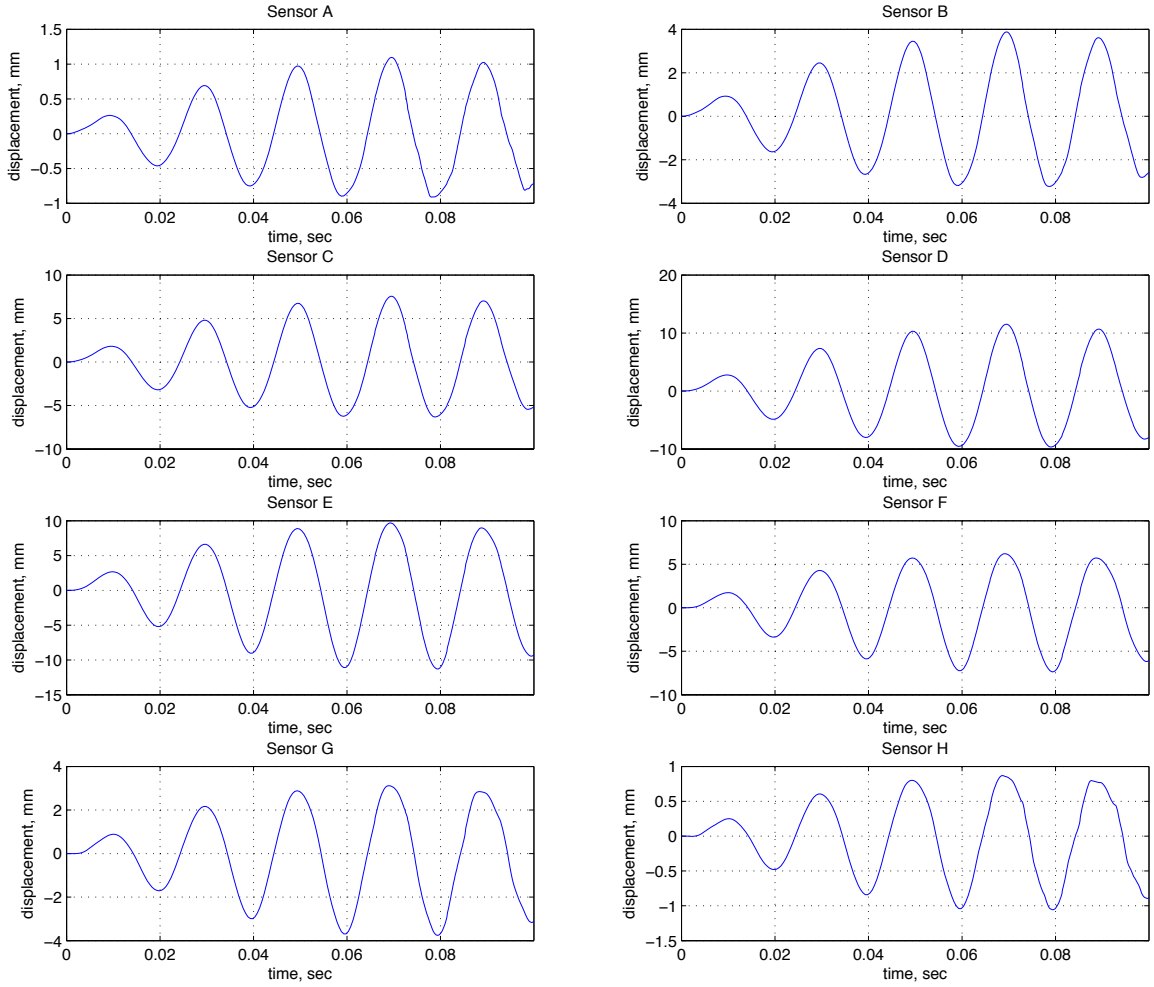

Figure 3: Sensors displacements due to a load of $F = 50\sin(300t)$ applied at sensor C.

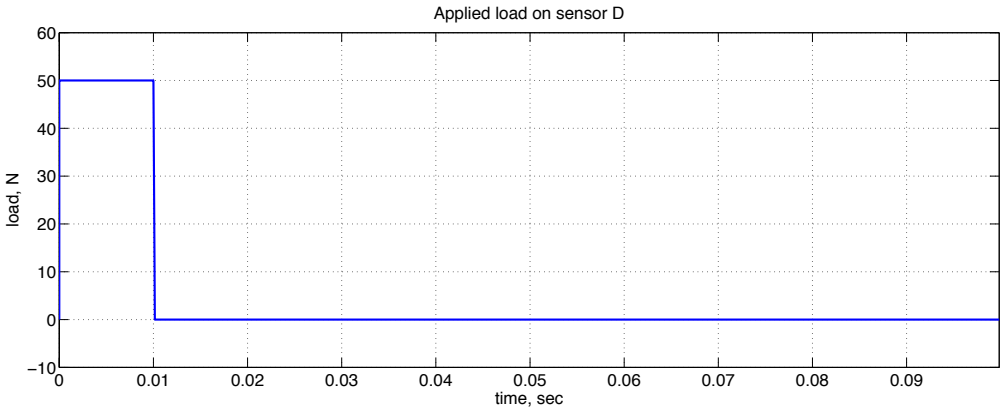

Figure 4: Square impulse of 50 N with a duration of 0.01 seconds.

Square impulse

We want to apply a square impulse of 50 N and a duration of 0.01 seconds (see Figure 4), on sensor D, and we are interested in a 0.1 seconds response of the system.The maximum allowable time step is 5e-4. We will specify a tabular load, and call the function as:

```
[time,d,v,a,load]=BeNSI2014v3(4,2,[0 50; 0.01 50; 0.010001 0; 0.1 0],0.1,5−4)
```

The results are shown in Figure 5. Note that it is necessary that the time values on the tabular input do not coincide, to avoid numerical issues.

RAMP LOAD

We would like now to perform a static test. We apply a slow ramp load, where the load reaches linearly the maximum value of 200 N in 10 seconds. The maximum allowable sampling rate is 0.5 seconds. The function call should look like this:

```
[time,d,v,a,load]=BeNSI2014v3(4,3,200,10,0.5);
```

The results are shown in Figure 6. Note that, since inertial effects are in this case neglected, tha maximum time `Tmax` can assume any value without affecting the results.

ACKNOWLEDGEMENTS

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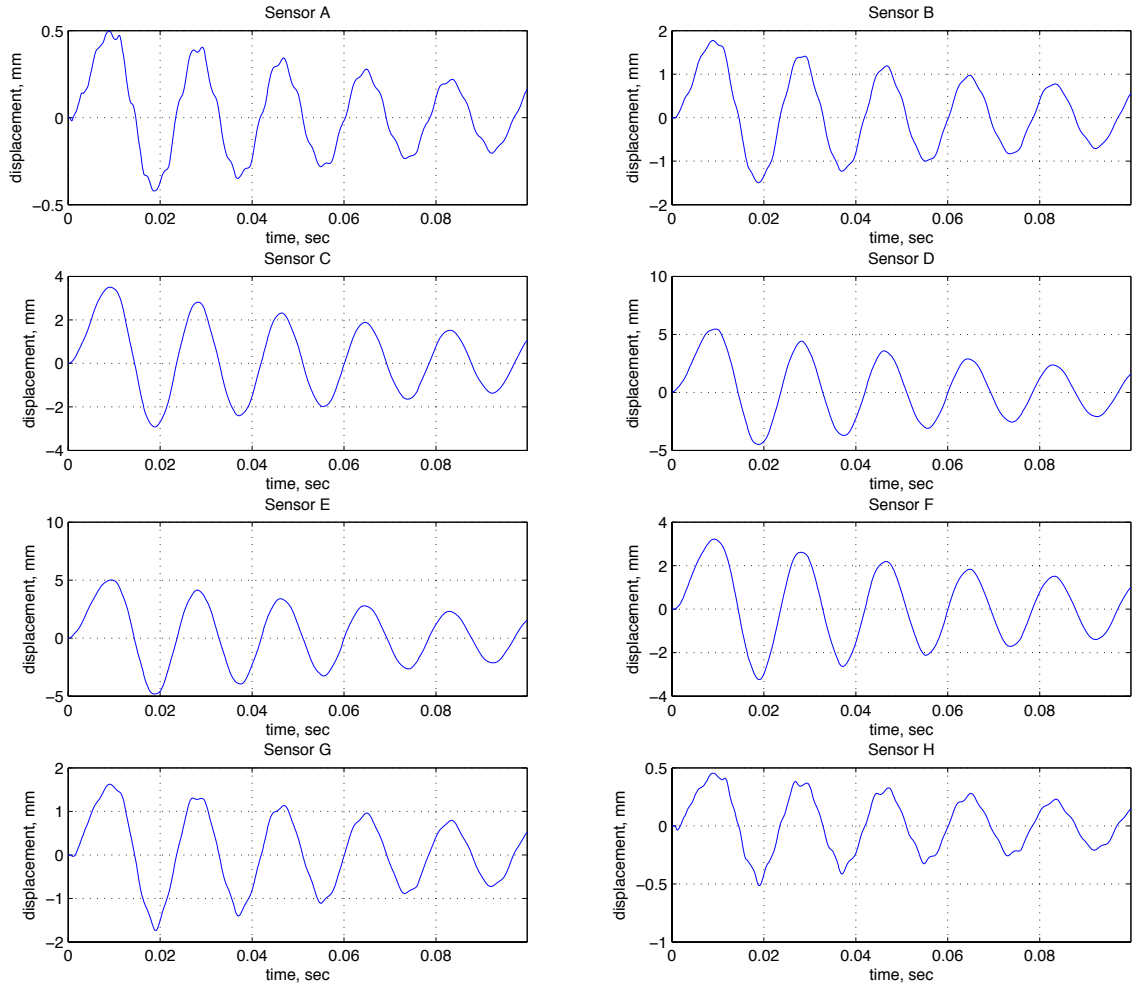

Figure 5: Sensors displacements due to a load of square impulse of 50 N and a duration of 0.01 seconds applied at sensor D.

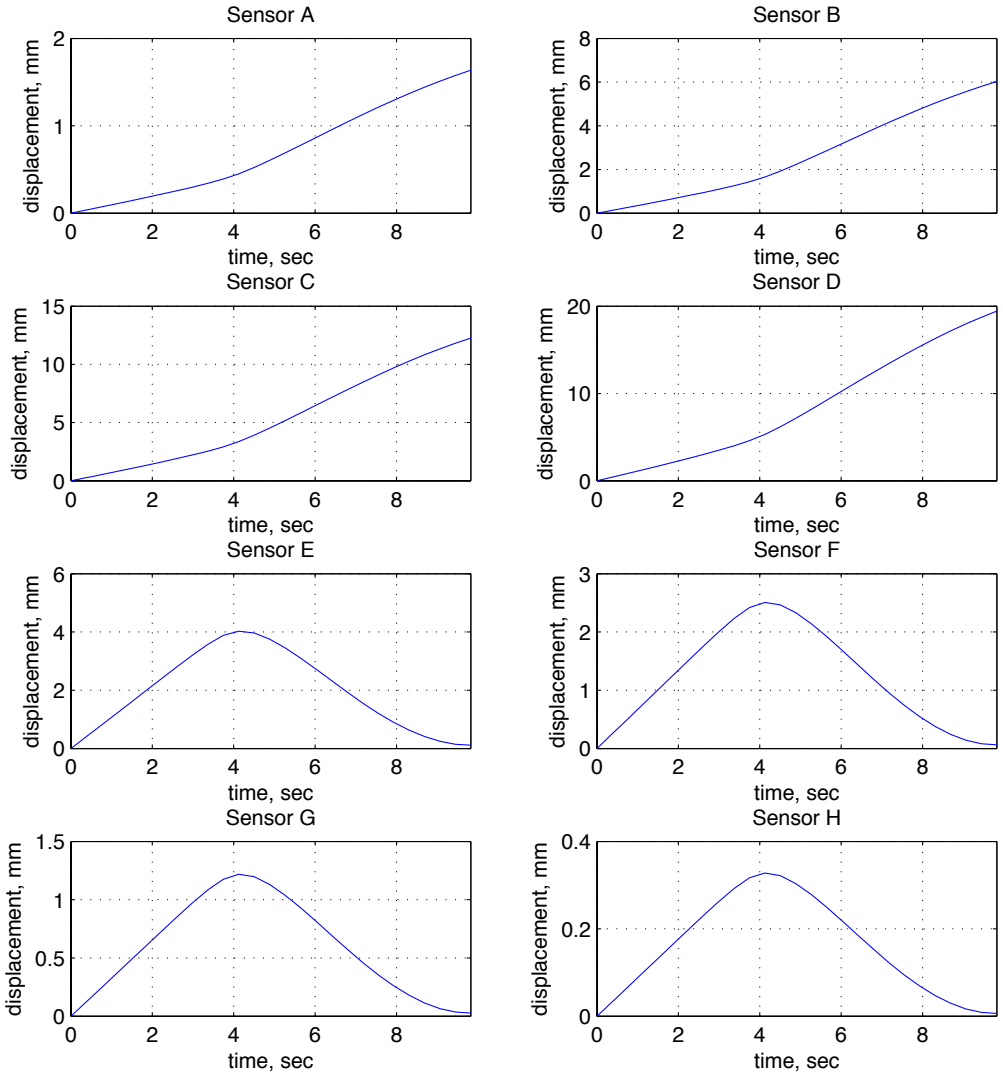

Figure 6: Sensors displacements due to a static ramp load on point D, with a maximum amplitude of 200 N