SSNL118 - Bar subjected to a velocity field of Summarized

wind:

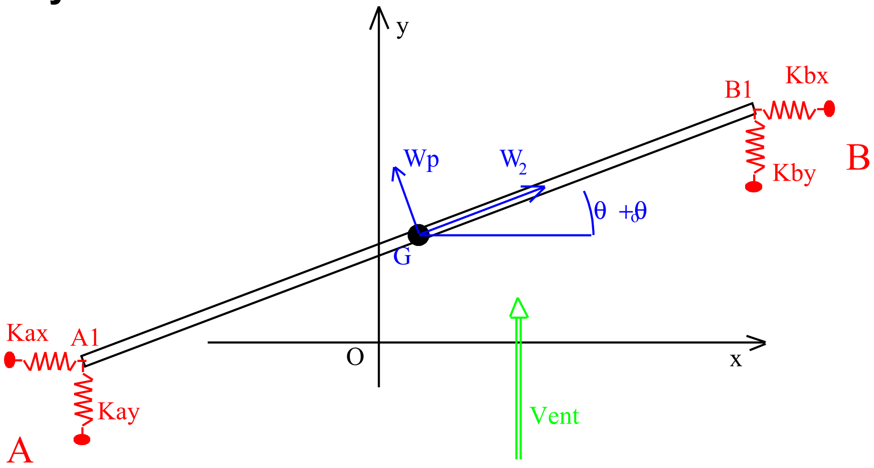
This test relates to the validation of the application of the loadings of wind on the linear elements. The loading is described by velocity fields of wind.

This problem makes it possible to test:

- linear finite elements [bars, cables, beams (except the curved beams)] with following loadings of natural “wind”,
- the loadings representing velocities of wind:
  - reading of the data of the fields of wind,
  - projection of the fields of wind attached to the group of dots on the deformed mesh of structure,
  - computation relative velocity,
- the taking into account of the function giving the distributed force according to the relative velocity of structure,
- the reactualization of the geometry to take account of large displacements and large rotations.

1 Problem of reference

1.1 Geometry



Length of the bar: 1.5m
Stiffness of the discrete ones: kax, kay, kbx, kby

1.2 Properties of the materials

Material for the linear element: $E=2.0\mathrm{E}{+}08\,Pa$, $\rho=1000.0\,kg/m^3$

Characteristic mechanics of the bar: $section='CERCLE'$ $rayon=0.5\,m$, $ep=0.5\,m$

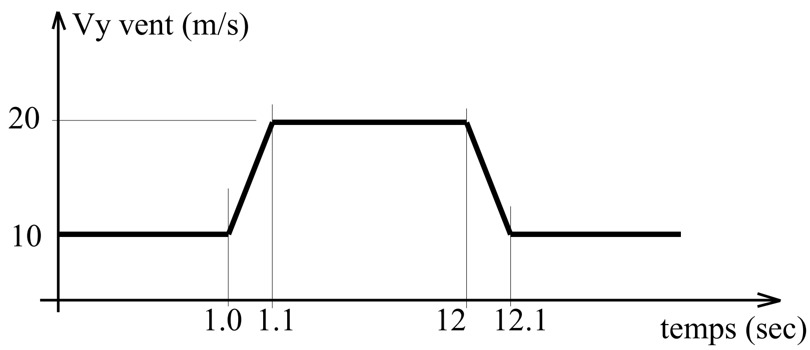
stiffness of springs:

Kxa	Kya	Kxb	Kyb
$10\,N/m$	$20\,N/m$	$25\,N/m$	$30\,N/m$

1.3 Boundary conditions and loadings

At the points A and B : blocking of the degrees of freedom: dx, dy, dz
At the points $A1$ and $B1$: blocking of the degrees of freedom: dz

Characteristics of the velocity field of wind, along the axis y :



1.4 Initial conditions

the bar forms an angle of 30° ($\theta_0=30°$) compared to the axis x .

2 Reference solution

2.1 Balance equations

Force to the point $A1$

$$Fa=\begin{Bmatrix} -kxa.\delta xa \\ -kya.\delta ya \\ L.(\delta ya.kya.\cos(\theta_o+\theta)-\delta xa.kxa.\sin(\theta_o+\theta))/2 \end{Bmatrix}$$

avec les déplacements du point $A1$

$$\delta xa = L.\cos(\theta_o)/2 - L.\cos(\theta_o+\theta)/2 + x$$
$$\delta ya = L.\sin(\theta_o)/2 - L.\sin(\theta_o+\theta)/2 + y$$

Force at the point $B1$

$$Fb=\begin{Bmatrix} -kxb.\delta xb \\ -kyb.\delta yb \\ L.(-\delta yb.kyb.\cos(\theta_o+\theta)+\delta xb.kxb.\sin(\theta_o+\theta))/2 \end{Bmatrix}$$

avec les déplacements du point $B1$

$$\delta xb = -L.\cos(\theta_o)/2 + L.\cos(\theta_o+\theta)/2 + x$$
$$\delta yb = -L.\sin(\theta_o)/2 + L.\sin(\theta_o+\theta)/2 + y$$

Force due to the wind

- Velocity of the wind in a point $M \in barre$

  $V_r=\begin{Bmatrix} Vvx \\ Vvy \\ 0 \end{Bmatrix}$ with Vvx Vvy : velocity of the wind following the axis x and the axis y .

- Relative velocity perpendicular to the bar to point: M

$$V_p=\begin{Bmatrix} Sin(qo+q).(-Vvy.Cos(qo+q)+Vvx.Sin(qo+q)) \\ Cos(qo+q).(Vvy.Cos(qo+q)-Vvx.Sin(qo+q)) \\ 0 \end{Bmatrix}$$

- Force due to the wind in a point M

  $Fvent_{(M)}=Fcx_{(M)}\dfrac{Vp}{||Vp||}$ in our case one chooses $Fcx_{(M)}=||V_p||$

  one thus obtains $Fvent_{(M)}=V_p$
- Resulting from the force due to the wind on the Fvent

$$\text{bar}=\begin{Bmatrix} L.Sin(qo+q).(-Vvy.Cos(qo+q)+Vvx.Sin(qo+q)) \\ L.Cos(qo+q).(Vvy.Cos(qo+q)-Vvx.Sin(qo+q)) \\ 0 \end{Bmatrix}$$

Balance equation: $Fa+Fb+Fvent=0$

2.2 Quantities and results of reference

Displacements of the points $A1$ and $B1$ at times: $1.s$, $1.05s$ and $2.s$. These times correspond respectively to velocities of wind of 10, 15 and $20\mathrm{m}/s$

the resolution of the 3 balance equations, projection of $Fa+Fb+Fvent=0$, is done by iterations. The 3 unknowns of the problem are the position of the center of gravity of the bar G : (x,y) and variation of the angle: θ.

In *Code_Aster*, the effect of the wind is taken into account by a distributed force along the linear element. The statement of the modulus of this distributed force is the following one:

$$Fcx_{(v)}=\frac{1}{2}.\rho.V^2.Cx(v).D_h$$

where $Fcx_{(v)}$: is the modulus of the distributed force along the cable in N/m, depend on the velocity.
ρ : is the density of the air in kg/m^3.
V : is the relative velocity of the cable in m/s.
$Cx(v)$: is the coefficient of drag of the cable, depend on the relative velocity.
D_h : is the hydraulic diamtere of the cable in m.

To obtain a simple analytical reference solution, the function $Fcx_{(Vp)}$ is taken equalizes with $\|V_p\|$. In the file of command of Code_Aster the function of $Fcxv$ the east thus in the following way definite:

```
FCXV=DEFI_FONCTION (
  NOM_PARA=' VITE',
  VALE= (  0.0,    0.0,10.0
         ,  10.0),
  PROL_GAUCHE=' LINEAIRE',
  PROL_DROITE=' LINEAIRE',
)
```

2.3 Uncertainties on the solution

None. The resolution of the balance equation is done by iterations with an error lower than $1.0\mathrm{E}-09$.

2.4 Bibliographical reference

• HM77/01/046/A. “M7-01-70 Project. The evolution of *the Code_Aster* for best taken into account of the loadings of dynamic wind on the linear elements”.

3 Modelization A

3.1 Characteristic of the modelization and the mesh

the linear element: "BAR"
the discrete ones: "DIS_T"

4 Results of the modelization A

4.1 Quantities tested and results

the equilibrium is calculated at times: $1.s$, $1.05s$ and $2.s$.

Balance with $1.s$	Analytical
$\delta xa(m)$	– 0.2092
$\delta ya(m)$	0.3276
$\delta xb(m)$	– 0.1418
$\delta yb(m)$	0.1965
Equilibrium with $1.05s$	**Analytical**
$\delta xa(m)$	– 0.2885
$\delta ya(m)$	0.5050
$\delta xb(m)$	– 0.1942
$\delta yb(m)$	0.3105
Equilibrium with $2.s$	**Analytical**
$\delta xa(m)$	– 0.3502
$\delta ya(m)$	0.6890
$\delta xb(m)$	– 0.2327
$\delta yb(m)$	0.4324

5 Synthesis

the test of type velocity of wind shows the good taking into account of the loadings on the linear elements.