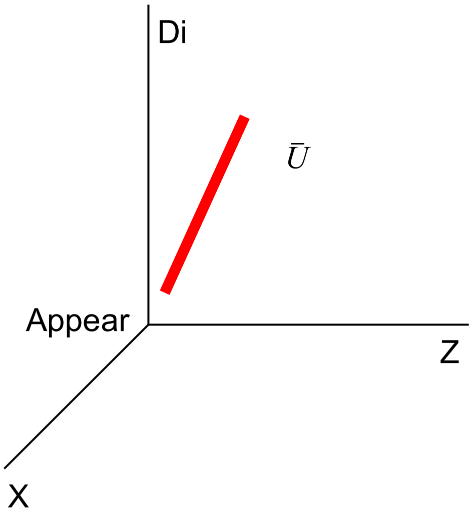
SSND103 - Validation of a bilinear constitutive law on a discrete element (application to the bolted assemblies)

Abstract:

The purpose of this benchmark is to validate a bilinear constitutive law relating to a discrete element.
This constitutive law was developed in the frame of a study in which the behavior of the screw of a bolted assembly is modelled by an affected discrete element of the same behavior.
Constitutive law DIS_BILI_ELAS requires in arguments the two apparent stiffness of the screw (fasteners in contact or not) as well as the value of the force of pretightening imposed on the screw.
It is checked, for various temperatures and various directions of request, that the slopes of the load diagrams obtained, when the discrete one is requested, correspond to the apparent stiffness and that the change of incline corresponds to the force of imposed pretightening.

1 Problem of reference

1.1



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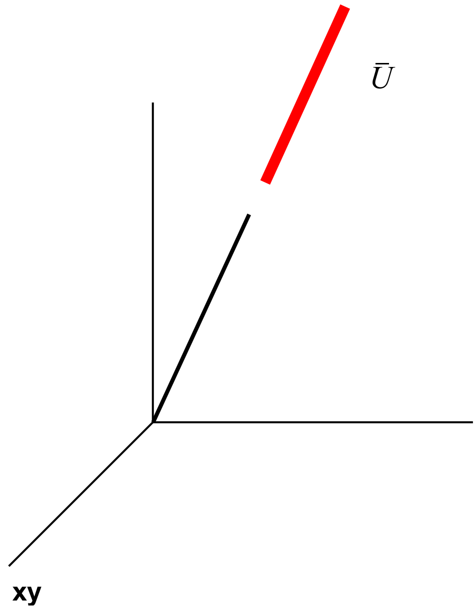


bDiscGe

In theory, one seeks to impose a loading (forces some or displacement) on a discrete element represented by a node such as in *Figure **A.***
In practice, it is necessary to introduce a condition of blocking on this node in order to avoid any motion of solid body and giving a physical meaning to its stiffness.
This is why the mesh will be composed of two nodes, the affected stiffness being at the segment made up by their junction (cf *Figure **b)***.
N.B. : If this segment has a non-zero length (i.e the two nodes are not confused), its direction fixes the directional sense of the discrete one. •
One calls $N1$ the node to which the conditions of blocking will relate. •
One calls $N2$ the node on which will be imposed the mechanical loadings. •
One calls $Disc$ the discrete element of the type SEG2 `to which` one affects the constitutive law to be validated. Properties

1.2 of the material One

arbitrarily chooses to assign to the discrete element the material characteristics of an elastic steel: $E=2.10^{11}\,Pa$. $\nu=0.3$ Boundary conditions

1.3 and loadings One

imposes a condition of fixed support on the node. $N1$ One
imposes a force of pretightening on F_p the discrete element. One
imposes a loading proportional in displacement to the node. $N2$ One
imposes a constant field of temperature in the course of time. It
is considered that the discrete element can work only in translation, one affects a modelization DIS_T to him . `Reference solution`

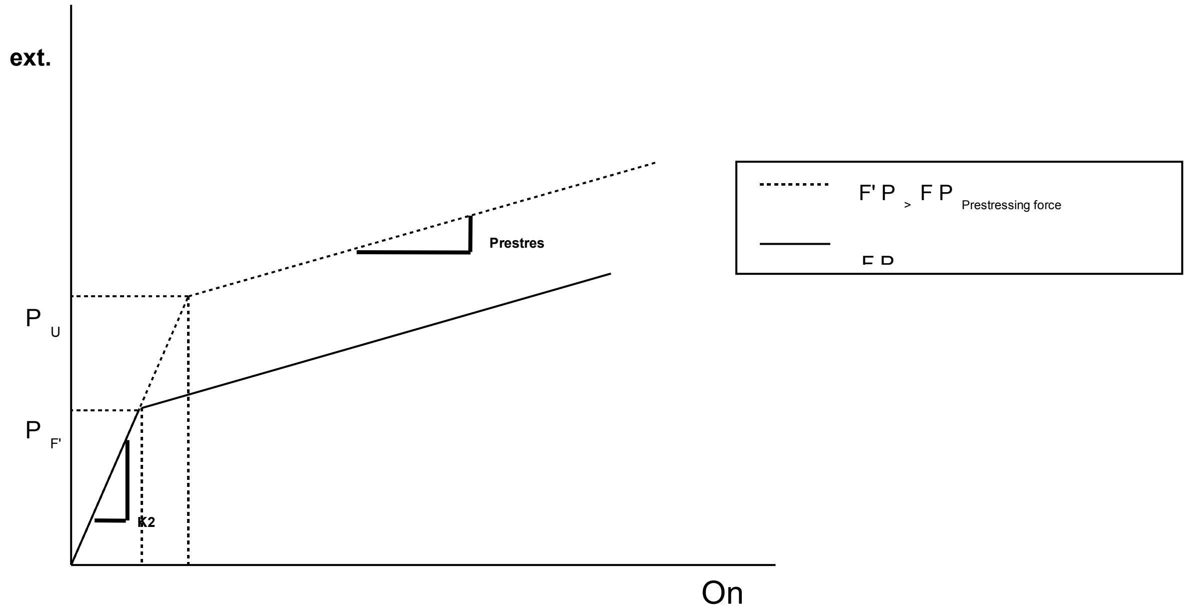
2 One

assigns to the discrete element, via the bilinear constitutive law, two stiffness and K_1 functions K_2 of the temperature of the form. $K_i=\alpha_i-\beta_i\dot{T}$ One

fixes arbitrarily here: It

$$\alpha_1=2\dot{\alpha}_2=2.10^8\,N.m^{-1}$$
$$\beta_1=2\dot{\beta}_2=4.10^6\,N.m^{-1}$$

is checked that, some is the displacement or U the force of stress which F_P one imposes, one obtains a nodal reaction of F discrete checking the elastic model, $\Delta F=K_i.\Delta U$ where if $i=1$ and $F\le F_P$ if $i=2$. $F>F_P$ F



raises the nodal reactions of discrete for the displacements () located $U_1<U_2$ on both sides of the change of incline.
The change of incline taking place for, $U_P=F_P/K_1$ one obtains the reference solutions directly: and

$F_1=K_1.U_1$ A $F_2=F_P+K_2.(U_2-U_P)$

Characteristic $F_2=F_P.(1-K_2/K_1)+K_2.U_2$

3 of the modelization

3.1 One is Modelization

requests the discrete element in a uniaxial way. One imposes to him: •

- a constant temperature, $T=0°C$ •
- a prestressing force and $F_P=5.10^4 N$ •
- a displacement of axis. $(0x)$ $U_{tot}=10^{-3} mm$ Characteristics

3.2 of the mesh The mesh

consists of two nodes connected by an element SEG2 of axis. Ox Quantities

3.3 tested and results One

chooses and $U_1=2.10^{-4} mm$. $U_2=8.10^{-4} mm$ After
numerical application, the reference solutions are: Nodes

$F_1=4.10^4 N$

$F_2=1,05.10^5 N$

Reference	U	Modelization
N1	$2.10^{-4} mm$	$-4.10^4 N$
N2	$2.10^{-4} mm$	$4.10^4 N$
N1	$8.10^{-4} mm$	$-1,05.10^5 N$
N2	$8.10^{-4} mm$	$1,05.10^5 N$

4 B Characteristic

4.1 of the modelization The modelization

B is in all points the same one as A except the temperature taken constant equal to Characteristics $25°C$

4.2 of the mesh The mesh

consists of two nodes connected by an element SEG2 `of` axis. Ox Quantities

4.3 tested and results One

chooses and $U_1=2.10^{-4} mm$. $U_2=8.10^{-4} mm$ After numerical application, the reference solutions are: Nodes

$F_1=2.10^4 N$

$F_2=6{,}5.10^4 N$

Reference	U	Modelization
$N1$	$2.10^{-4} mm$	$-2.10^4 N$
$N2$	$2.10^{-4} mm$	$2.10^4 N$
$N1$	$8.10^{-4} mm$	$-6{,}5.10^4 N$
$N2$	$8.10^{-4} mm$	$6{,}5.10^4 N$

5 C Characteristic

5.1 of the modelization The modelization

C is in all points same as the A safe one as regards meaning of the request. One
does not request any more the discrete one solely along his axis, but in the direction of the first trisecting one. One
chooses, in addition, $K_{ix}=K_{iy}=2.K_{iz}=K_i$ where K_i is given to the §2. Characteristics

5.2 of the mesh The mesh

consists of two nodes connected by an element SEG2 `of` axis. Ox Quantities

5.3 tested and results One

chooses and $U_1=2.10^{-4} mm$. $U_2=8.10^{-4} mm$ After
numerical application, the reference solutions are: Node

$F_{1x}=4.10^4 N$
$F_{1y}=4.10^4 N$
$F_{1z}=2.10^4 N$
$F_{2x}=10,5.10^4 N$
$F_{2y}=10,5.10^4 N$
$F_{2z}=6,5.10^4 N$

Components	U	Reference	Summary
N2	$2.10^{-4} mm$	F_{1x}	$4.10^4 N$
		F_{1y}	$4.10^4 N$
		F_{1z}	$2.10^4 N$
N2	$8.10^{-4} mm$	F_{2x}	$10,5.10^4 N$
		F_{2y}	$10,5.10^4 N$
		F_{2z}	$6,5.10^4 N$

6 of the results

constitutive law DIS_BILI_ELAS `gives` results perfectly in conformity with those resulting from the analytical statements, that the stiffness is function of the temperature or differentiated according to the directions from space.