# SSNV503 - Shoe slipping on a Summarized rigid

**level:**

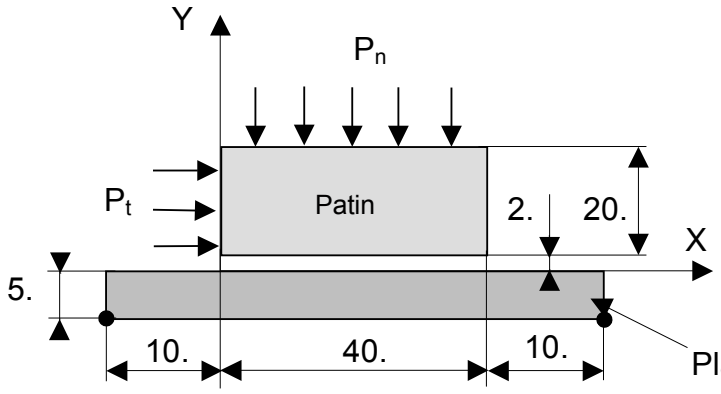
This test represents a computation of contact of a shoe slipping on a rigid level. The purpose of this test is to make it possible to validate in an unquestionable way computation of the criterion of Coulomb and the good transmission of the pressure.

The various modelizations of the contact zone tested are the following ones:

- **Modelization A** (2D): contact node-mesh, Lagrangian method for the contact and friction, geometrical clearance.
- **Modelization B** (2D): contact node-mesh with Lagrangian method and clearance defined by a function.
- **Modelization C** (2D): contact node-mesh, method Lagrangian for the contact and penalized for friction, geometrical clearance.
- **Modelization D** (2D): contact node-mesh, method penalized for the contact and friction, geometrical clearance.
- **Modelization E** (3D): contact node-mesh, method Lagrangian for the contact and penalized for friction, geometrical clearance.
- **Modelization F** (3D): contact node-mesh, method Lagrangian for the contact and penalized for friction, clearance defined by a function.
- **Modelization G** (3D): contact node-mesh, method penalized for the contact and friction, geometrical clearance.
- **Modelization H** (2D): contact node-mesh, continuous method for the contact and friction, geometrical clearance.
- **Modelization I** (3D): contact node-mesh, continuous method for the contact and friction, geometrical clearance.
- **Modelization J** (2D): contact by elements of joint, model JOINT_MECA_FROT

# 1 Problem of reference

## 1.1 Geometry




Patin : épaisseur = 20.mm
largeur = 20.mm
Plan rigide : épaisseur = 5.mm
largeur = 60.mm
Jeu : 2.mm

Le patin est situé au milieu du plan rigide

## 1.2 Properties of the material

Shoe:

$E = 2.1106\,N/mm^2$ Modulus Young
$\nu = 0$ rigid Plane Poisson's ratio

by kinematical conditions.

Contact zone:

$\mu = 0.3$ Coefficient of kinetic friction

## 1.3 Boundary conditions and loadings

Boundary conditions:

- All the nodes of the rigid plane are clamped.

3 cases of loading:

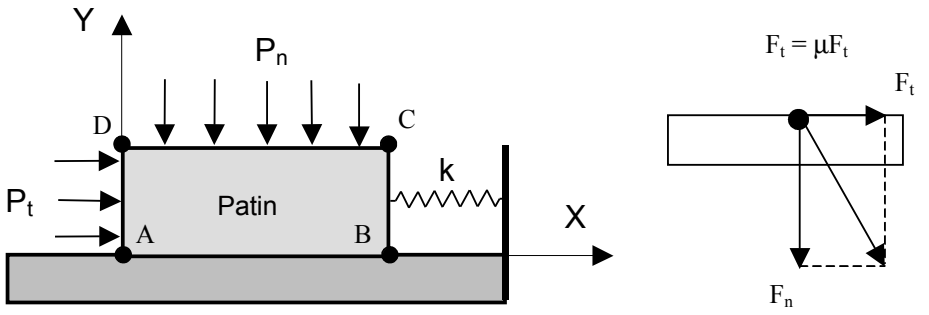
- Normal pressure $P_n = 300\mathrm{N}/mm^2$
- normal Pressure $P_n = 300\mathrm{N}/mm^2$ and tangential pressure $P_t = 178.2\,N/mm^2$
- normal Pressure $P_n = 300\mathrm{N}/mm^2$ and tangential pressure $P_t = 181.8\,N/mm^2$

## 1.4 Initial conditions

None.

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution




Assumption design: The strain of the shoe is neglected.

**Loading 1 – normal Pressure** $P_n: 300\mathrm{N}/mm^2$

One checks:
1.Good transmission of the normal force on the level of the contact zone: the normal pressure on the level of the contact zone is equal to the pressure applied $\left(P_n = P_n^{contact}\right)$
2.That the vertical displacement of the shoe on the level of the contact zone $AB$ is equal to clearance.

**Loading 2 – normal Pressure** $P_n: 300\mathrm{N}/mm^2$ **and tangential pressure** $P_t = 178.2\mathrm{N}/mm^2$

It is a situation of dependancy. It is checked that the nodes of the shoe located in the zone of sliding ( $AB$ ) do not move tangentially: $P_t = \dfrac{\mu P_n S_{CD}}{S_{AD}} 0.99$

**Loading 3 – normal Pressure** $P_n: 300\mathrm{N}/mm^2$ **and tangential pressure** $P_t = 181.8\mathrm{N}/mm^2$

It is a situation of sliding. It is checked that the nodes of the shoe located in the zone of sliding ( $AB$ ) move of $9\mathrm{mm}$ following $X$ : $P_t = \dfrac{\mu P_n S_{CD}}{S_{AD}} 1.01$

Determination of the stiffness $k$ of spring: one wants to determine the stiffness of spring according to desired displacement. At the time of the sliding, the force in spring is of:

$F_r = F_t - \mu \quad F_n = 0{,}01\,\mu F_n$ with ( $F_t = 181.8 \times 20$ , $F_n = 300 \times 40$ )

| | | |
|---|---|---|
| $F_r = K U_t$ | : | force in spring |
| $F_t = P_t \times S_{AD}$ | : | tangential force |
| $F_n = P_n \times S_{CD}$ | : | normal force |
| $U_t$ | : | tangential displacement |
| $S_{AD}$ | : | surface |
| $S_{DC}$ | : | surface |

For a displacement of $9.mm$ the stiffness $k$ of spring must-being of results $0.01\,\mu F_n / 9 = 4\,N/mm$

## 2.2 of reference

- **Loading 1 (normal Pressure $P_n$ ):** $P_n^{contact} = 300N/mm^2$
- **Loading 2 (** $P_n : 300\mathrm{N}/mm^2$ **and** $P_t = 178.2\mathrm{N}/mm^2$ **):** it is checked that there exists at least a node of the contact surface which does not slip. One test that at least one of the nodes located on the face opposed to the application of the side loading does not slip.
- **Loading 3 (** $P_n : 300\mathrm{N}/mm^2$ **and** $P_t = 181.8/mm^2$ **):** it is checked that all the nodes of contact surface slip. One tests that all the nodes located on the face opposed to the application of the side loading slip.

## 2.3 Uncertainties on the solution

Lower than 0,1%

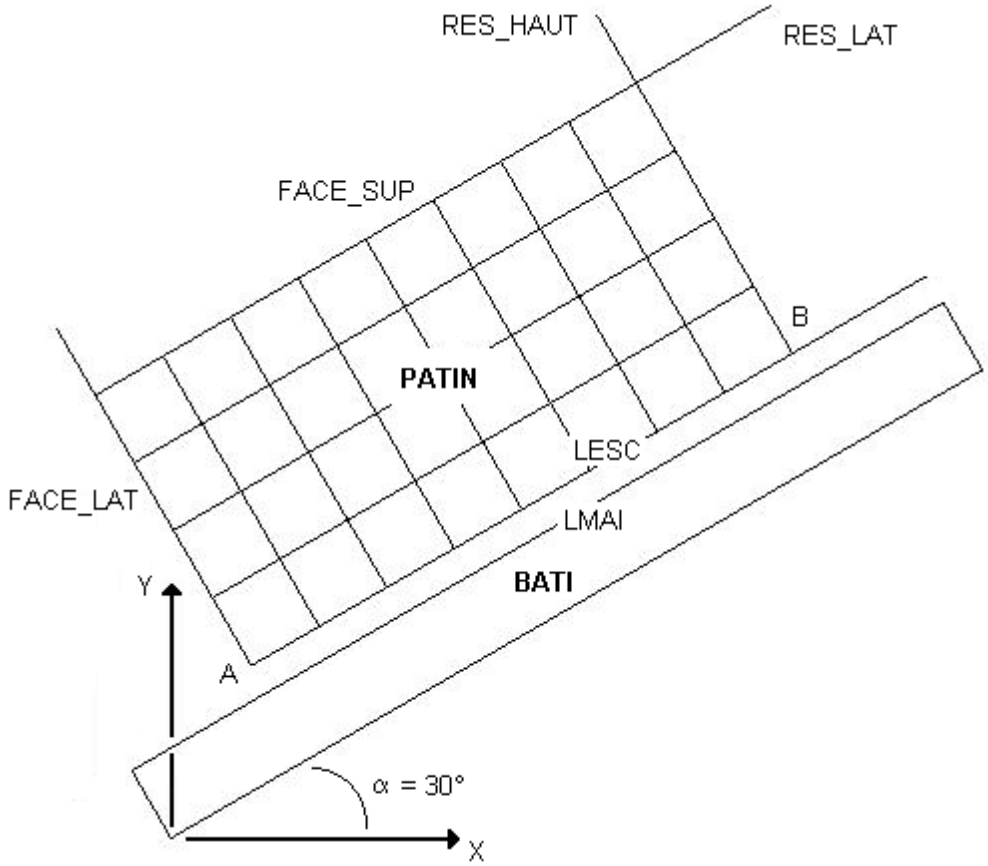
## 2.4 bibliographical References

Without Modelization

# 3 object A

## 3.1 Characteristic of the modelization

a modelization D_PLAN with elements QUAD4 testing the functionalities of contact node-mesh with friction treated with the Lagrangian method (discrete formulation) was implemented.



Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:
RES_LAT : $k = 2\,N/mm$
RES_HAUT : $k = 0{,}005\,N/mm$

Boundary conditions:
Loose lead of springs: $DX = DY = 0$ .
Frame: $DX = DY = 0$ .

## 3.2 Characteristics of the mesh

Many nodes: 53
Number and types of meshes: 33 QUAD4, 32 SEG2

# 4 Results of the modelization A

## 4.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,3 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

## 4.2 Remarks

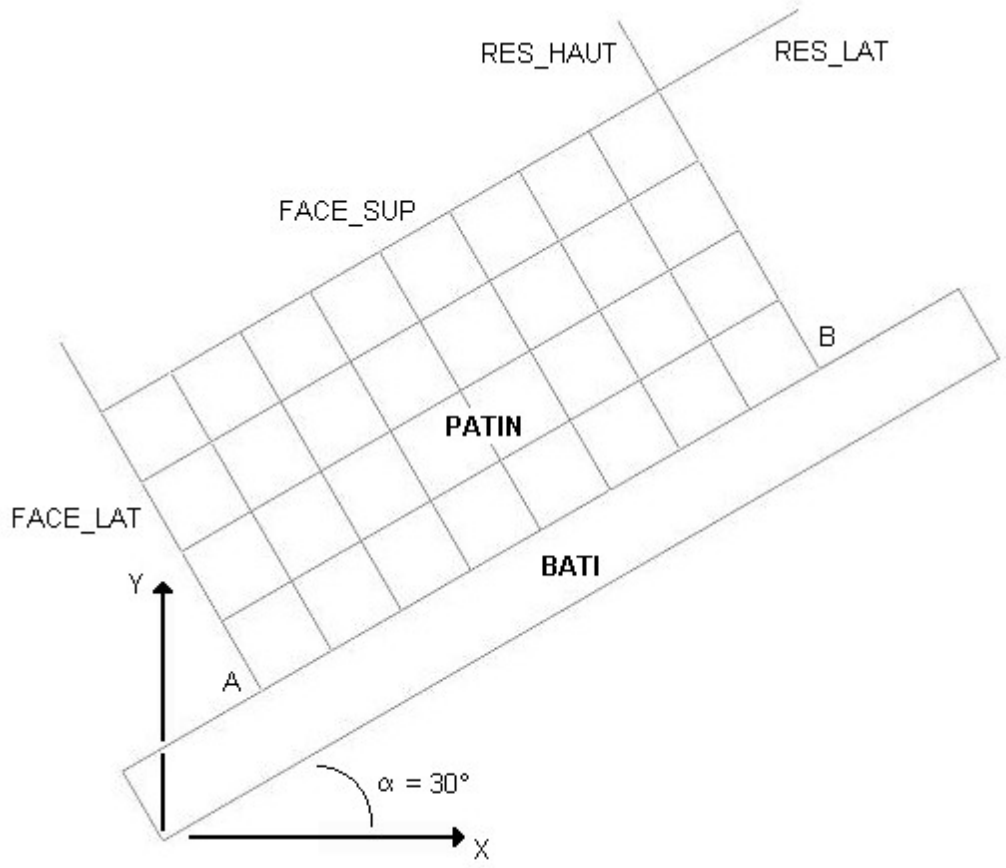
- clearance are defined in this case in a geometrical way. There is the possibility of defining it via key keys DIST_1 and DIST_2. This is done in the model according to.
- The pressures norm and tangential on the level of the contact zone are checked by testing the total force of contact in the normal and tangential meaning:

$$F_n^{CTAC} = p_n S_{DC} = 300*40*1 = 12000N$$
$$F_t^{CTAC} = p_t S_{AD} = 178.2*20*1 = 35640N \quad (\text{Chargement 2})$$
$$F_t^{CTAC} = p_t S_{AD} = 181.8*20*1 = 36240N \quad (\text{Chargement 3})$$

# 5 Modelization B

## 5.1 Characteristic of the modelization

a modelization D_PLAN with elements QUAD4 testing the functionalities of contact node-mesh with friction treated with the Lagrangian method was implemented.




Clearance between the shoe and the frame is defined by a function using key word " DIST_2 ".

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:
RES_LAT : $k = 2\ N/mm$
RES_HAUT : $k = 0{,}005\ N/mm$

Boundary conditions:
Loose lead of springs: $DX = DY = 0$ .
Frame: $DX = DY = 0$ .

## 5.2 Characteristics of the mesh

Many nodes: 53
Number and types of meshes: 33 QUAD4 , 32 SEG2

# 6 Results of the modelization B

## 6.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,3 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

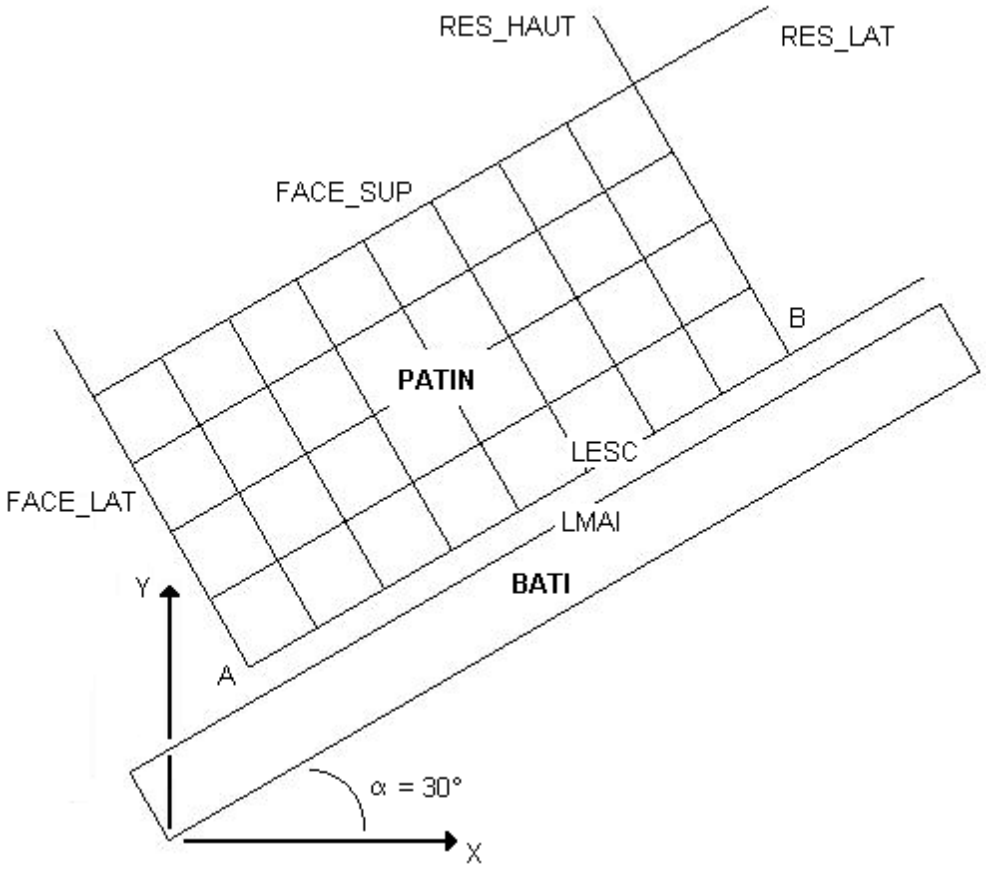
## 6.2 Remark

clearance are defined in this case by a function. There is no difference with the model preceding where clearance is defined in a geometrical way.

# 7 Modelization C

## 7.1 Characteristic of the modelization

a modelization D_PLAN with elements QUAD4 testing the functionalities of contact node-mesh with friction treated with the method Lagrangian for the contact and penalized for friction was implemented.




Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:

RES_LAT : $k = 2\,N/mm$

RES_HAUT : $k = 0{,}005\,N/mm$

Boundary conditions:

Loose lead of springs: $DX = DY = 0$ .

Frame: $DX = DY = 0$ .

## 7.2 Characteristics of the mesh

Many nodes: 53

Number and types of meshes: 33 QUAD4, 32 SEG2

# 8 Results of the modelization C

## 8.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |

| | | | |
|---|---|---|---|
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,3 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

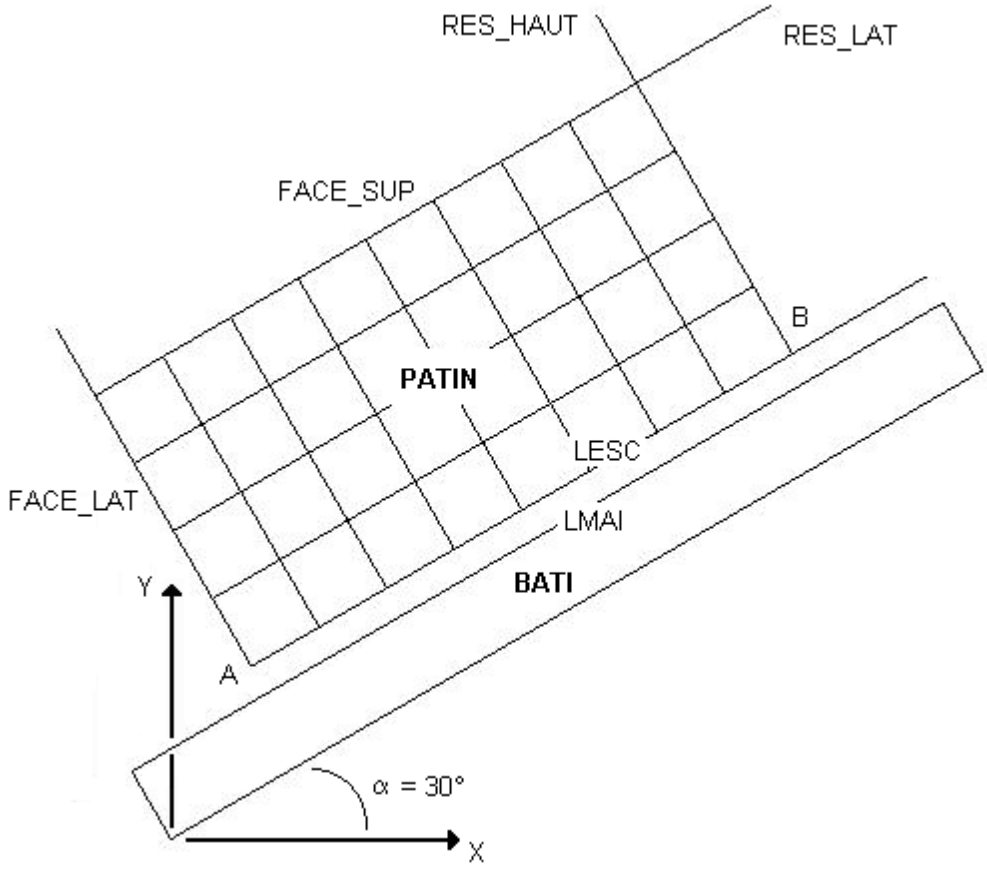
## 8.2 Remark

clearance are defined in this case in a geometrical way. There is the possibility of defining it via key keys DIST_1 and DIST_2 . After checking, this second case does not change anything with result.

# 9 Modelization D

## 9.1 Characteristic of the modelization

a modelization D_PLAN with elements QUAD4 testing the functionalities of contact node-mesh with friction treated with the method penalized for the contact and friction was implemented.



Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:
RES_LAT : $k = 2\,N/mm$
RES_HAUT : $k = 0{,}005\,N/mm$

Boundary conditions:
Loose lead of springs: $DX = DY = 0$ .
Frame: $DX = DY = 0$ .

## 9.2 Characteristics of the mesh

Many nodes: 53
Number and types of meshes: 33 QUAD4, 32 SEG2

# 10 Results of the modelization D

## 10.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,6 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

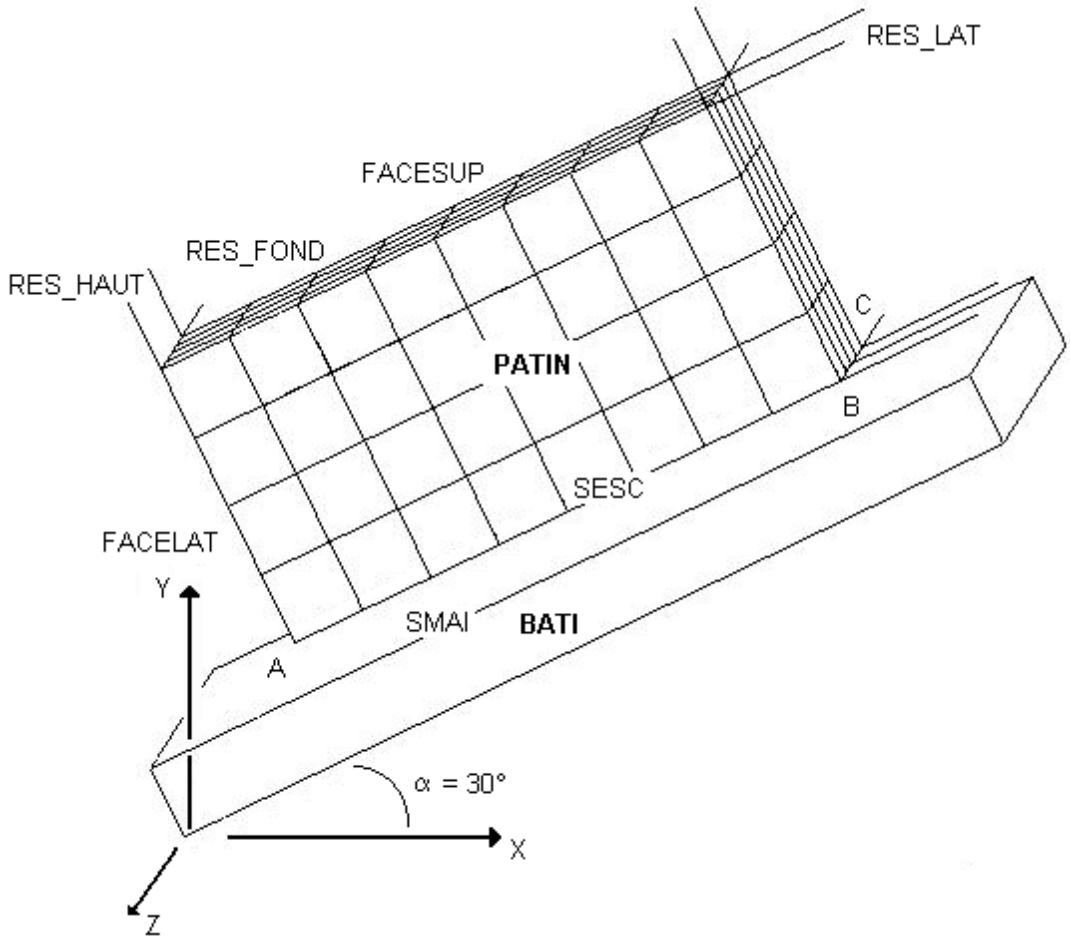
## 10.2 Remark

clearance are defined in this case in a geometrical way. There is the possibility of defining it via key keys DIST_1 and DIST_2. After checking, this second case does not change anything with result.

# 11 Modelization E

## 11.1 Characteristic of the modelization

a modelization 3D with elements HEXA8 testing the functionalities of contact node-mesh with friction treated with the method Lagrangian for the contact and penalized for friction was implemented.




Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:

RES_LAT : $k=1\,N/mm$
RES_FOND : $k=1\,N/mm$
RES_HAUT : $k=20\,N/mm$

Boundary conditions:

Loose lead of springs: $DX=DY=DZ=0$ .
Frame: $DX=DY=DZ=0$ .

## 11.2 Characteristics of the mesh

Many nodes: 269
Number and type of meshes: 129 HEXA8, 103 QUAD4

# 12 Results of the modelization E

## 12.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 2,0784E+05 N | ANALYTIQUE | RELATIF – 5,00% |

| | | | |
|---|---|---|---|
| tangential Force of contact | -1,2000E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,722E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,8173E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,6 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,71486E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,82977E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

## 12.2 Remarks

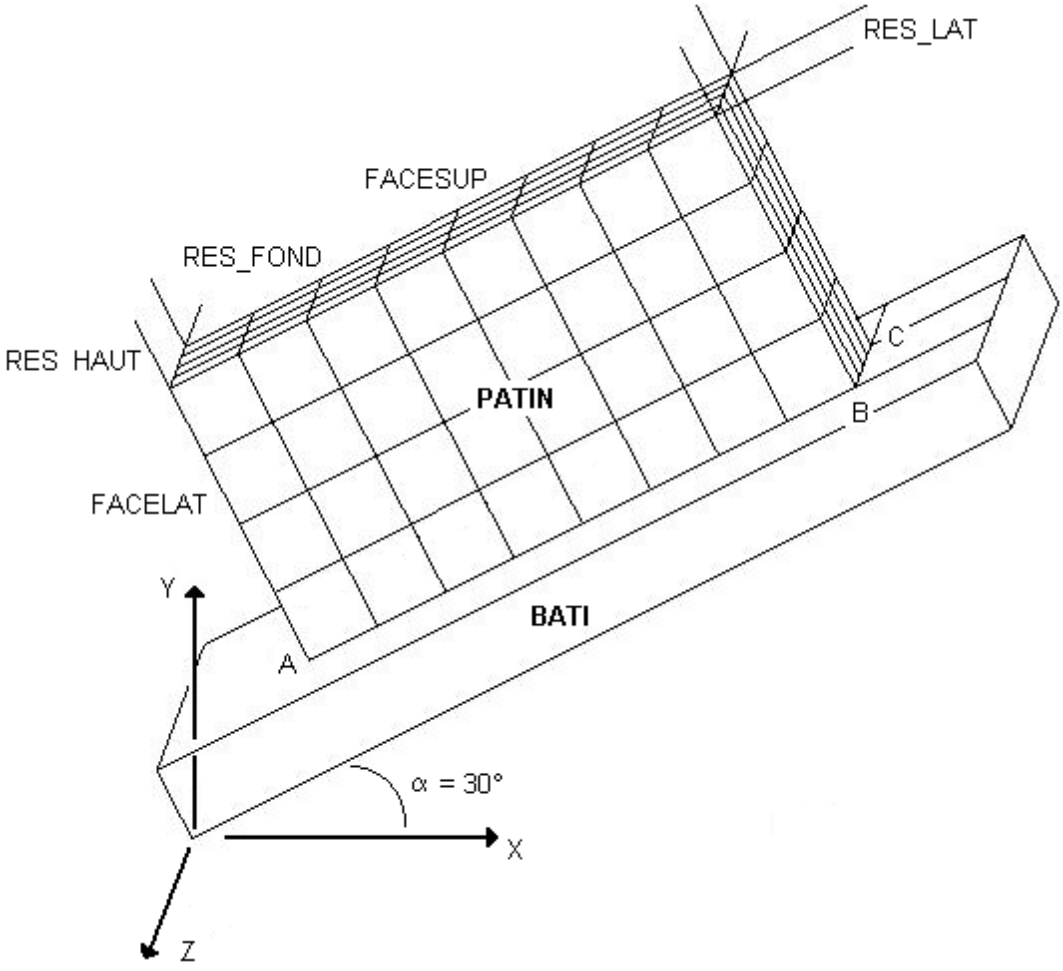
- clearance are defined in this case in a geometrical way, the results are identical to those found in the preceding modelization.
- The pressures norm and tangential on the level of the contact zone are checked by testing the total force of contact in the normal and tangential meaning:

$$F_n^{CTAC} = p_n S_{DC} = 300\text{x}40\text{x}20 = 24000\text{N}$$
$$F_t^{CTAC} = p_t S_{AD} = 178.2\text{x}20\text{x}20 = 71280\text{N} \text{ (Loading 2)}$$
$$F_t^{CTAC} = p_t S_{AD} = 181.8\text{x}20\text{x}20 = 72720\text{N} \text{ (Loading 3)}$$

# 13 Modelization F

## 13.1 Characteristic of the modelization

a modelization 3D with elements HEXA8 testing the functionalities of contact node-mesh with friction treated with the method Lagrangian for the contact and penalized for friction was implemented.




Clearance between the shoe and the frame is defined by the function using key word " DIST_2 ".

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:
HIGH RES_ : $k = 1\,N/mm$

RES_FOND : $k = 1\ N/mm$
RES_ LAT : $k = 20\ N/mm$

Boundary conditions:
Loose lead of springs: $DX = DY = DZ = 0$ .
Frame: $DX = DY = DZ = 0$ .

## 13.2 Characteristics of the mesh

Many nodes: 269
Number and type of meshes: 129 HEXA8, 103 QUAD4

# 14 Results of the modelization F

## 14.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 2,0784E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | -1,2000E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,722E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,8173E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,6 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,71486E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,82977E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

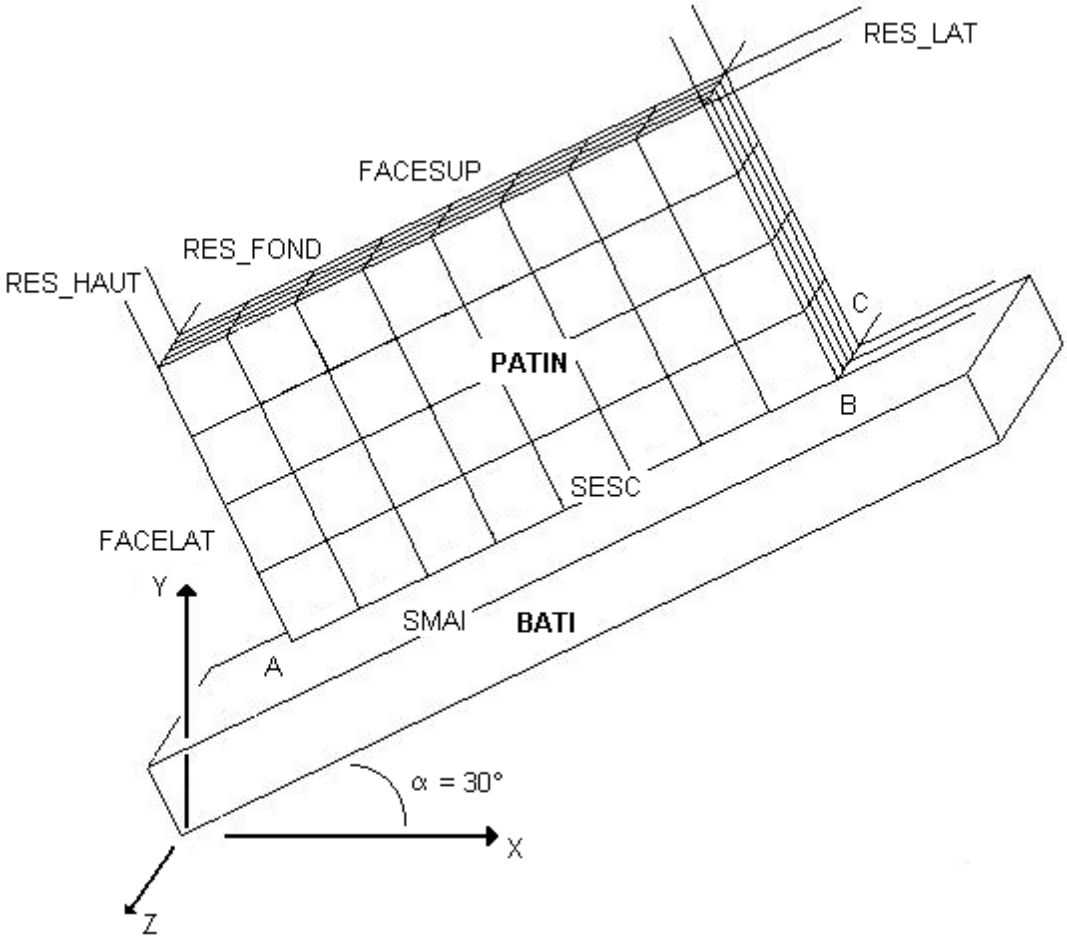
## 14.2 Remark

In this modelization, clearance are defined using a function, the results are identical to those found in the preceding modelization.

# 15 Modelization G

## 15.1 Characteristic of the modelization

a modelization 3D with elements HEXA8 testing the functionalities of contact node-mesh with friction treated with the method penalized for the contact and friction was implemented.




Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:

HIGH RES_ : $k=1\,N/mm$
RES_FOND : $k=1\,N/mm$
RES_ LAT : $k=20\,N/mm$

Boundary conditions:

Loose lead of springs: $DX=DY=DZ=0$ .
Frame: $DX=DY=DZ=0$ .

## 15.2 Characteristics of the mesh

Many nodes: 269
Number and type of meshes: 129 HEXA8, 103 QUAD4

# 16 Results of the modelization G

## 16.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 2,0784E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | -1,2000E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,722E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,8173E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,3 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,71486E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,82977E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

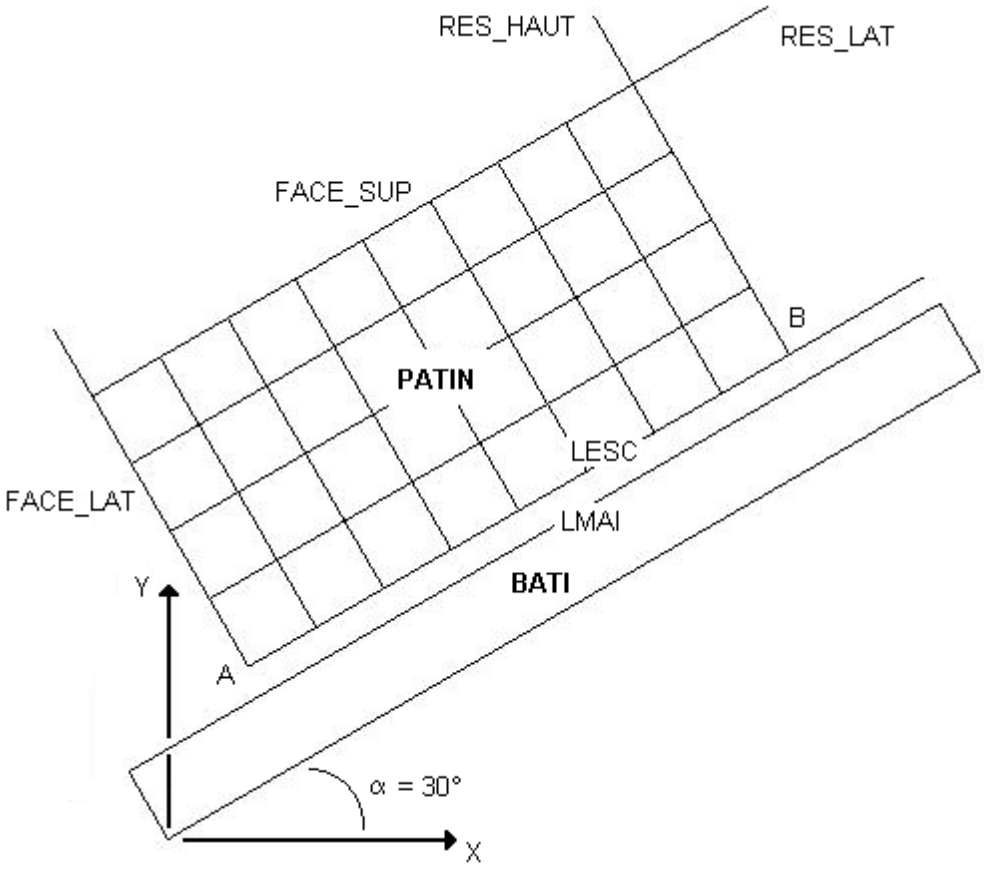
## 16.2 Remark

clearance are defined in this case in a geometrical way. The results are less good than those obtained with the penalization only on friction. Moreover, this method is longer.

# 17 Modelization H

## 17.1 Characteristic of the modelization

a modelization D_PLAN with elements QUAD4 testing the functionalities of contact node-mesh with friction treated with the continuous method for the contact and friction was implemented.




Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:

RES_LAT : $k=2\,N/mm$

RES_HAUT : $k=0{,}005\,N/mm$

Boundary conditions:

Loose lead of springs: $DX=DY=0$ .

Frame: $DX=DY=0$ .

## 17.2 Characteristics of the mesh

Many nodes: 53

Number and types of meshes: 33 QUAD4, 32 SEG2

# 18 Results of the modelization H

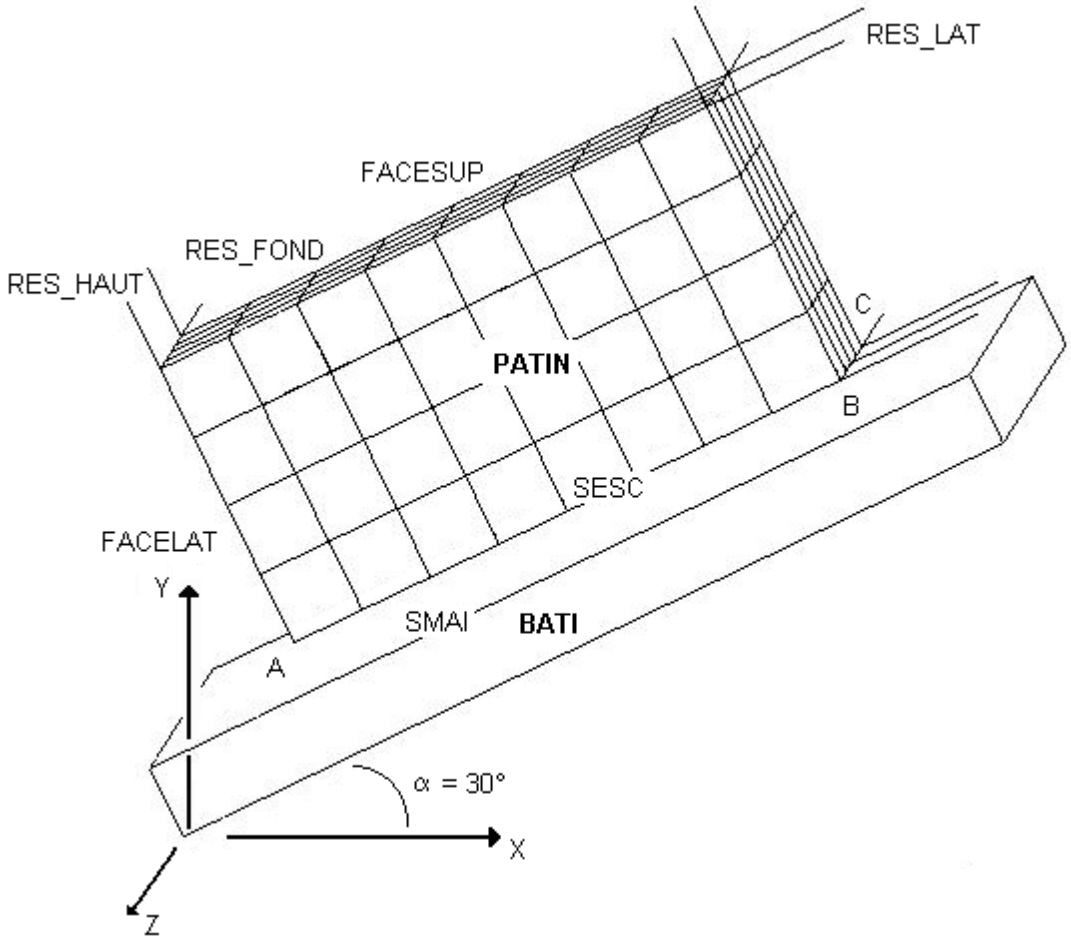
## 18.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,6 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,787 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

# 19 Modelization I

## 19.1 Characteristic of the modelization

a modelization 3D with elements HEXA 8 testing the functionalities of contact node-mesh with friction treated with the continuous method for the contact and friction was put in work.




Clearance between the shoe and the frame is defined by the geometrical coordinates of the mesh.

To avoid rigid body motions, the shoe is maintained by springs of low stiffness:

HIGH RES_ : $k=1\,N/mm$
RES_FOND : $k=1\,N/mm$
RES_ LAT : $k=20\,N/mm$

Boundary conditions:

Loose lead of springs: $DX=DY=DZ=0$ .
Frame: $DX=DY=DZ=0$ .

## 19.2 Characteristics of the mesh

Many nodes: 269
Number and type of meshes: 129 HEXA8, 103 QUAD4

# 20 Results of the modelization I

## 20.1 Values tested

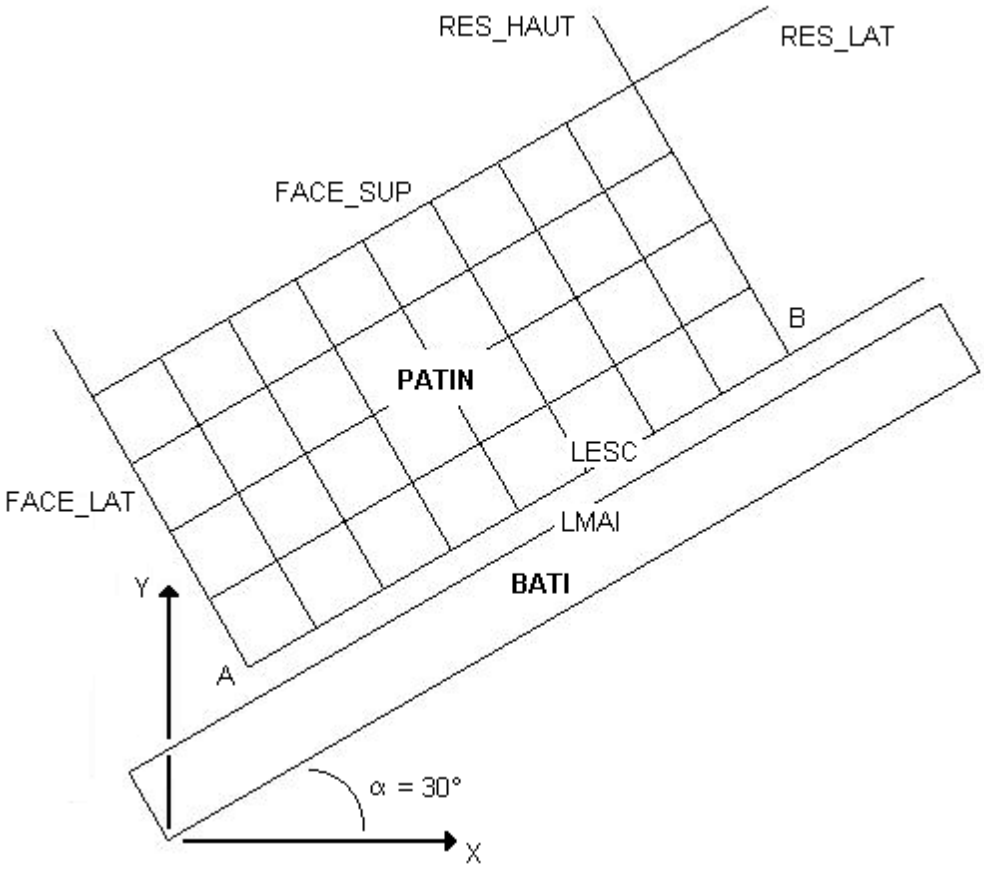
| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |

| | | | |
|---|---|---|---|
| Normal force of contact | 2,0784E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | -1,2000E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,722E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,8173E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 1,000 mm | NON_REGRESSION | RELATIF – 2,3 0% |
| DY (not A) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 1,000 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | – 1,732 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,71486E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| tangential Force of contact | – 1,82977E+05 N | ANALYTIQUE | RELATIF – 5,00% |
| DX (not A) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (point C) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (point C) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not D) | 8,794 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not D) | 2,768 mm | NON_REGRESSION | RELATIF – 1,00% |

# 21 Modelization J

## 21.1 Characteristic of the modelization

a simulation in flat strains are carried out: a modelization with elements QUAD4 in D_PLA N for meshes of the SHOE and FRAME and D_PLA N_JOINT for joint FISS. One tests the features of contact penalized in compression with friction treated via a constitutive law JOIN_MECA_FROT.




Clearance between the shoe and the frame is defined only for visualization of the contact, it does not influence the results physique (characteristic of modelization of joint). The parameter of regularization of the model east chooses of kind not to influence not (less than $0.01\%$) the replacement final one of shoe in glissemnt.

K_N : $K_n = 10^5\ N/mm^3$ parameter of penalization in compression and sliding

to avoid rigid body motions, the shoe is maintained by springs of low stiffness:

RES_LAT : $k = 2\ N/mm$
RES_HAUT : $k = 0{,}005\ N/mm$

Boundary conditions:

Loose lead of springs: $DX = DY = 0$ .
Frame: $DX = DY = 0$ .

## 21.2 Characteristics of the mesh

Many nodes: 134
Number and types of meshes: 96 QUAD4, 68 SEG2

# 22 Results of the modelization J

## 22.1 Values tested

| Standard | Identification | Reference | Tolerance |
|---|---|---|---|
| **Loading 1** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 1,00% |
| tangential Force of contact | 0 N | ANALYTIQUE | ABSOLU – 5,00% |
| DX (not A) | 1,5E-3 mm | ANALYTIQUE | RELATIF – 1,00% |
| DY (not A) | – 2.598E-3 mm | ANALYTIQUE | RELATIF – 1,00% |
| DX (not B) | 1,5E-3 mm | ANALYTIQUE | RELATIF – 1,00% |
| DY (not B) | – 2.598E-3 mm | ANALYTIQUE | RELATIF – 1,00% |
| **Loading 2** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 1,00% |
| tangential Force of contact | – 3,564E+03 N | ANALYTIQUE | RELATIF – 1,00% |
| DX (not A) | 0.0234 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not A) | 0.0122 mm | NON_REGRESSION | RELATIF – 1,00% |
| DX (not B) | 4.032E-03 mm | NON_REGRESSION | RELATIF – 1,00% |
| DY (not B) | -4.747 mm | NON_REGRESSION | RELATIF – 1,00% |
| **Loading 3** | | | |
| Normal force of contact | 1,200E+04 N | ANALYTIQUE | RELATIF – 1,00% |
| tangential Force of contact | – 3,624E+03 N | ANALYTIQUE | RELATIF – 1,00% |
| DX (not A) | 2.598 mm | ANALYTIQUE | RELATIF – 1,00% |
| DY (not A) | 1.5 mm | ANALYTIQUE | RELATIF – 1,00% |
| DX (not B) | 2.598 mm | ANALYTIQUE | RELATIF – 1,00% |
| DY (not B) | 1.5 mm | ANALYTIQUE | RELATIF – 1,00% |

the analytical values for loading 1 are obtained by means of the fact that the joint is elastic thanks to the parameter of penalization. It is this value which one projects in the reference total.

$$D_{norm} = P_{norm} / K_n = 300/10^5 = 3 \cdot 10^{-3} \ ; \ DX = D_{norm} \cos(\pi/6) ; DY = D_{norm} \sin(\pi/6)$$

# 23 Summary of the results

Whatever that is to say the modelization (2D or 3D) and the method of processing of contact-friction, the got results are satisfactory. They are very close to the analytical results.