POLYTECH NICE SOPHIA

UNIVERSITÉ CÔTE D'AZUR

Mécanique des solides

3. Déformées modales

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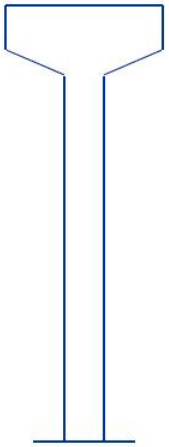
Cours de Modélisation par Abaqus

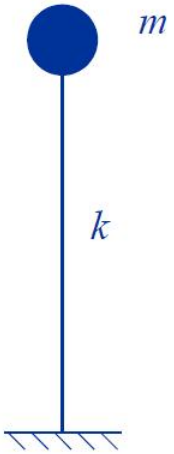
- Comportement cyclique des matériaux
  - Élément cubique unitaire pour tester les lois de comportement
- Poutre 1D appuyée et encastrée
  - Données : géométrie, charges, matériau, conditions aux limites
  - Résultats : flèche, contrainte max, réactions
- Déformées modales d'une structure
  - Premiers modes de vibration et masses associées
- Portique 3D sous charge dynamique
  - Données : géométrie, matériau, charges statiques et dynamiques
  - Résultats : déformées modales, déplacement dans le temps, contraintes
- Poutre 3D en béton armé
  - Géométrie 3D, éléments finis solides

Oscillateur élémentaire : 1 ddl

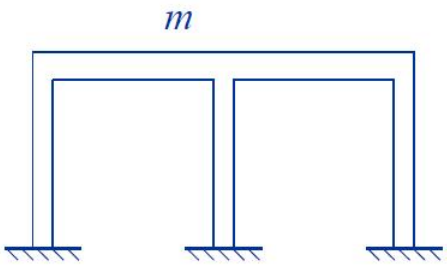
Photo

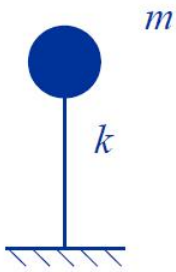


Schéma



Modèle de calcul





Condition d'équilibre

Forces en jeu :

- Force d'inertie : Masse [kg], Accélération

$$F(t) = m\ddot{u}(t)$$

- Force élastique : Raideur [N/m], Déplacement

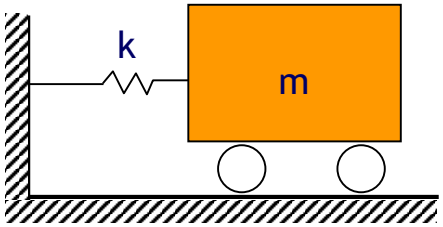
$$F(t) = k\,u(t)$$

- Force visqueuse : Dissipation [Ns/m], Vitesse

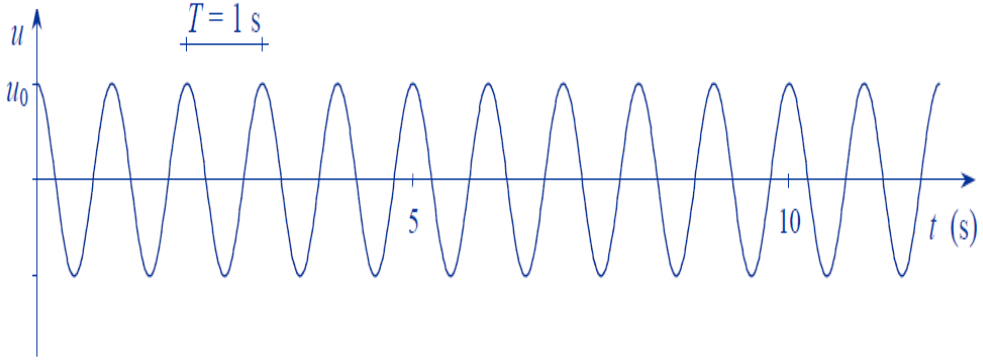
$$F(t) = c\dot{u}(t)$$

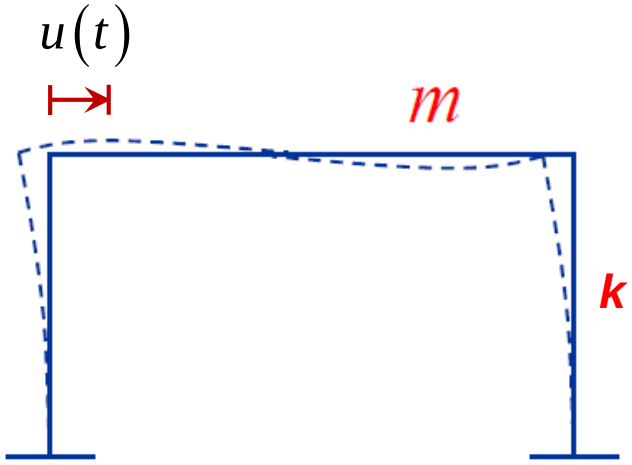
Oscillateur élémentaire 1/4

Oscillation libre



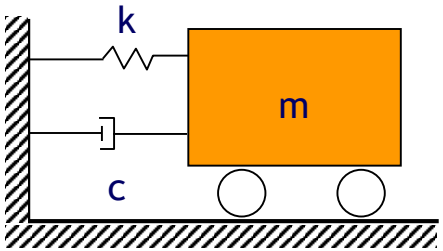
$$m\ddot{u}(t) + ku(t) = 0$$



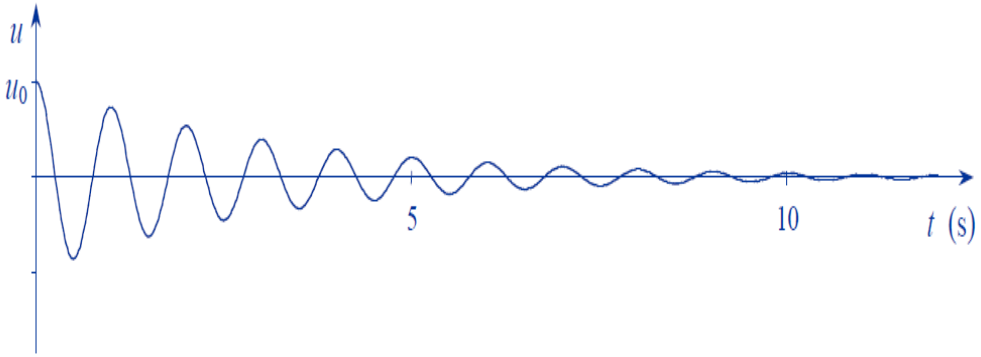


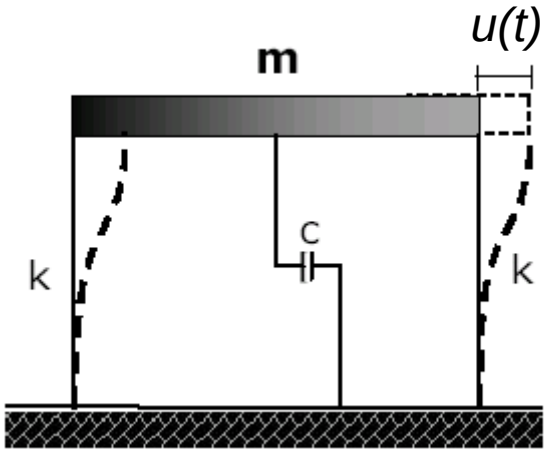
Oscillateur élémentaire 2/4

Oscillation amortie



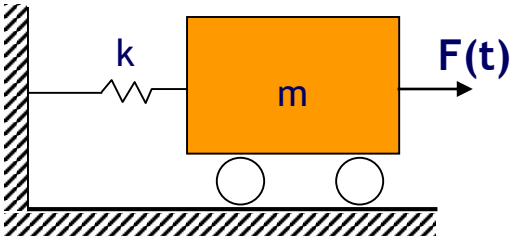
$$m\ddot{u}(t) + c\dot{u}(t) + ku(t) = 0$$



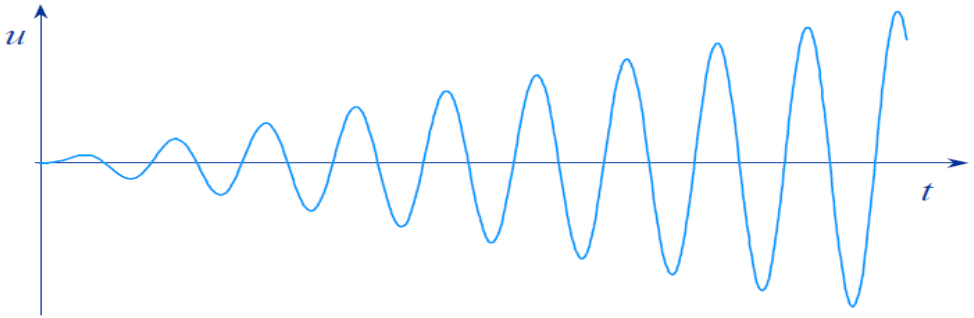


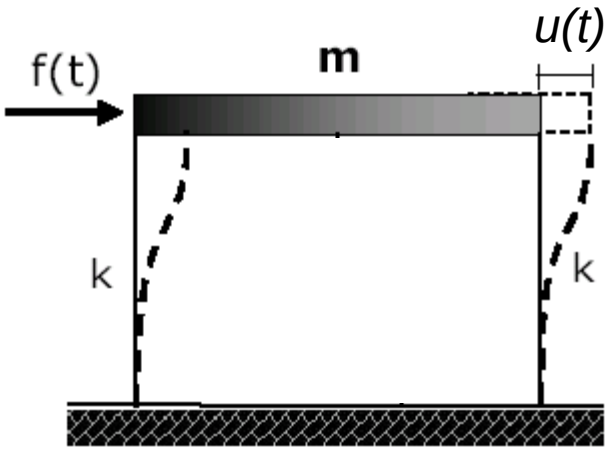
Oscillateur élémentaire 3/4

Oscillation forcée



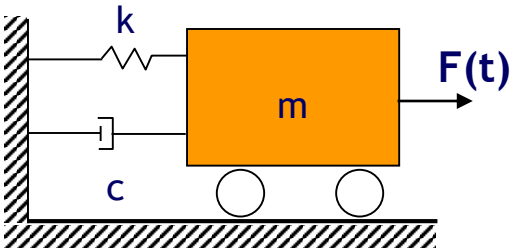
$$m\ddot{u}(t) + ku(t) = F(t)$$





Oscillateur élémentaire 4/4

Oscillation amortie et forcée

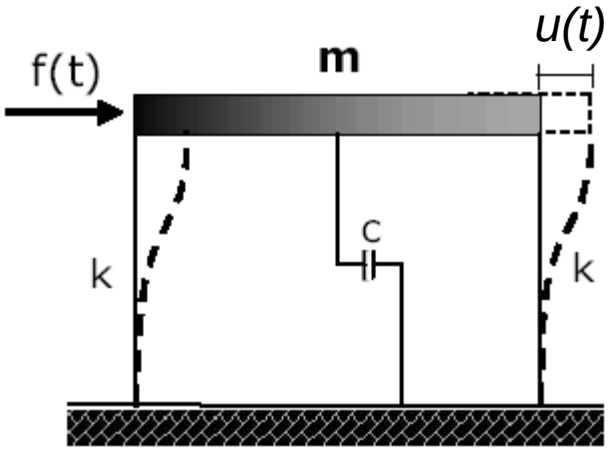


$$m\ddot{u}(t) + c\dot{u}(t) + ku(t) = F(t)$$

Hypothèse de

plancher rigide

et poteaux souples



Période propre de vibration

Pulsation propre

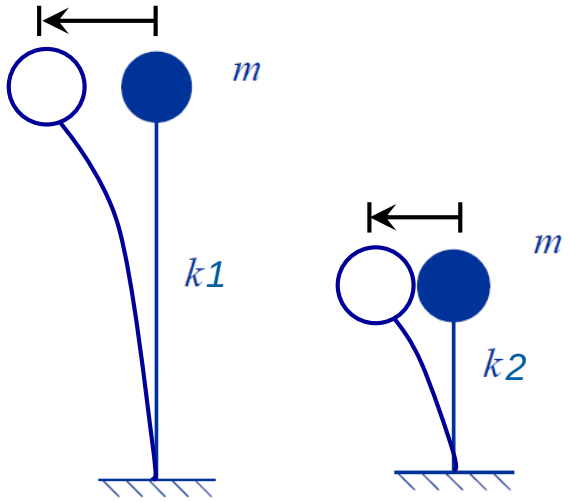
$$\omega_0 = \sqrt{\frac{k}{m}}$$

Fréquence propre

$$f_0 = \frac{\omega_0}{2\pi}$$

Période propre

$$T_0 = \frac{2\pi}{\omega_0}$$



$k_1 < k_2$

$T_1 > T_2$

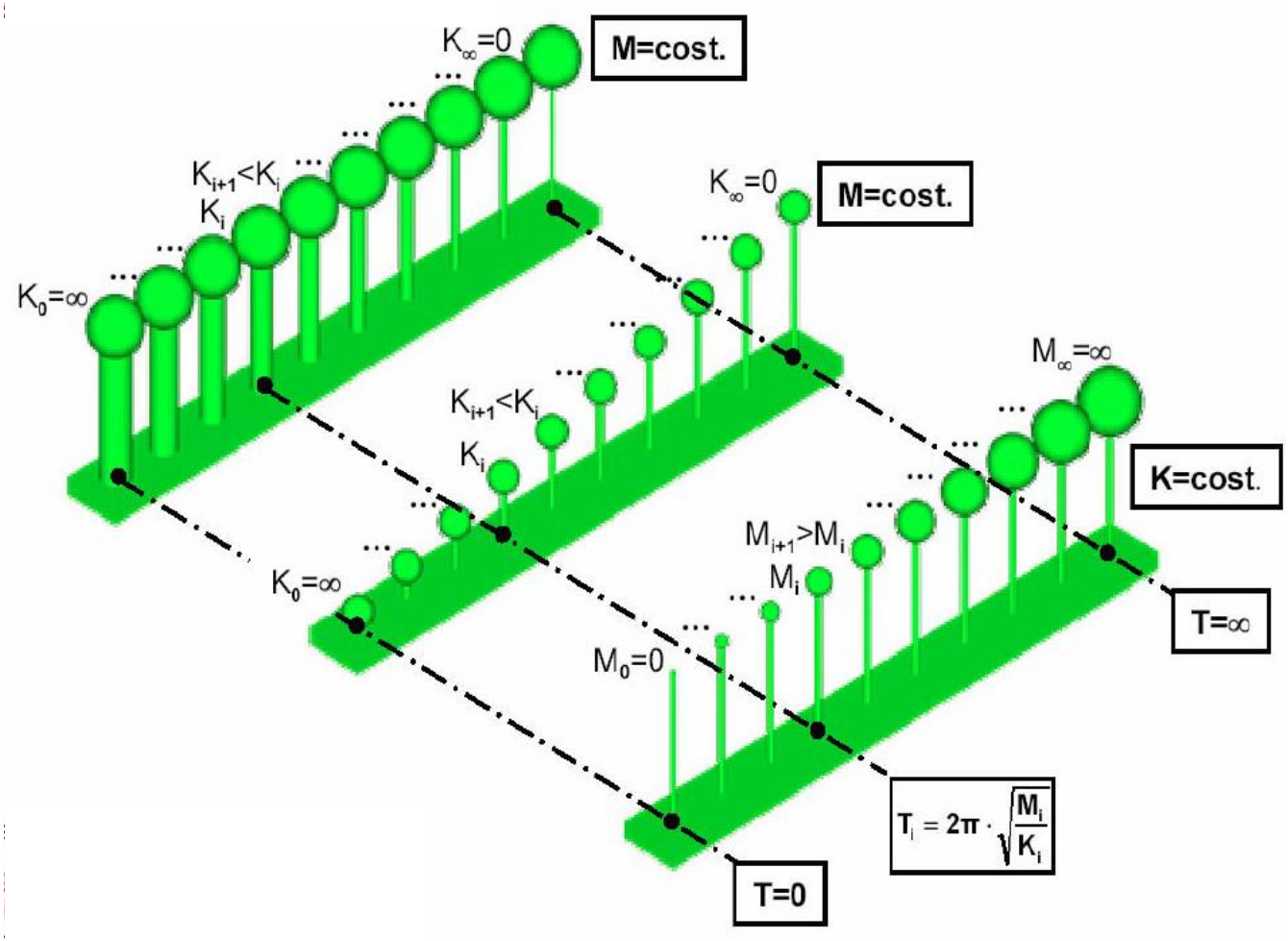
$f_1 < f_2$

$\omega[\mathrm{rad/s}] \quad k[\mathrm{N/m}] \quad m[\mathrm{kg}] \quad f[\mathrm{Hz}] \quad T[\mathrm{s}]$

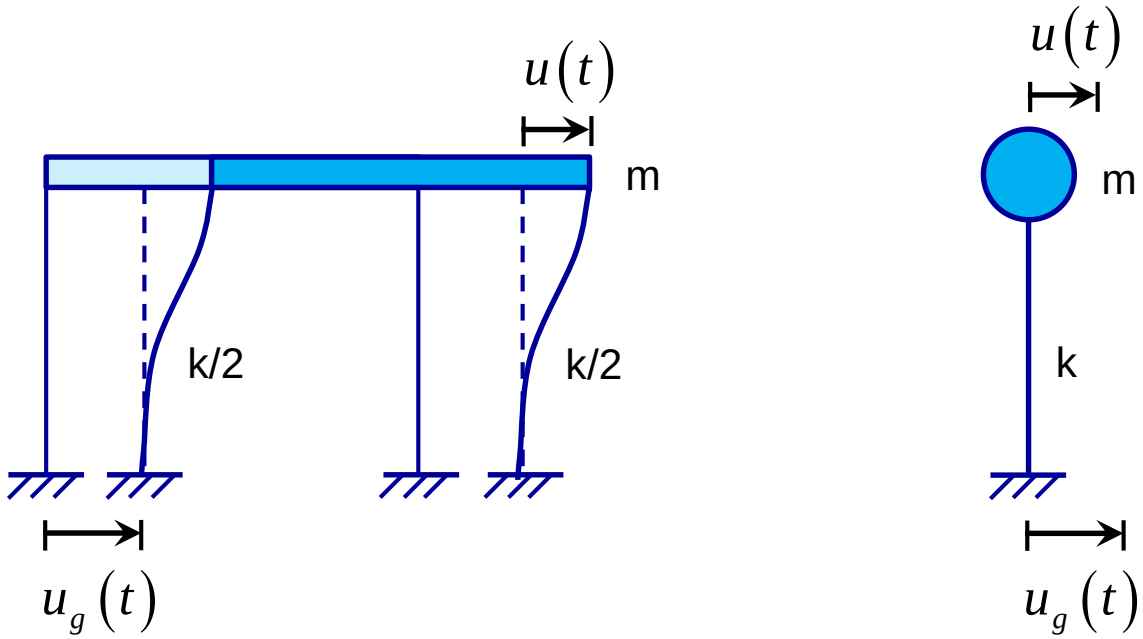
Analogie avec l'oscillateur élémentaire

+ T_0 - f_0 + structure souple

- T_0 + f_0 + structure rigide



Oscillateur élémentaire 1/3



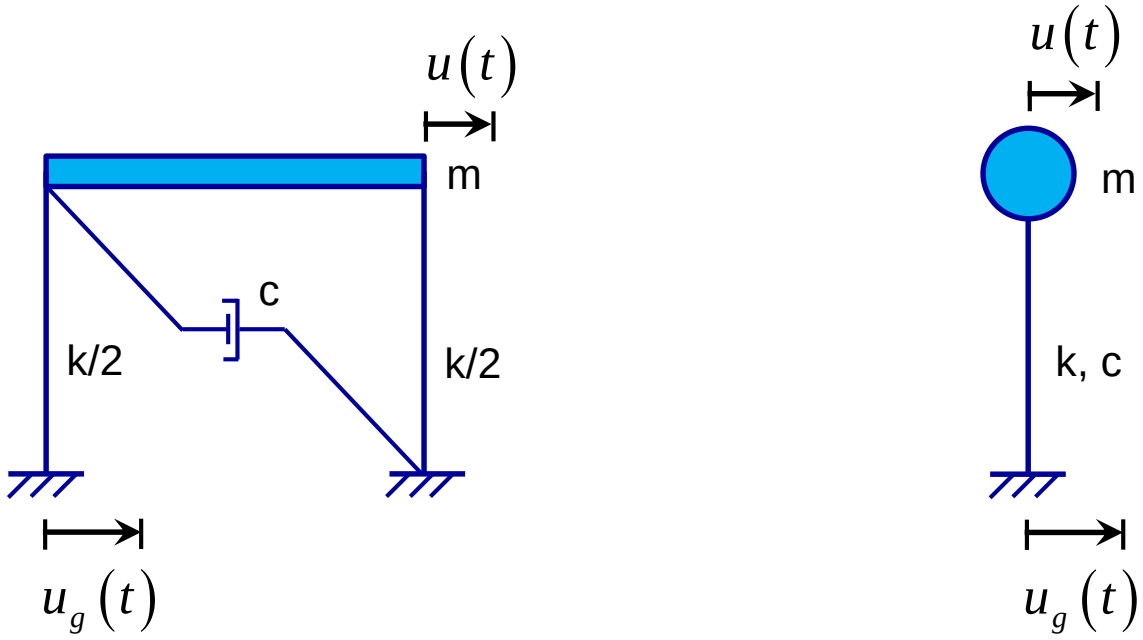
Hypothèses :

- Poteaux : indéformables axialement, masse négligeable
- Plancher rigide

Équation d'équilibre dynamique d'un oscillateur élémentaire

$$m\ddot{u}(t) + c\dot{u}(t) + ku(t) = -m\ddot{u}_g(t)$$

Oscillateur élémentaire 2/3



Équation d'équilibre dynamique d'un oscillateur élémentaire

$$\ddot{u}(t)+\frac{c}{m}\dot{u}(t)+\frac{k}{m}u(t)=-\ddot{u}_g(t)$$

Rapport d'amortissement $\zeta_0=\dfrac{c}{2\,\omega_0\,m}$ **Pulsation propre** $\omega_0^2=\dfrac{k}{m}$

Oscillateur élémentaire 3/3

$$\ddot{u}(t) + 2\zeta_0 \omega_0 \dot{u}(t) + \omega_0^2 u(t) = -\ddot{u}_g(t)$$

$$\dot{u}(0) = 0, \qquad u(0) = 0$$ ***Condition statique initiale***

- Amplification des effets :
  - Sol rigide + Bâtiment rigide
  - Sol mou + Bâtiment souple
- Peu de dommages :
  - Sol rigide + Bâtiment souple
  - Sol mou + Bâtiment rigide
- Lien entre le contenu en énergie du séisme aux différentes fréquences et la période fondamentale de vibration de la structure
- La réponse sismique dépend du **signal et** de la **structure**

Réponse dynamique d'un oscillateur 1/2

- **Données** :
  - Masse : m = 18000 kg
  - Géométrie **1D** :

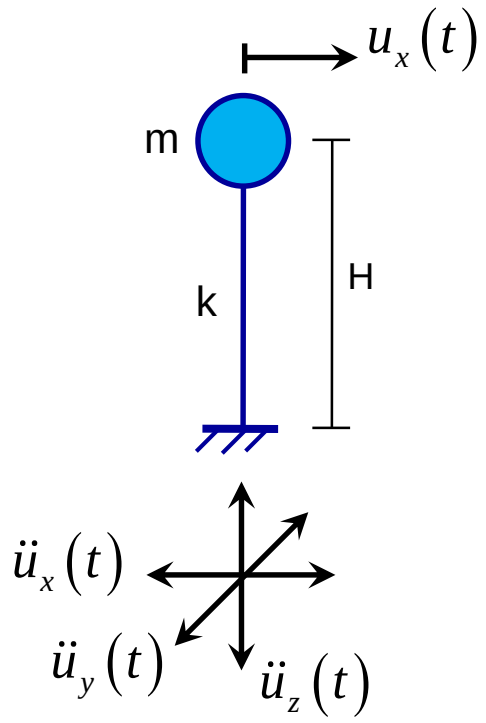
    section 30 x 30 cm ou 30 x 60 cm

    H = 3 m
  - Matériau : béton, ρ = 2500 kg/m^3

    E = 31220 N/mm^2, ν = 0.2
  - Loi de comportement :

    élastique linéaire
  - Conditions aux limites :

    1. Base encastrée $u_x = u_y = u_z = 0$
    2. Accélération imposée $\ddot{u}_x(t), \ddot{u}_y(t), \ddot{u}_z(t)$

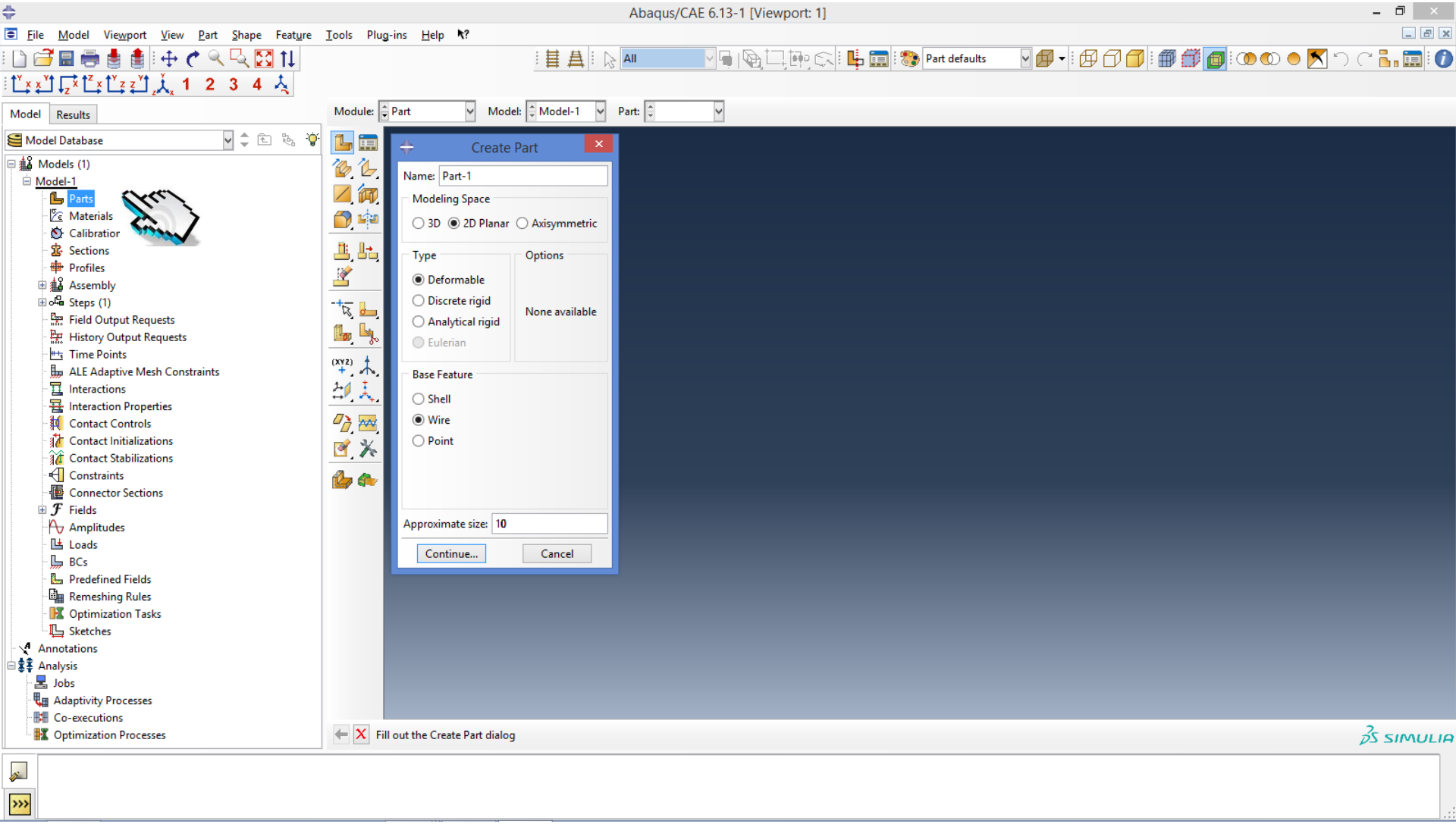


Réponse dynamique d'une structure 3/3

- **Modélisation** :
  - Masse m, raideur $k = 12EI/H^3$
  - Fréquence propre $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, période $T_0 = \frac{1}{f_0}$
- **Résultats** :
  - Step 1 : Fréquences propres
  - Step 1 : Formes modales
  - Step 2 : Histoire temporelle à la base en termes d'accélération [m/s^2] (input)
  - Step 2 : Histoire temporelle au sommet en termes de déplacement [m] (déformation)
  - Step 2 : Histoire temporelle au sommet en termes de vitesse [m/s] et accélération
  - Déplacement max au sommet

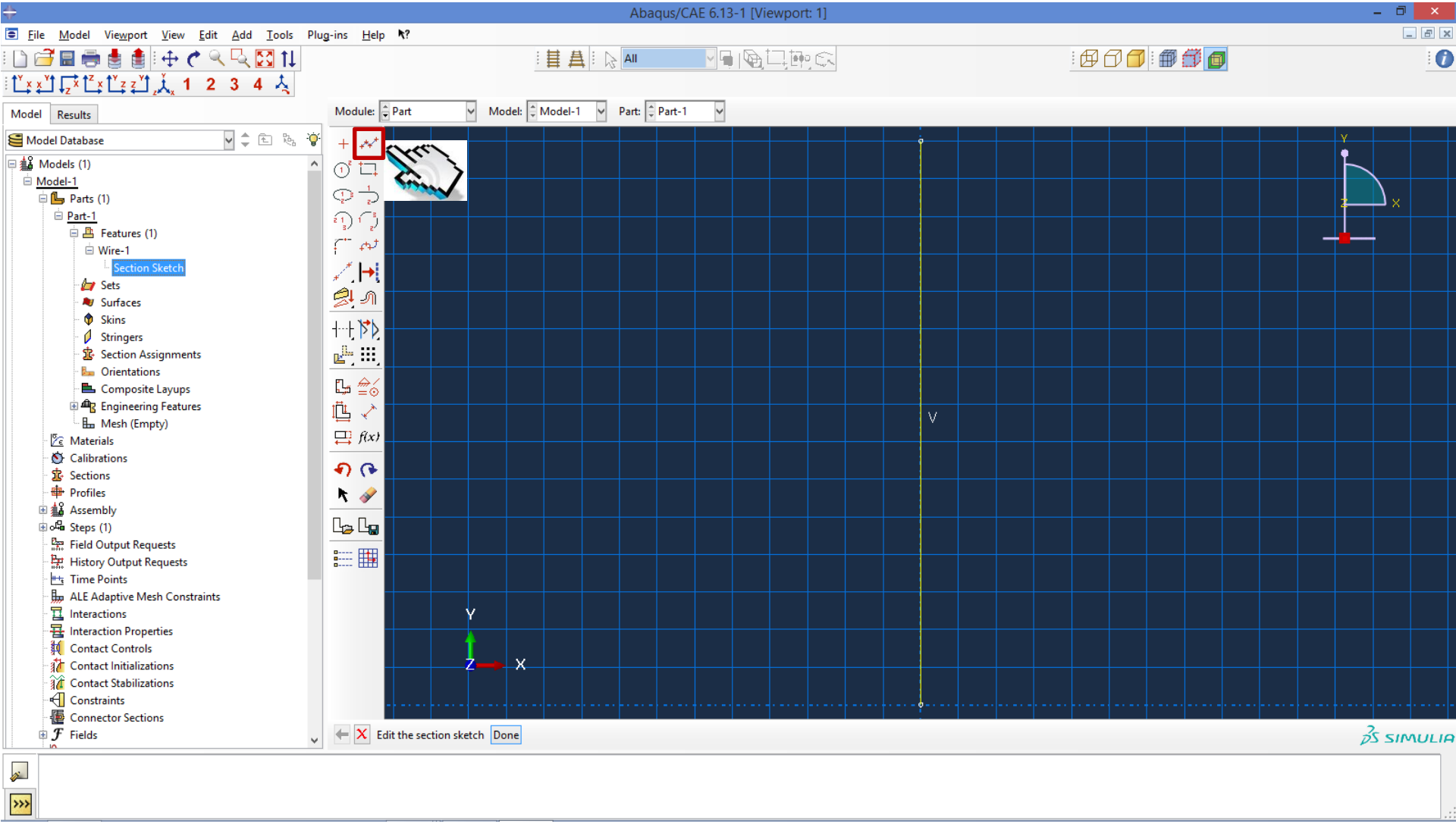
Model - Parts

1. Géométrie : type d'analyse (1D), type d'élément (poutre)



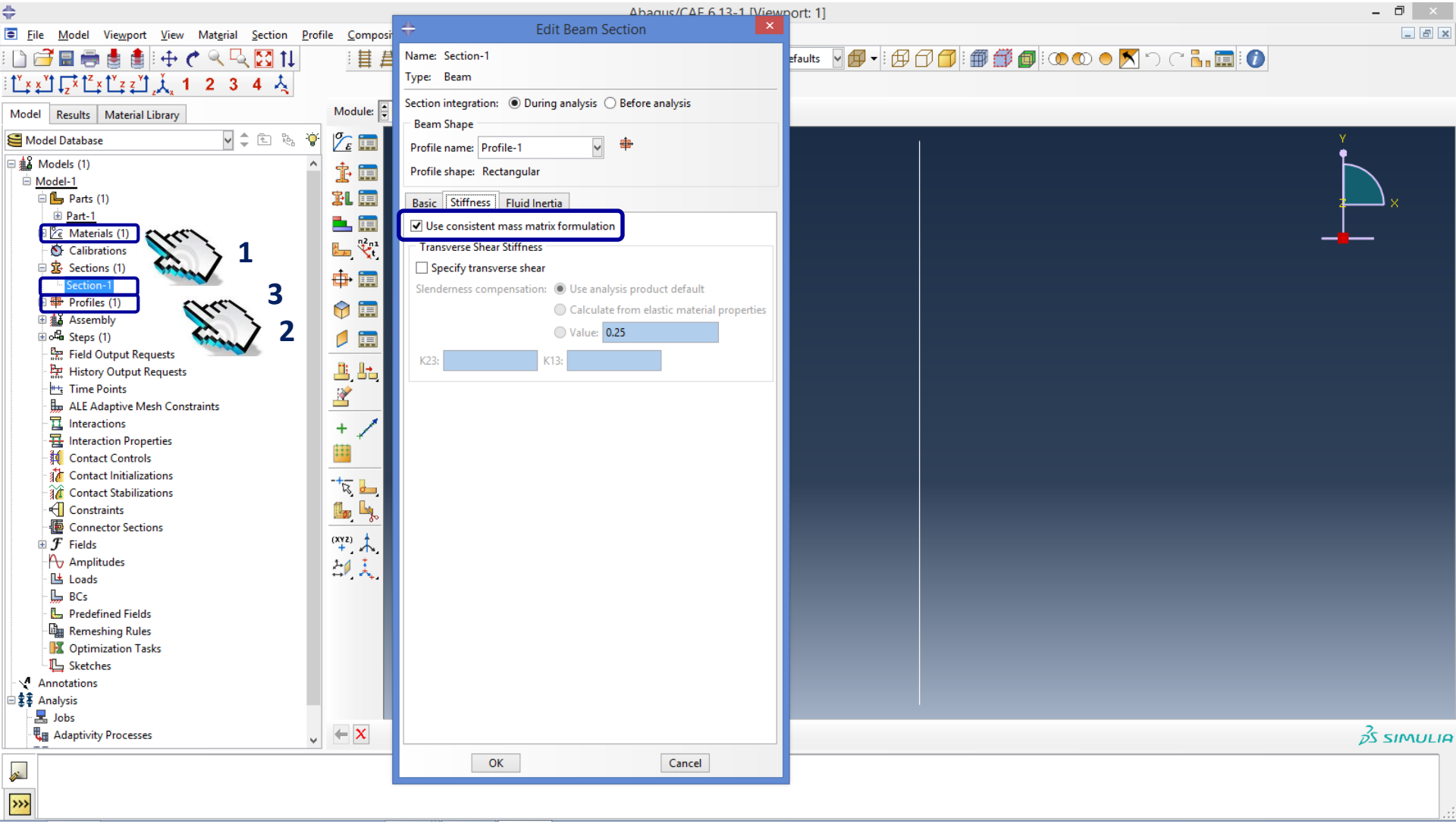
Model - Parts

2. Géométrie : tracer la poutre



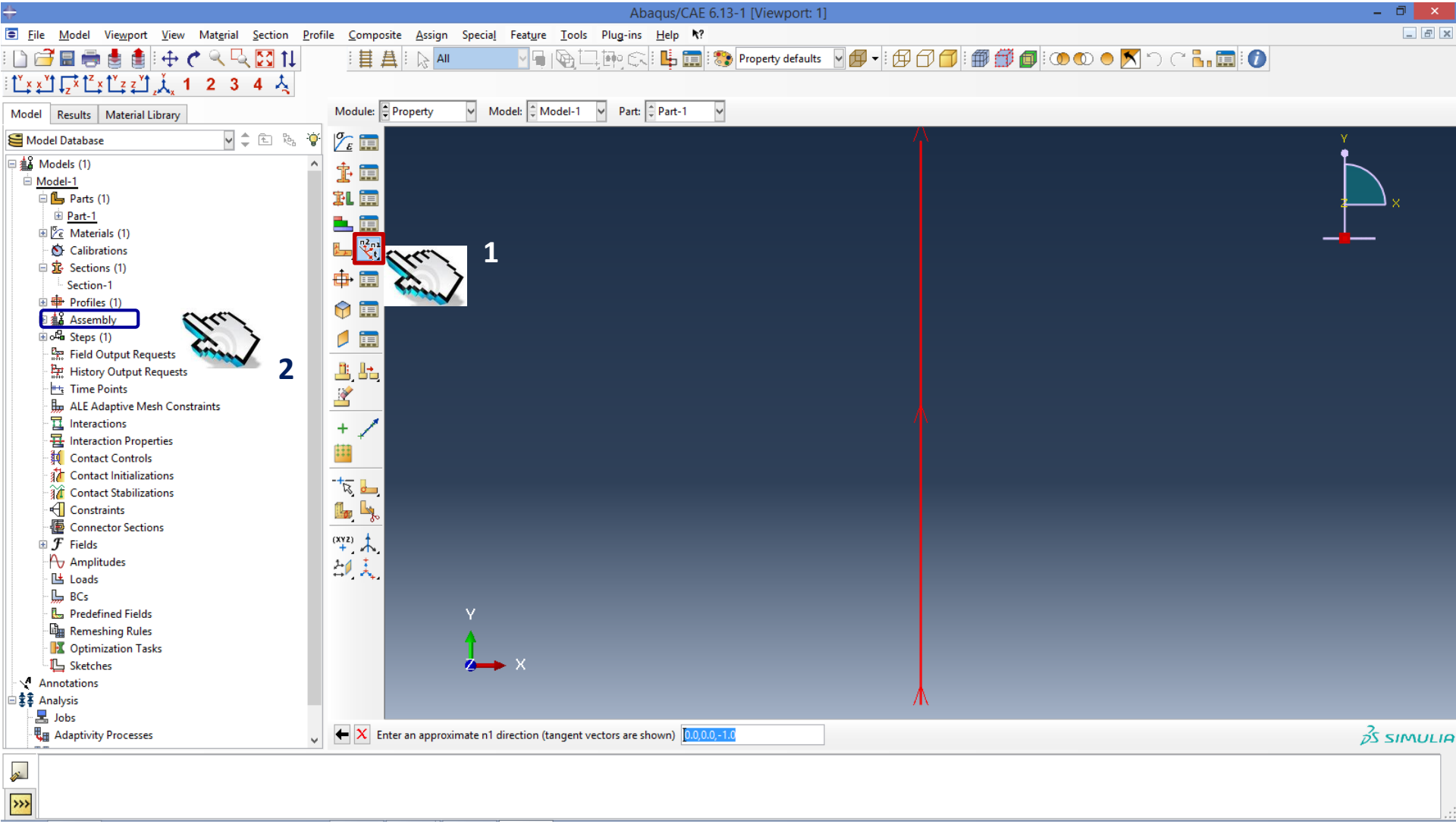
Model

3. Propriétés : Matériau, Profilé R30x30, Section, **Attribution de la section**



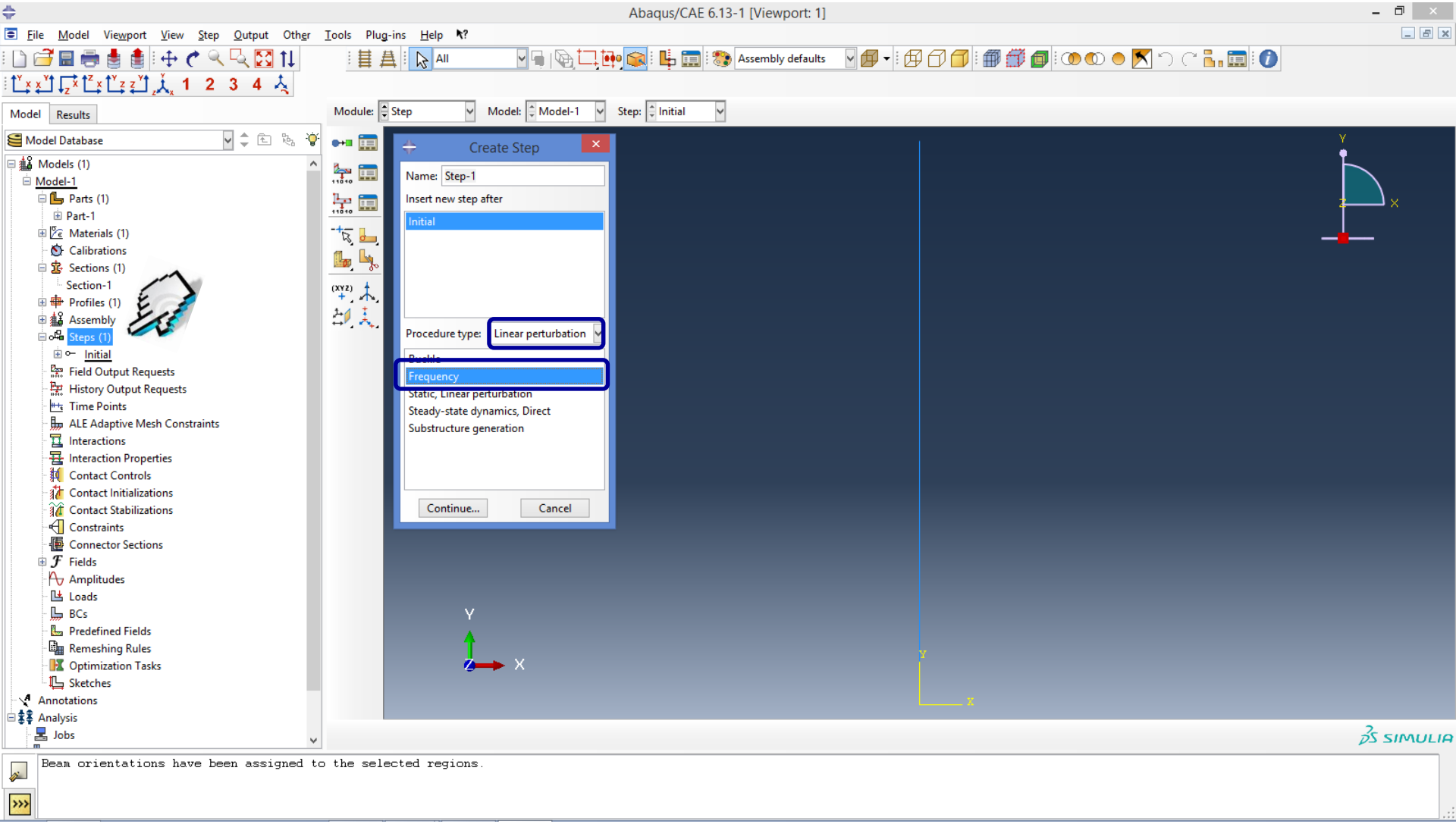
Model

4. Propriétés : Orientation des poutres, Assemblage



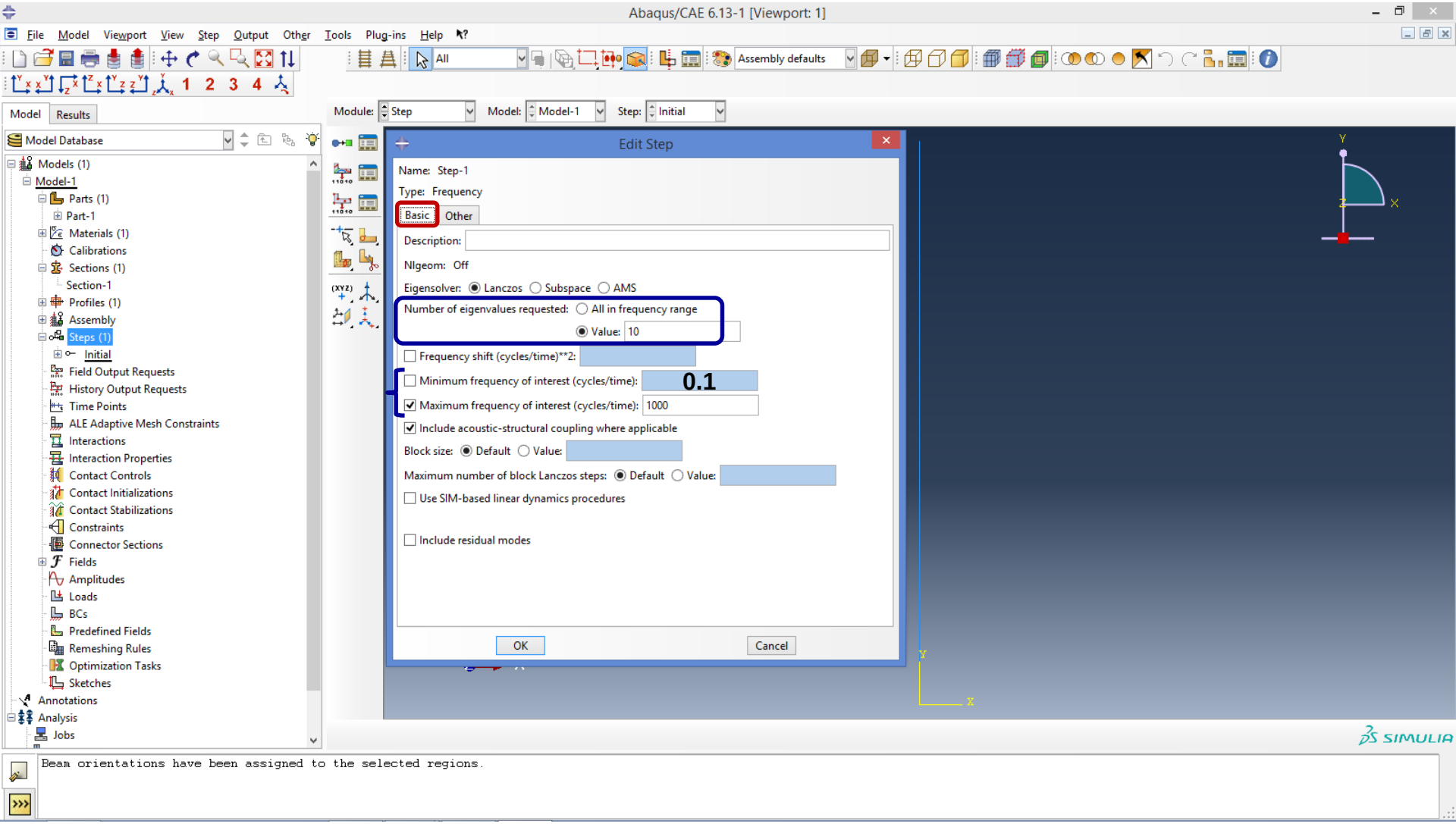
Model - Steps

5. Pas de calcul 1 : fréquences propres



Model - Steps

5. Pas de calcul 1 : fréquences propres



Model - Steps

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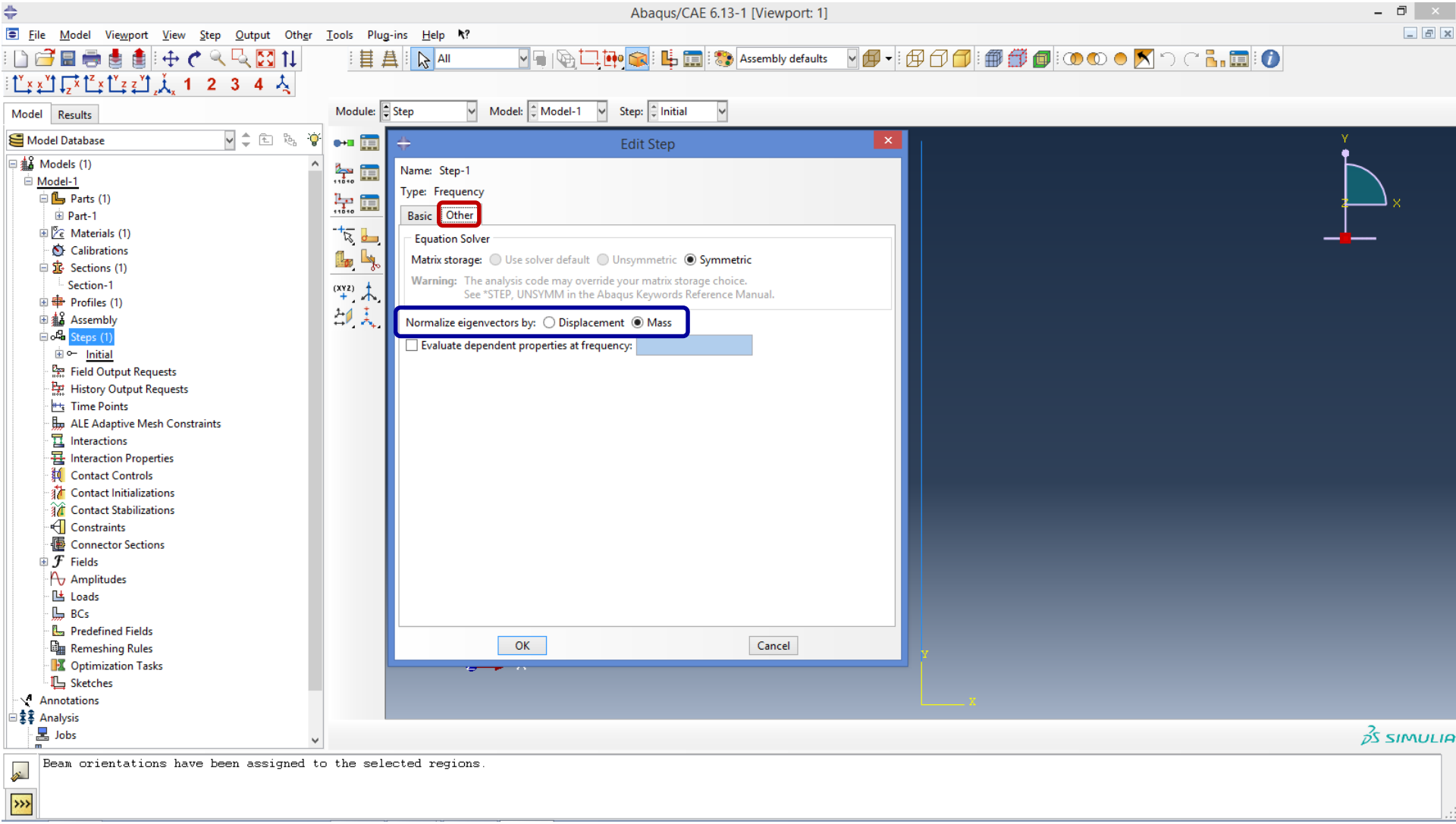
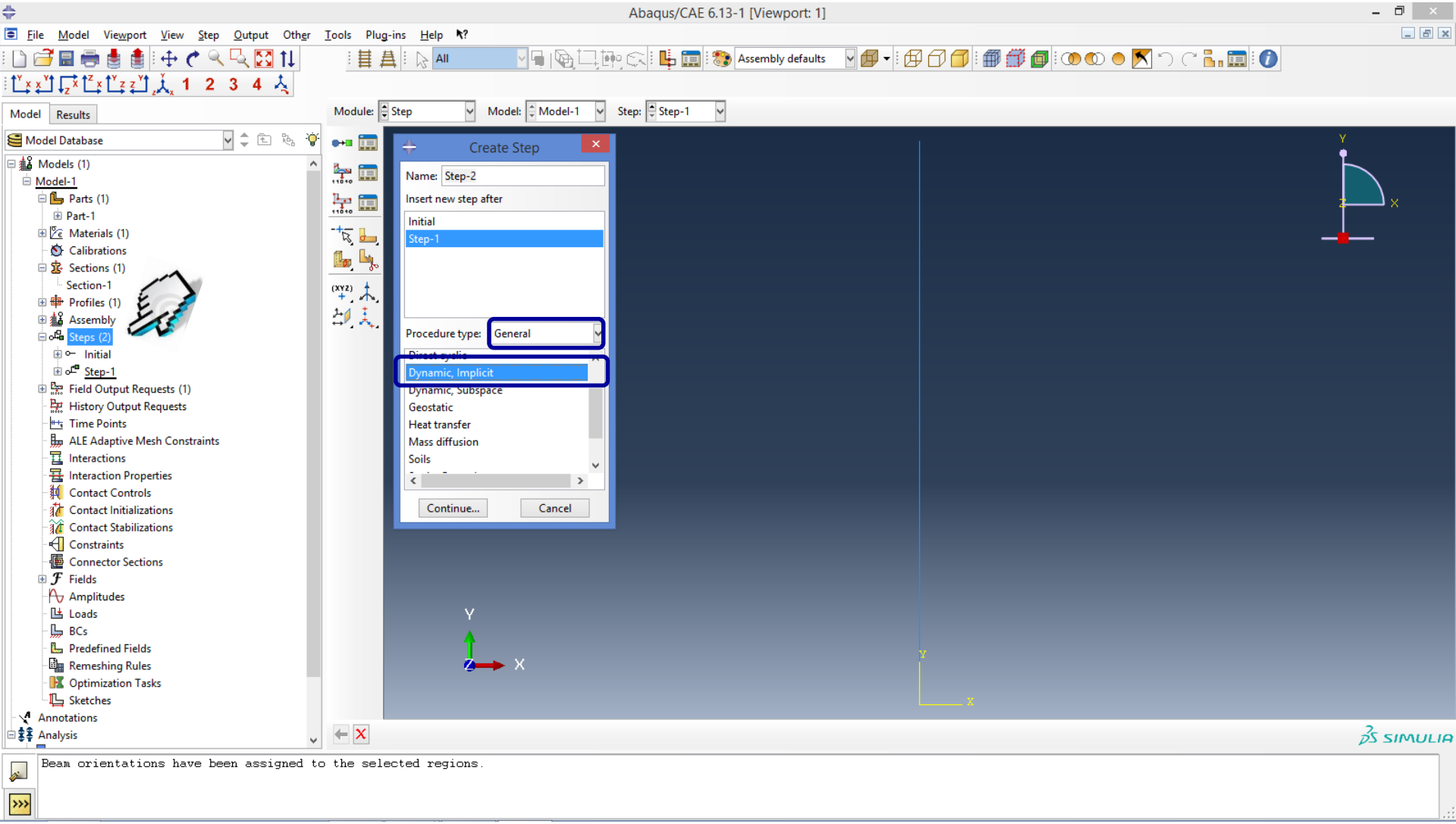


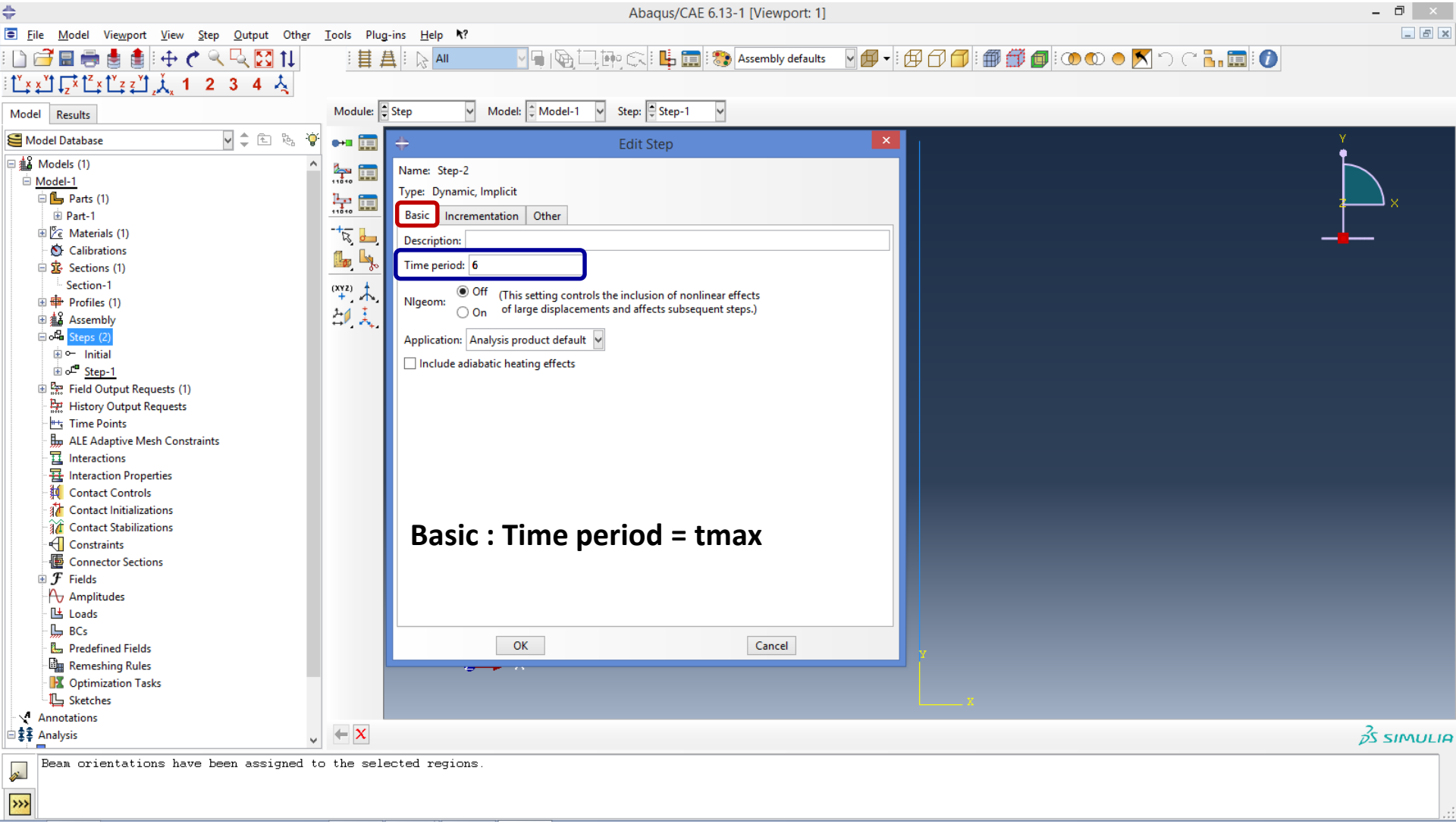
Model - Steps

6. Pas de calcul 2 : mouvement dans le temps



Model - Steps

6. Pas de calcul 2 : mouvement dans le temps



Model - Steps

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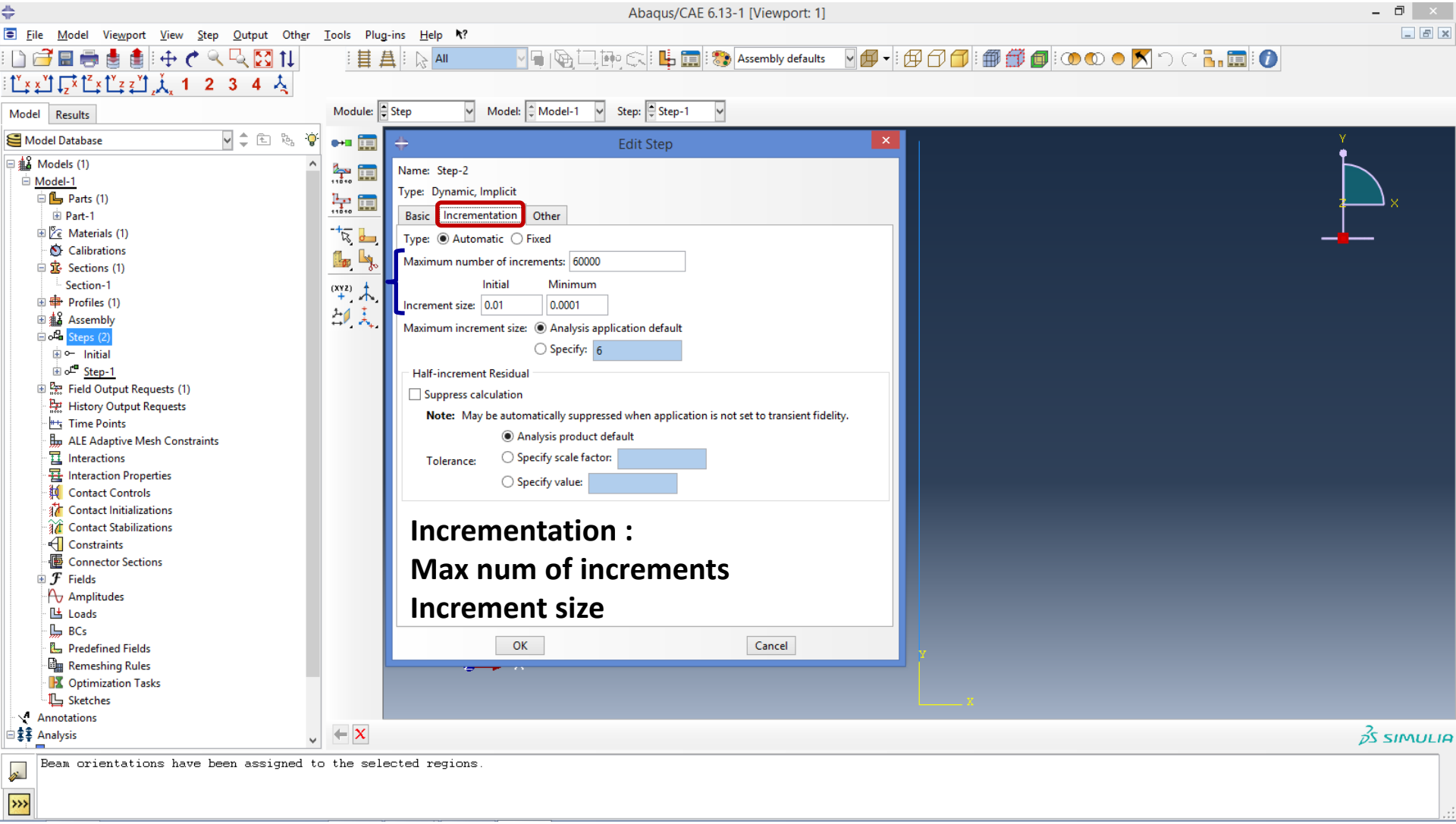
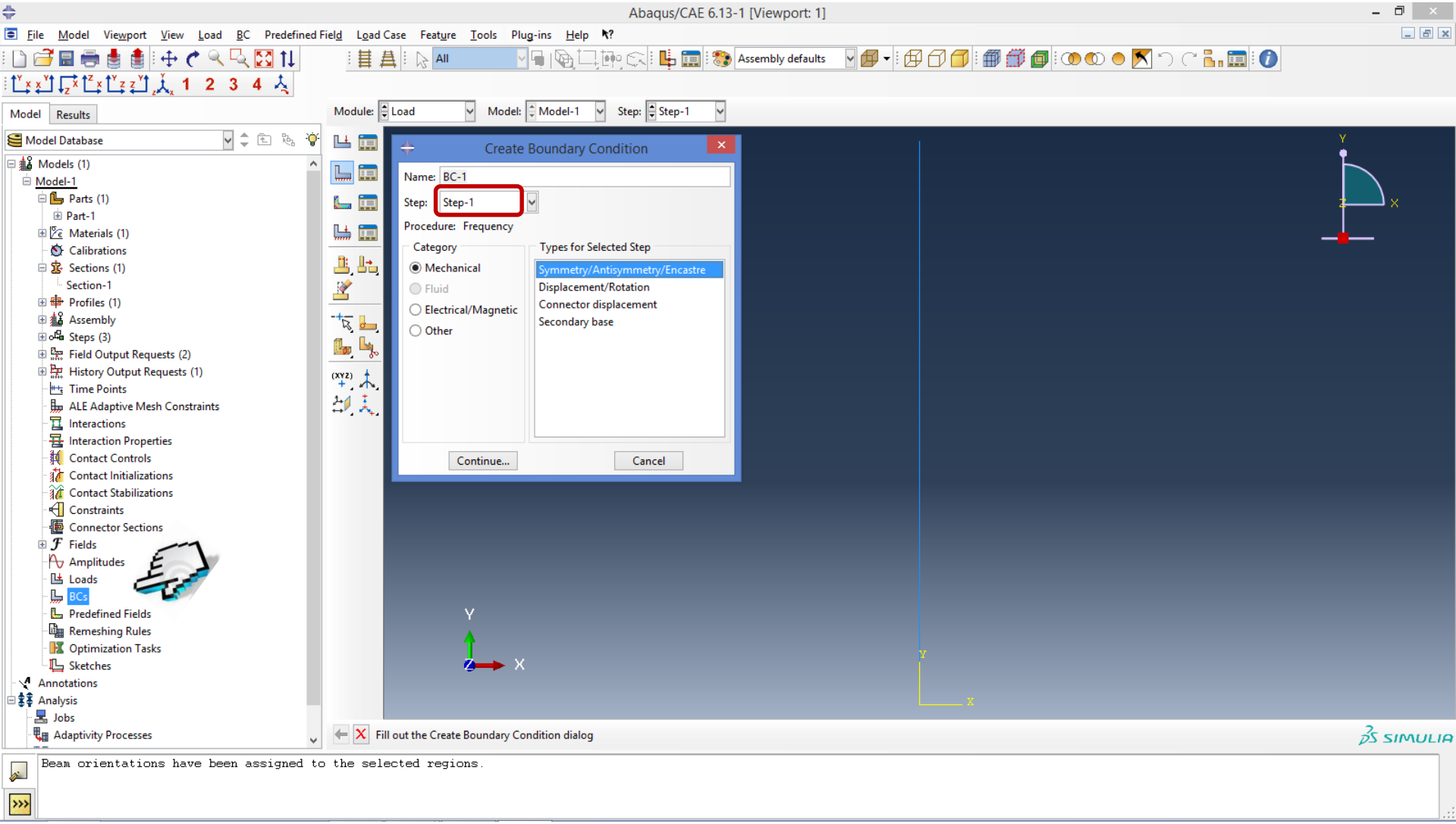


Model - BCs

7. Conditions aux limites : encastrement à la base (step 1)



Model - BCs

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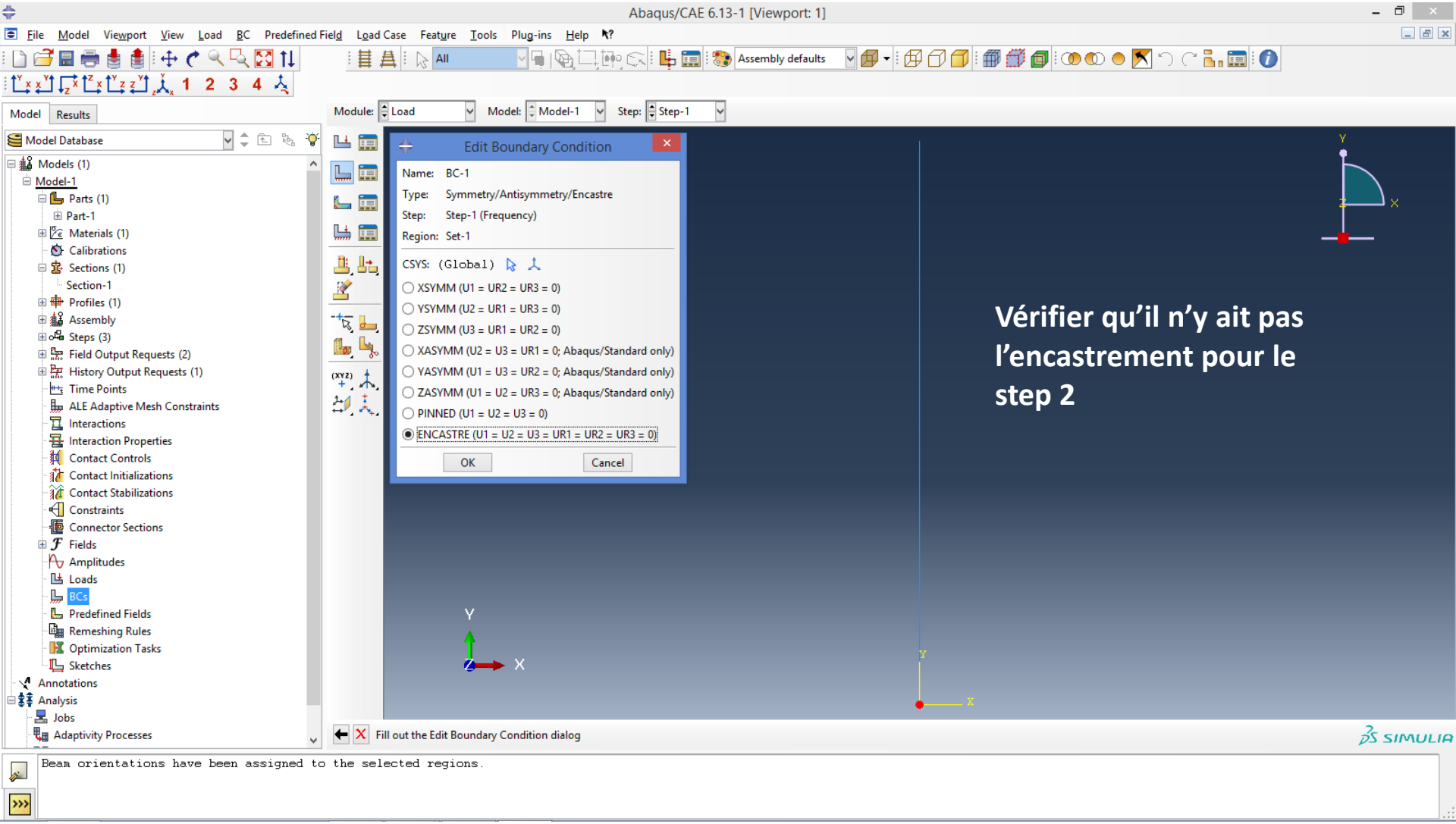
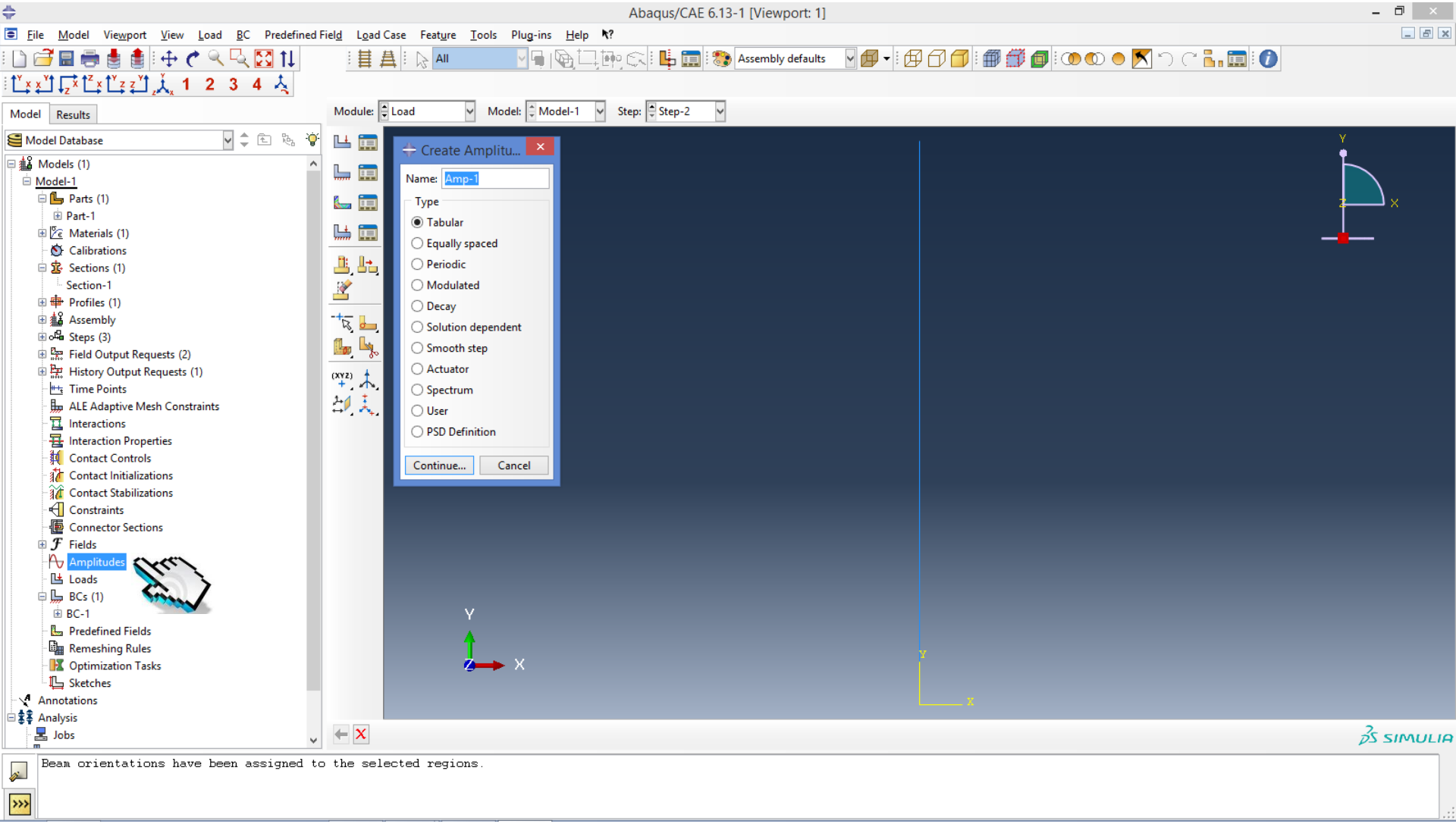


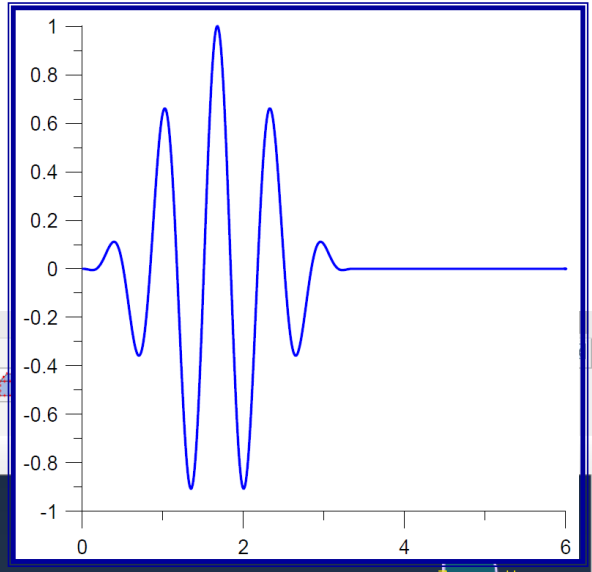
Model - Amplitudes

8. Histoire de charge : amplitude dans le temps



Model - Amplitudes

8. Histoire de charge : amplitude dans le temps



Abaqus/CAE 6.13-1 [Viewport: 1]

File Model Viewport View Load BC Predefined Field Load Case Feature Tools Plug-ins Help

Module: Load Model: Model-1 Step: Step-2

Model Results

Model Database

- Models (1)
  - Model-1
    - Parts (1)
      - Part-1
    - Materials (1)
    - Calibrations
    - Sections (1)
      - Section-1
    - Profiles (1)
    - Assembly
    - Steps (3)
    - Field Output Requests (2)
    - History Output Requests (1)
    - Time Points
    - ALE Adaptive Mesh Constraints
    - Interactions
    - Interaction Properties
    - Contact Controls
    - Contact Initializations
    - Contact Stabilizations
    - Constraints
    - Connector Sections
    - Fields
    - Amplitudes
    - Loads
    - BCs (1)
      - BC-1
    - Predefined Fields
    - Remeshing Rules
    - Optimization Tasks
    - Sketches
- Annotations
- Analysis
- Jobs

Edit Amplitude

Name: Amp-1

Type: Tabular

Time span: Step time

Smoothing: Use solver default

Specify:

Amplitude Data | Baseline Correction

	Time/Frequency	Amplitude
1	0.01	0
2	0.02	-8.84741366524456E-005
3	0.03	-0.000349146713636409
4	0.04	-0.0007678771519008
5	0.05	-0.00132145897462093
6	0.06	-0.00197815487958209
7	0.07	-0.00269843262646837
8	0.08	-0.00343588877070535
9	0.09	-0.00413834391727775
10	0.1	-0.00474909006306943
11	0.11	-0.00520826779350037
12	0.12	-0.00545434864293868
13	0.13	-0.0054256958579039
14	0.14	-0.0050621751512136
15	0.15	-0.00430678583162192
16	0.16	-0.00310728195830877

OK Cancel

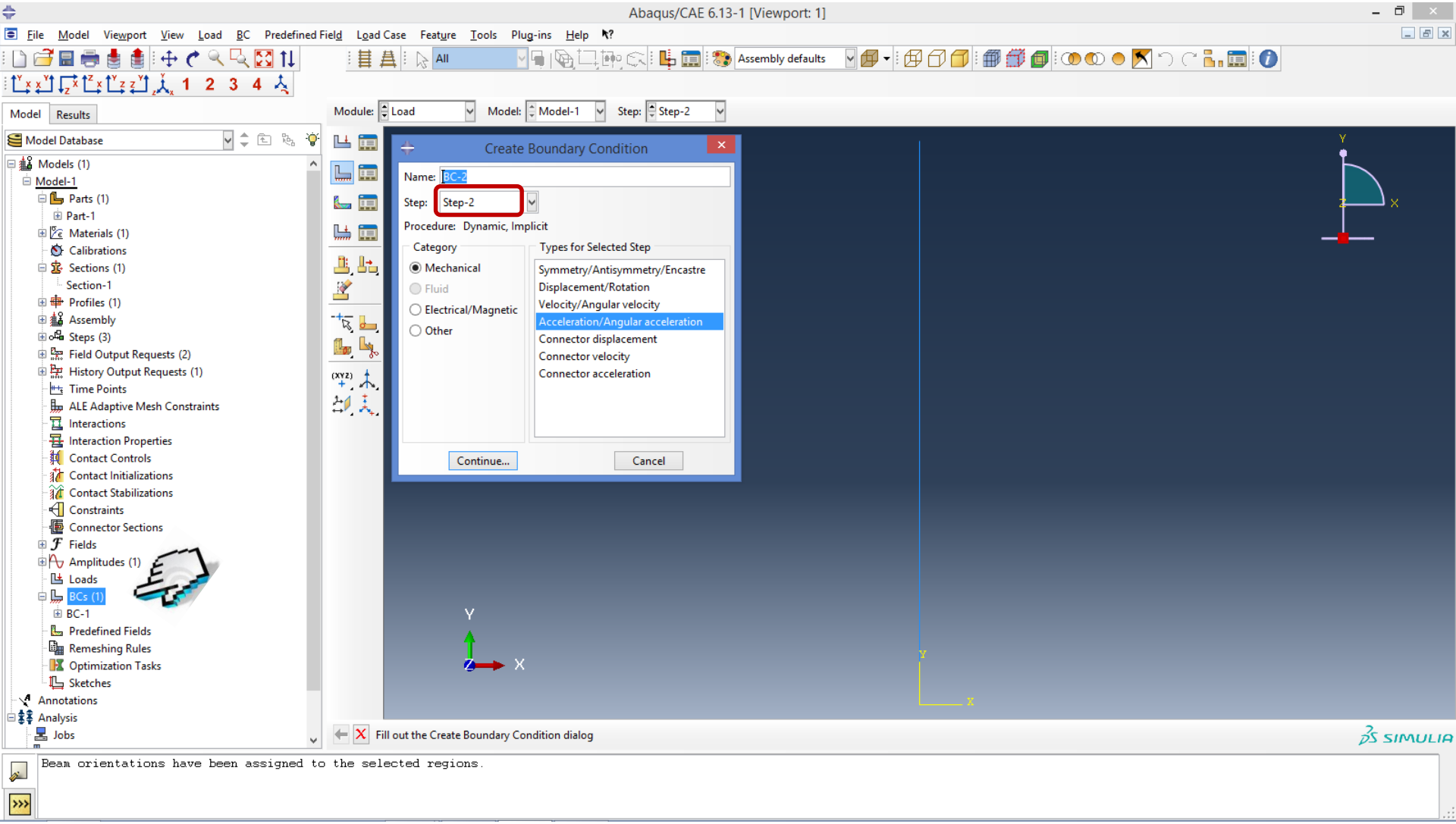
Amplitude = A(x) / Amax

SIMULIA

Beam orientations have been assigned to the selected regions.

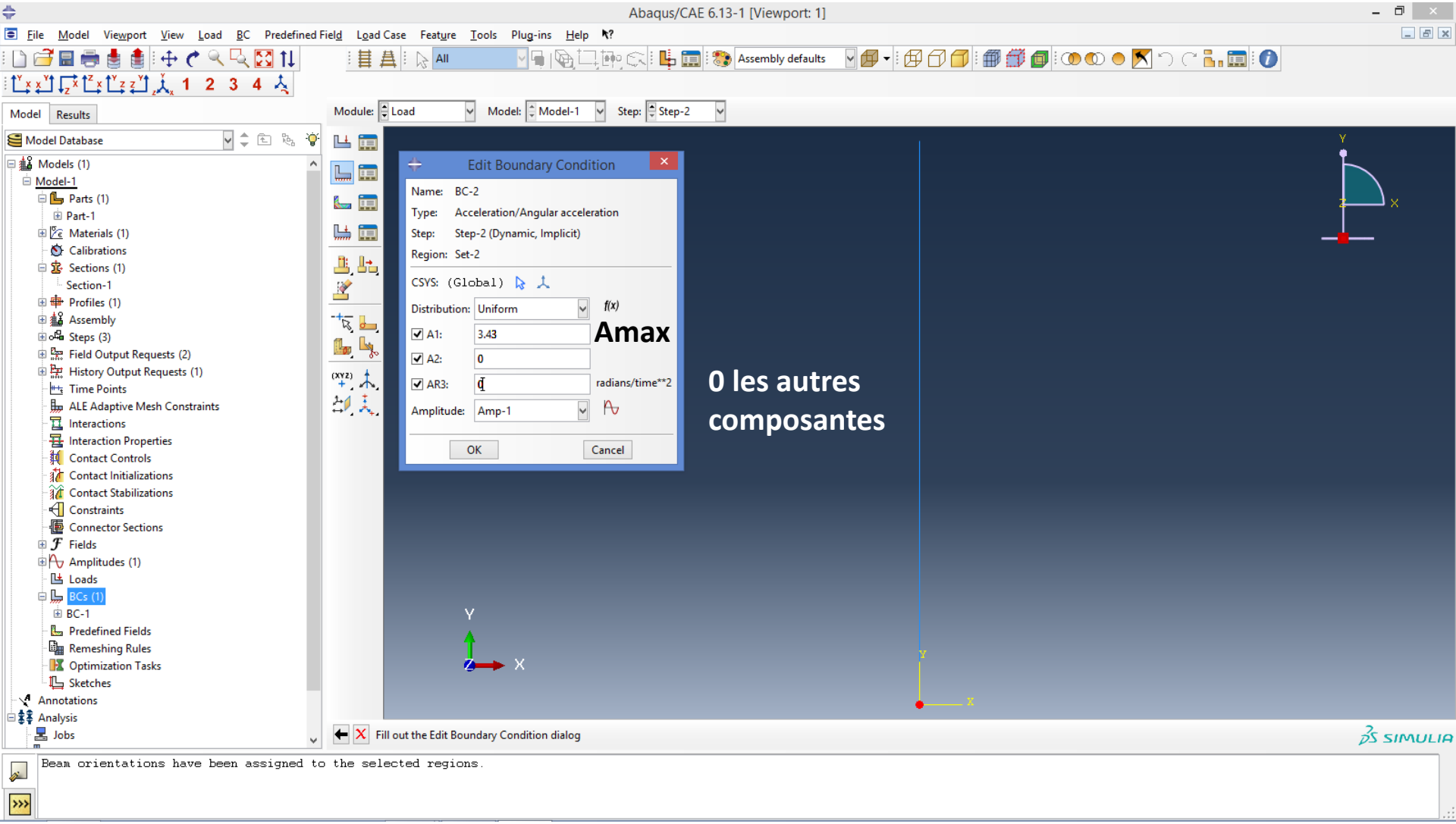
Model - BCs

9. Conditions aux limites : accélération imposée (step 2)



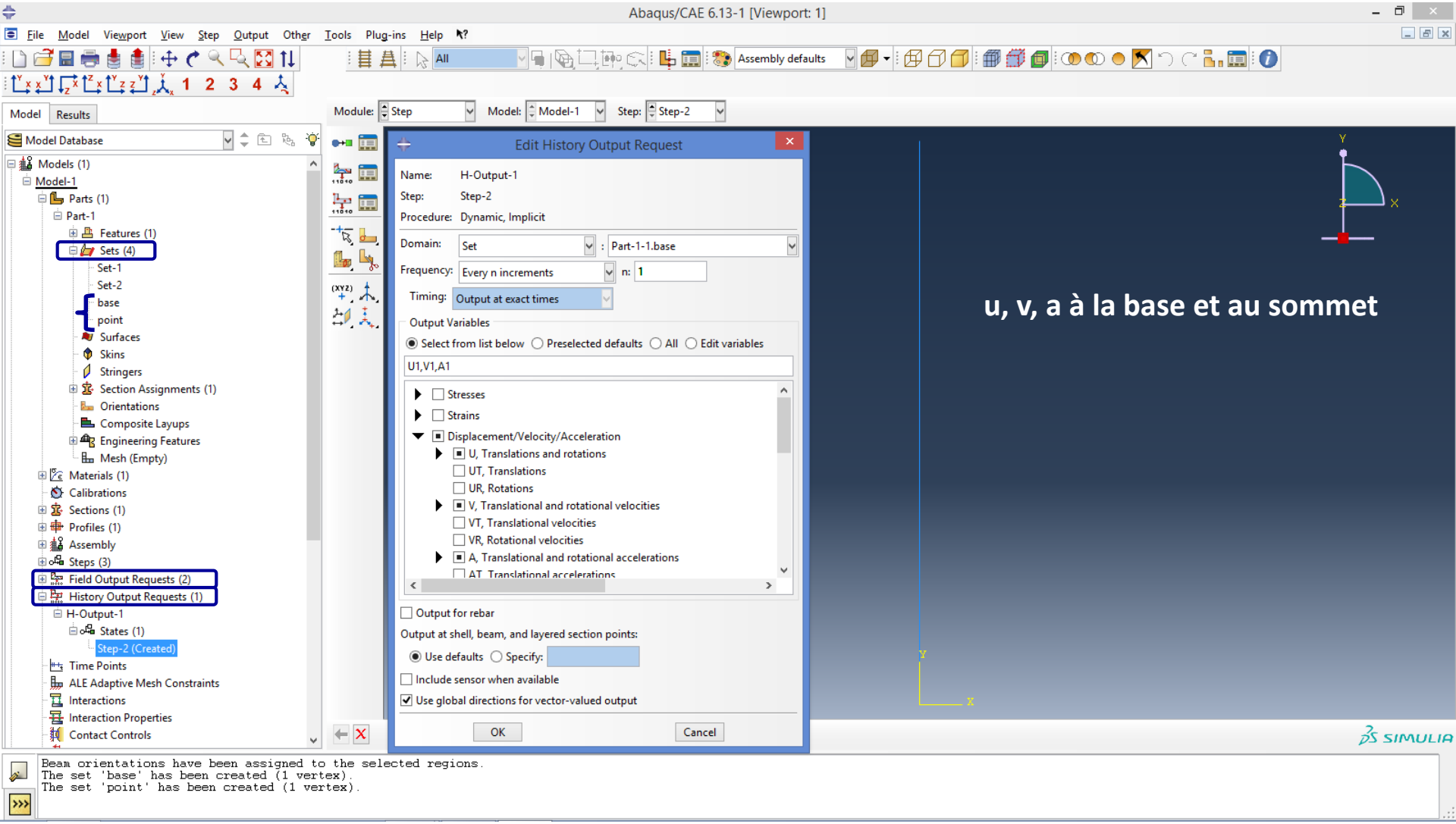
Model - BCs

9. Conditions aux limites : accélération imposée



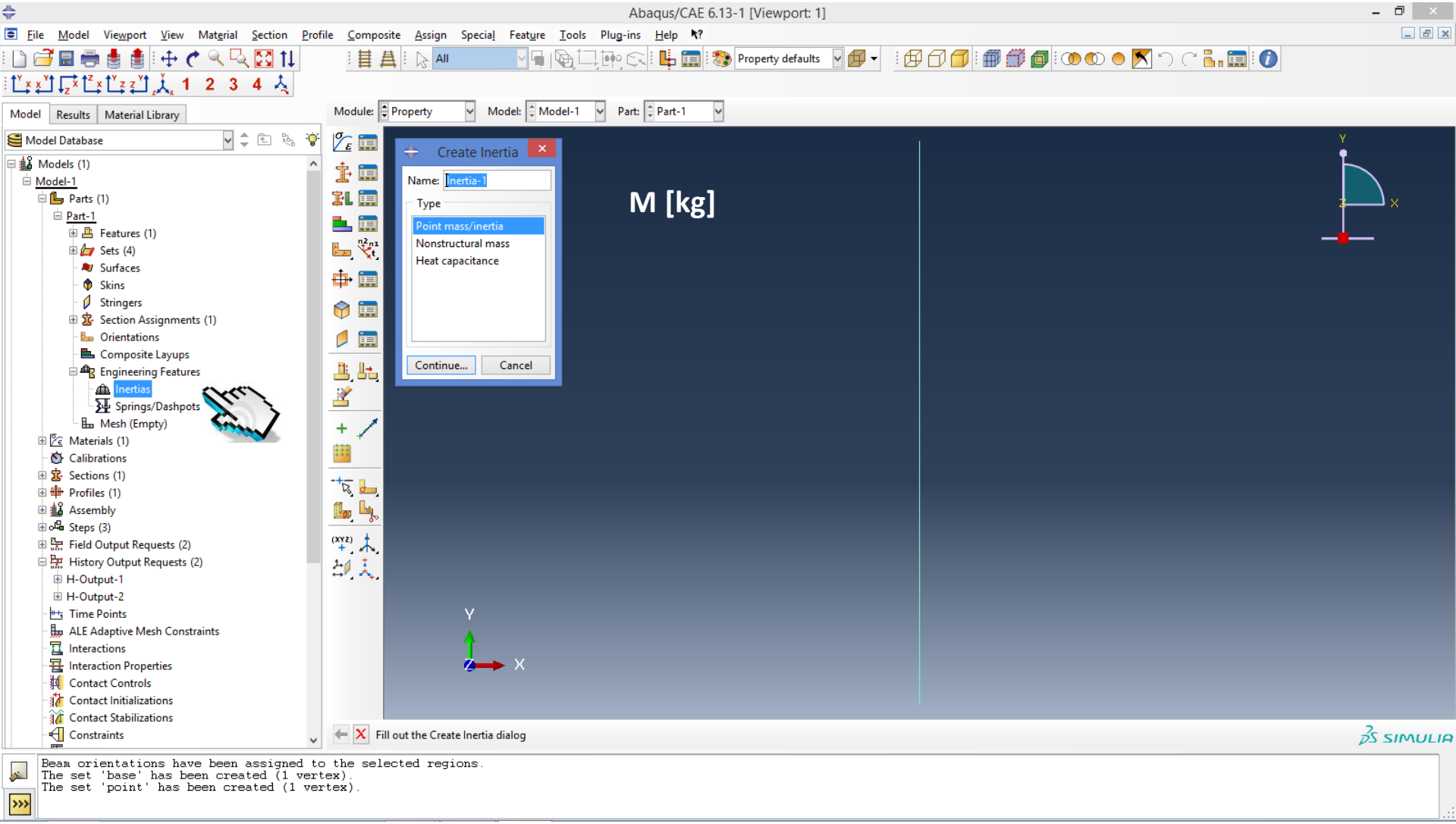
Model

10. Mouvement dans le temps : Sets, Field Output Request, History Output Request



Model - Parts

11. Masse concentrée aux noeuds : éléments de la matrice des masses



Model - Parts

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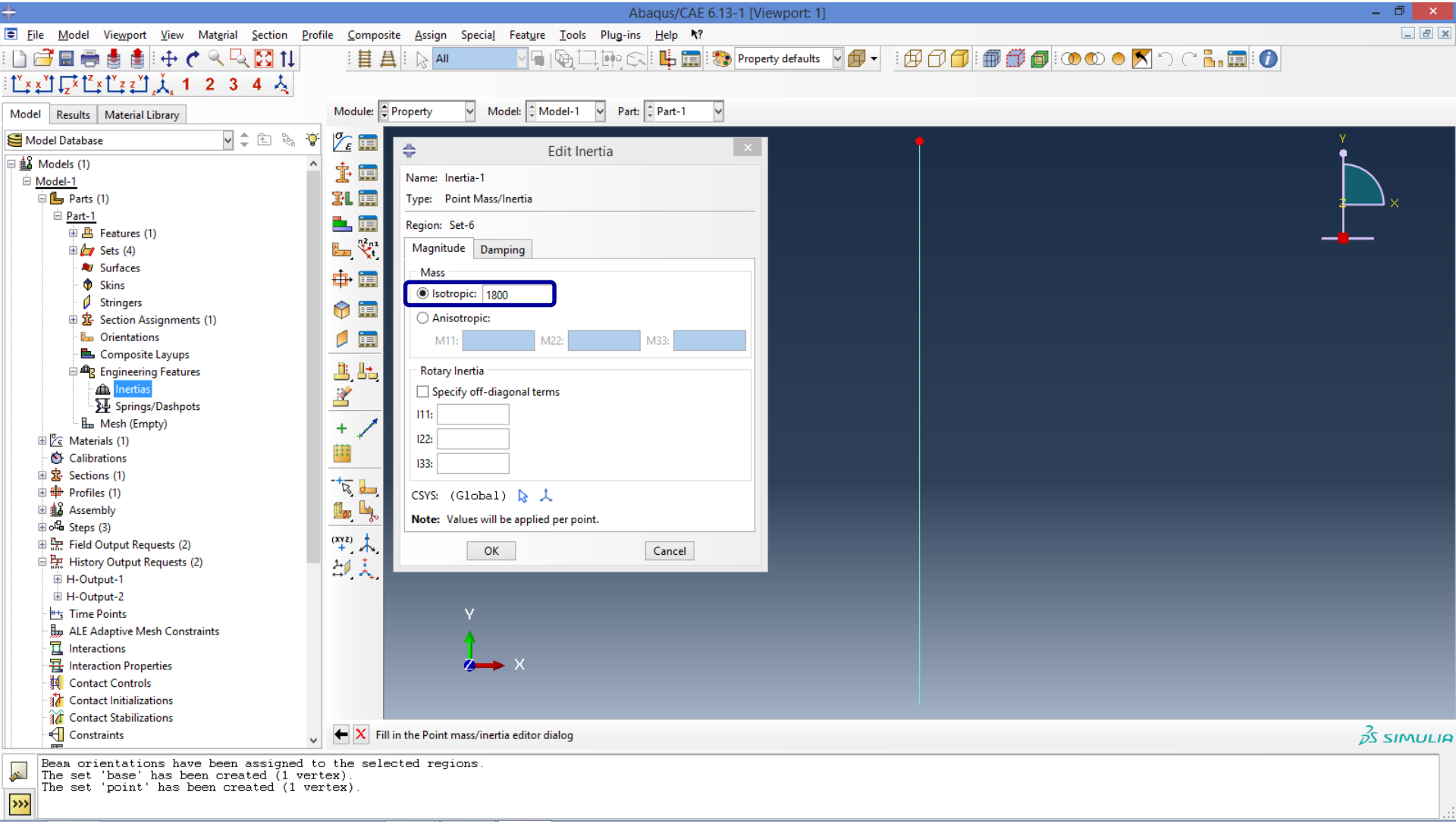
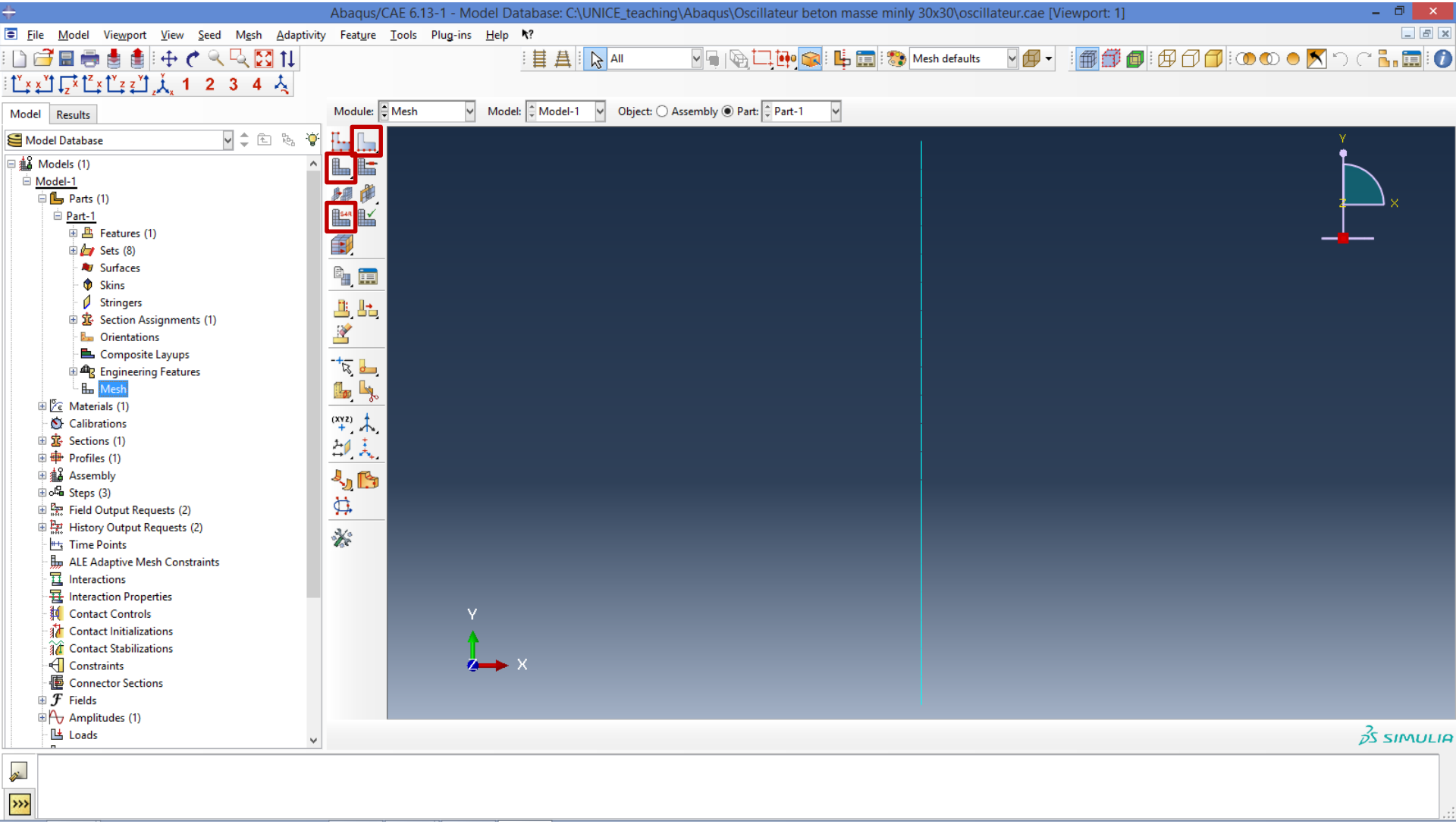


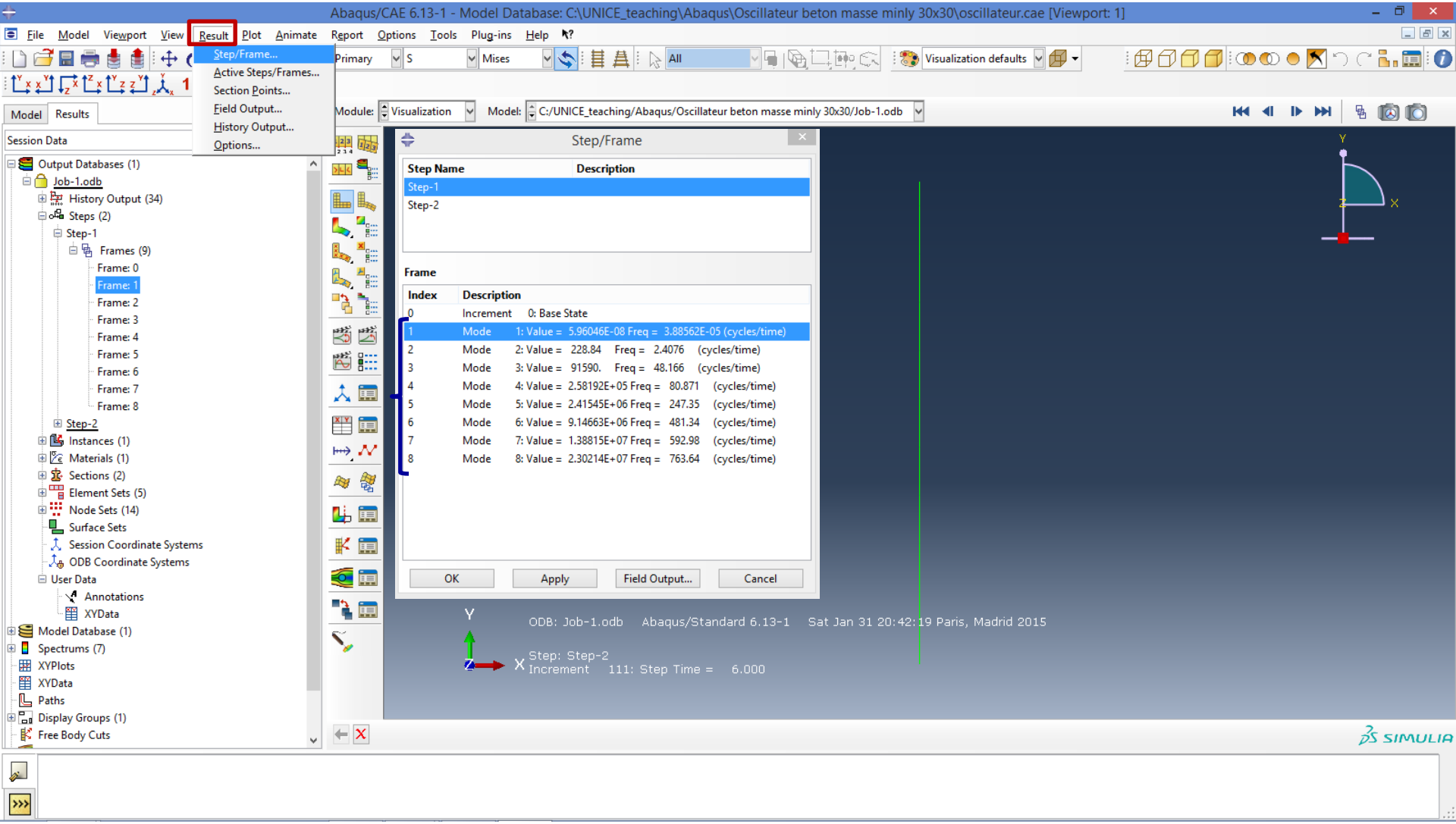
Model

12. Maillage (Parts-Mesh) et Calcul (Analysis-Job, Data check, Submit)



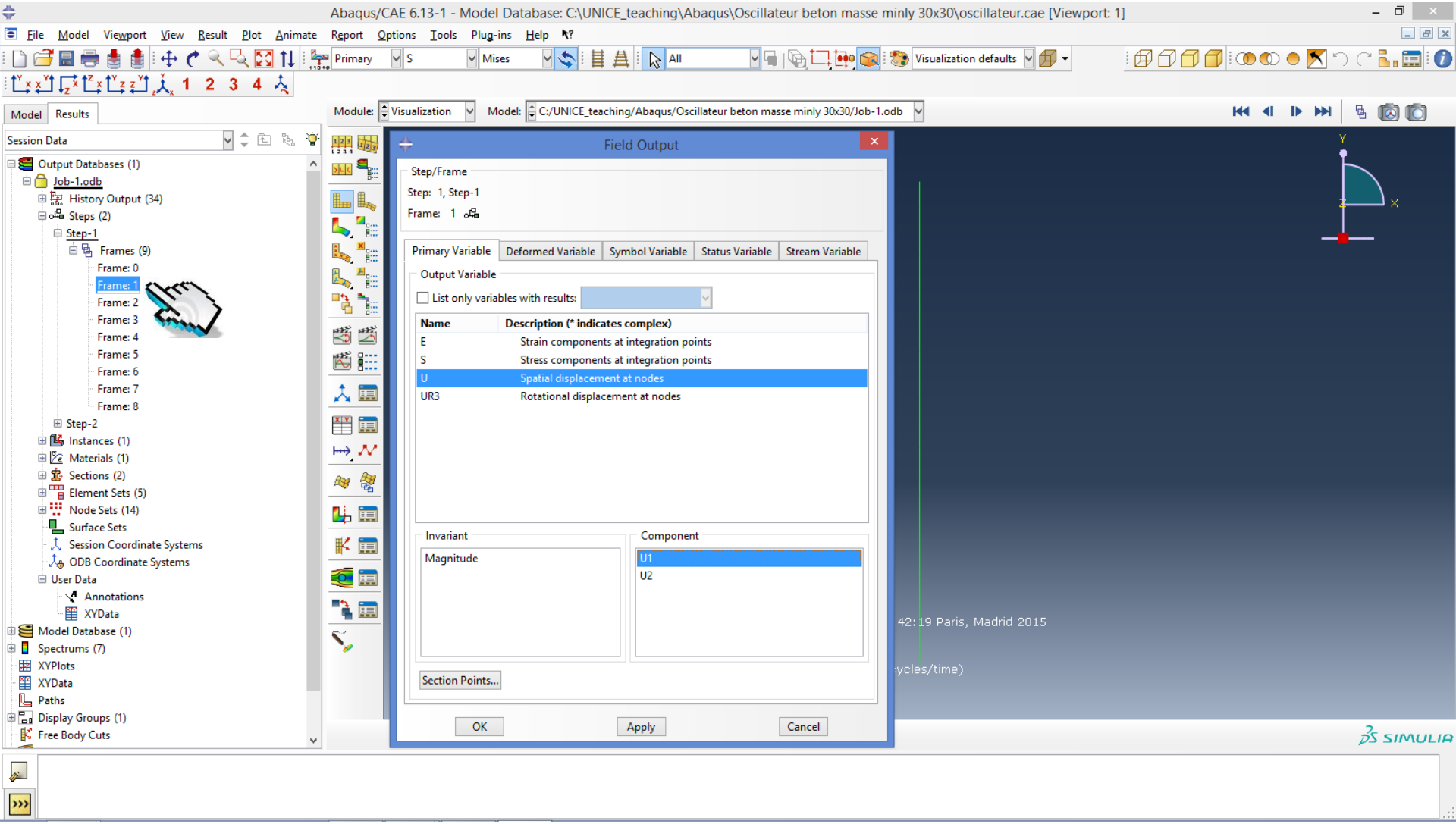
Results

1. Fréquences propres



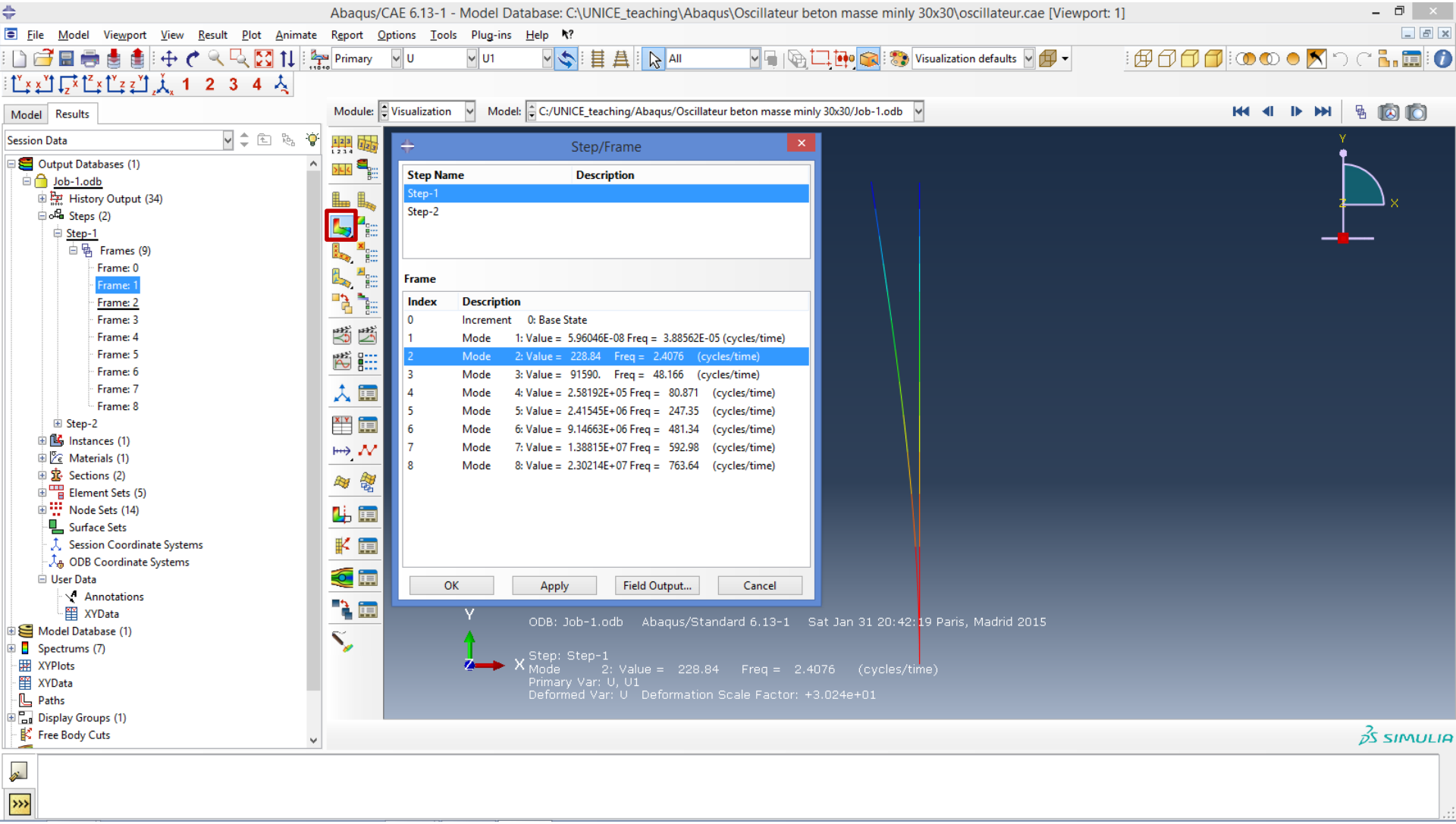
Results

2. Modes propres



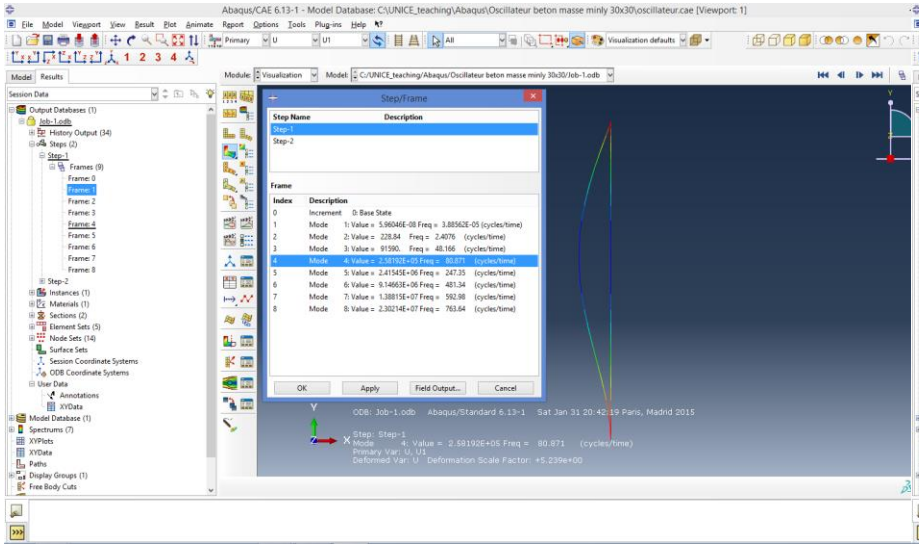
Results

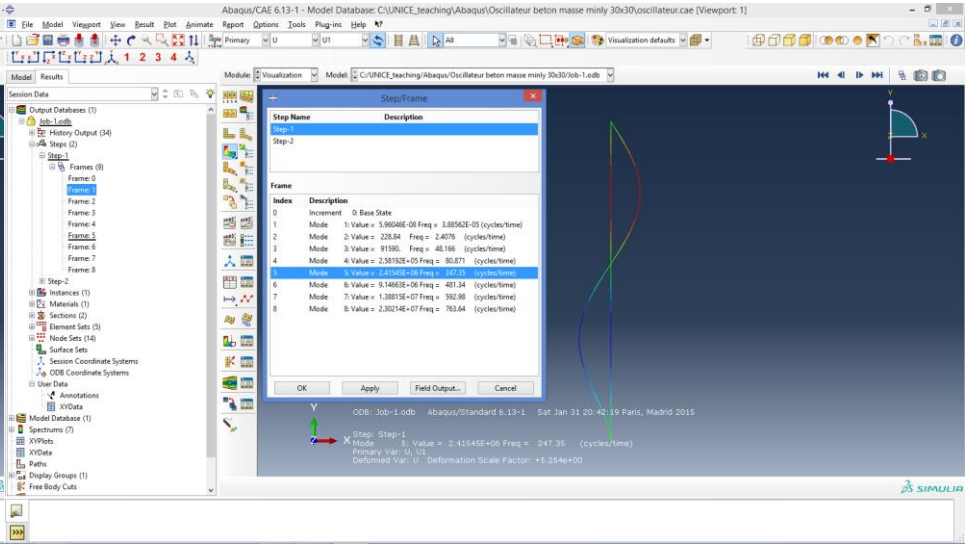
2. Modes propres

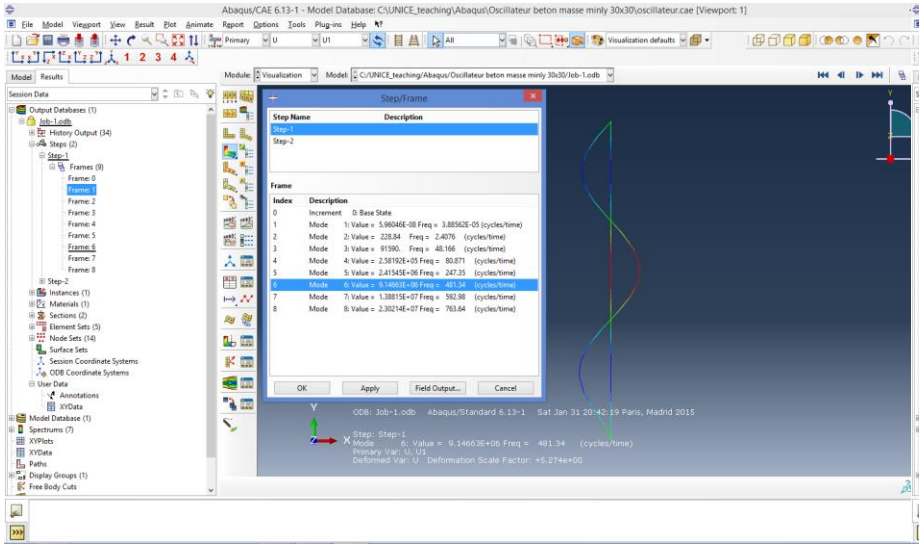


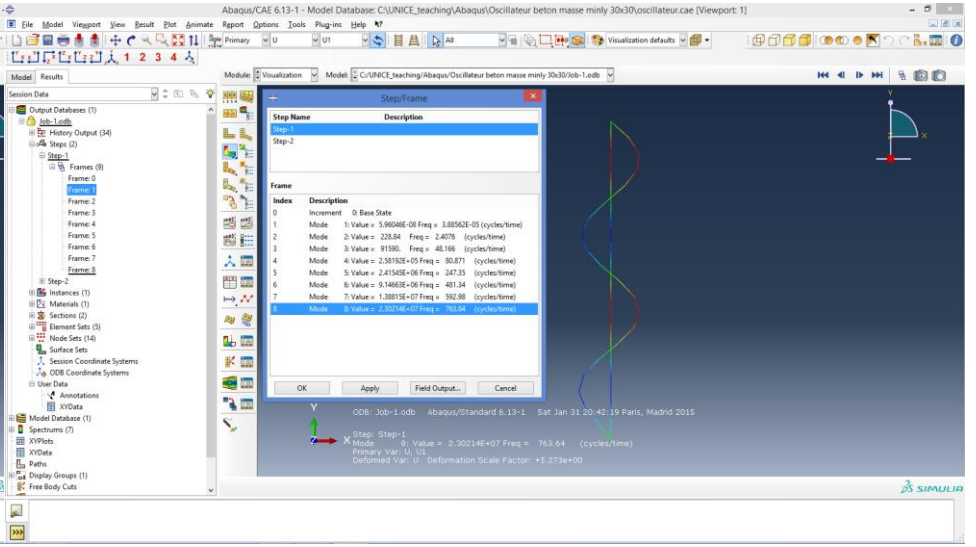
Results

2. Modes propres



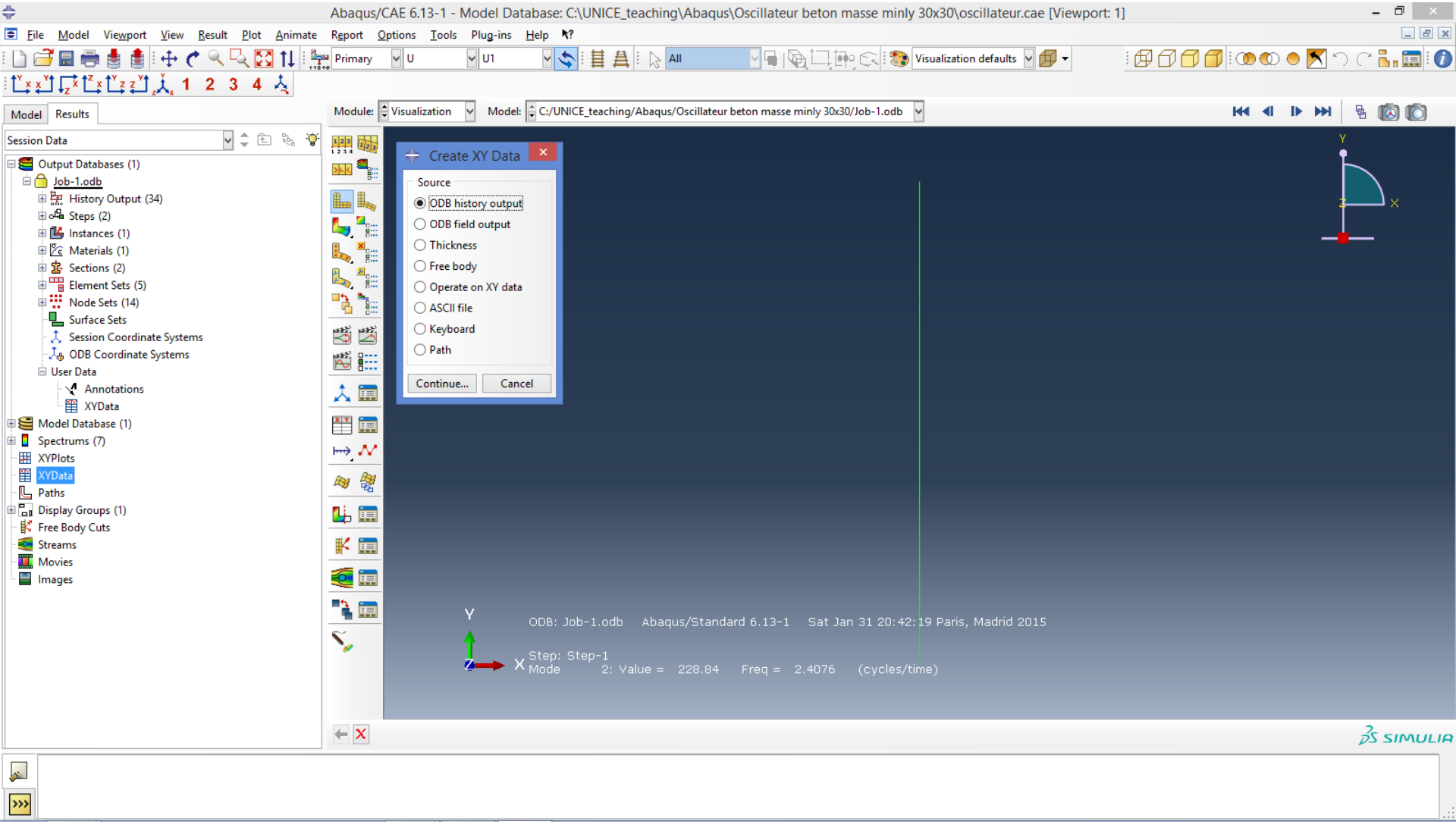






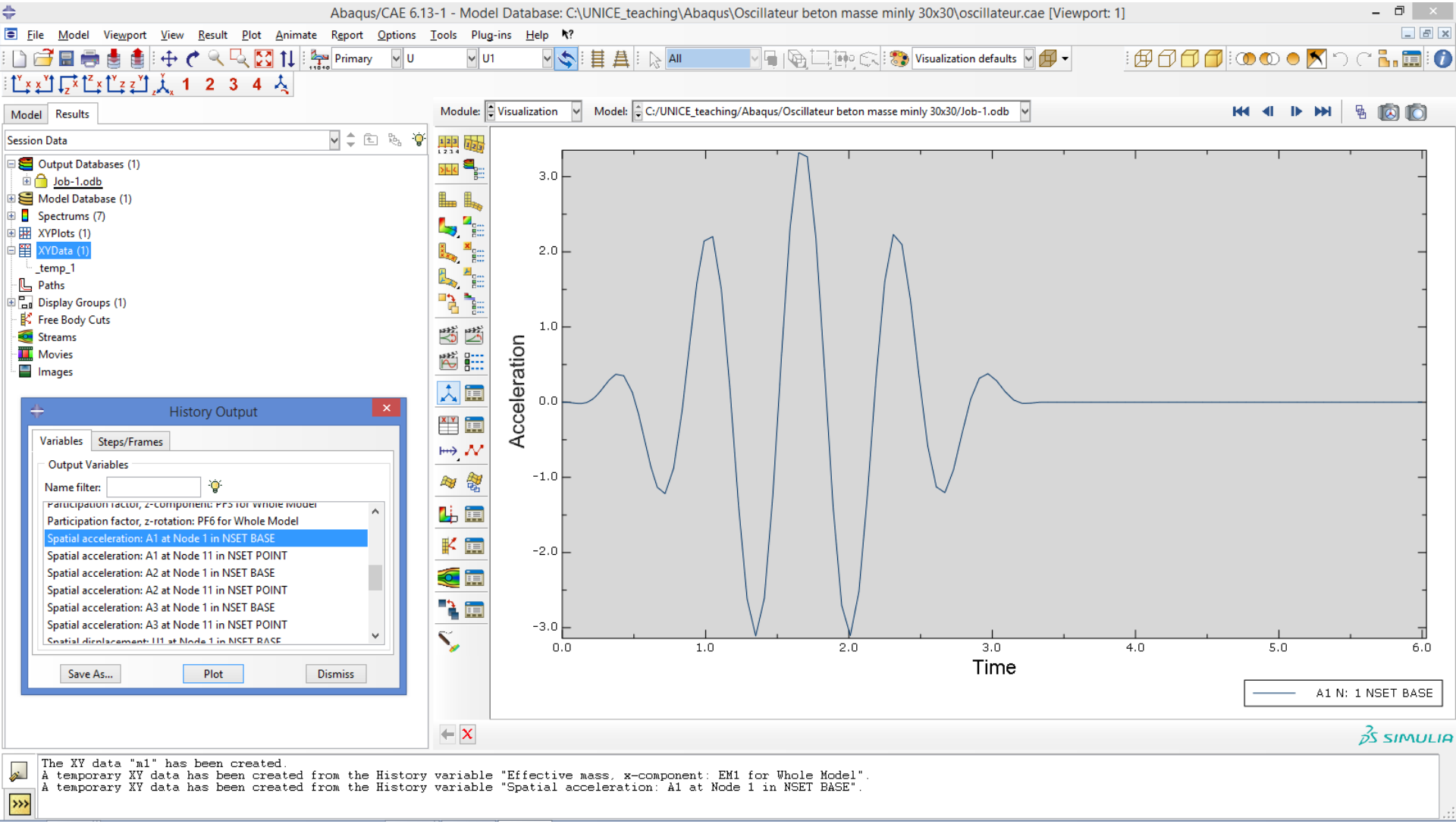
Results - XY Data

3. Courbes : déplacement du sommet dans le temps, vitesse/accélération à la base



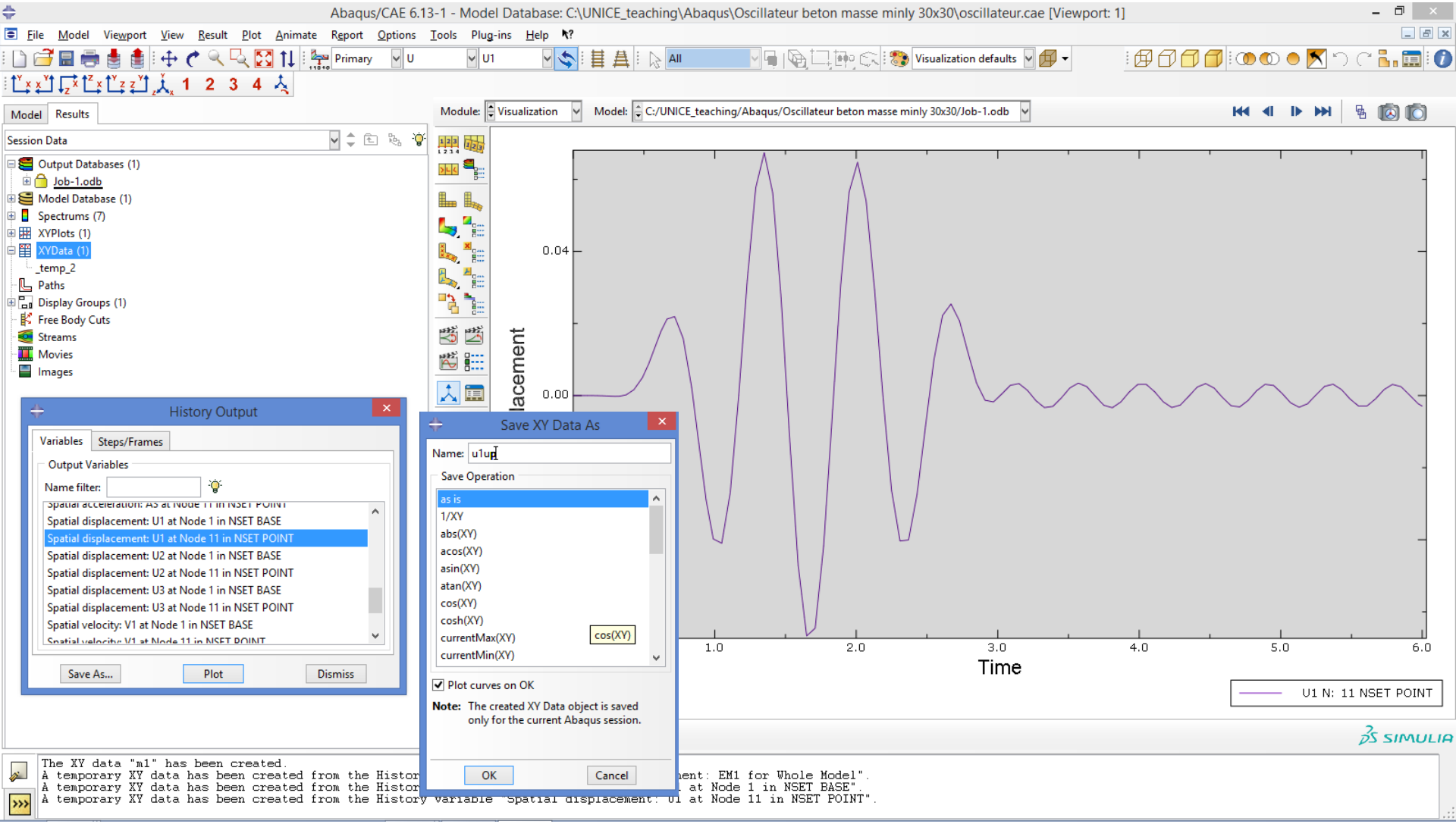
Results - XY Data

4. Courbes : accélération à la base (input)



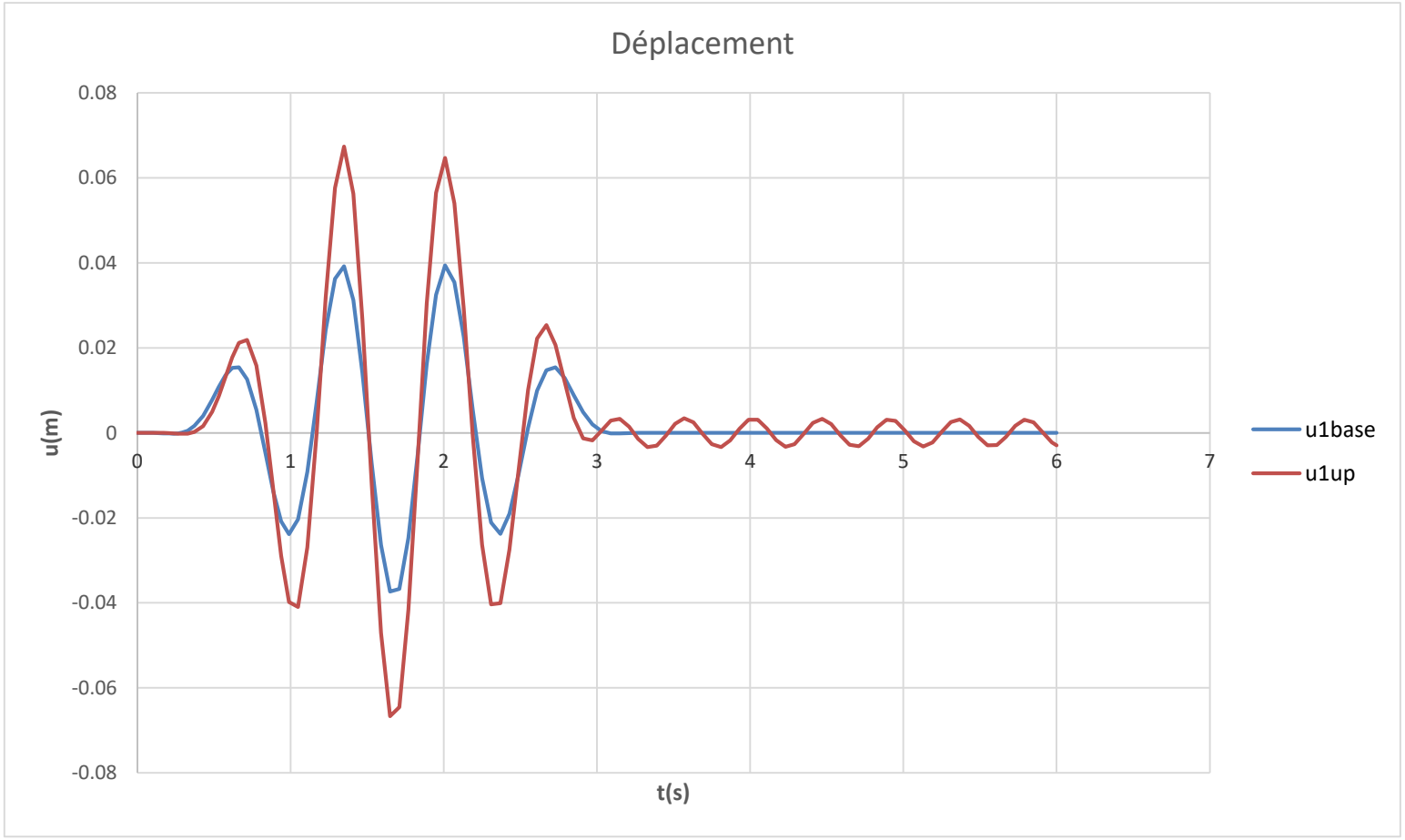
Results - XY Data

5. Courbes : déplacement en tête



Results

6. Courbes : déplacement à la base et en tête



Fichiers dans le dossier de calcul

Vérifier les données :

- File ***.cae**
- File ***.inp**

Résultats :

- File ***.dat** (Getting Started 7.1.2)
- File ***.odb**

Messages d'erreurs :

- File ***.log**
- File ***.msg**