Question 4

Murata Software

Q: How does Femtet specify the direction of materials?

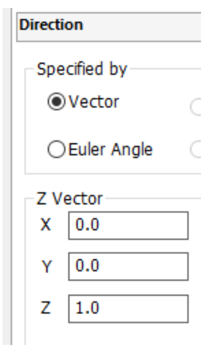
A: The direction of materials is specified on the [Direction] tab in the [Edit Body Attribute] dialog box. In the piezoelectric analysis, it is specified by either vector or Euler angle.

Please refer to the Femtet help menu below for more information.
Home>How to Set Body Attribute, Material Property, and Boundary Condition>Body Attribute Tabs>Direction Tab

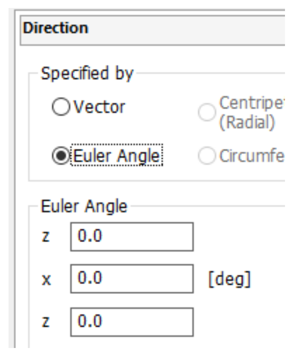
Additional information is provided on the next slides.

- To specify the direction of materials, Femtet uses two types of specifying methods: [Vector] and [Euler Angle].
- If a material has one special axis and two other physically equal axes, [Vector] is recommended. If a material is a polarized polycrystalline material, [Vector] is better than [Euler Angle] for easy setting.
- If a material is single crystal material, [Euler Angle] is recommended.
- Be aware that the specifying methods of [Vector] and [Euler Angle] are different.

Specify by [Vector]
Specify a vector indicating the Z direction of a material.



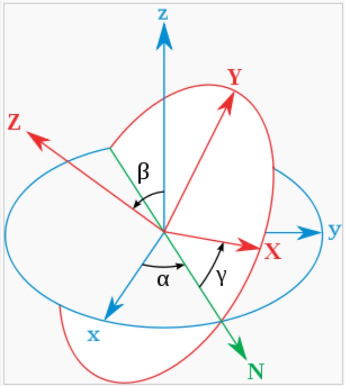
Specify by [Euler Angle]
Specify rotation angles of the coordinate system of a model based on or by fixing the coordinate system of a material.



Definition of Euler Angle

- By using Euler angles, one coordinate system can be transferred to another coordinate system. The transformation consists of three rotating operations.
- There are multiple methods to define Euler angles. Femtet uses a widely used z-x-z convention.
- Rotation Procedure in the Z-X-Z Convention

  1. Rotate (x, y, z) about z-axis by an angle of α, turning into (x', y', z’).
  2. Rotate (x', y', z') about x'-axis by an angle of β, turning into (x", y", z").
  3. Rotate (x", y", z") about z”-axis by an angle of γ, turning into (X, Y, Z).



Euler angle of z-x-z convention

From Wikipedia

Definition of coordinate systems of material and model

- The coordinate system to determine anisotropic materials is defined as [Coordinate System of a Material]. In the material property dialog box of Femtet, the axis of materials is represented in (x, y, z).
- The coordinate system of the entire model is defined as [Coordinate System of a Model].

Example of material property (Elasticity)

Elasticity matrix (compliance)

X10 -11 [1/Pa]

	xx	yy	zz	yz	zx	xy
xx	0.76					
yy	-0.16	0.76				
zz	-0.17	-0.17	0.82			
yz	0	0	0	1.85		
zx	0	0	0	0	1.85	
xy	0	0	0	0	0	1.85

With no rotation operation,
the coordinate system of a model will match with the coordinate system of a material.

[Coordinate System of a Model] and [Coordinate System of a Material]

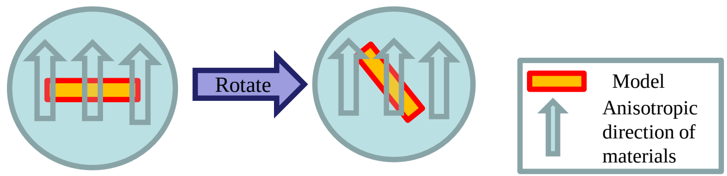
- If the coordinate systems of a model and a material are different, the transformation between them is defined by Euler angle.
- Femtet defines Euler angle as the angle to rotate the coordinate system of a model based on the coordinate system of a model, not vice versa.

*It might seem that rotating the coordinate system of a material is easy to understand intuitively. But from the academic background, Euler angle has been defined as an angle to rotate the coordinate system of a model based on or by fixing the coordinate system of a material.

- Rotation of Coordinate System of a Model (Euler Angle)

(1) Fix the coordinate system of a material (Reference)

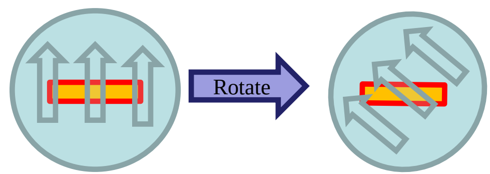
(2) Rotate the model



- In an internal calculation, the coordinate is transformed in such a way that the coordinate system of a material is rotated.

(1) Fix the coordinate system of a model (Reference)

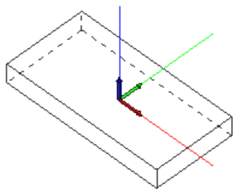
(2) Rotate the coordinate system of a material



Explanation of Diagram

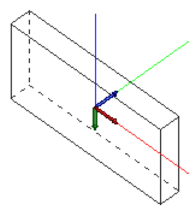
- Three lines, R, G, and B, represent the coordinate axes of a material, x, y, and z.
- Three arrows, R, G, and B, represent the coordinate axes of a model, X, Y, and Z.
- By using Euler angle, rotate the coordinate axes of a model, X, Y, and Z, based on or by fixing the coordinate axes of a material, x, y, and z.

Example



Rotate -90° about the red arrow.

β=-90

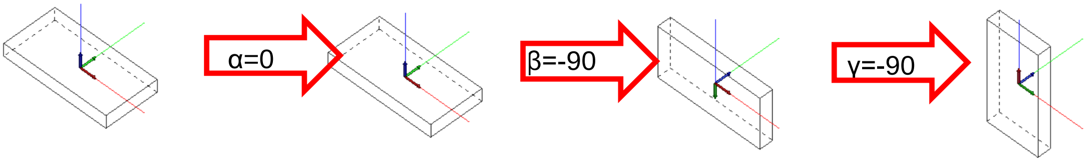


Example: Ceramics polarized in the X direction

Explanation

- Suppose that ceramics is polarized in the X direction.
- With Euler angle, this operation indicates the X axis of a model, the red arrow, directs to the 3rd axis of a material, the blue line.
- This can be specified by a vector as (1, 0, 0) as well.

Euler angle	
Z(α)	0
X'(β)	-90
Z''(γ)	-90

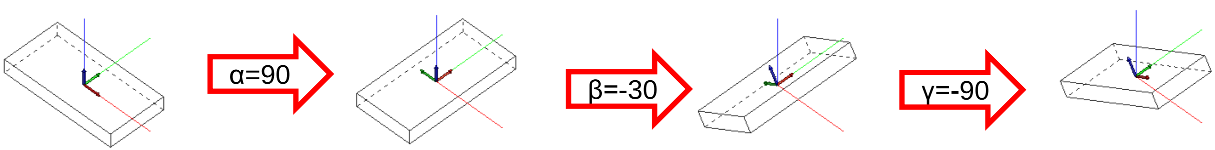


Example: Ceramics rotated by 30° about Y axis

Explanation

- Suppose that the 1st axis of a material is rotated by 30°about the Y-axis of a model.
- With Euler angle, the model is rotated by -30° about the 2nd axis, the green line, of a material
- This can be specified by a vector as (cos30°, 0, sin30°) as well.

Euler angle	
Z(α)	90
X'(β)	-30
Z''(γ)	-90

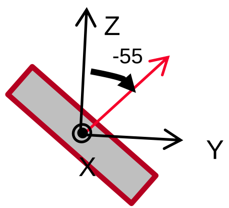


Example: AT-Cut Quartz

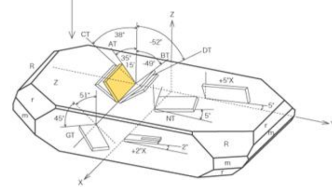
- Euler angle if AT-cut quartz element is adhered on the XY plane.
- The X-axis, the red arrow, of a model matches with the 1st axis, the red line, of a material.

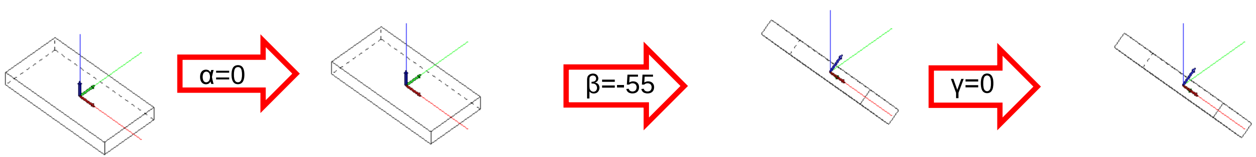
Euler angle	
Z(α)	0
X'(β)	-55
Z''(γ)	0

Reference: ST cut (X'=-48), CT cut (X'=-52), BT cut (X'=41), DT cut (X'=38)



Quartz
Cutting angle





Example: AT-Cut Quartz

- Euler angle if AT-cut quartz element is adhered on the YZ plane.

- The Z-axis, the blue arrow, of a model matches with the 1st axis, the red line, of a material.

Euler angle	
Z(α)	90
X'(β)	90
Z''(γ)	35

Quartz
Cutting angle