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Numerical analysis for mesoscale design of weaving and its structural rigidity

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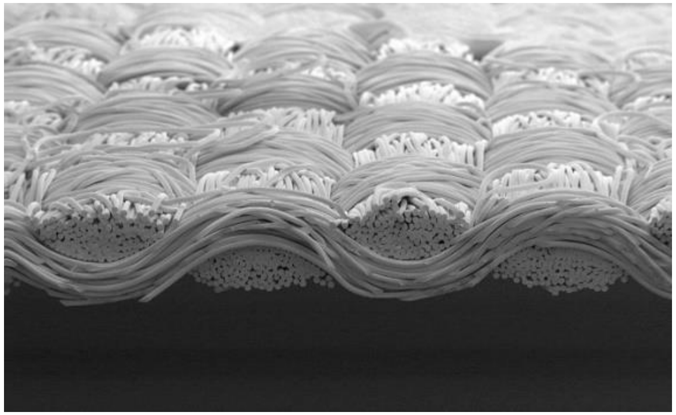
Computational modeling of woven textile

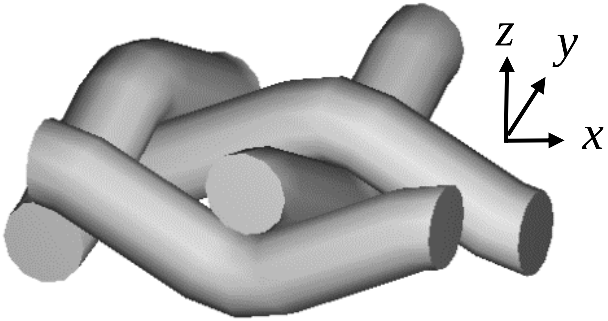
Multi-scalability in woven fabrics

Weaving problem of fiber bundle as yarn



http://www.carryology.com/interviews-regular/cordura-business-fabrics/

Modeling of mesoscopic structure



'Wise Tex', https://www.mtm.kuleuven.be/Onderzoek/Composites/software/wisetex Stepan V. Lomov, Katholieke Universuteit Leuven, Belgium

Woven structure is modeled as initial situation

Multiscale modeling for woven fabrics

Processes

1. Materials	2. Spinning	3. Twisting	4. Weaving	5. Textile

Size of Scale [m]

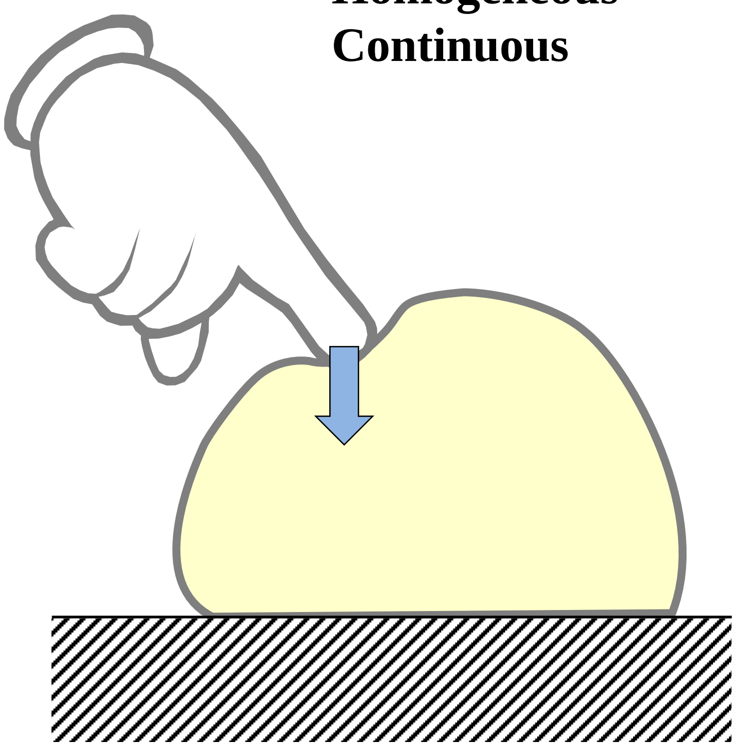
10^{-9} 10^{-6} 10^{-5} 10^{-4} 10^{-1}

Computational modeling of woven textile

Multi-scalability in woven fabrics

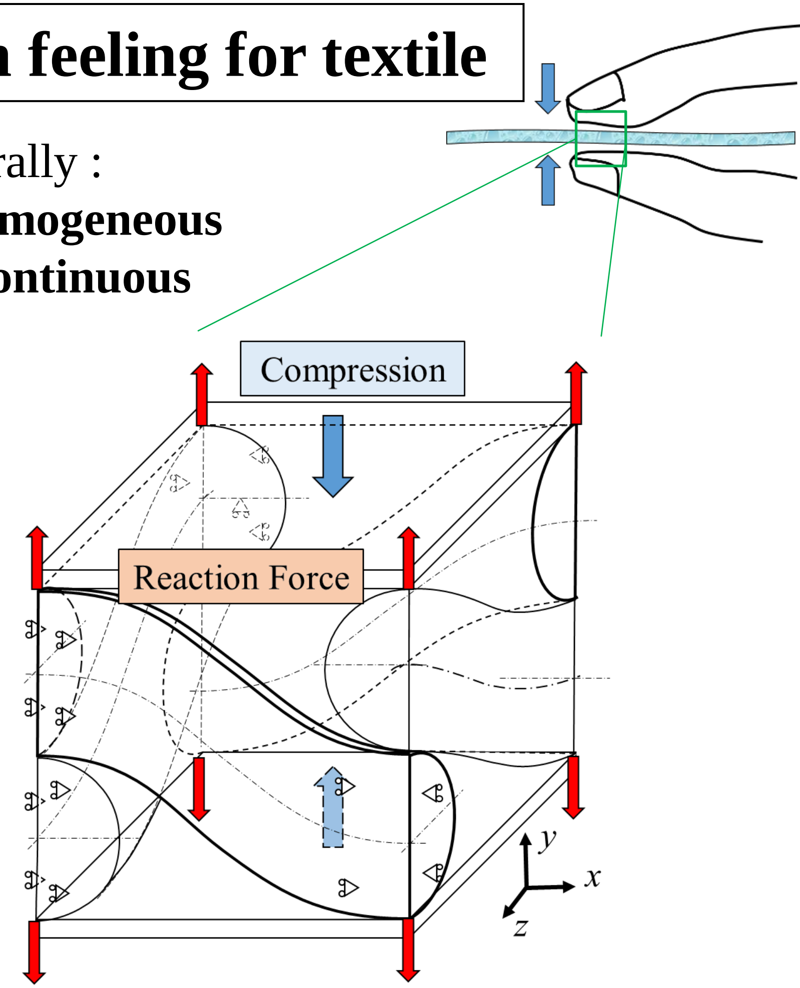
Touch feeling for soft matter

Generally :
Homogeneous
Continuous



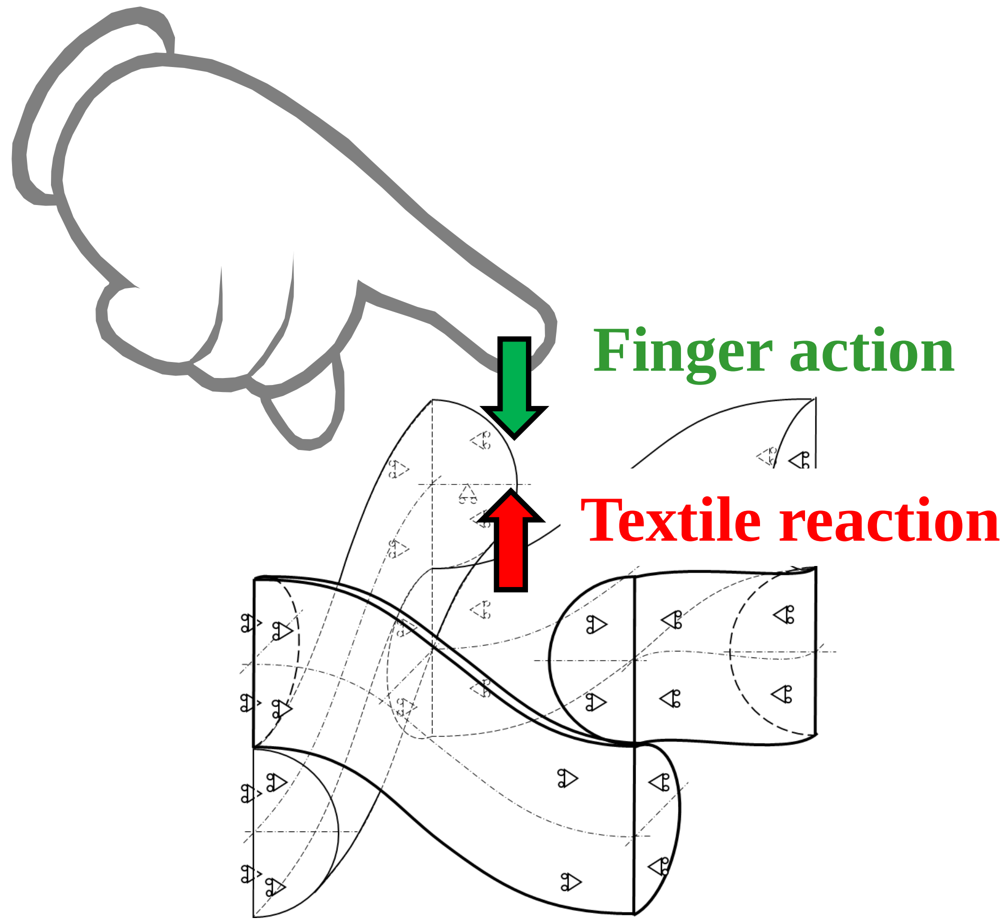
Touch feeling for textile

Generally :
Inhomogeneous
Discontinuous



Computational modeling of woven textile

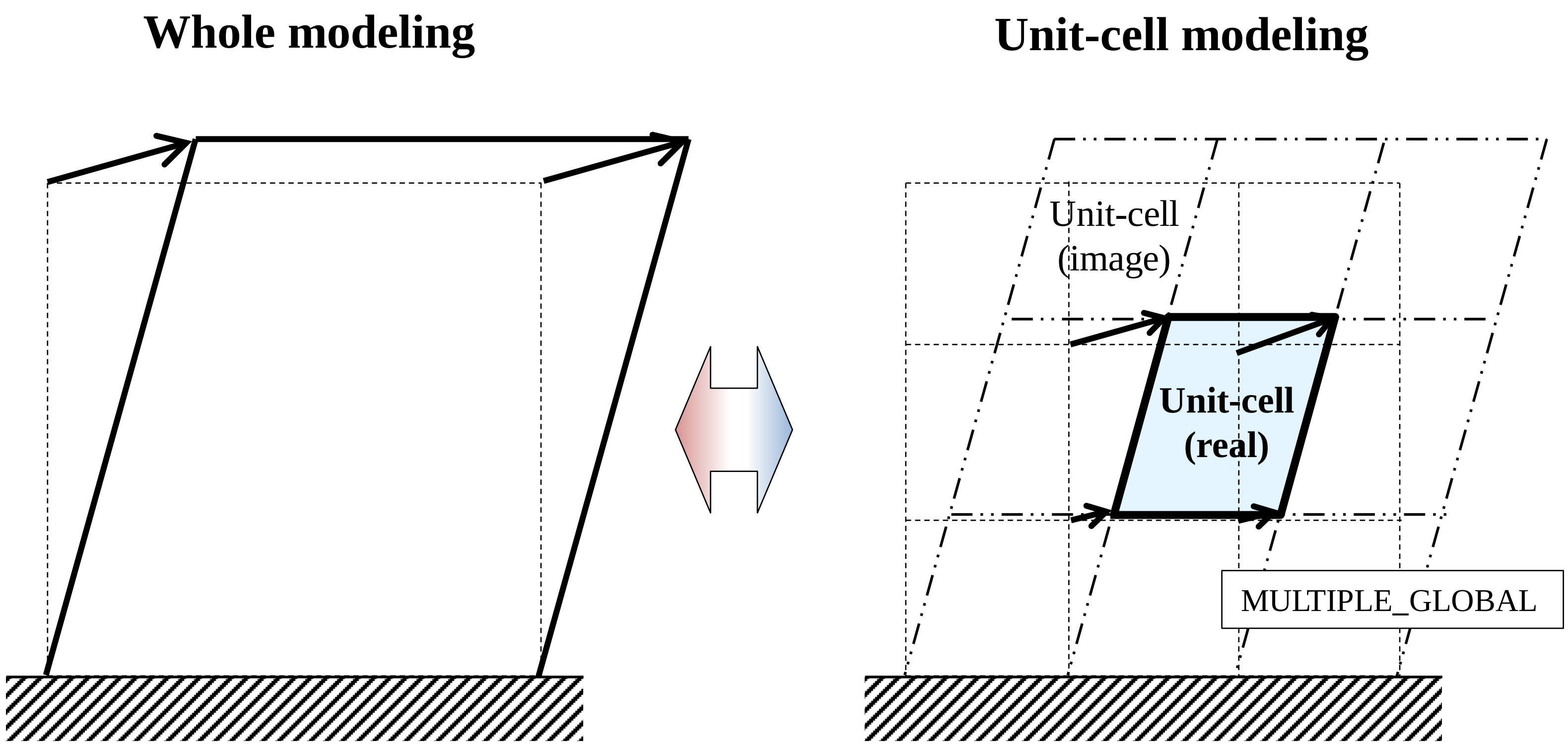
Development of Digital Design Technology on “Touch Feeling”



Formulation of weaving

Unit-cell Modeling to Solve Periodic Boundary Problem

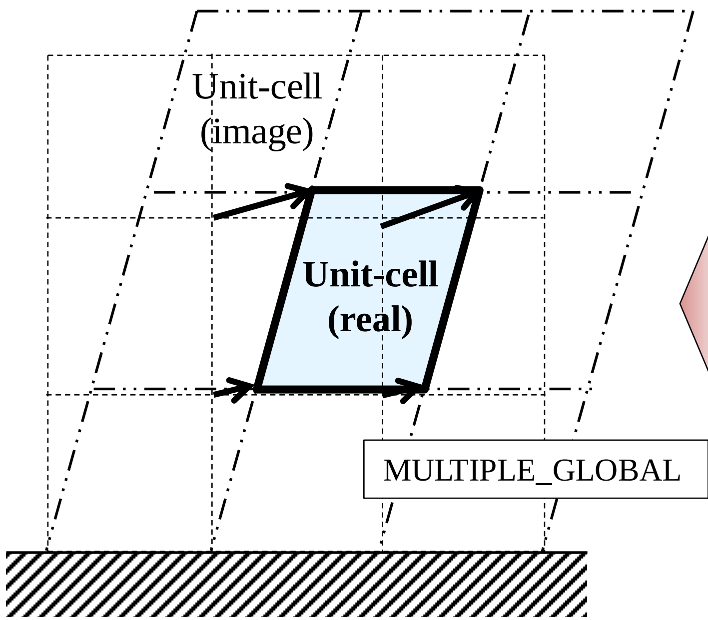
- ***Orthogonal symmetric deformation*** (*orthogonal coordinates*) -



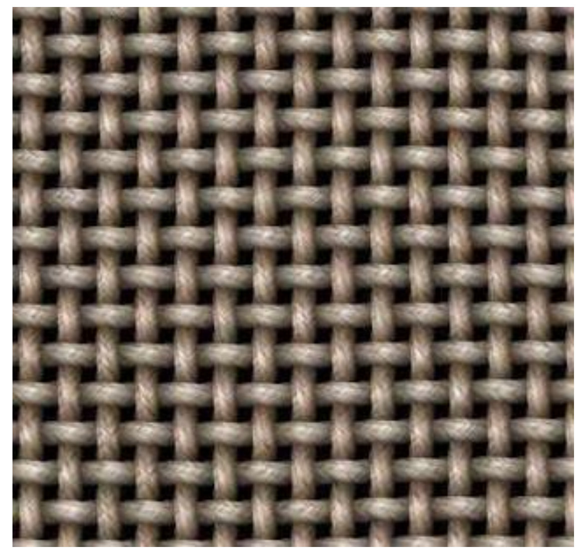
Unit-cell realizes **simplification of modeling** in analysis

Unit-cell Modeling due to Symmetricity

Orthogonal symmetric



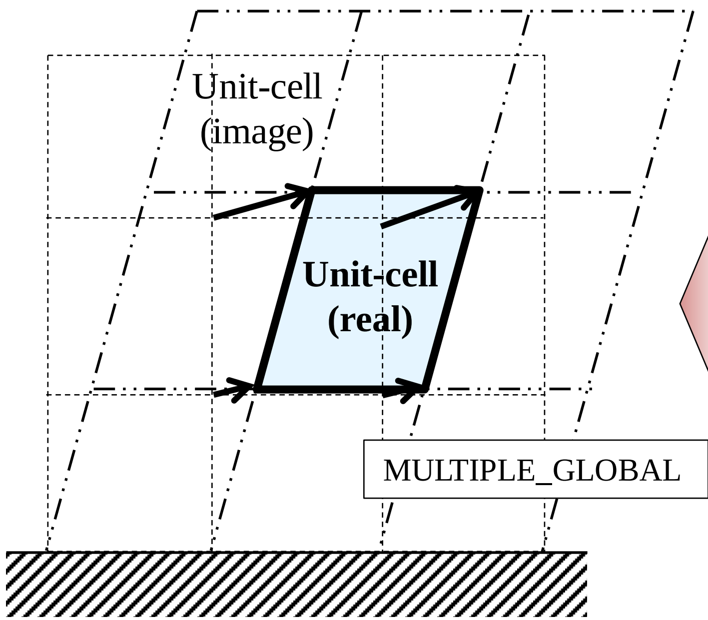
Plain woven fabric



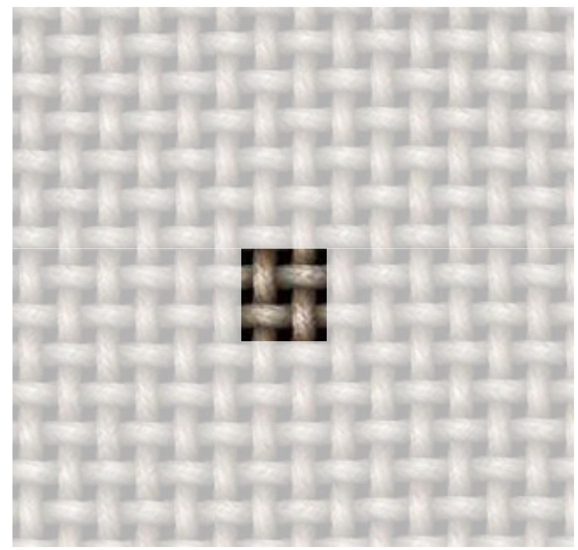
http://textilelearner.blogspot.com/2011/03/definition-and-characteristics-of-plain_4390.html

Unit-cell Modeling due to Symmetricity

Orthogonal symmetric



Plain woven fabric

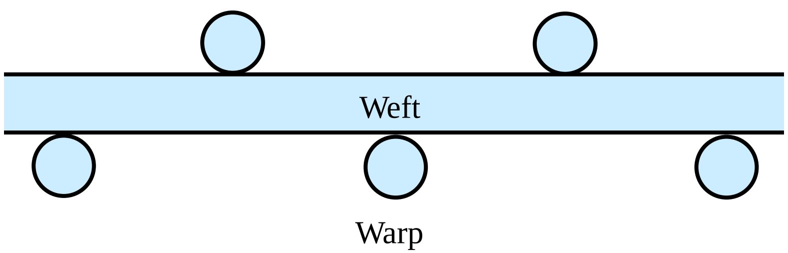


http://textilelearner.blogspot.com/2011/03/definition-and-characteristics-of-plain_4390.html

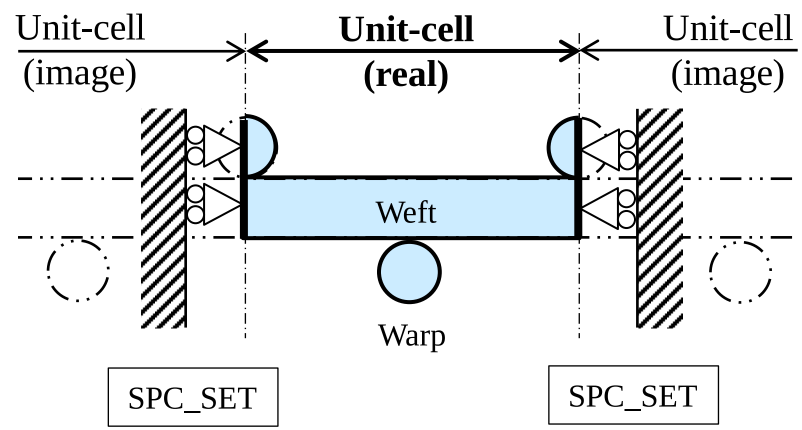
Unit-cell modeling depends on **geometrical symmetricity**

Symmetricity and Unit-cell Modeling of Woven Fabrics

Whole weaving
(2D)



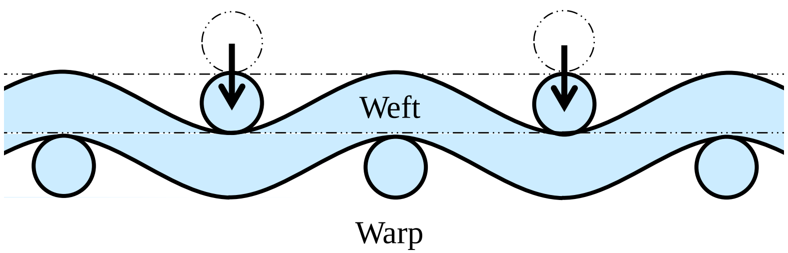
Unit-cell weaving
(2D)



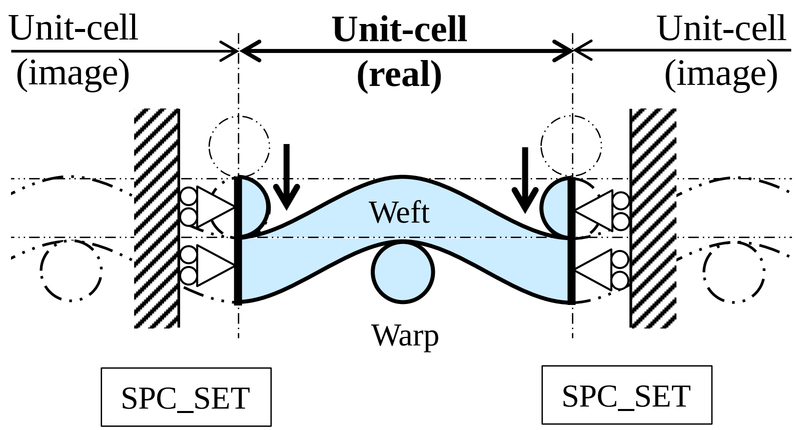
Brick type

Symmetricity and Unit-cell Modeling of Woven Fabrics

Whole weaving
(2D)



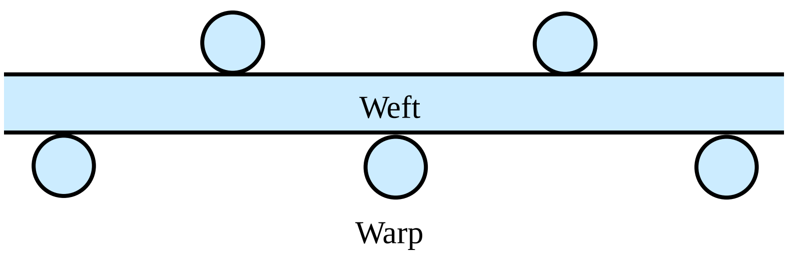
Unit-cell weaving
(2D)



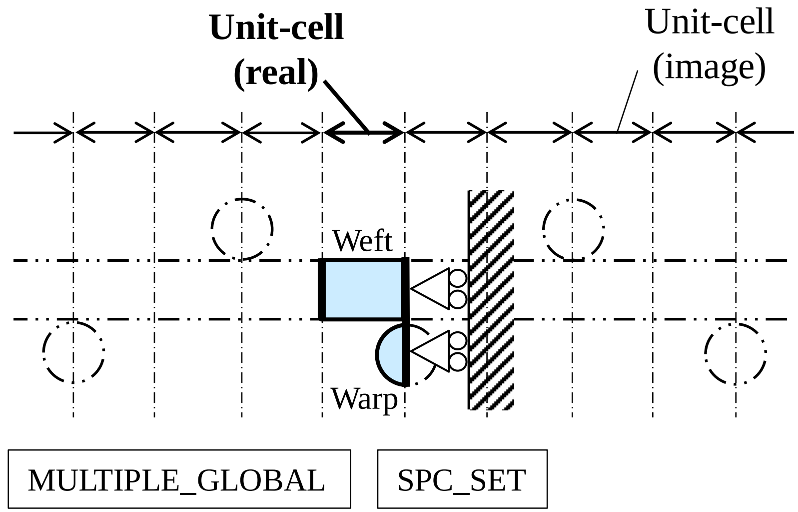
Brick type

Symmetricity and Unit-cell Modeling of Woven Fabrics

Whole weaving
(2D)



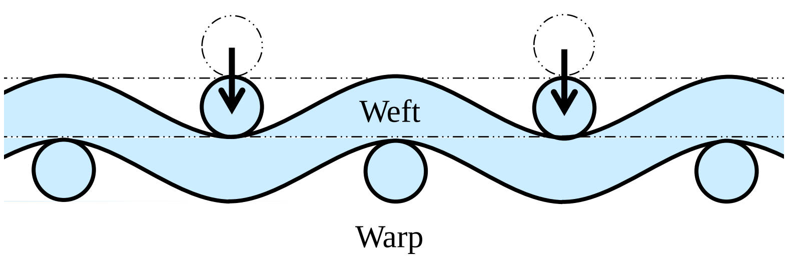
Unit-cell weaving
(2D)



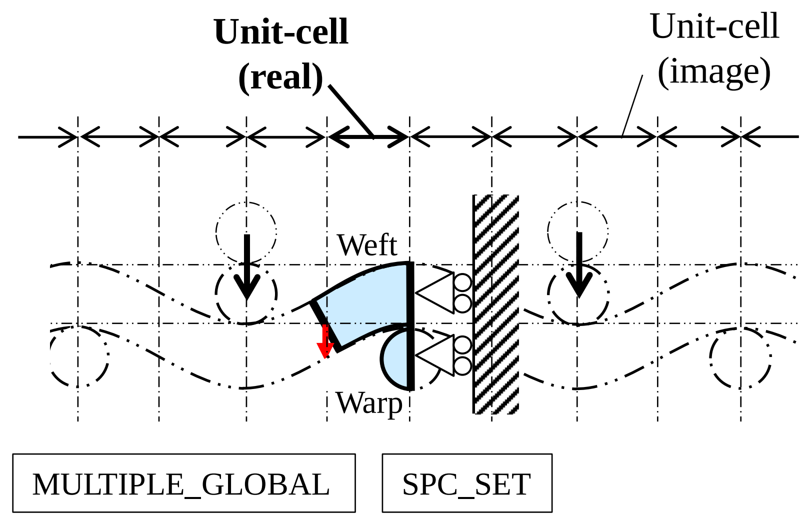
Corner type

Symmetricity and Unit-cell Modeling of Woven Fabrics

Whole weaving
(2D)



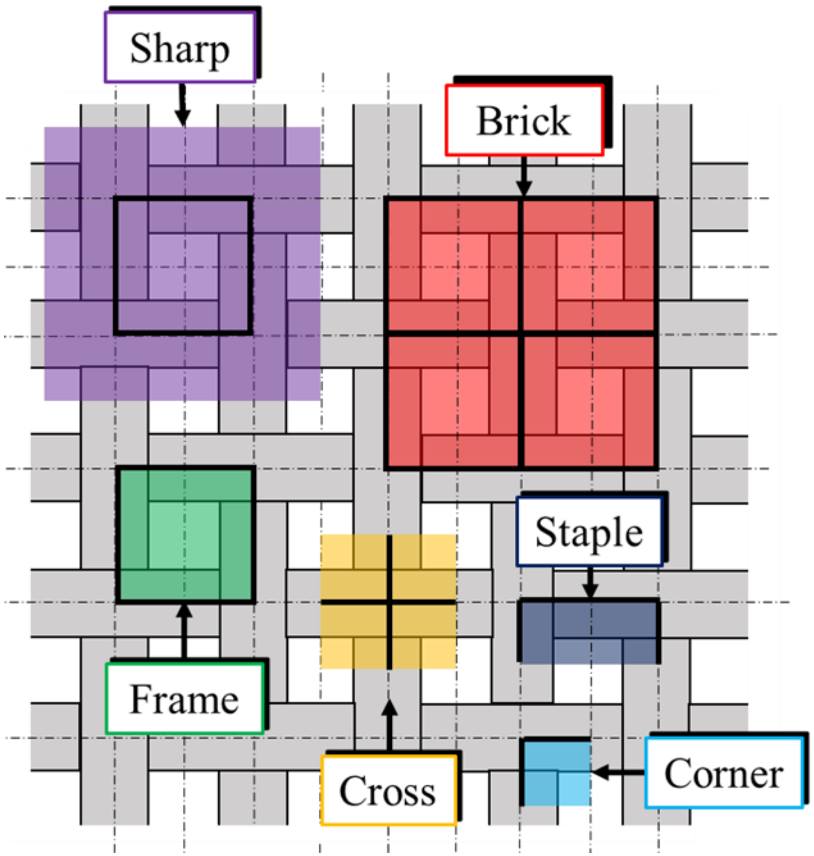
Unit-cell weaving
(2D)



Corner type

Computation

Cell type selection

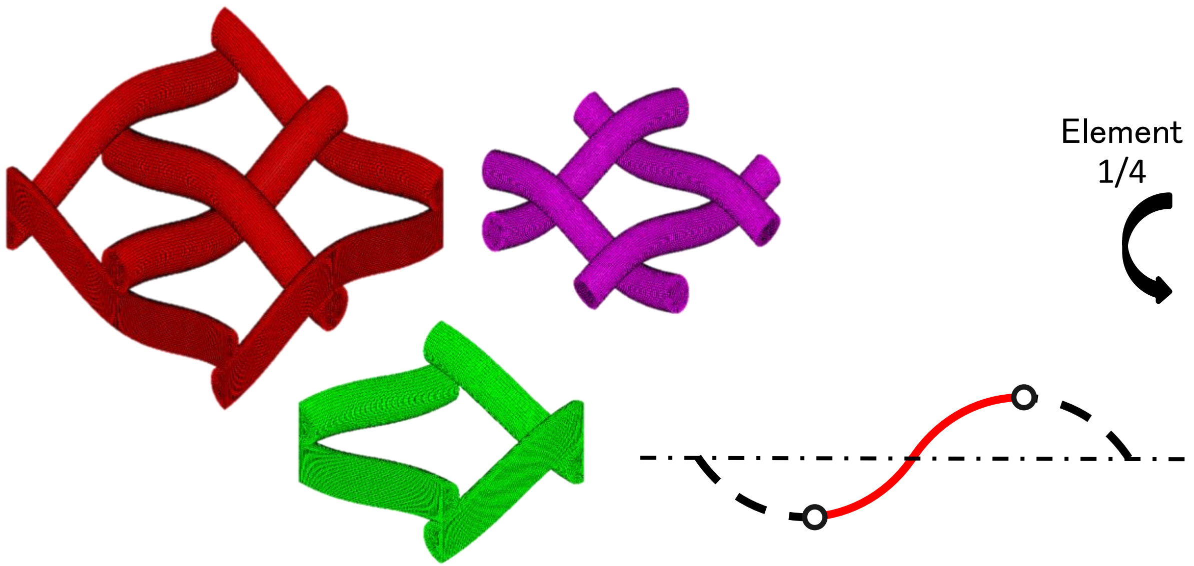


Target: (yellow)

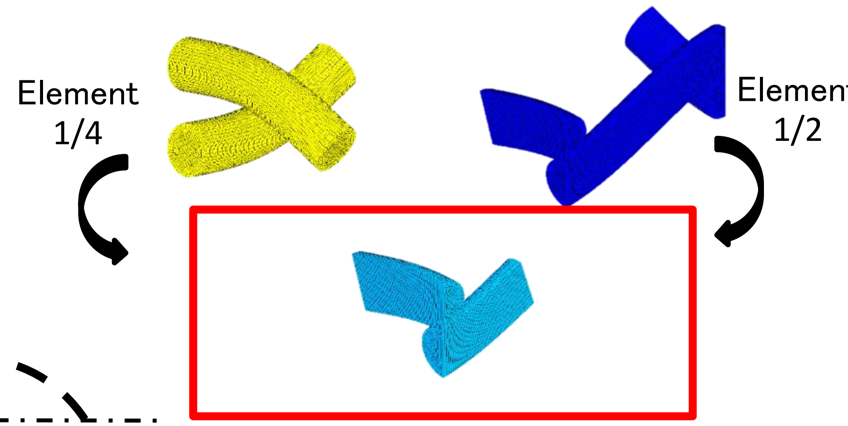
Model	Twisting	Weaving	Imhomogenius Cramp
Sharp	○	×	○
Brick	×	×	○
Frame	×	×	○
Cross	○	○	×
Staple	×	○	○
Corner	×	○	×

Cell type selection

Closed-set model



Opened-set model



Miyaki, Sakuma, *Proc. TMSJ*, (2018) .

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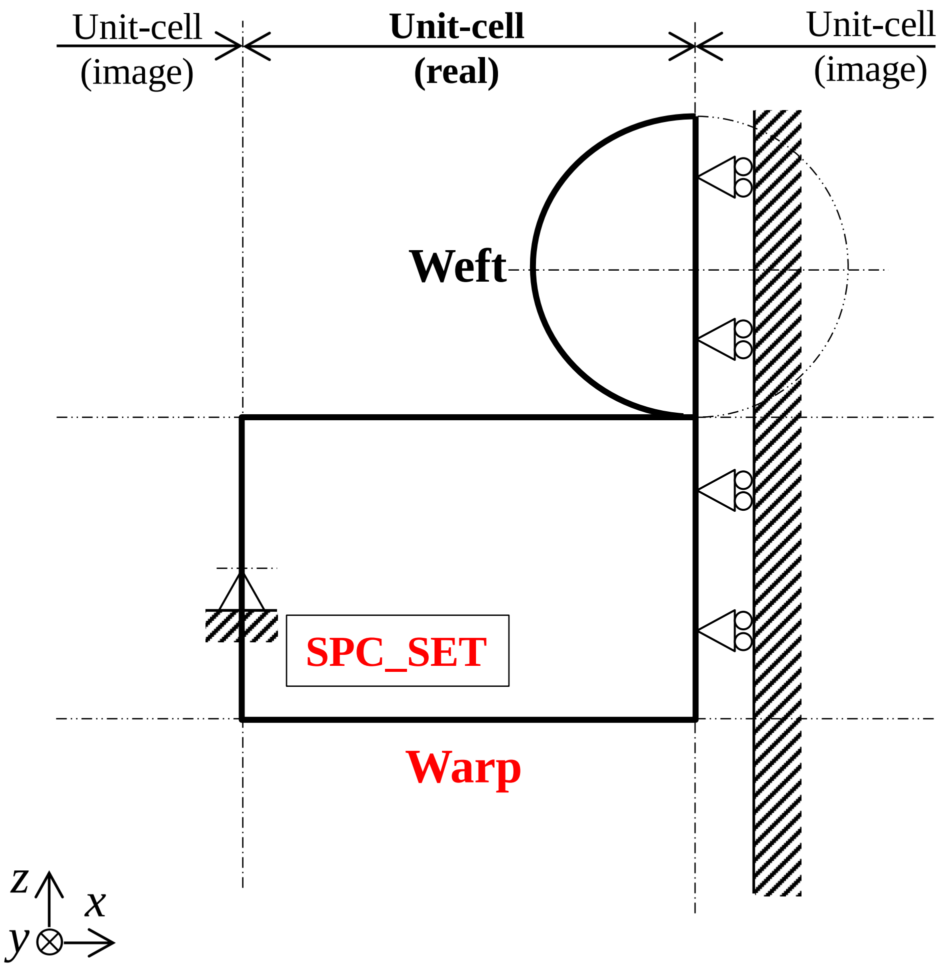
Periodic Boundary Condition for Corner Model

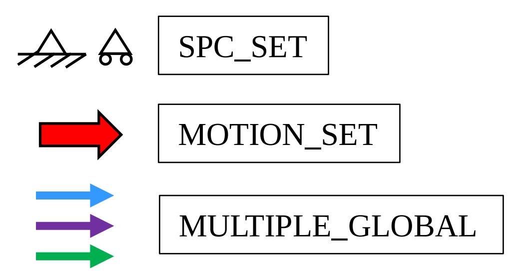


Constraint equation

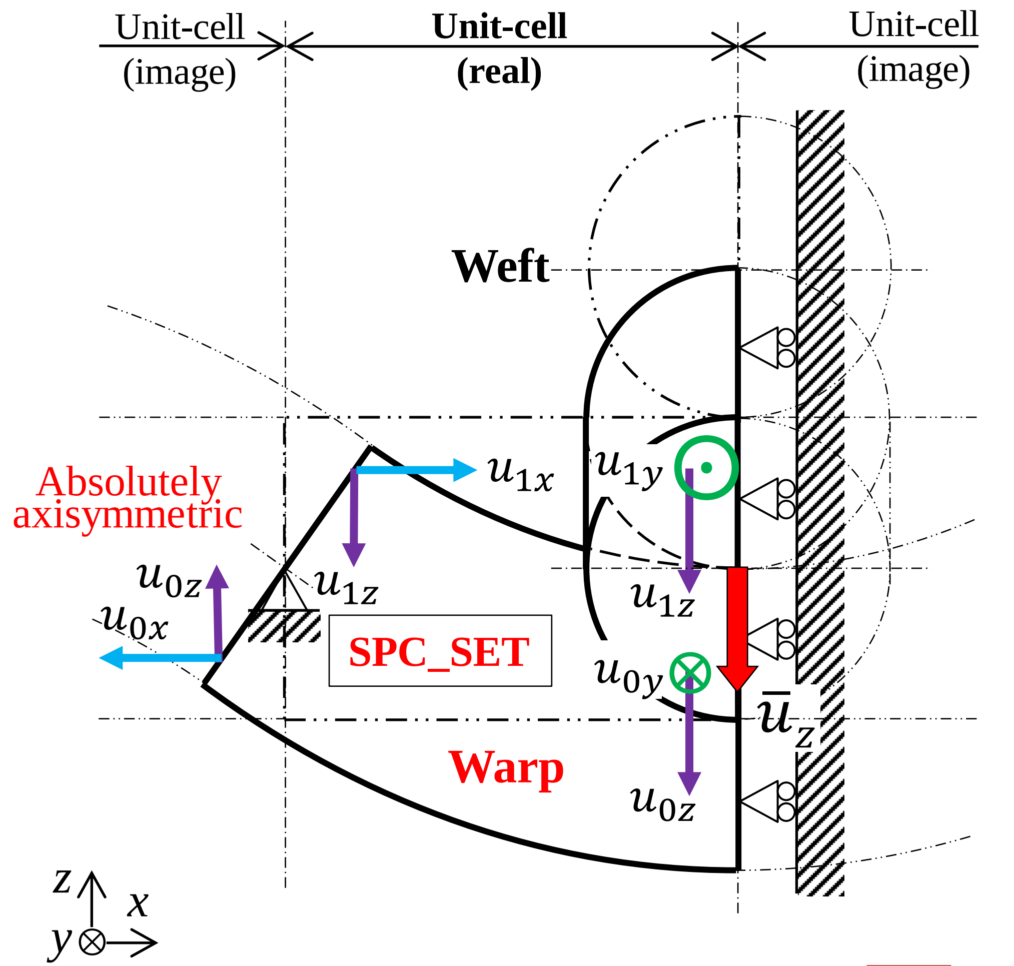
$$\sum \alpha_n u_{si}^n = 0$$

n : Nodal ID, s : Section ID, i : Direction

For warp :



Periodic Boundary Condition for Corner Model



Constraint equation

$$\sum \alpha_n u_{si}^n = 0$$

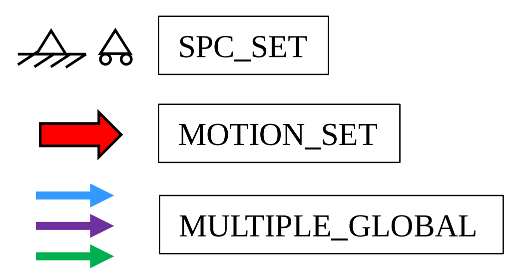
n : Nodal ID, s : Section ID, i : Direction

For warp : Absolutely axisymmetric

$$\sum_n (\alpha_n u_{0x}^n|_{\mathrm{warp}} + \alpha_n u_{1x}^n|_{\mathrm{warp}}) = 0$$

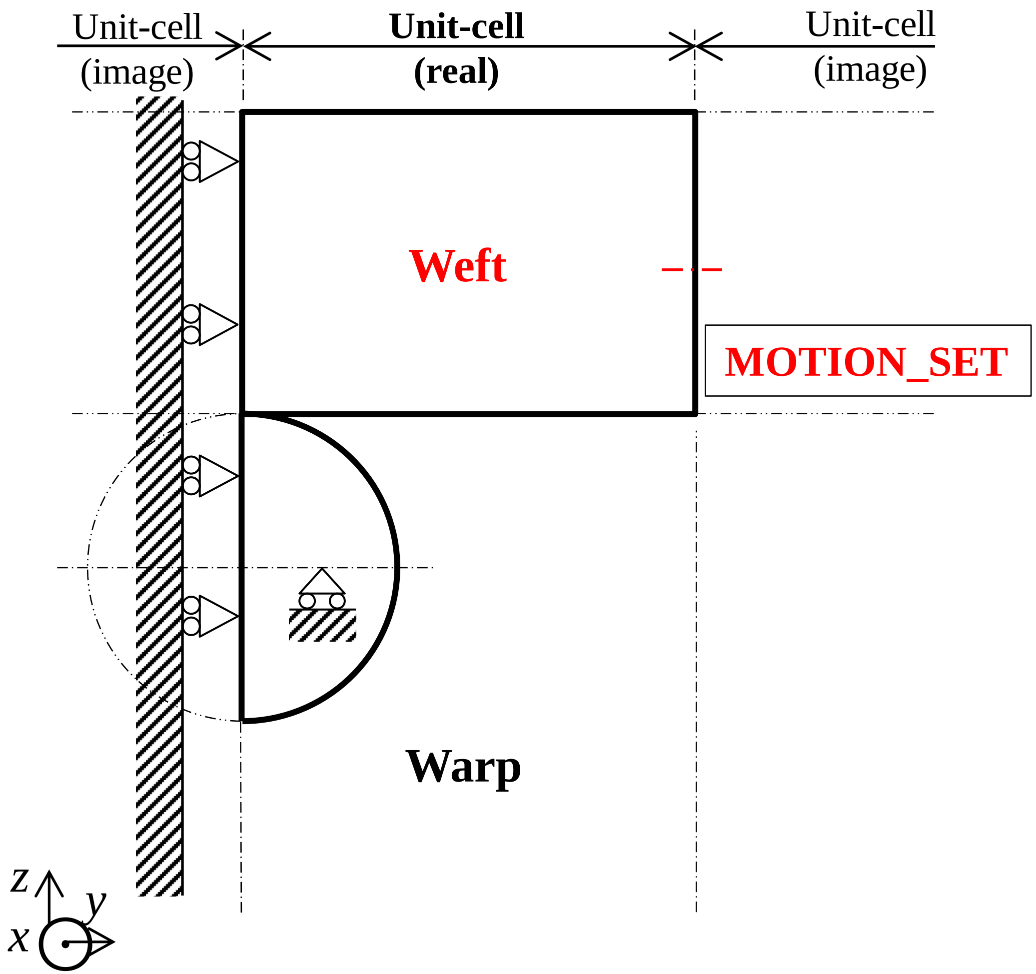
$$\sum_n (\alpha_n u_{0z}^n|_{\mathrm{warp}} + \alpha_n u_{1z}^n|_{\mathrm{warp}}) = 0$$

$(\alpha_n = 1.0)$



MULTIPLE_GLOBAL can be defined without definition of SPC_SET

Periodic Boundary Condition for Corner Model



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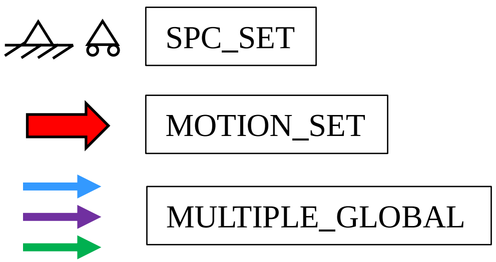
$$\sum_n (\alpha_n u_{0z}^n|_{\text{warp}} + \alpha_n u_{1z}^n|_{\text{warp}}) = 0$$

(α_n = 1.0)

For weft :



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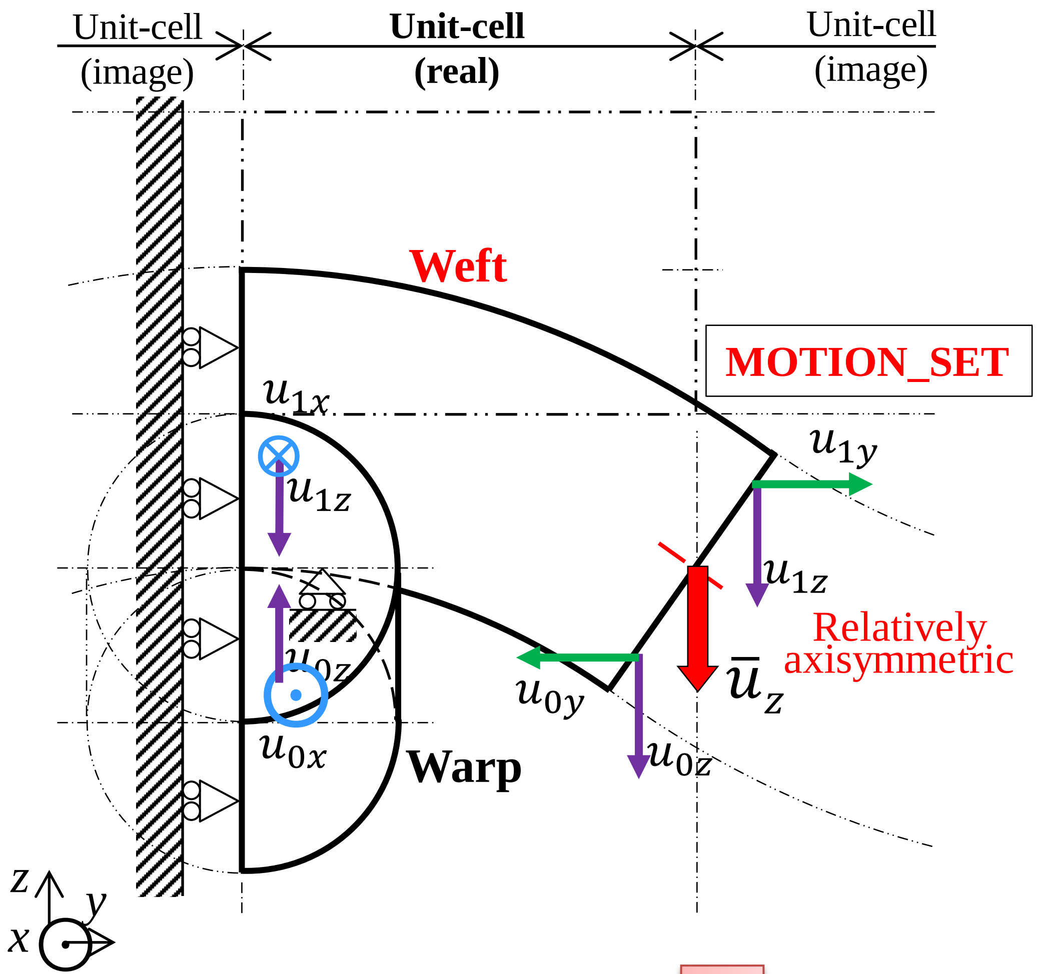
Periodic Boundary Condition for Corner Model



Constraint equation

$$\sum \alpha_n u_{si}^n = 0$$

n : Nodal ID, s : Section ID, i : Direction

For warp : Absolutely axisymmetric

$$\sum_n (\alpha_n u_{0x}^n|_{\mathrm{warp}} + \alpha_n u_{1x}^n|_{\mathrm{warp}}) = 0$$

$$\sum_n (\alpha_n u_{0z}^n|_{\mathrm{warp}} + \alpha_n u_{1z}^n|_{\mathrm{warp}}) = 0$$

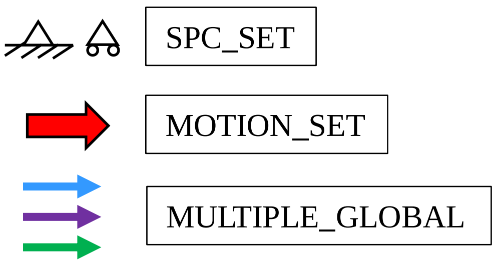
(α_n = 1.0)

For weft : Relatively axisymmetric

$$\sum_n (\alpha_n u_{0y}^n|_{\mathrm{weft}} + \alpha_n u_{1y}^n|_{\mathrm{weft}}) = 0$$

$$\sum_n (\alpha_n u_{0z}^n|_{\mathrm{weft}} + \alpha_n u_{1z}^n|_{\mathrm{weft}} + \bar{\alpha}_n \bar{u}_z^n|_{\mathrm{weft}}) = 0$$

(α_n = 1.0, $\bar{\alpha}_n$ = -2.0)

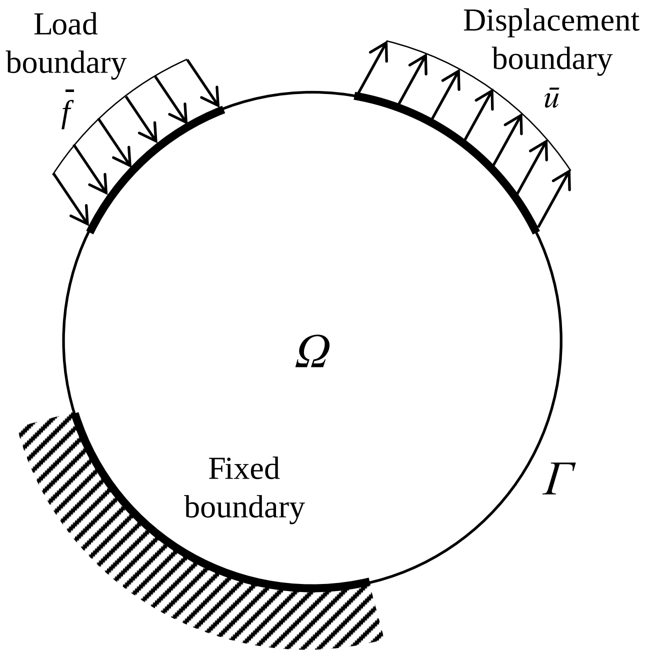


MOTION_SET causes conflict with MULTIPL_GLOBAL in LS-DYNA

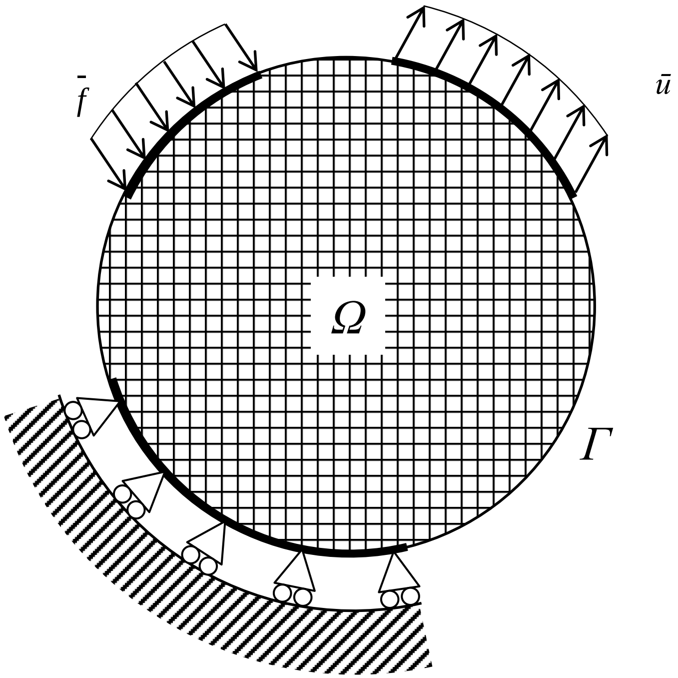
9.4 Application to comfort design

FE Modeling to Solve Deformation Problem

Mechanical model and boundary condition

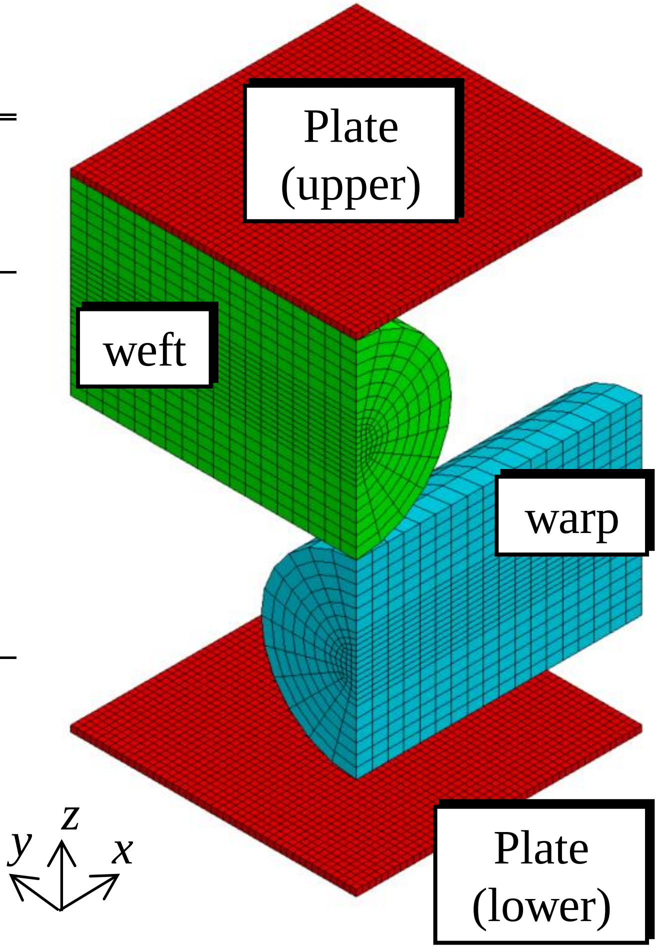


FE modeling



Weaving Simulation of Plain Fabrics

	Rigid Plate	Warp & Weft
Density ρ [g/cm^3]	1.14	0.40
Young's Modulus E [kPa]	100	1
Poisson's Ratio ν	0.45	0.45
Number of Nodes	8464	5510
Number of Elements	4050	4536



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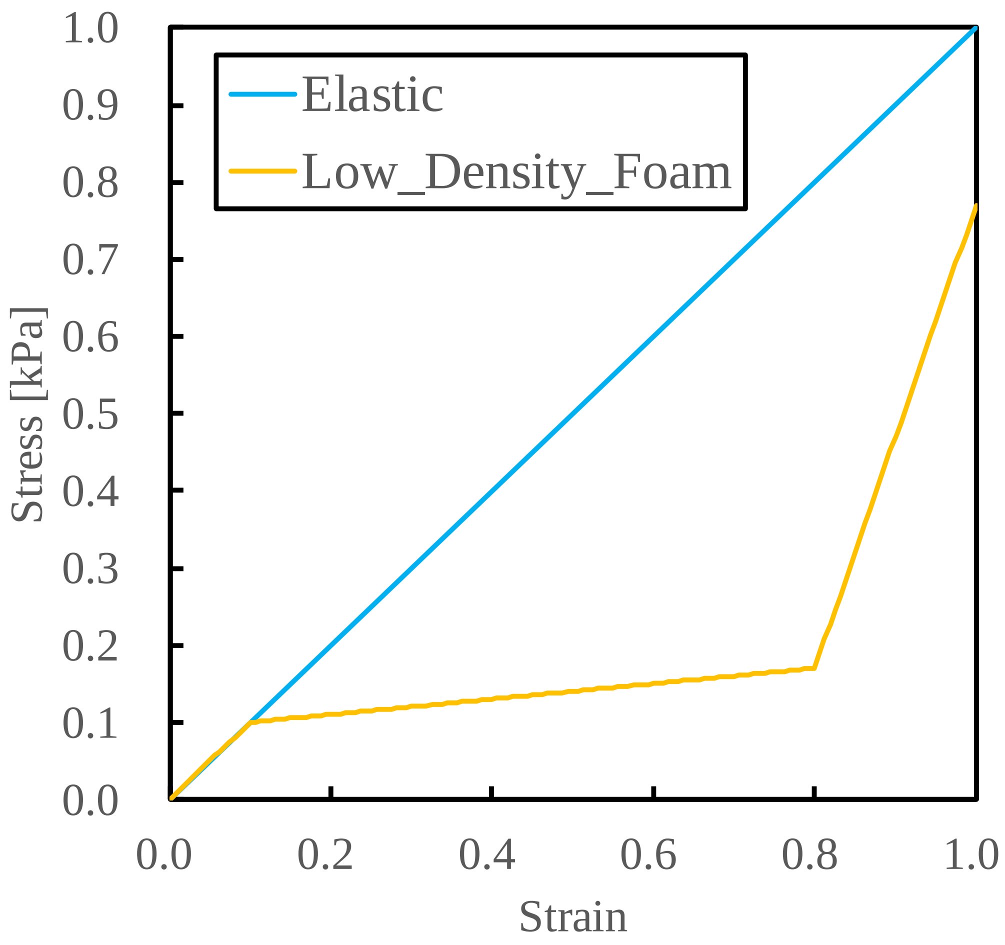
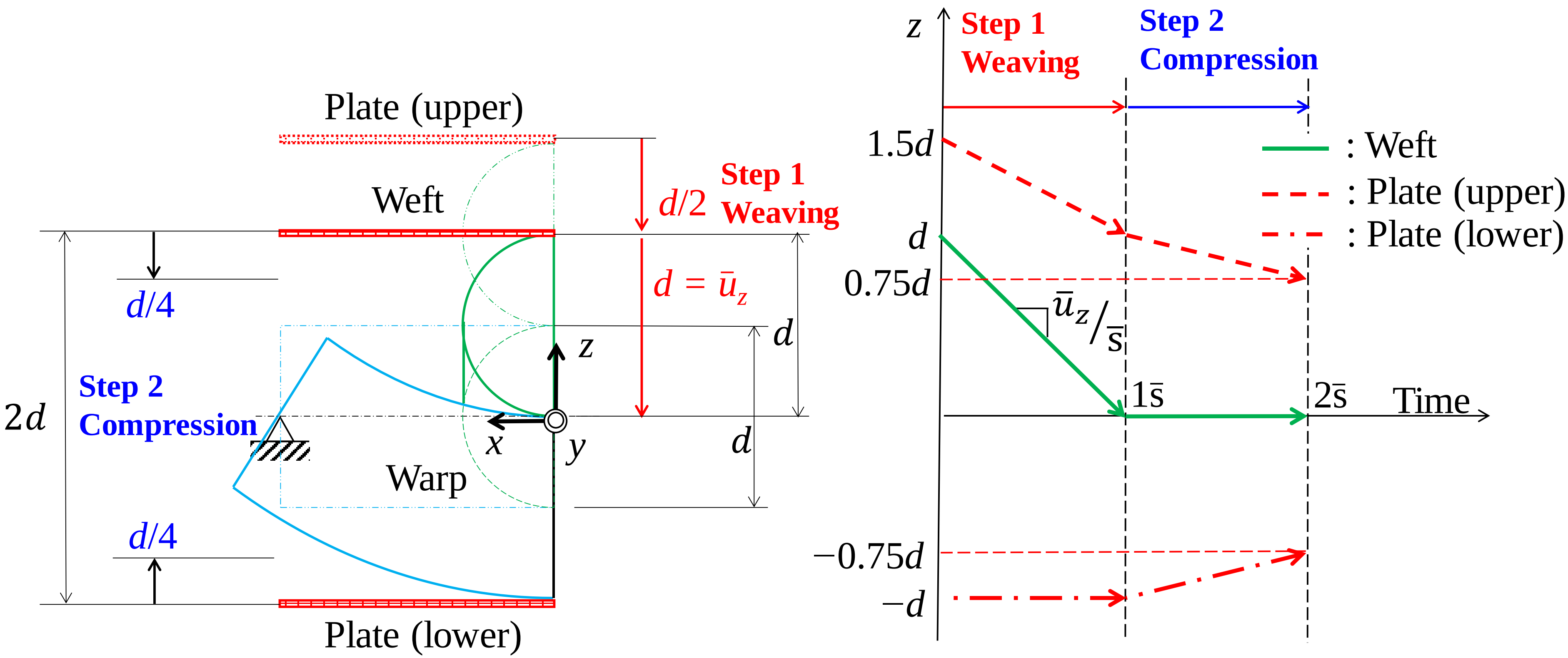
Weaving Simulation of Plain Fabrics

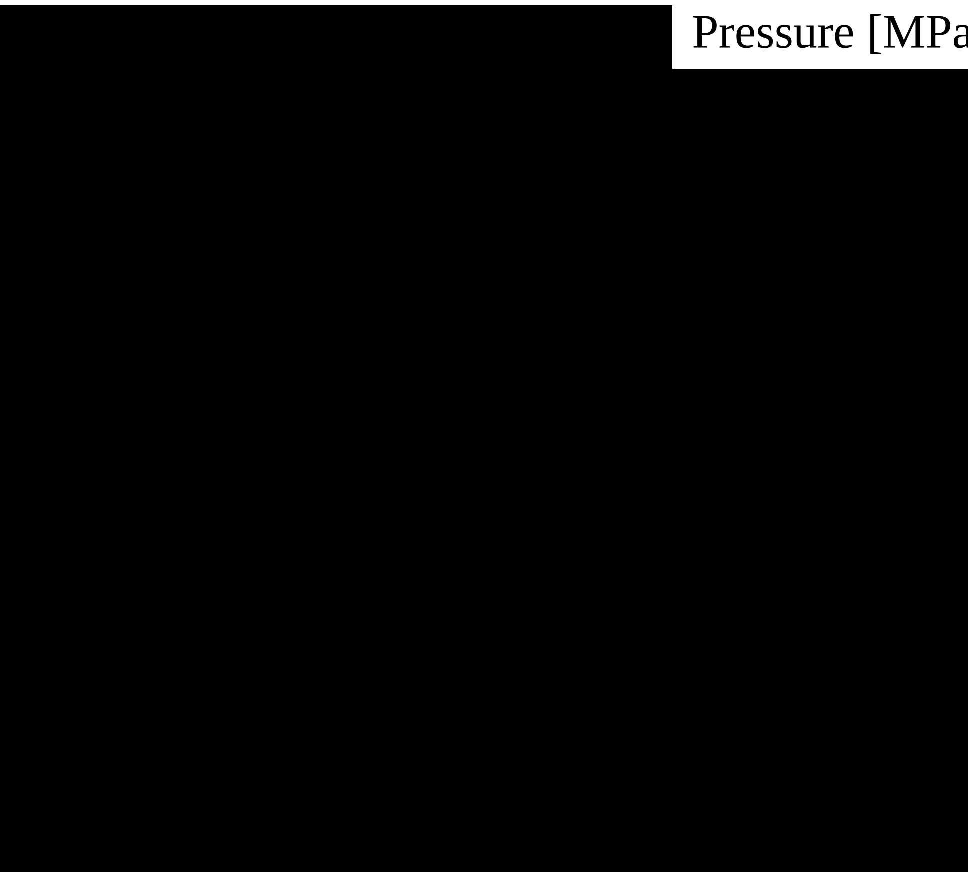


Weaving Simulation of Plain Fabrics

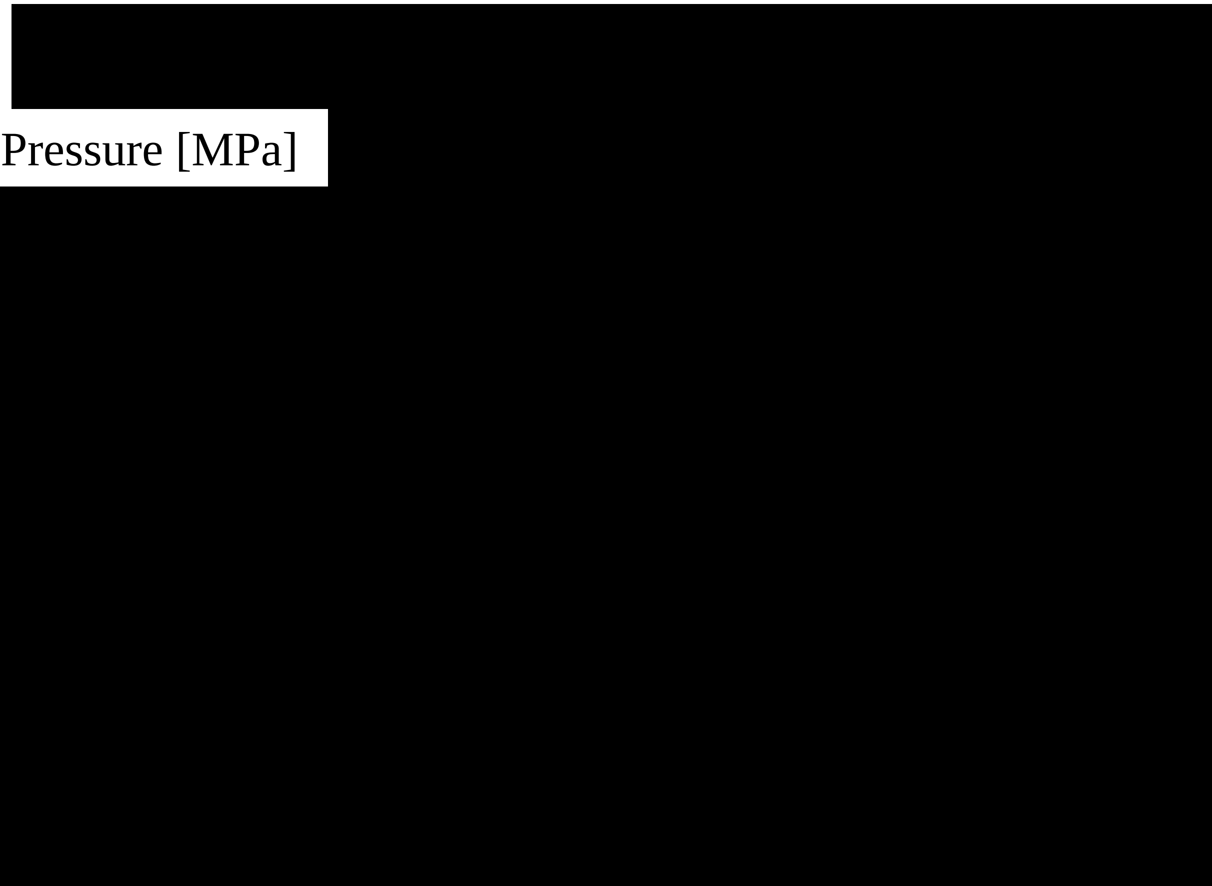


Weaving Simulation of Plain Fabrics

Pressure [MPa]



Elastic



Low_Density_Foam

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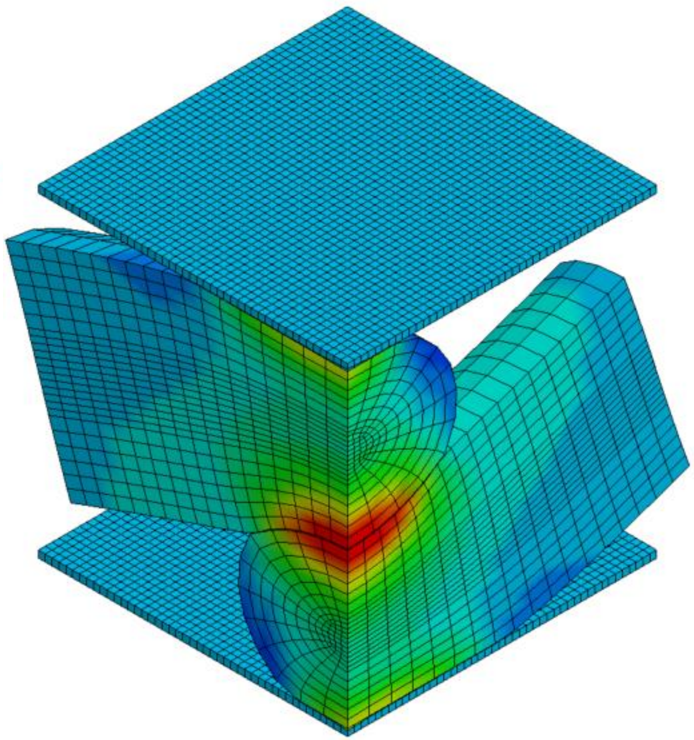
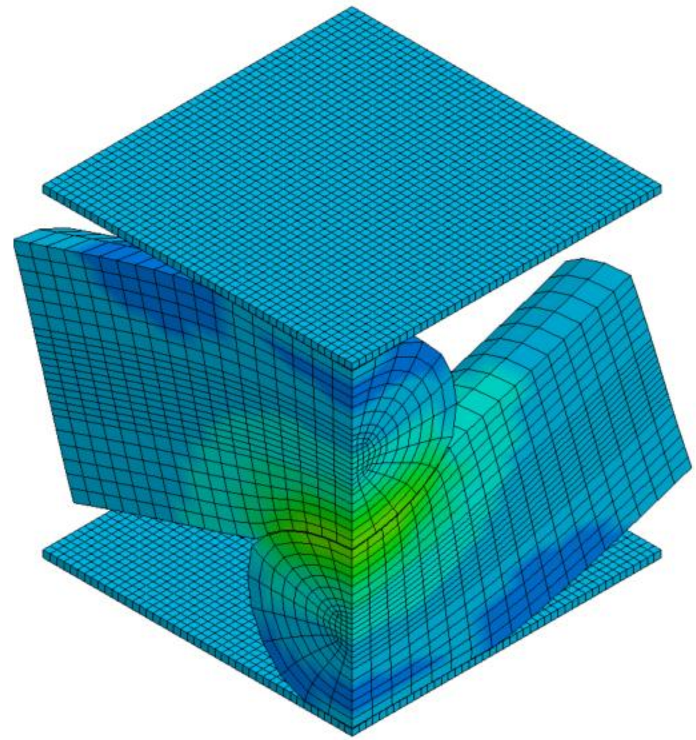
Weaving Simulation of Plain Fabrics

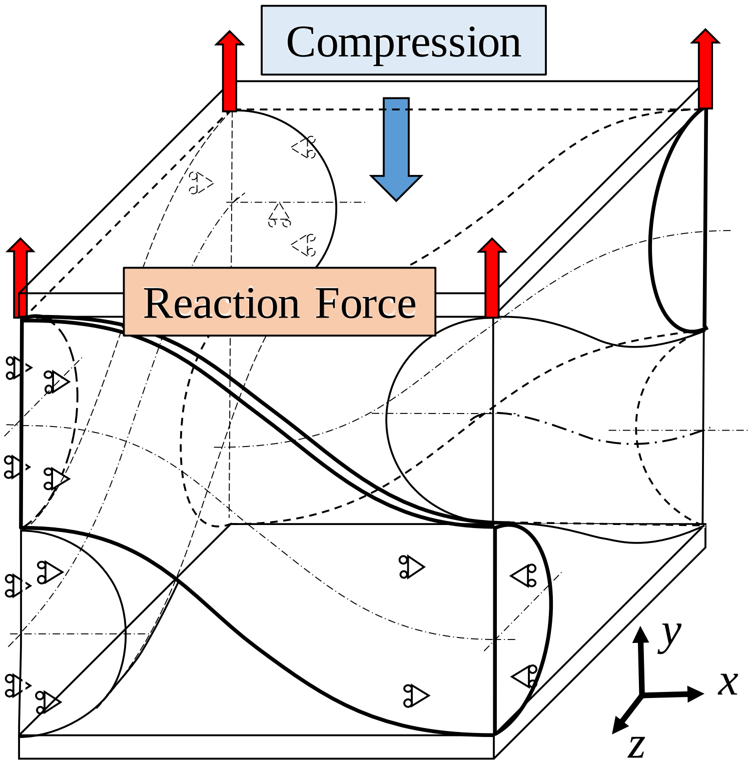


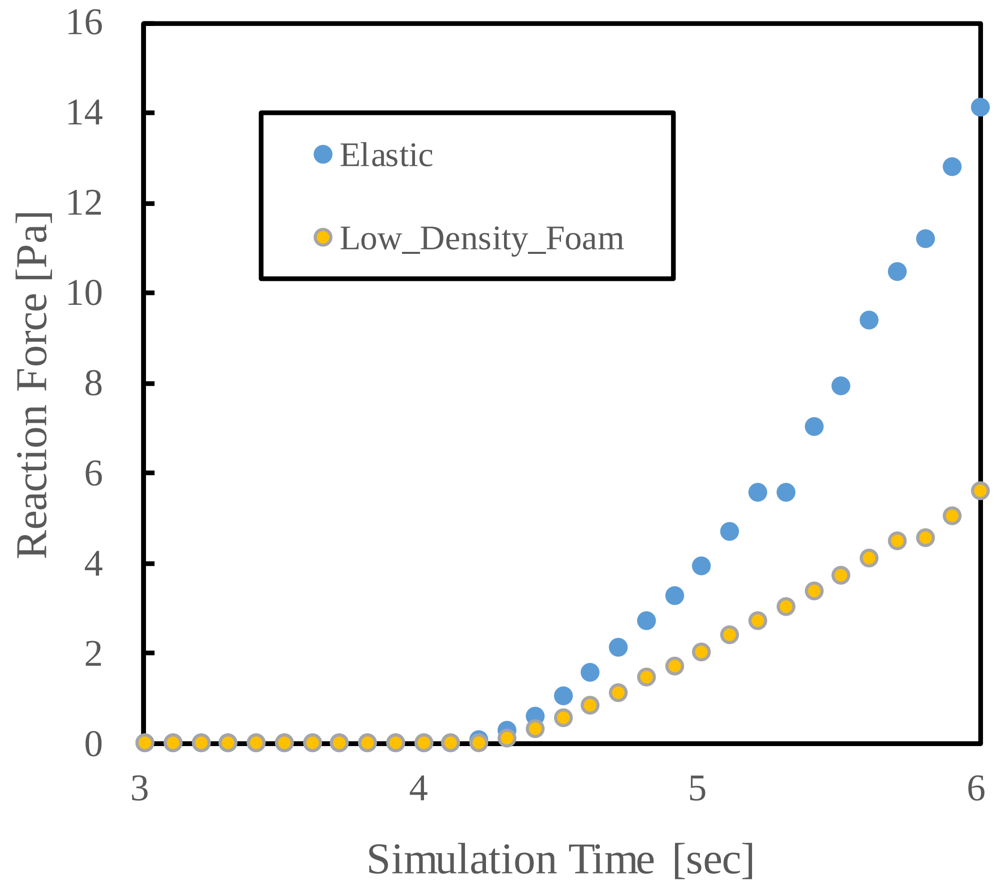
Elastic



Low_Density_Foam

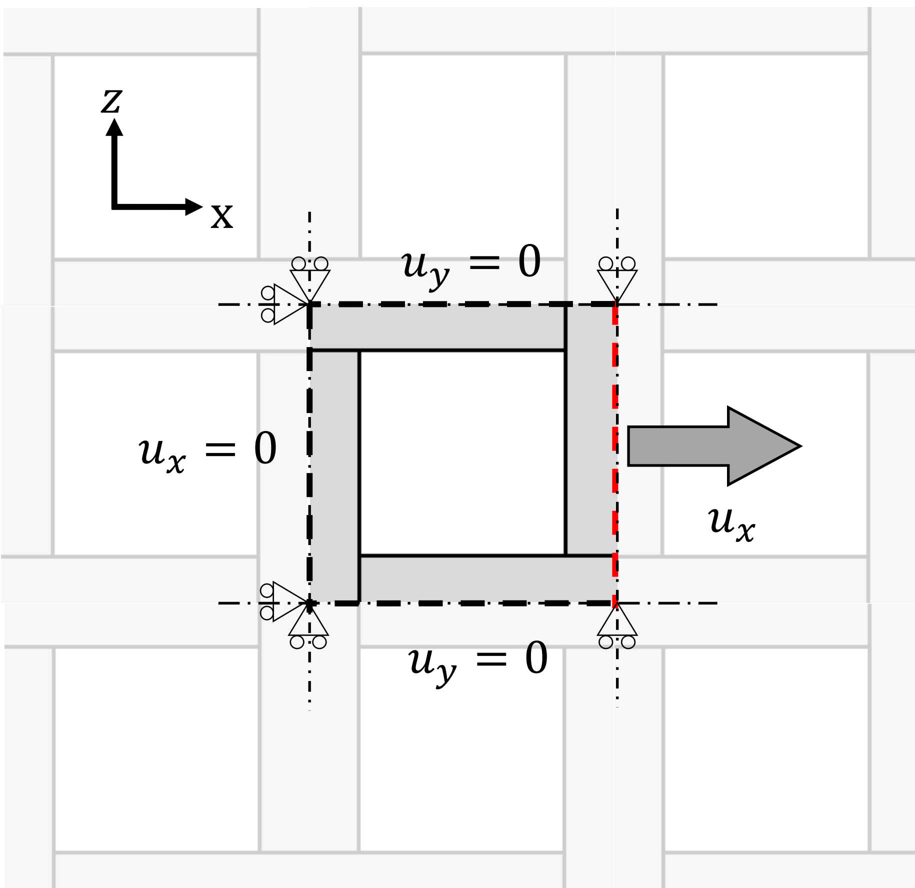
Weaving Simulation of Plain Fabrics

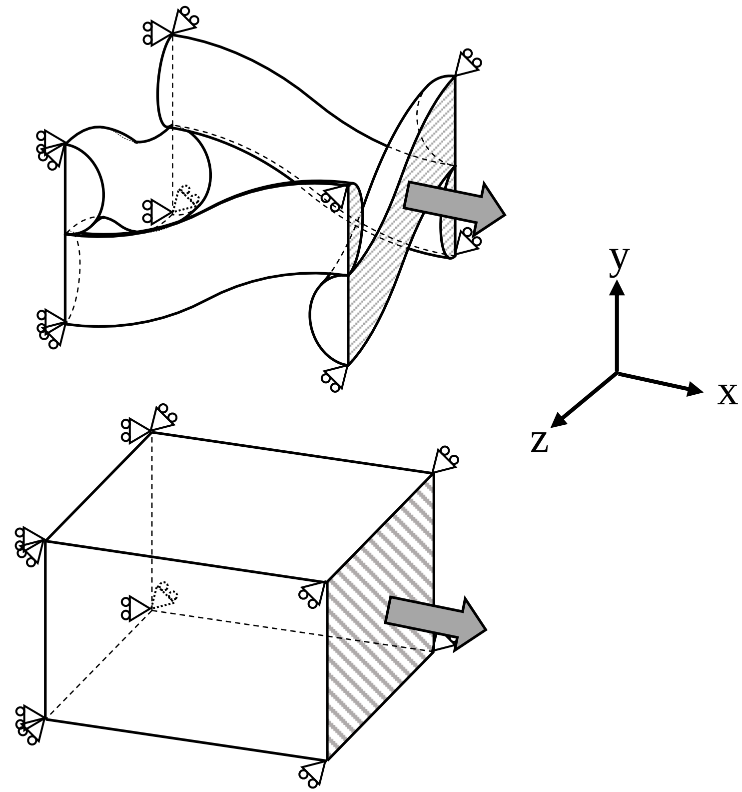




Tensile rigidity

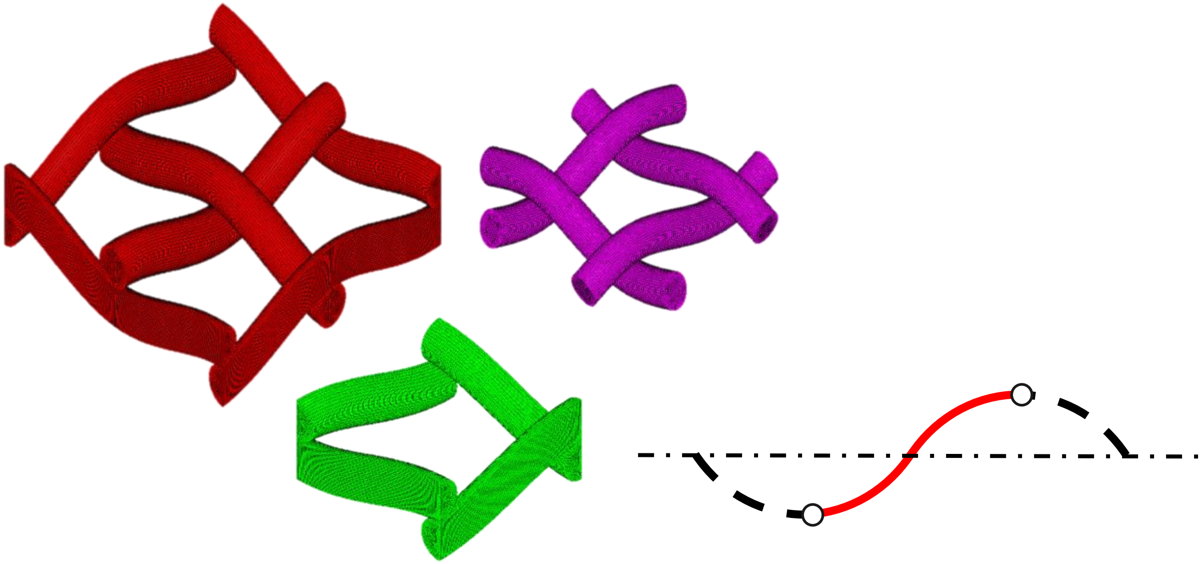
Tensile rigidity



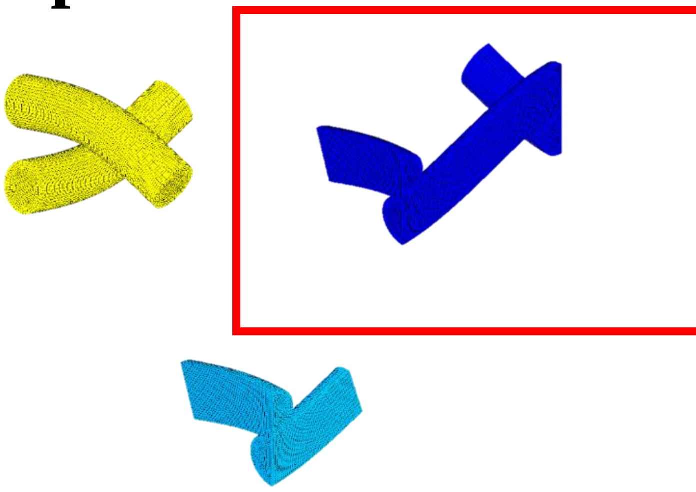


Cell type selection

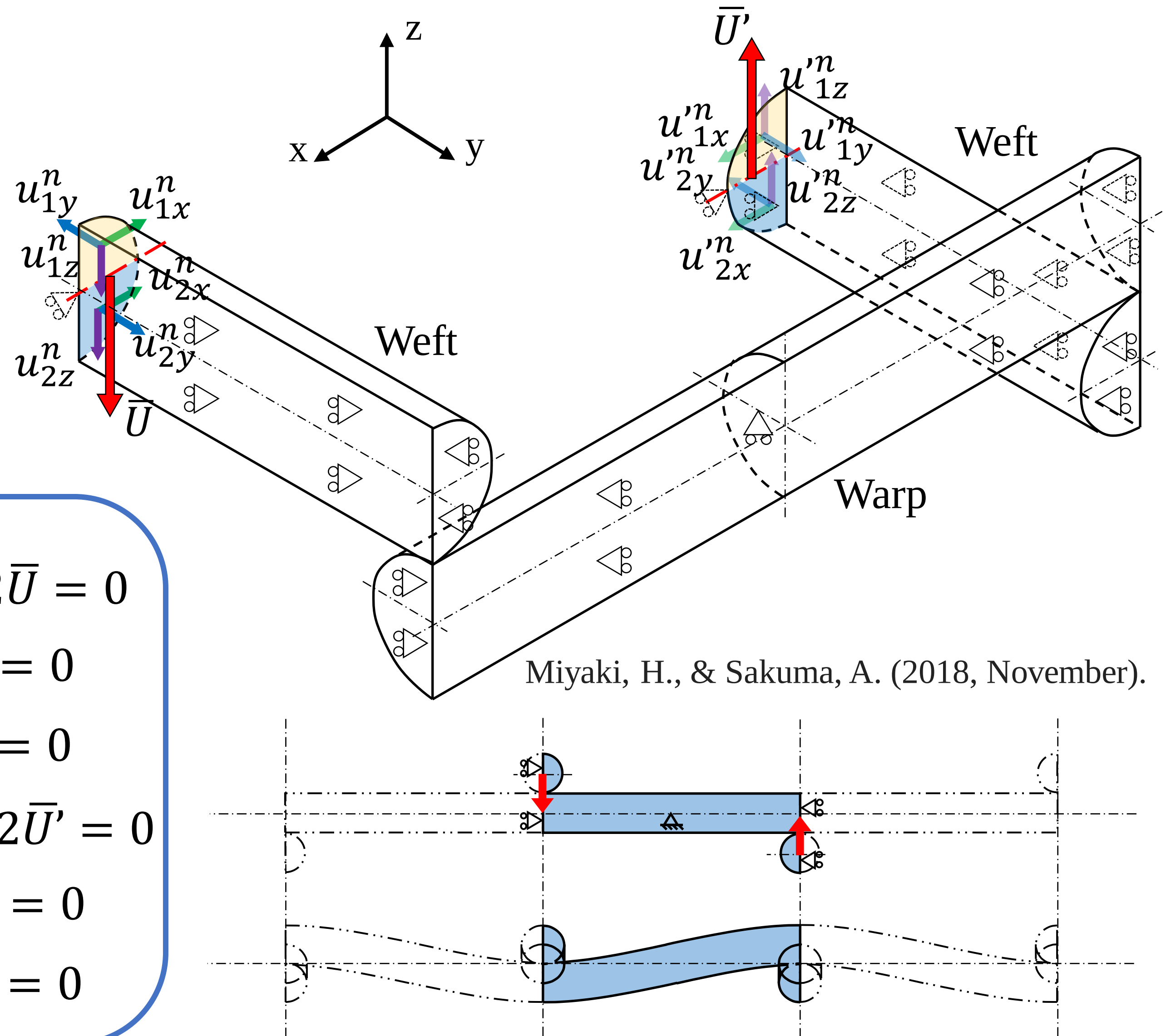
Closed-set model



Opened-set model



Tensile rigidity



Miyaki, H., & Sakuma, A. (2018, November).

$$u^n_{1z} + u^n_{2z} - 2\bar{U} = 0$$

$$u^n_{1y} + u^n_{2y} = 0$$

$$u^n_{3x} - u^n_{4x} = 0$$

$$u'^n_{1z} + u'^n_{2z} - 2\bar{U}' = 0$$

$$u'^n_{1y} + u'^n_{2y} = 0$$

$$u'^n_{3x} - u'^n_{4x} = 0$$

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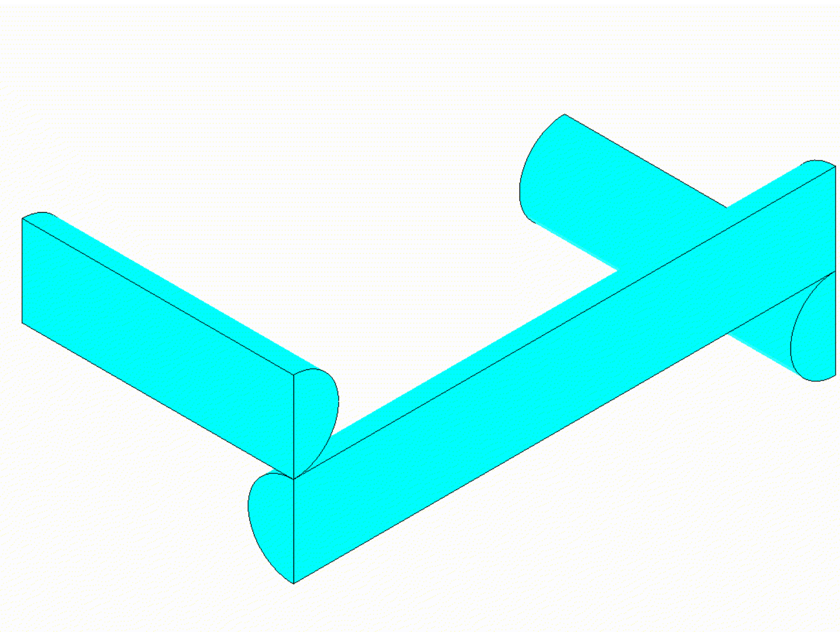
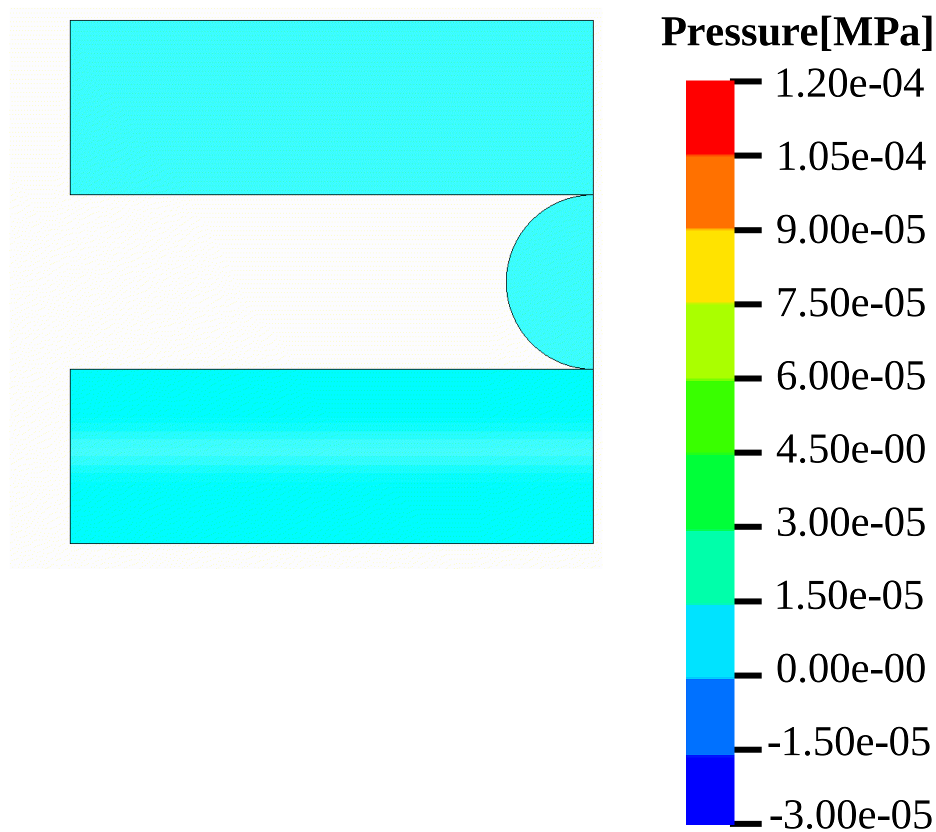
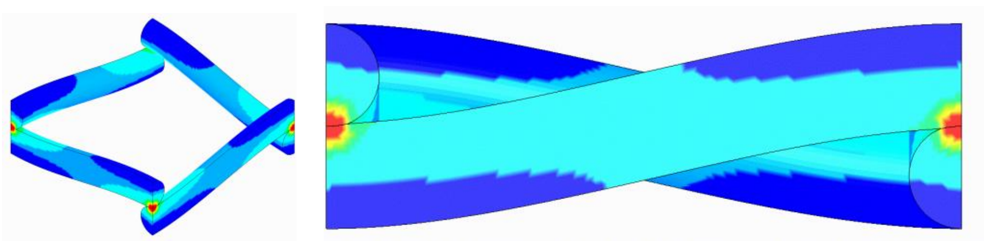
Tensile rigidity

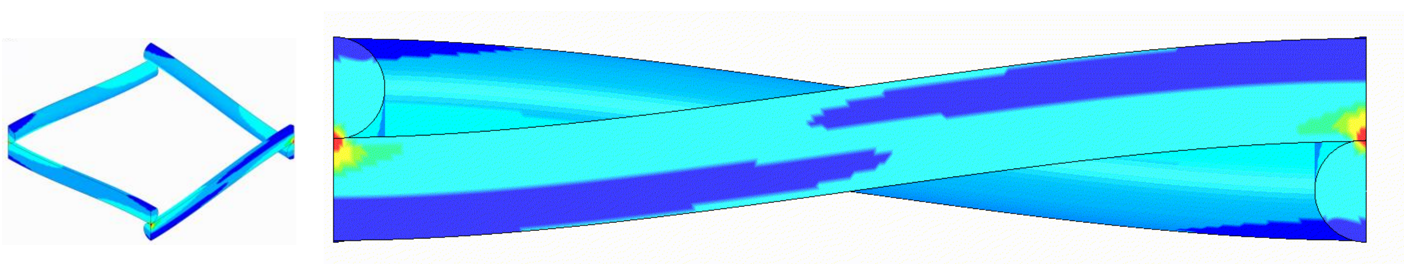




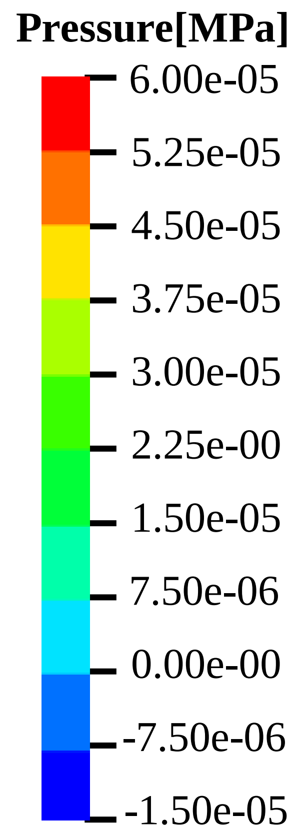
Tensile rigidity



$\lambda = 6$



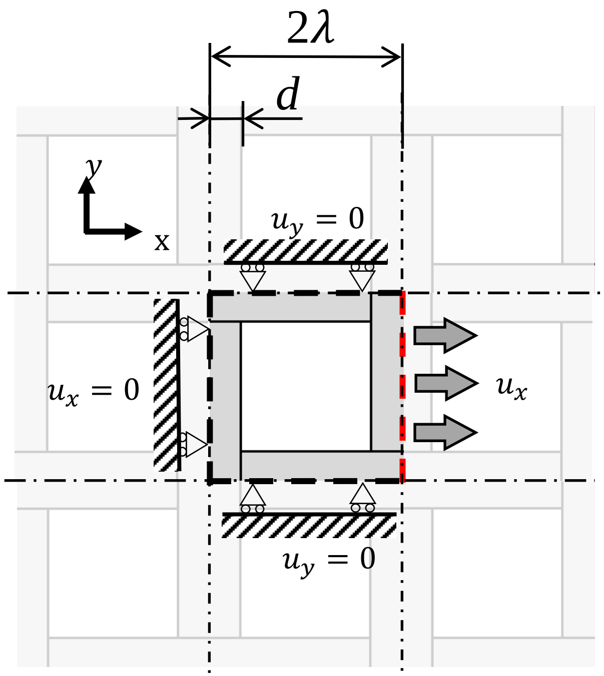
$\lambda = 10$



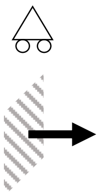
Analysis parameters in tensile behavior

Tensile Analysis condition

Weave pattern ratio $\Upsilon = 2\lambda/d$



	γ=6	γ=12	γ=20
Wire Diameter d [mm]	1.0	1.0	1.0
Weave pattern ratio γ	**3.0**	**6.0**	**10.0**
Constitutive equation	Elastic	Elastic	Elastic
Density ρ [kg/m^3]	400	400	400
Young's modulus E [Pa]	1000	1000	1000
Poisson ratio ν	0.49	0.49	0.49
Number of Nodes	98304	109500	179580
Number of Elements	56940	95232	156672
Analysis method	Implicit	Implicit	Implicit
Forced displacement u_x[mm]	**0.3**	**0.6**	**1.0**

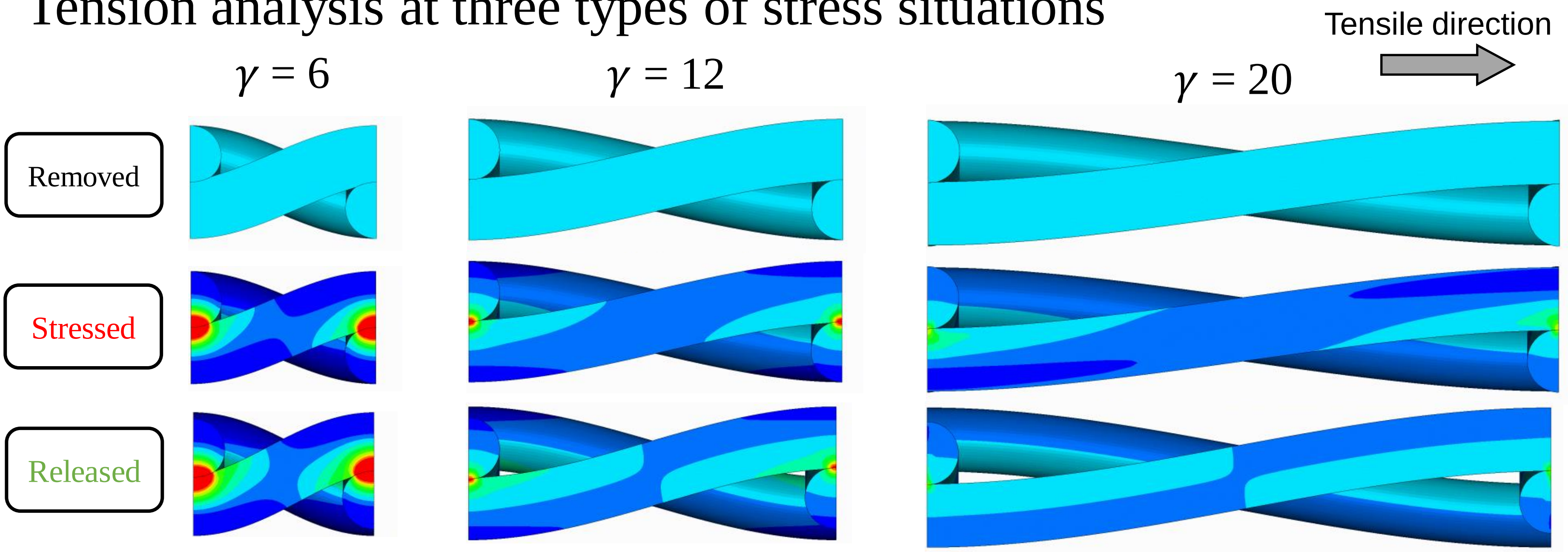


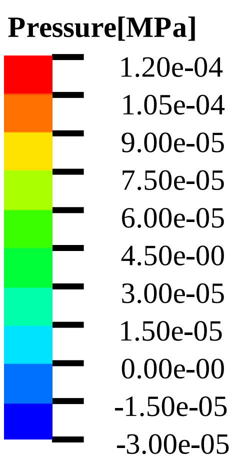
Boundary condition (Constraints)

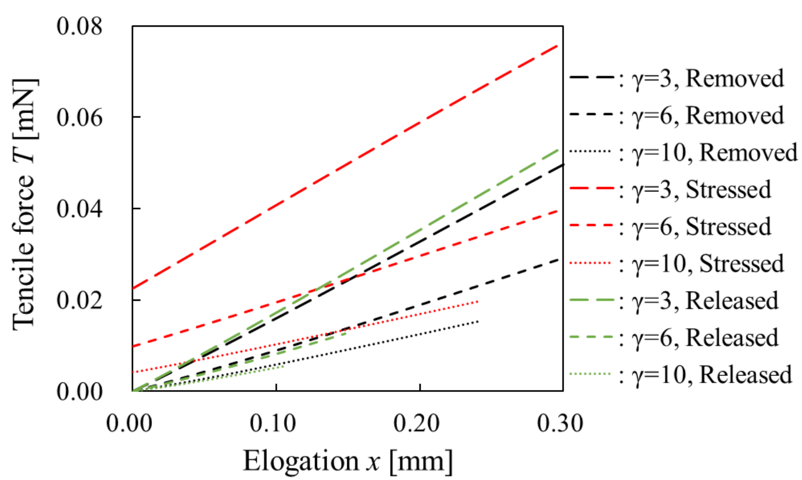
Forced displacement u_x

Analysis of tensile

Tension analysis at three types of stress situations



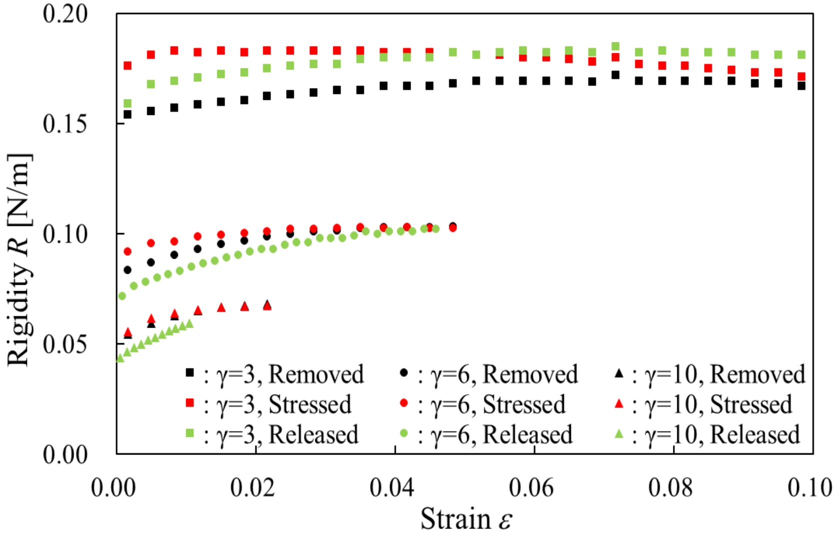




- The stress at the interweaving point affects the initial tensile force
- the discrepancy in slope shows that the tensile trend is affected after Releasing

Discussion

The effect of strain

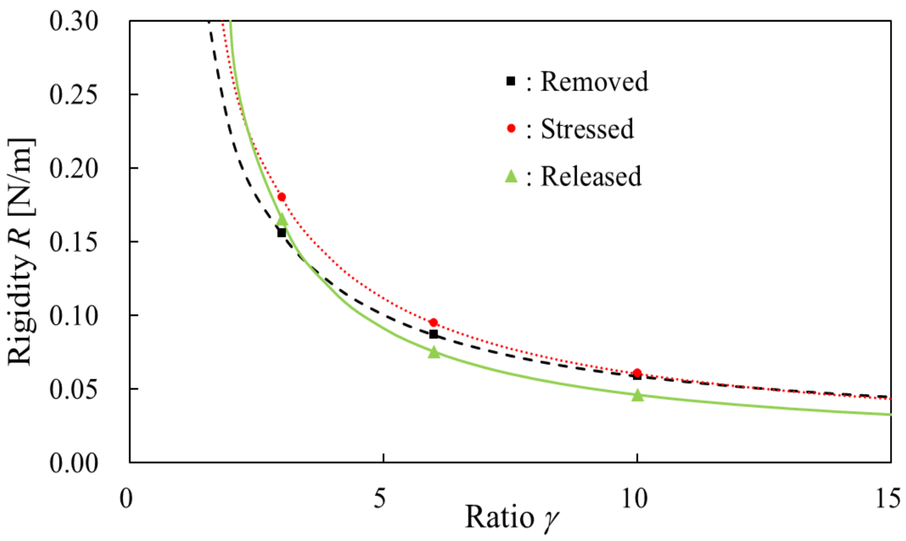


- Stiffness per unit length of fabric structure changes with increasing tensile length
- The consideration of residual stress will obviously affect the stiffness,
- It will show different effects with different weave pattern ratios,

- The "weave" increases the rigidity of the structure.
- A certain rigid cloth, which can be obtained with a lower soft thread

Discussion

The effect of weave pattern ratio



- Relationship between stiffness per unit length and fabric pattern ratio at the beginning of tensile
- Residual stresses give fabric structures higher stiffness at smaller weave pattern ratio, but this effect is not always maintained

- The presence or absence of internal stresses must be taken into consideration.
- The way to consider is also important .

Conclusion

1. A method to consider the weaving stress of the plain weave structure is introduced by homogenization

2. The elastic deformation of a structure after weaving process also computed by numerical simulation.

3. Quantitative evaluation of the stress effect in weaved structure is simulated after unloading, and effect of the weave pattern ratio is also discussed.

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Thank you for your attention

ご清聴 ありがとう ございました