Ecodesign and 3D topology optimization

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Summary

Summary

In-plane fibre orientations

- Optimisation problem formulation

$$\min_{\boldsymbol{\rho},\boldsymbol{\theta}} c(\boldsymbol{\rho},\boldsymbol{\theta}) = \sum_e \rho_e^p \, \boldsymbol{u_e^T} \, \boldsymbol{k_0}(\theta_e) \, \boldsymbol{u_e^T}$$

$$\text{s.t.} \begin{cases} \frac{V(\boldsymbol{\rho})}{V_0} \leq f \\ \boldsymbol{KU} = \boldsymbol{F} \\ 0 < \rho_{min} \leq \boldsymbol{\rho} \leq 1 \\ -\pi \leq \boldsymbol{\theta} \leq \pi \end{cases}$$

- Filters

$$\rho_e \widetilde{\frac{\partial c}{\partial \rho_e}} = \frac{1}{\sum_i H_{ei}^{\rho}} \sum_i H_{ei}^{\rho} \, \rho_i \, \frac{\partial c}{\partial \rho_i}$$

$$H_{ei}^{\rho} = \max(0, r_{\rho} - \Delta(e,i))$$

$$\tilde{\theta}_e = \frac{1}{\sum_i H_{ei}^{\theta} \, \rho_i} \sum_i H_{ei}^{\theta} \, \rho_i \theta_i$$

$$H_{ei}^{\theta} = \max(0, r_{\theta} - \Delta(e,i))$$

Free fibre orientations

- Optimisation problem formulation

$$\min_{\boldsymbol{\rho},\boldsymbol{\theta},\boldsymbol{\alpha}} c(\boldsymbol{\rho},\boldsymbol{\theta},\boldsymbol{\alpha}) = \sum_e \rho_e^p \, \boldsymbol{u_e^T} \, \boldsymbol{k_0}(\theta_e,\alpha_e) \, \boldsymbol{u_e^T}$$

$$\text{s.t.} \begin{cases} \frac{V(\boldsymbol{\rho})}{V_0} \leq f \\ \boldsymbol{KU} = \boldsymbol{F} \\ 0 < \rho_{min} \leq \boldsymbol{\rho} \leq 1 \\ -\pi \leq \boldsymbol{\theta} \leq \pi \\ -2\pi \leq \boldsymbol{\alpha} \leq 2\pi \end{cases}$$

- Filters

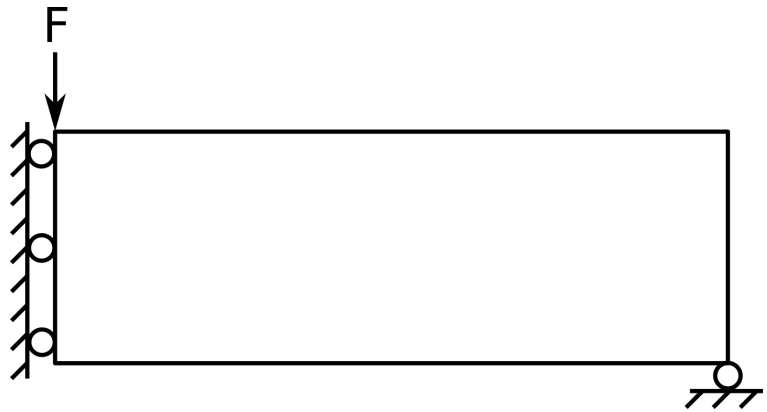
$$\rho_e \widetilde{\frac{\partial c}{\partial \rho_e}} = \frac{1}{\sum_i H_{ei}^{\rho}} \sum_i H_{ei}^{\rho} \, \rho_i \frac{\partial c}{\partial \rho_i} \qquad \begin{pmatrix} \tilde{\theta}_e \\ \tilde{\alpha}_e \end{pmatrix} = \frac{1}{\sum_i H_{ei}^{\theta} \, \rho_i} \sum_i H_{ei}^{\theta} \, \rho_i \begin{pmatrix} \theta_i \\ \alpha_i \end{pmatrix}$$

$$H_{ei}^{\rho} = \max(0, r_\rho - \Delta(e,i)) \qquad H_{ei}^{\theta} = \max(0, r_\theta - \Delta(e,i))$$

Summary

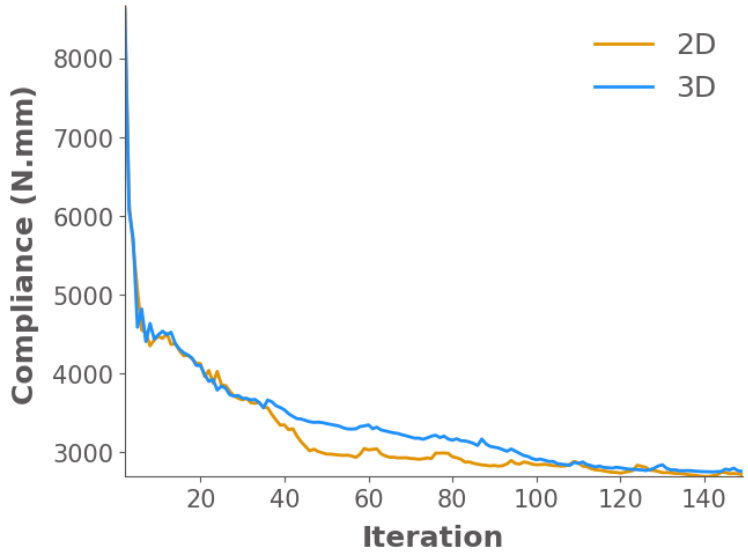
Problem 1 - MBB beam

2D and in-plane 3D solutions were compared to verify the sensitivity calculations for 3D elements

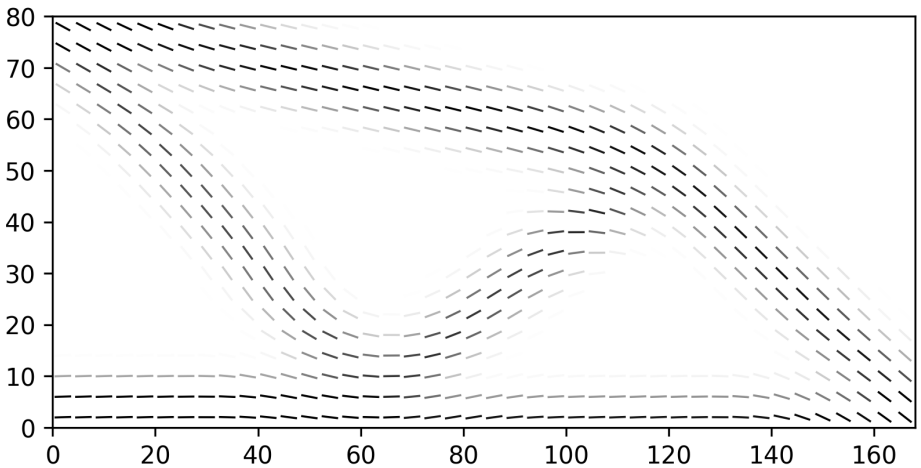


- Half MBB beam, 186 mm $\times$ 80 mm $\times$ 8 mm
- Element size: 4 mm
- Volume fraction constraint: 0.3
- Density filter radius: 8 mm $\Rightarrow$ 3D layers behave similar to 2D
- Orientation filter radius: 20 mm
- Same initial orientation: 50°

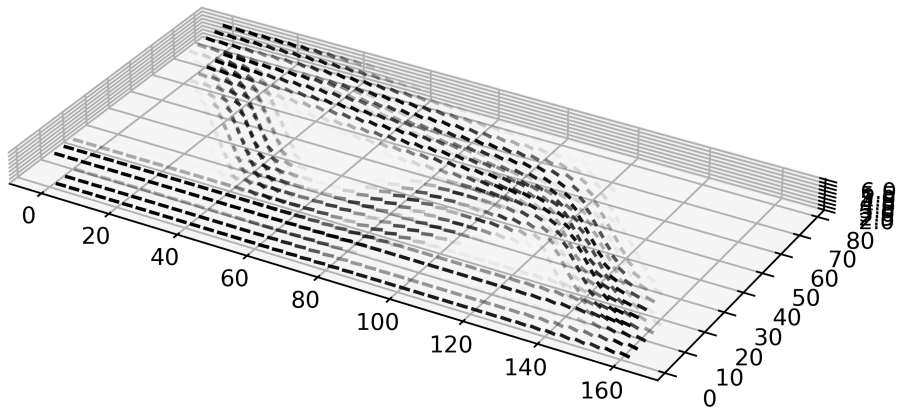
Problem 1 - MBB beam



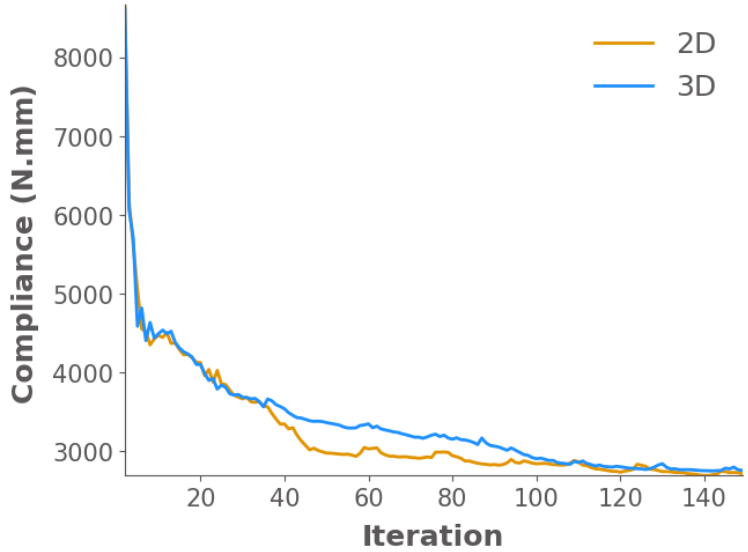
- 2D - Comp. = 2691 N.mm



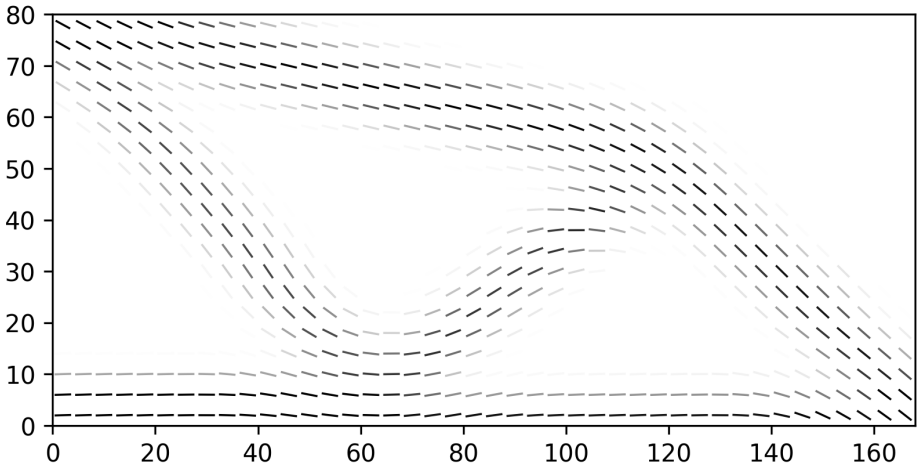
- 3D - Comp. = 2733 N.mm



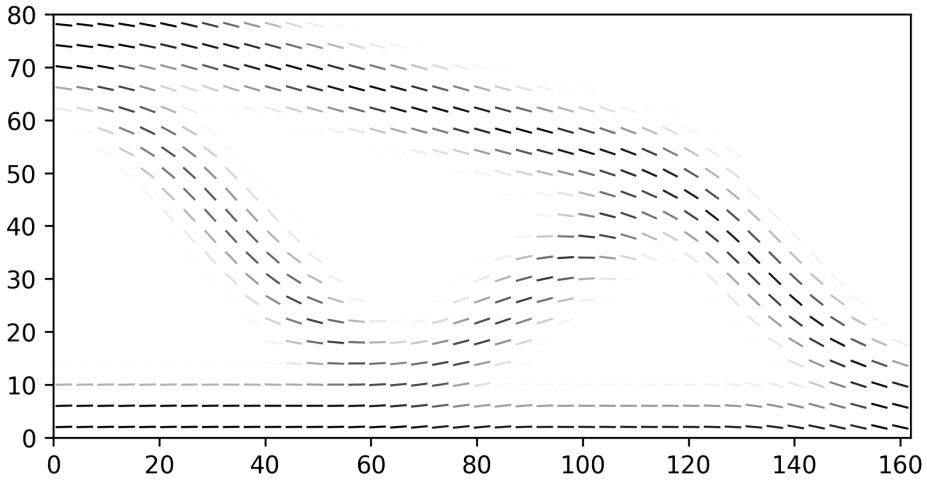
Problem 1 - MBB beam



- 2D - Comp. = 2691 N.mm

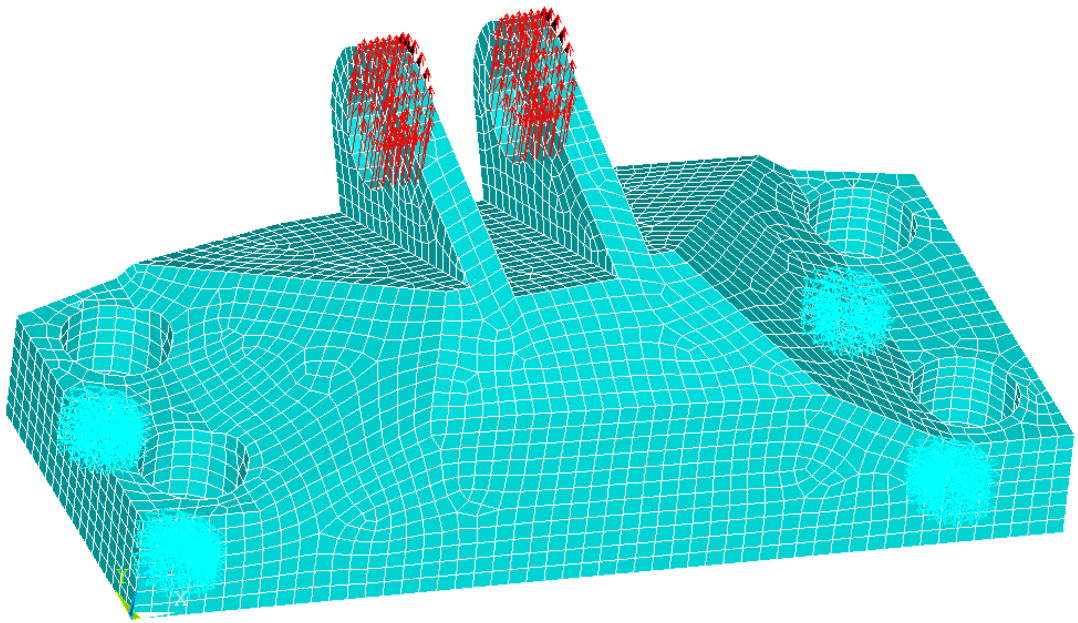


- 3D - Comp. = 2733 N.mm



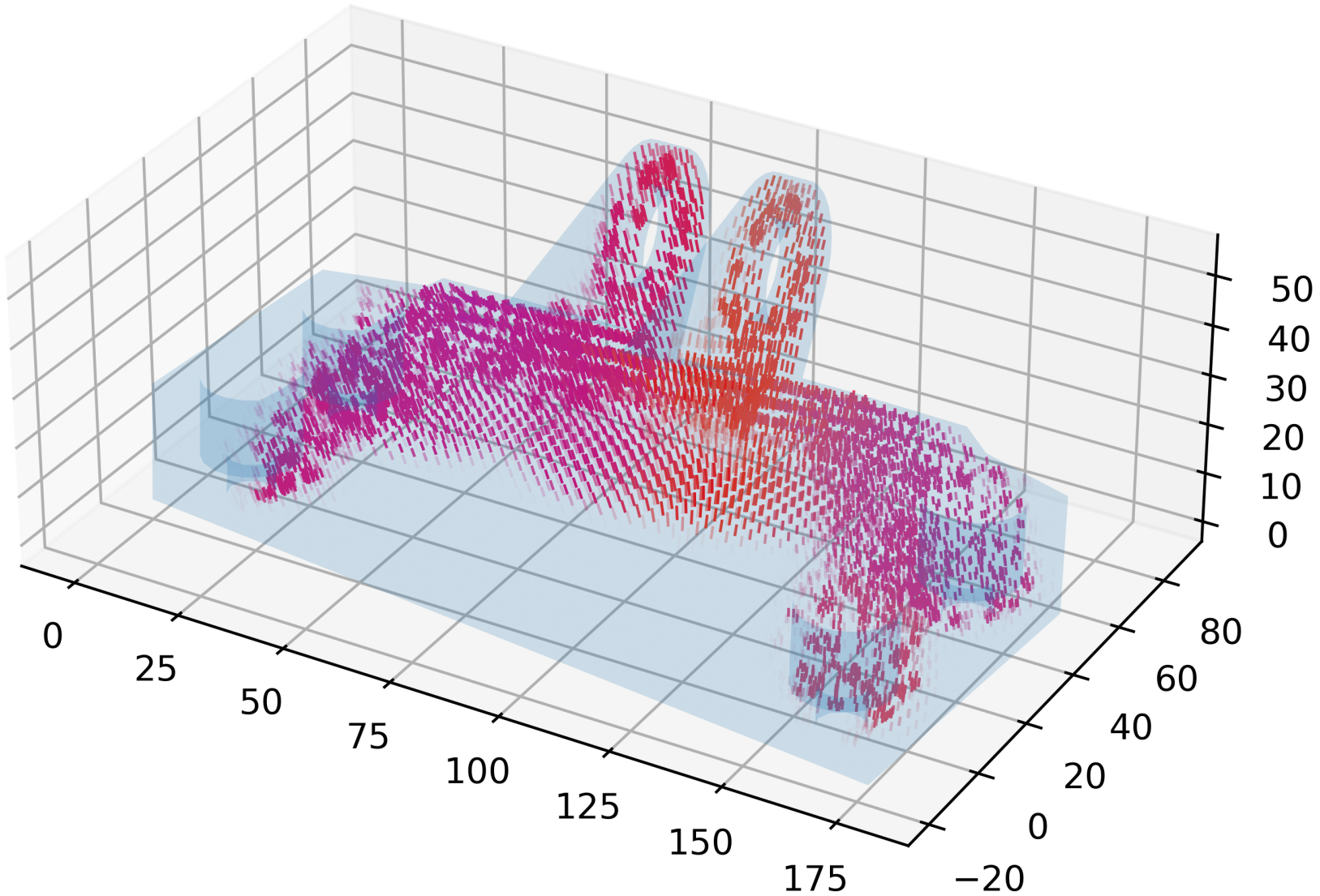
Problem 2 - Bracket

In-plane and free orientation results were compared to study the inclusion of α as design variable



Problem 2 - Bracket

Free - Compliance = $20.96 \cdot 10^4$ N.mm



Problem 2 - Bracket

In-plane - Compliance = $18.05 \cdot 10^4$ N.mm