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A highly accurate and efficient meshfree method for elastoplastic analysis

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Introduction

This study introduces a meshfree collocation method for path-dependent elastoplastic problems, using high-order continuous shape functions and low-order quadrature. It achieves superior accuracy, stability, and efficiency versus traditional methods, offering an effective tool for engineering deformation simulations.

Methods

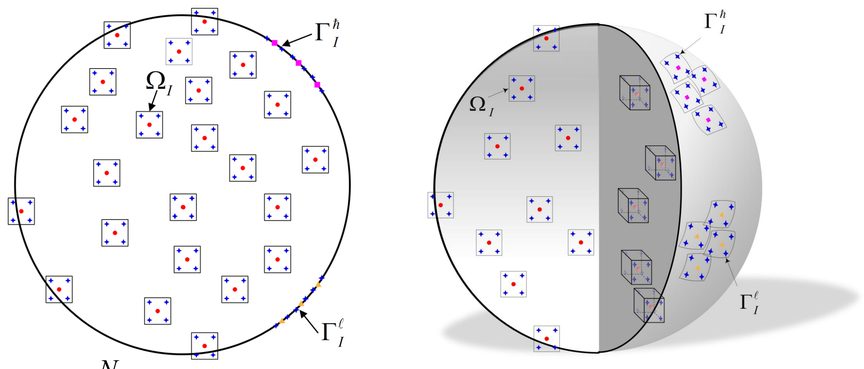
➢Reproducing kernel (RK) approximation

$$u(\mathbf{x}) \approx u^a(\mathbf{x}) = \sum_{J=1}^{N} \psi_J(\mathbf{x}) d_J$$

➢Reproducing kernel shape function

$$\psi_J = \mathbf{H}^{\mathrm{T}}(\mathbf{x}-\mathbf{x}_J)\mathbf{M}^{-1}(\mathbf{x})\mathbf{H}(\mathbf{0})\varphi_\rho(\mathbf{x}-\mathbf{x}_J)$$

➢Stabilized collocation Method (SCM)



$$\int_{\Omega^I} \sum_{J=1}^{N} \psi_J(\mathbf{X}) \mathbf{X}_J^\alpha \mathrm{d}\Omega = \int_{\Omega^I} \mathbf{X}^\alpha \mathrm{d}\Omega, \quad |\alpha| \le \kappa$$

➢Using Hencky's theory of plasticity

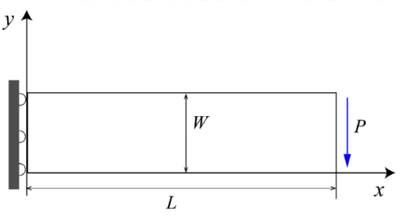
$$v_{eff} = E_{eff}\left(\frac{\%}{E} + \frac{\varpi}{6G}\right) \qquad G_{eff} = E_{eff}/3 = \sigma_{eq}/3\varepsilon_{eq}$$

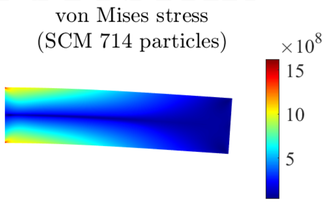
$$E_{eff} = 1\Big/\left(\frac{1}{E} + \frac{\varpi}{3G}\right)$$

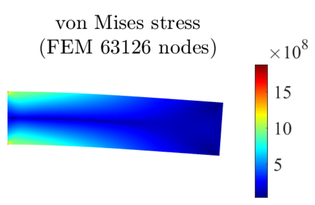
$$\varpi = G/G_{eff} - 1$$

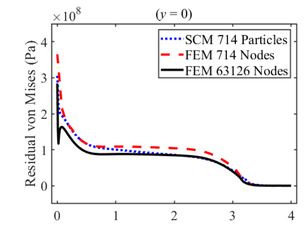
Graphics / Images

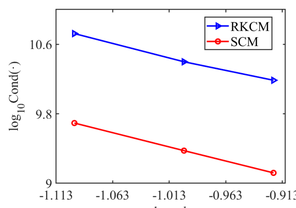
➢Cantilever beam problem

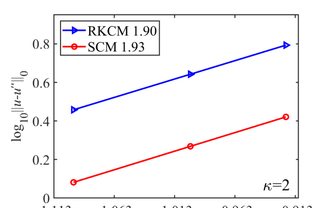


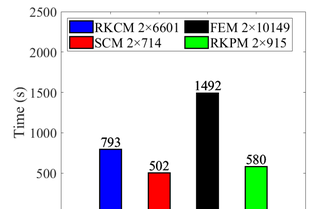




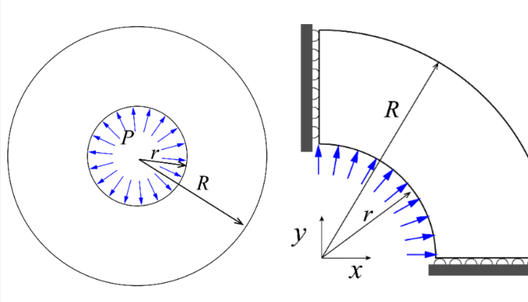


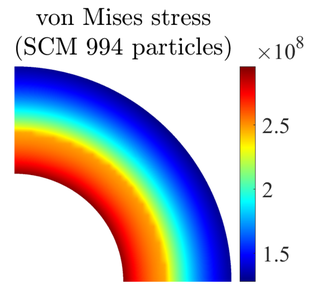


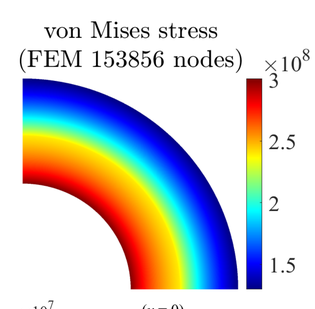


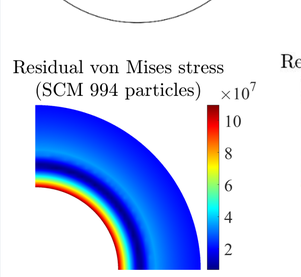


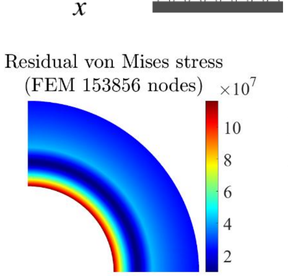
➢A perforated plate

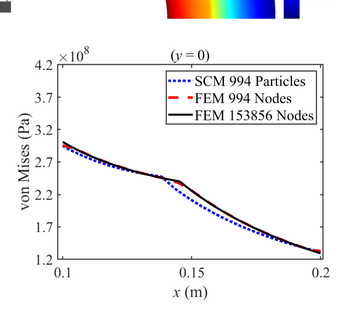


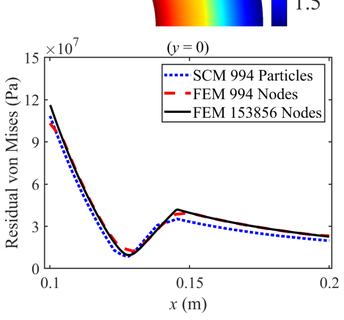




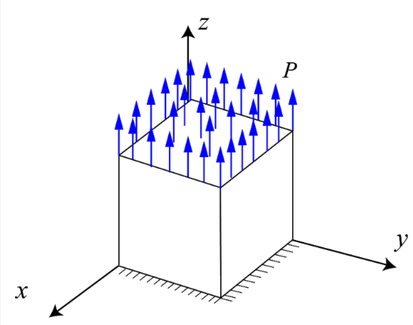


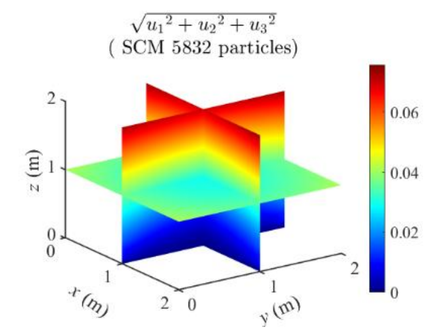


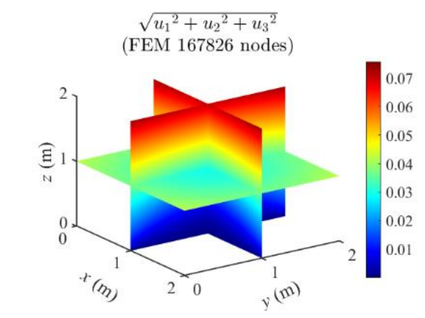


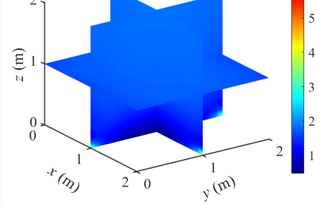


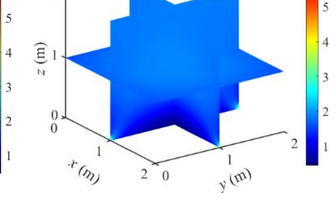
➢A cube subjected to uniform load

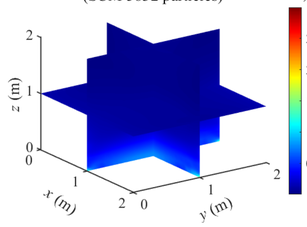


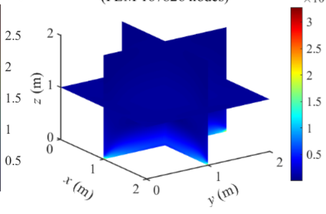












Conclusions

- A meshfree SCM is proposed for elastoplastic analysis;
- Hencky's theory and von Mises criterion are adopted;
- SCM achieves higher accuracy and stability than RKCM;
- Exact subdomain integration reduces the condition number;
- High-order continuity is preserved in displacement and stress solutions;
- SCM is more efficient than RKCM under the same accuracy level.