# Reliability measure approach considering mixture uncertainties under insufficient input data

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# Determinate Variables and Uncertain Variables



- Product dimensions
- Geometric parameters
- Material properties
- Manufacturing tolerance
- Assembly tolerance
- Deformation
- Wear
- Input loads
- Environment loads
- …

**Mechanical System** → **Design Variables**

Ideal Design → **Determinate Variables**

Practical Design → **Uncertain Variables**

# Uncertainty Types Due to Insufficient Input Data

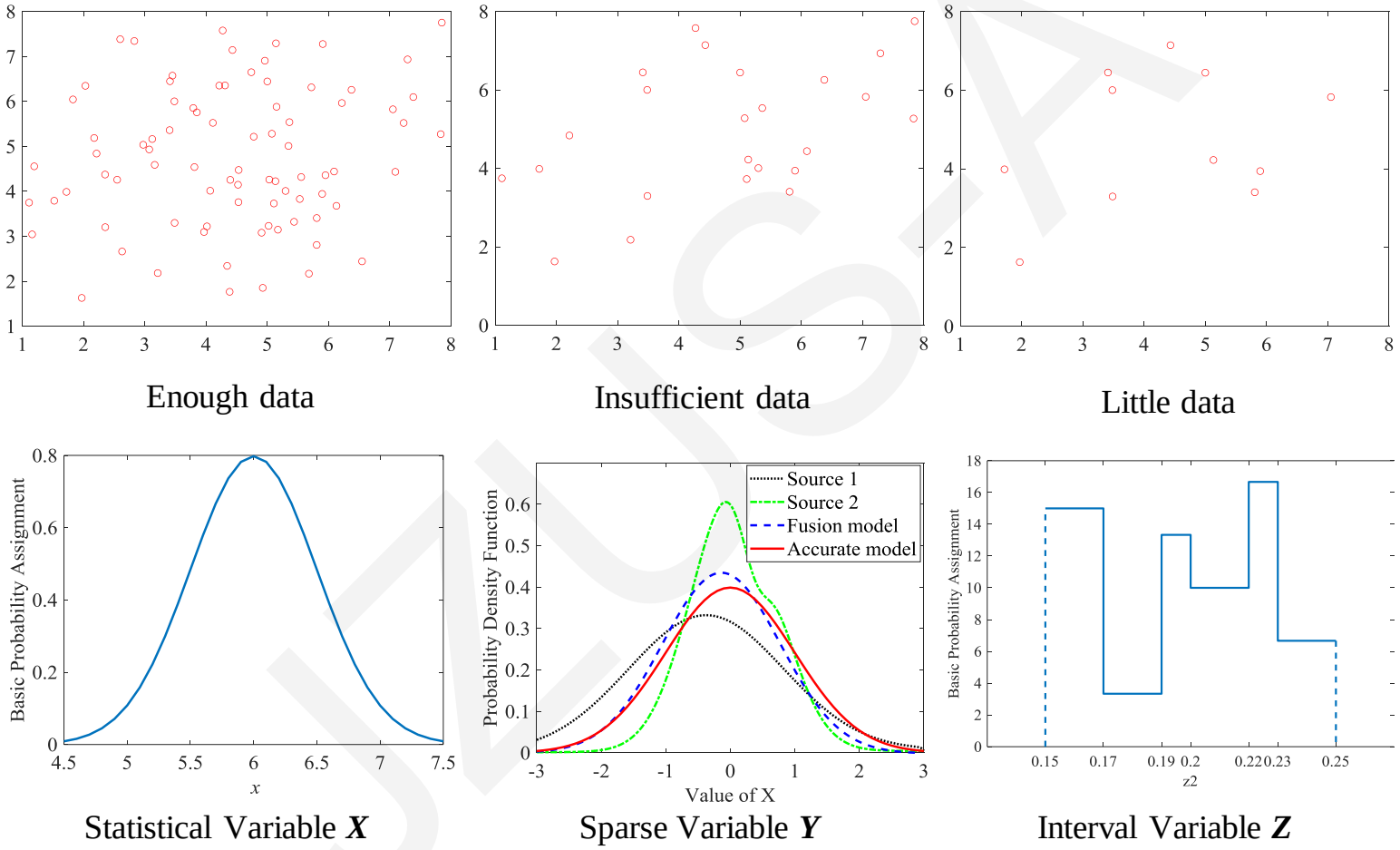



Fig 1. Multiple uncertainty types due to insufficient input data

# Main Method

- **Statistical Variables *X*,**
- **Sparse Variables *Y*,**
- **Iterval Variables *Z***

**Unified Calculation of Probability of Failure Probability**

**Sensitivity Analysis of Reliability Index**

**Extension to More Uncertainty Presentation Types**

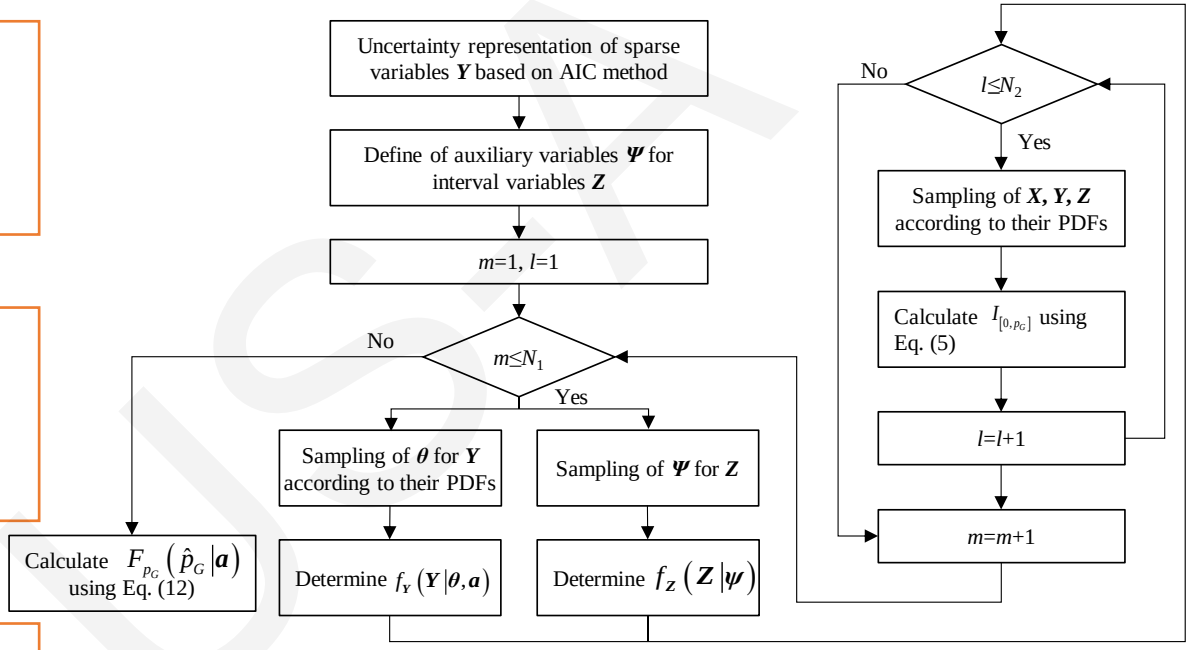
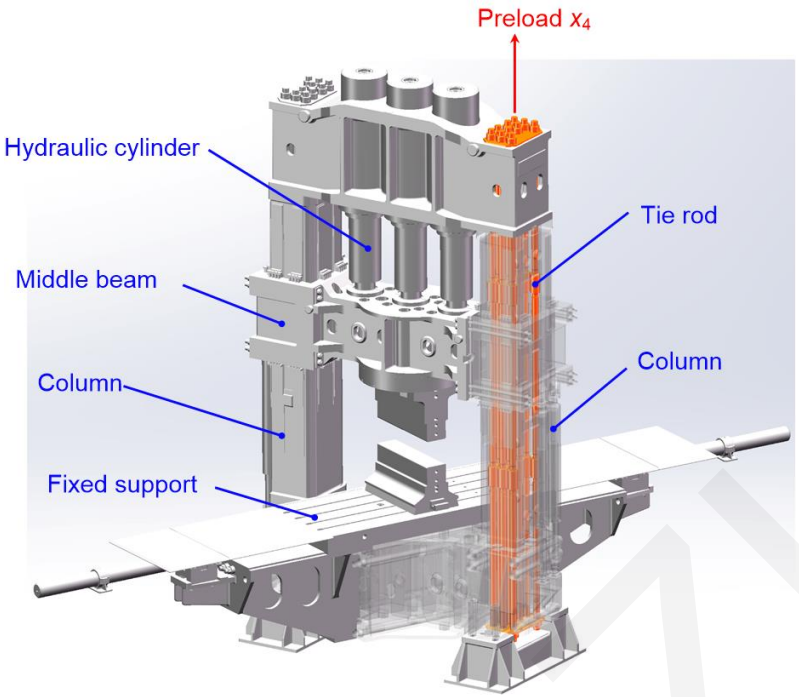
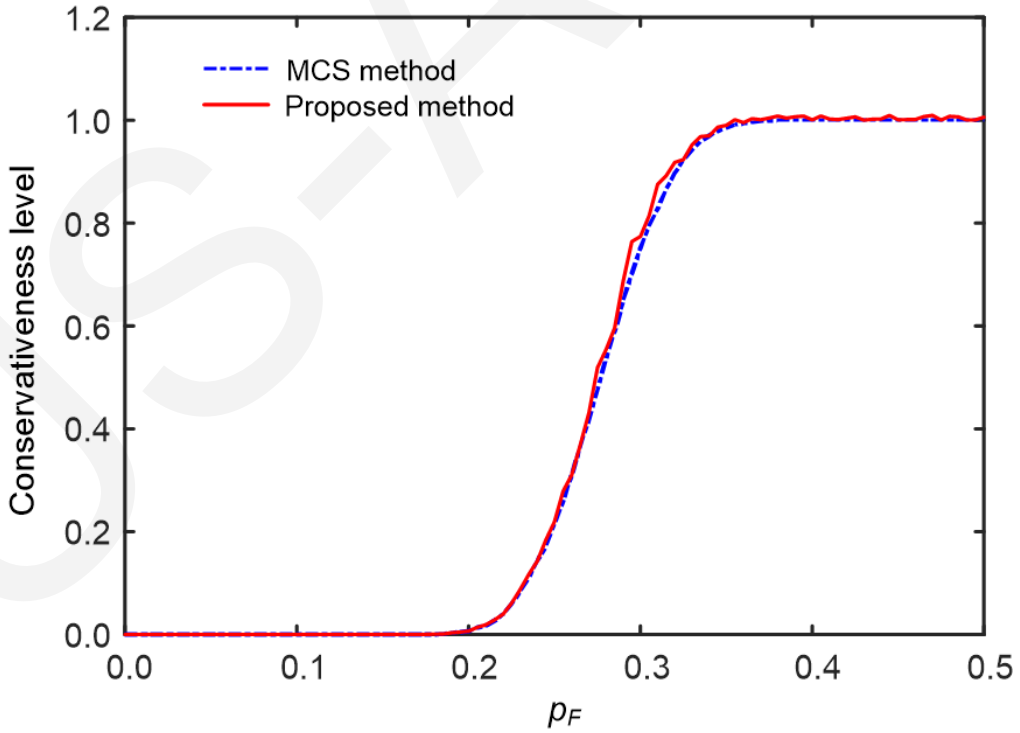



Fig. 2 Calculation flow chart for failure probability

- ***p*-box uncertainty variables**
- **Multi-modal distribution variables**
- **Evidence theory variables**

# Engineering Example: Forging Hydraulic Press

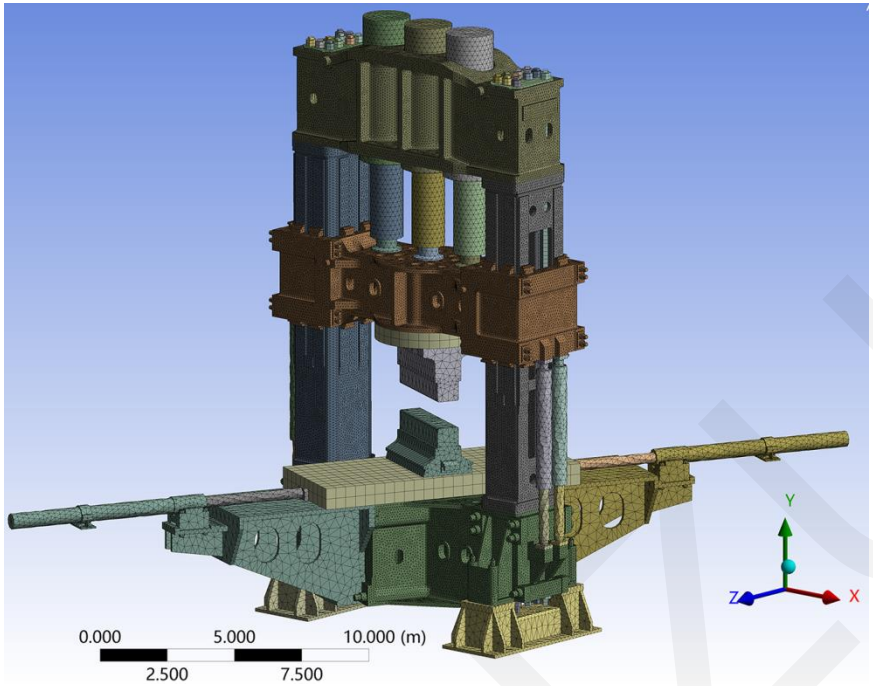



- The load of the hydraulic press $x_1$
- The diameter of tie rods $x_2$
- The Young's modulus of tie rods $x_3$
- The preload acting on tie rods $x_4$

Fig. 13 Reliability result of forging hydraulic press

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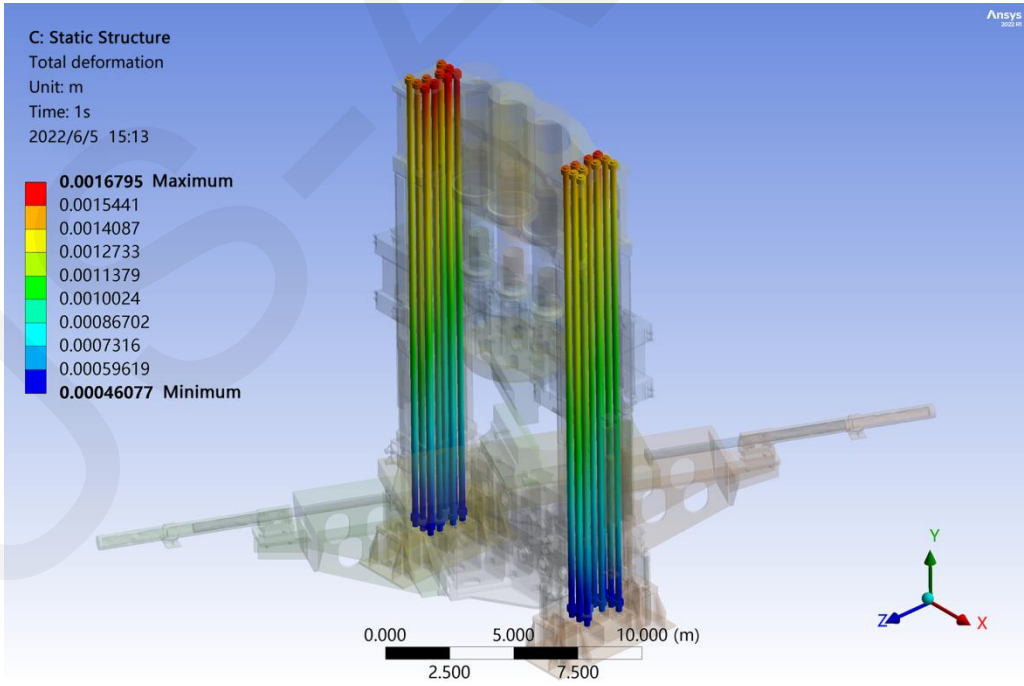




Fig 11. FEA of the forging hydraulic press: (a) mesh; (b) deformation of the tie rods

# Conclusions

In this study, a reliability measure approach considering mixture uncertainties under insufficient input data is proposed.

- First, the sparse variable is represented using weight summation of multiple distribution types based on AIC method under insufficient input data.
- Second, the failure probability under mixture uncertainties is calculated using the proposed two-level sampling method. Then, a semi-analytical method is proposed to calculate the sensitivity indices of mixture uncertainty variables.
- Finally, the proposed reliability measure method is extended to deal with *p*-box variables, multi-modal variables, and evidence theory variables.