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A study on the effects of the Quantum Computer measurement errors on the Quantum Finite Element Algorithm performance

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The rise of Quantum Computing (QC) is opening the floor to many novel engineering applications. One of the most promising applications in mechanical engineering is the Quantum Finite Element Method (QFEM), which leverages quantum technology to solve large-scale models that would be computationally prohibitive for classical solvers. However, practical use of QFEM is strongly influenced by the intrinsic uncertainty of quantum measurements, which introduces stochastic variability in the computed results. This study investigates the impact of quantum measurement uncertainty on the performance and reliability of a QFEM formulation specifically developed for structural mechanics simulations of beam elements. A quantum-inspired model has been implemented using parameterised quantum circuits to evaluate stiffness matrix assembly and solution accuracy under different levels of measurement precision. The analysis quantifies how shot noise, the number of qubit measurements, and circuit depth affect the global convergence, energy norm error, and computational efficiency of the resulting structural model. Results show that beyond a certain uncertainty threshold, the accuracy degradation becomes negligible, indicating a strong relation between algorithmic robustness and hardware-imposed measurement limits. The findings highlight the importance of uncertainty-aware algorithm design in hybrid quantum-classical solvers for engineering applications. This research provides initial insights into the trade-off between quantum noise and model fidelity, contributing to the broader understanding of quantum numerical mechanics and guiding future development of scalable QFEM implementations.

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