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FINITE ELEMENT MESH SIZE OPTIMIZATION FOR STEEL BOLTED CONNECTION

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Abstract: Bolted connections are important components of steel structures and as such must be based on good design and detailing. Popularity of bolted connections entails that their failure mechanisms are thoroughly researched and adequately analytically described. A prerequisite for a robust and reliable analytical description of a failure mode is a large base of results, collected experimentally or numerically, usually via finite element analysis. FEM simulations are a common approach for research purposes, but the modelling procedure can significantly influence result accuracy. One of the most important parameters for successful convergence and accuracy is spatial discretization, i.e. mesh size. Mesh size presents a delicate balance between accuracy, efficiency and convergence issues, especially in bolted connection analysis where mesh quality amplifies these effects, through contact, material and geometric nonlinearity. Sensitivity studies are, due to increased complexity of nonlinear behaviour, often difficulty to interpret and time expensive, which is why in this study, based on previous research, a mesh size optimization procedure is presented. This optimization is based on a previously verified and validated numerical model parametric study, which produced a large enough dataset of results. The numerical model is of a single-bolt lap connection, as such a connection represents challenging problems in modelling, such as complex boundary conditions (rotation due to longitudinal eccentricity), contact formulation, several possible failure mechanisms. Two-stage optimization was performed in order to determine for which mesh size results of the numerical analysis (bolt-hole elongation and load) converge to those obtained experimentally. The first step included forming of an optimization model based on an artificial neural network (ANN). Results were extrapolated and compared to those attained experimentally, which indicated that the mesh size of 0.87 mm would provide near optimal (experimental) results. However, estimated solving wall time was significantly longer. In the second step, a nonlinear optimization model was structured in order to find a mesh size for which the difference between experimental and optimization results would be equal, whilst the optimization objective was to find a mesh size which requires minimal solving wall time. The optimization model provided insights into mesh size quality to efficiency ratios and rendered that the minimal difference between experimental and numerical results (1.57 %) can be obtained with a mesh size of 2.19 mm. For this mesh size, the model estimated a solving wall time of 1.3 hours, instead of the step one optimization modelling estimated 36 hours.