

HOW DESIGN CODE-BASED ADMISSIBILITY RESHAPES ATTAINABLE PARETO FRONTS IN NOZZLE DESIGN

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Abstract

Pressure Vessel nozzle design is a critical aspect of equipment design. It is governed by layered feasibility constraints: physics-based structural response, industrial availability of discrete metal stock sizes (e.g. specific thickness), and mandatory pressure vessel design-code admissibility rules. While code conservatism is widely discussed through pointwise validation studies, its effect on attainable multi-objective trade-offs and feasibility discovery remains insufficiently characterized in an optimization setting.

Three observations motivate our study. First, code-admissible solutions typically form a strict subset of the physics-feasible set; however, code admissibility does not guarantee favorable FEA response, and in some configurations designs that satisfy ASME admissibility tests can still violate FEA-based stress criteria, underscoring the value of FEA as a companion check to code screening. Second, even within the code-admissible design envelope, the design space remains large and heterogeneous: for a fixed allowable stress ratio, candidate designs can span a wide range of weights, indicating significant opportunity for optimization beyond ad hoc iteration. Third, the severity and structure of these feasibility layers vary markedly across regions of the underlying high-dimensional (~20-parameter) design space, implying that conclusions drawn from a single scenario do not generalize.

We study these effects by decomposing feasibility into three nested sets: (i) physics feasibility assessed by high-fidelity finite element analysis in a continuous parameter space, (ii) availability feasibility obtained by discretizing thickness-related variables to standard plate and pipe sizes, and (iii) code admissibility enforced through ASME design-by-rule reinforcement requirements. For each layer, we approximate the corresponding Pareto front in weight–stress space and quantify the impact of added restrictions using frontier displacement, coverage loss, and the additional weight required to achieve the same stress ratio.

By interpreting code admissibility as a projection of the feasible design space rather than a mere pass/fail filter, the proposed framework provides a feasibility-first view of regulated design optimization and clarifies how industrial and normative constraints reshape attainable trade-offs. Although demonstrated on nozzle

reinforcement design, the approach generalizes to engineering optimization problems where discreteness and admissibility dominate feasibility discovery and inverse design reasoning.