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A New Look at the Simultaneous Analysis and Design of Structures

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The minimum weight optimization of structural systems, subject to strength and displacement constraints as well as size side constraints, was investigated by the Simultaneous **AN**alysis and **D**esign (SAND) approach. As an optimizer, the code NPSOL was used which is based on a sequential quadratic programming (SQP) algorithm. The structures were modeled by the finite element method. The finite element related input to NPSOL was automatically generated from the input decks of such standard FEM/optimization codes as NASTRAN or ASTROS, with the stiffness matrices, at present, extracted from the FEM code ANALYZE.

In order to avoid ill-conditioned matrices that can be encountered when the global stiffness equations are used as additional nonlinear equality constraints in the SAND approach (with the displacements as additional variables), the matrix displacement method was applied. In this approach, the element stiffness equations are used as constraints instead of the global stiffness equations, in conjunction with the nodal force equilibrium equations. This approach adds the element forces as variables to the system.

Since, for complex structures and the associated large and very sparce matrices, the execution times of the optimization code became excessive due to the large number of required constraint gradient evaluations, the Kreisselmeier-Steinhauser function approach was used to decrease the computational effort by reducing the nonlinear equality constraint system to essentially a single combined constraint equation. As the linear equality and inequality constraints require much less computational effort to evaluate, they were kept in their previous form to limit the complexity of the KS function evaluation.

To date, the standard three-bar, ten-bar, and 72–bar trusses have been tested. For the standard SAND approach, correct results were obtained for all three trusses although convergence became slower for the 72–bar truss. When the matrix displacement method was used, correct results were still obtained, but the execution times became excessive due to the large number of constraint gradient evaluations required. Using the KS function, the computational effort dropped, but the optimization seemed to become less robust. The investigation of this phenomenon is continuing.

As an alternate approach, the code MINOS for the optimization of sparse matrices can be applied to the problem in lieu of the Kreisselmeier-Steinhauser function. This investigation is underway.