Global and Clustered approaches for Stress and Fatigue Constraints in Topology Optimization

Erik Holmberg†, **Bo Torstenfelt**‡, **Anders Klarbring**†

Divisions of Mechanics† and Solid Mechanics‡, Department of Management and Engineering
Linköping University, SE-581 83 Linköping, Sweden
erik.holmberg@liu.se, bo.torstenfelt@liu.se, anders.klarbring@liu.se

ABSTRACT

We present a global (one constraint) version of the clustered approach developed for stress constraints in [1] and applied to fatigue constraints in [2]. A global stress constraint has previously been discussed by several authors, but in the present approach we manage to avoid large stress concentrations and geometric shapes that would cause stress singularities. For example, we solve the standard L-beam problem and obtain a radius at the internal corner; a result which, to the authors knowledge, previously has not been obtained with just one global stress constraint.

The clustered approach means that stress constraints are applied to stress clusters, where each cluster contains the stresses from several stress evaluation points. This gives an acceptable control of the local stresses even though a small number of constraints are used; the global approach is obtained as a special case if only one cluster is used. A global stress constraint allows for creating, at low computational cost, light weight conceptual designs that are free from large stress concentrations. Using our formulation, the local stresses will be higher than the stress limit [1]; however, topology optimization is a tool for conceptual design and the aim is to obtain a good structural shape, which will be sized in later design stages.

The clustered approach is based on a P-norm of penalized local stresses which are divided by the number of members in the cluster. The stress penalization increases the stress for intermediate design variable values and together with the SIMP-penalization it forces the solution to a black-and-white design. The method is formulated so that different element types as well as three-dimensional problems can be treated, even though two-dimensional problems using four-node elements are considered in the examples.

The global and the clustered approaches will be shown and compared for stress and fatigue constrained problems, where the objective is to minimize the mass. The stress constraints are based on either von Mises stresses or principal stresses, where the latter allows for high-cycle fatigue constraints according to the methodology in [2]. The settings of the solver and the P-norm based stress measure, required in order to obtain good solutions with the global approach, will be discussed. The theoretical discussions will be confirmed by well known examples, such as the L-beam and the MBB-beam.

References

[1] Holmberg, E., Torstenfelt, B., Klarbring, A.: Stress constrained topology optimization. Accepted for publication in Structural and Multidisciplinary Optimization (2012)

[2] Holmberg, E., Torstenfelt, B., Klarbring, A.: Fatigue constrained topology optimization. To be submitted.