A case study of multicriteria shape optimization of thin structures

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Beverage and spray cans are usually made of thin high performance steel and are filled with fluid at high pressure. For these two reasons, and considering usage and packaging requirements, the structural stability of their ends, top and bottom is then delicate to maintain. In the present work, we address the problem of shape optimization of the bottom of a can, in order to control the *dome growth* DG at a given filling pressure as well as the *dome reversal pressure* DRP , a critical pressure at which the can bottom looses stability (e.g. initiates buckling). We first implemented and validated an RBF-like metamodel to have at hand cheap criteria surrogates (DG,DRP) using a 2D spline representation in an axi-symmetric setting. Then, we implemented a Normal Boundary Intersection -NBI- with filtering formulation in order to capture the -approximate- Pareto Front, using an FSQP method for the NBI-related sub-optimizations.
The obtained approximate Pareto Fronts corroborate the antagonistic behavior of the DG and DRP criteria, and are successfully compared to the projection on the exact cost evaluations. We also identify Pareto-optimal solutions which lie in a restrictive industrial-prescribed acceptable interval for the DG-DRP costs.
We then consider the problem of selection of solutions among the Pareto Front. We model the selection problem as a Nash game played by the two costs DG and DRP, and show that an arbitrary splitting of the shape parameters among the two players may lead to inefficient solutions (strictly dominated by Pareto-optimal ones). Then, we set an original formulation of Nash equilibria where the split of the shape parameters is given with a probability vector P to the first player and Q to the second. We define an NBI-like method, where the optimization variables are not only the shape and the distance from the convex hull of individual minima -CHIM- (denoted by x and t in the paper by Das and Dennis [1], but also the starting point over the CHIM (denoted by β ibid) and the allocation tables P and Q. We show for mathematical examples that the iterates converge to -generalized- Nash equilibria close to, if not on, the Pareto Front. Application of the latter approach to our structural shape optimization case is ongoing.

References

[1] Das, I., Dennis J. E *Normal-Boundary Intersection, A new Method for Generating the Pareto Surface in Nonlinear Multicriteria Optimization Problems*, SIAM Journal on Optimization, 8(3), 631, 1998.