Bidirectional Evolutionary Structural Otimization Method using Inequality Constraints

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Abstract
In this research, an evolutionary optimization method was used to obtain a topology of a structure which maximizes its stiffness. An inequality constraint was added, implemented by a Lagrangian multiplier.

Key words:
Optimization, Lagrangian, BESO

Introduction

Obtaining structures with lower volume has always been a challenge of engineering. Topology optimization presents a way to minimize its volume while maintaining good properties.

In this paper, a stiffness maximization problem with a displacement inequality constraint is presented. In order to couple them, a Lagrangian multiplier was used.

Results and Discussion

In this work, the stiffness of a structure was maximized, which is equivalent to minimizing its compliance. The BESO (Bi-direction Evolutionary Structural Optimization) method obtains the optimal topology by removing and adding elements on each iteration. For that, all elements are ordered in respect to their sensitivities, removing those with the lowest ones.

The Lagrangian multiplier for the additional constraint was estimated using a bisection method. The interval of the bisection method was not linear, in a way that the value of the Lagrangian multiplier varied a little on each iteration.

The decision whether to increase or decrease the Lagrangian multiplier came from the estimated displacement for the next iteration, calculated using a first order Taylor expansion. After approximately 17 iterations, the multiplier's value becomes almost constant, and therefore, was fixed.

Finally, the objective function became a combination of compliance and displacement optimization problems, as shown below.

$$f_1(x_i) = \frac{1}{2}\mathbf{u}^T\mathbf{f} + \lambda\left(u_j - u_j^*\right) \qquad \textbf{(1)}$$

The optimization was tested using a simply supported beam in which the displacement on its roller support was fixed to a maximum of 1 mm. The parameters that were used are shown on the Table 1.

Table 1. BESO parameters.

ER	2%
r_{min}	1.5 mm
x_{min}	0.001
p	3
V_{fin}	30%

The evolution of compliance and displacement are presented in Figure 1 along with some of the topologies obtained throughout the optimization.

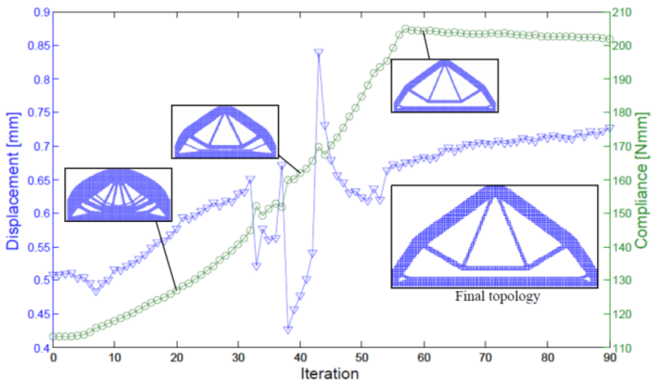

Figure 1. Evolution throughout the optimization.

In the final topology, the compliance is 202 Nmm and the roller's displacement is 0.73 mm.

It can be noted that, without the displacement constraint, the program stops after 65 iterations, resulting in a topology with a compliance of 191 Nmm and displacement of 1.3 mm.

Therefore, it can be concluded that, in this case, the implementation of this method of updating the Lagrangian multiplier granted a result coherent to the problem, while also minimizing the compliance, as seen by its low increase in comparison to the single-objective case.

Conclusions

This method of Lagrangian multiplier update provided a good way to couple additional inequality constraints with the objective function, in a way that the results satisfy the restrictions imposed.

In the future, this method can be implemented in others optimization problems in order to find their optimal solutions.

Acknowledgement

The authors are grateful to CNPq for the financial support of this work.

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