16th International Conference on Composite Structures
ICCS 16
A. J. M. Ferreira (Editor)

CONTINUOUS-DISCRETE VARIABLE OPTIMIZATION ON COMPOSITES USING KRIGING SURROGATE MODEL

Samuele De Guido[*], H.J.M. Geijselaers[**] and Andre de Boer[†]

[*] Faculty of Engineering Technology, Applied Mechanics Section
University of Twente
P.P Box 217, 7500 AE Enschede, The Netherlands
Phone: +31 53 4893605, e-mail: s.deguido@utwente.nl

[**] Faculty of Engineering Technology, Applied Mechanics Section
University of Twente
P.P Box 217, 7500 AE Enschede, The Netherlands
Phone: +31 53 4893605, e-mail: h.j.m.geijselaers@utwente.nl

[†] Faculty of Engineering Technology, Applied Mechanics Section
University of Twente
P.P Box 217, 7500 AE Enschede, The Netherlands
e-mail: a.deboer@utwente.nl

Key words: Thermoplastic Composite Panel, Discrete Optimization, Kriging.

Summary. *This work describes a mixed continuous-discrete variable optimization procedure for thermoplastic composite panels. Minimum weight configuration is the goal. Buckling constraint is applied to the problem. A Kriging surrogate model of the constraint is generate to evaluate the optimum solution.*

The tendency of reducing the weight on aircrafts has brought up the idea of using composite materials for the structure in change of the aluminum ones. In the past these applications were limited.

Nowadays, due to the improvement on the materials and on the process techniques available, the research focuses more on using thermoplastic composites also on primary structures. In particular, these materials show more suitable properties then the ones previously used. Another advantage as opposed to conventional materials is that composites can be tailored with a specific lay-out to satisfy particular requirements. However, the high number of variables involved and the complex mechanics associated to composites, together with the necessity to use expensive models and/or test set-up, makes the optimum design difficult to achieve. Structural optimization, due to its systematic nature and to the possibility of setting defined objectives (and, if necessary, constraints), becomes the most suitable approach to support the designer and to obtain the expected performances. Moreover, the use of surrogate models to represent the objectives and the constraints reduces the evaluation time in the optimum seeking process.

In literature, conventional optimization codes are set to handle continuous variable. Unfortunatly, the optimum solution derived from a continuous optimization is usually meaningless for the designer. Due to the new automated technologies, i.e. tape layering, some parameters can assume only discrete values (e.g. thickness), while there is more freedom in setting other process variables (e.g. orientation). To take into account this aspect, the authors propose a mixed continuous-discrete optimization approach. First, a continuous optimization is carried out. The continuous optimum is used as starting point for the mixed continuous-discrete optimization. The problem is then branched in *k* sub-optimization problems as many as the discrete parameters are. In every branch, only one variable, among the possible ones that can assume discrete values, is rounded-off to the nearest discrete value. Keeping the rounded value fixed, a new continuous optimization is run for ***k-1*** variables. As further step, a second varable (one in every branch) is then fixed to the closest discrete value. Now two discrete values are kept constant. A continuous optimization with ***k-2*** values is run. The process is repeated *k* times. At the end of the process, ***k!*** soultions are available. Among them, the one that shows the minimum (maximum) valuefor the objective and that better satisfy the constraints (if they exist) is selected as optimum.

The mixed continuous-discrete optimization is demonstrated on composite panels under axial-compression. Minimum weight configuration is the goal. Thicknesses of the single layers of the panel are the discrete variables. Fiber angles assume values from a defined continuous interval. Furthermore, first buckling inequality constraint is applied to the optimization. Due to the fact that the constraint function is not known a priori, a surrogate model is applied: the Kriging surrogate of the first buckling is generated. That is done not considering the original variables, but converting the thickness and orientation information in the equivalent ABD matrix and generating the surrogate from it. The advantage of using the ABD information consists in the fact that the surrogate model of buckling results in a combination of fixed number of variables involved, indipendently from the number of plies. Moreover, considering the ABD information, unlike the use of thickness and orientation, the non-linear beahviour of the buckling function can be reduced.

The mixed continuous-dicrete optimzation, as previuosly described, is carried out using Genetic Algorithm in combination with a gradient based technique. After the optimum is found, the result must be validated. The validation consist in running a single FEM analysis to verify the correspondance of the approximated solution given from the surrogate and the real solution in output from the FEM.The optimum found is then used as new information to improve the surrogate representation of the first buckling. Afterwords, the optimization process is repeated.

Finally, the loop end when no improvement in the optimum value are shown after a previously fixed number of generations.