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METAMODELING TECHNIQUES FOR ALL STEEL SANDWICH PANEL OPTIMIZATION

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ABSTRACT

A broad selection of different core profiles as (I, O, C, Oc, Z, V) can be used in design of laser welded all-steel sandwich panels (Fig.1). For the parametric optimization of such structural elements the metamodeling approach is commonly used [1]. Several metamodeling applications are distinguished by the employed design of computer experiments, approximation method and optimization method for constrained global optimization. We used sequential samplings optimized according to the Average Mean Square Error criteria [2] which give almost the best approximation results in combination with non-parametric approximation methods like Kriging or locally weighted polynomial (LWP) approximations. For exact modeling the FEM analysis with combined loading scheme of concentrated and uniformly distributed load has been carried out by ANSYS software. Calculated were the numerical values of the panel's global deflection, local deflection - between the stiffeners, stresses and nodal reactions at the sample points of sequential design. Simulated annealing method was used for constrained global optimization.

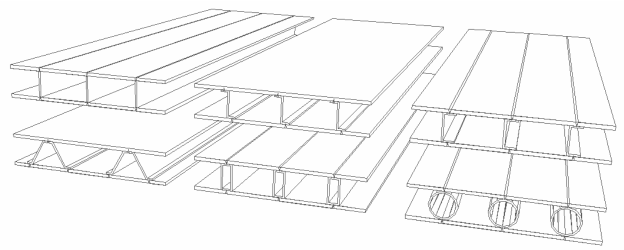

Figure.1. Different core types of all-steel laser welded sandwich panels

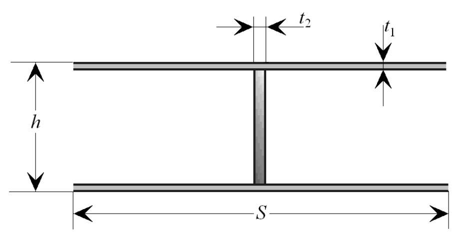

Figure.2. Parameters for Cross-Section Inertia calculating

One problem is the choice of input parameters for metamodeling. The design variables are geometrical characteristics such as length, height, thickness and etc. The number of stiffeners N is an integer parameter and the thicknesses of plates are discrete parameters. In order to increase metamodel accuracy an additional parameter – the inverse value of Cross-Sectional Inertia (Fig.2.) was introduced. The value of this parameter for I-core stiffening can be calculated with a simple expression and can be extended for any other core type:

$$I^{-1} = \frac{12}{Sh^3 + (t_2 - S)(h - 2t_1)^3} \qquad (1)$$

It is well known that I^{1} is the governing term in deflection calculation of the beams, therefore addition of this input parameter in the metamodeling procedure increases the prediction accuracy of the metamodel. Parameter I^{1} is not an independent variable; therefore the equality constraint of type (1) must be used by optimization.

Table 1. shows the crossvalidation error of approximation for several approximation methods using 500 training sample points. The relative crossvalidation error was calculated relative to the standard deviation from mean of experimental response data.

Table 1. Crossvalidation errors for I-Core type panel metamodels

	Def_Bot	Def_Dif	Eqv_Top	Eqv_Bot	Shear_Core	Mass
Polynomial	4.45%	8.23%	7.85%	3.21%	6.61%	0.89%
LWP	3.31%	4.06%	7.71%	3.06%	6.55%	0.078%
Kriging	1.69%	2.08%	4.57%	3.95%	3.72%	0.03%

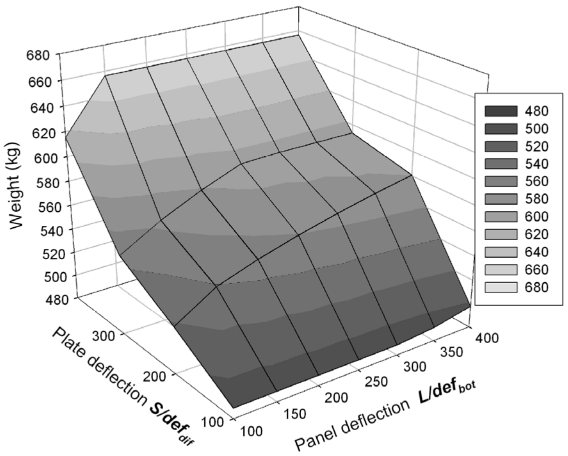

Figure 3. Pareto Frontier plot

In order to assess the robustness of alternative application or even for increasing the load carrying capacity of the secondary structure a Pareto Frontier could be efficiently applied. In particular if the design is conducted restraining the local deflection to 1/200 of the span between sandwich core stiffeners, a sufficient reduction of the weights can be achieved accommodating either its primary or secondary structure. On the contrary, if the local deflection is highly restricted there is only one explicit optimal weight design solution.

Conclusions. The introduction of an additional input parameter I^{1} dramatically increases the accuracy of the sandwich metamodel. Kriging gives the most accurate prediction of responses. Metamodels allow to build several Pareto frontiers for several combinations of multiple criteria such as mass, costs, durability etc.

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