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Surrogate Model-Based Reliability Analysis of High Performance Engine Gaskets

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Many parameters involved in the design of internal combustion engine high critical gaskets components are generally considered as constants. In fact several of them are non deterministic and influence the in service behavior of these gaskets. The variability of the parameters depends on their nature and may be due to material parameters, geometrical tolerances of dimensions, variability of loadings and boundary conditions...
In addition these gaskets are subjected to extreme load conditions and their behavior, during their clamping or in service conditions, is generally non-linear. Any variation in their "characteristics" may lead to micro or macro failure of the design with, eventually, very serious consequences (gas or fluid leaks, …).
We address in our paper an innovative methodology for robust design of critical gasket components.

The proposed methodology breaks down as follows:

- The implementation of a "smart" Design Of Experiment (DOE) using a minimum number of FE evaluations for the response functions. Several methods are explored (LHS, LCVT,...)
- A realistic statistical analysis of the parameters, the responses, their correlations... is conducted, allowing a better understanding of the mechanical model
- Adequate surrogate models using the produced DOE with a limited number of "high fidelity" evaluations are built. Several type of surrogate models are compared: RBF, RBFN, Kriging...
- Several failure criteria characterizing the design are set up: Contact pressure, maximal loading for the clamping of the gasket, residual displacement after relaxation of the gasket....
- A reliability analysis is then conducted by doing some hypothesis on the distributions of the parameters (normal, Weibul, uniform...) and evaluating the distributions of the principal responses using the produced "surrogate models". The influence of the parameter distributions is studied. The failure probability P_f with respect to the fixed criteria is evaluated.
- An optimization problem can also be defined by minimizing the evaluated failure criteria and setting it lower than an admissible value P_a.

All the optimization and statistical analysis are computed using the surrogate models obtained by a smart DOE. The evaluation of the different responses and so the optimization are very fast, promoting the reduction of cost calculation.
The methodology is applied to critical gaskets designed for very high performance engines that equip Grand Tourism sport cars.

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