Tolerance analysis of a wiper blade using the probabilistic approach

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Abstract

Engineers are aware that uncertainties in the dimension of manufactured products cannot be avoided, *i.e.* mechanical components manufactured using the same tools and the same raw materials have slightly different shapes; and their dimensions are also different from the designer's request. Tolerance analysis offers a rational framework to study such uncertainties, and allows guaranteeing that the quality associated with the production remains acceptable. This quality is quantified by estimating the defect probability, which is often expressed in parts per million. In this contribution, the probabilistic approach is used, and the dimensions of the components are modeled using random variables. A reliability analysis is then performed to estimate the probability of manufacturing a component which does not meet its functional requirement. The procedure described previously is applied to an industrial problem; the method is developed in collaboration with Valeo Wiper Systems.

Components of the wiping systems have been periodically collected from the production lines and their dimensions have been measured. These results are then used to identify the distributions of the random variables associated with the geometry of the components. It is assumed that the model of uncertainty can be fully represented using the marginal distributions and the linear coefficient of correlation. For each random variable, several distributions are considered, and the most suitable one is select using the Akaike information criterion [1].

The performance of the wiping systems can be estimated using Finite Element (FE) simulations. The FE model is parameterized, which allows investigating the consequences of the shape imperfections. A meta-model is subsequently calibrated in order to reduce the numerical efforts.

The formulation of the probabilistic model is similar to the one introduced in [2], the quantifiers *for all* and *there exists* are introduced and the problem is expressed using system reliability. The reliability algorithm relies on the use of a Kriging meta-model [3], which is used to identify the regions of the standard normal space with a major contribution to the defect probability. The calibration of surrogate models in high dimensions is a challenging task, and in this study as many as 39 random variables are

required to describe the geometry. The Karhunen–Loève expansion is used to reduce the number of input parameters. An eigenvalue decomposition of the covariance matrix is performed, and only the variables associated with the largest eigenvalues are used.

References

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