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Modeling of the bolted joint behavior variability with the Lack of Knowledge theory

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Summary

Widely used in aeronautics, bolted and riveted joints are subject to high and various loads during flight. The design of such elements is quite a challenge because of their large number and uncertain nonlinear behavior. Indeed, the control of joint properties such as bolt pretension, bolt hole clearance, and friction during manufacturing processes is an issue.

Engineering design uses a factor of safety (FoS) to quantify uncertainties, which often leads to an oversized structure. Here, the aim is to model uncertainty effects on quantities of interest in order to redefine a more accurate FoS that could reduce manufacturing costs.

Choose the prevalent stochastic approach [1] among the random system modeling techniques [2, 3, 4, 5] leads us to consider one random variable per bolted joint behavior property. This modeling implies the use of a large number of parameters: as soon as several bolts are present, the computation becomes too much time-consuming.

Here, we use a linear fixation model [6] coupled with the Lack Of Knowledge (LOK) theory [7]. This theory globalizes all sources of variability into a few internal variables (basic LOKs) at different scales. Intervals of variability (effective LOKs) of quantities of interest can be calculated from these basic LOKs. Finally, basic LOKs are updated [8, 9] with respect to virtual testing in order to retrieve the actual interval of variability.

LOK theory is applied on 1D and 2D models of a multiple-bolted joint structure. The updating is carried out with respect to a Monte Carlo simulation performed on a 3D nonlinear multiple-bolted joint model [10] that represents simulated experiments.

To conclude, the developed envelope model is an efficient approximation of the variability of a structure, allowing to achieve more accurate values than classic engineering FoS. Also, such an approach proves numerically much less time-consuming than a full stochastic simulation.

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