RPCM: A strategy to perform reliability analysis using polynomial chaos and resampling - application to fatigue design

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In reliability analysis, the failure criterion is defined as a limit state function which depends on random inputs and response quantities. Using stochastic finite elements, the response quantity can be written as series expansion which allows an approximation of the limit state function. For computational purpose, the series must be truncated in order to retain only a finite number of terms. In the context of industrial applications, no information is available concerning the smoothness of the model. This way, the accuracy of the truncated polynomial chaos expansions cannot be directly computed. To tackle this problem, we propose a new approach coupling polynomial chaos expansions and confidence intervals. This approach, which we call RPCM (Resampling Polynomial Chaos Method), aims at exploring an existing database to find the best chaos order which allows to reach the reliability index. The proposed approach takes advantage of two efficient methods to perform reliability analysis in fatigue design: the polynomial chaos to build the response and resampling techniques for validation. As the fatigue is a random process in essence, the use of the polynomial chaos makes the statistical study and reliability analysis easier. The Bootstrap is used to compute confidence intervals which indicate the reliability of an estimate according to a confidence level. This way, confidence intervals are a natural complement to the reliability analysis. Providing a learning step and an enrichment step, the RPCM method finds the best chaos order according to the reliability and accuracy goal. This learning step gives information on the quality of the design of experiments (DOE) and provide a decision tool for further measurements or computations in order to enrich the existing database. Because the estimation of the fatigue lifetime is critical in the industry in order to assess and verify safety margins, we focus on the reliability index deduced from the probability P_f of not exceeding a lifetime limit. The information provided by the confidence interval is very important because the knowledge of the reliability index range gives confidence or not in the result and could help to make a decision in terms of design: it provides important information on the accuracy of the failure probability predictions knowing the input randomness; it can help to assess product life extension or improve the fixing of inspection times. The method is first validated on numerical examples and then applied on two industrial ones.