TIME-DOMAIN SIMULATIONS OF GROOVING PROCESS WITH STIFFNESS UNCERTANTITIES

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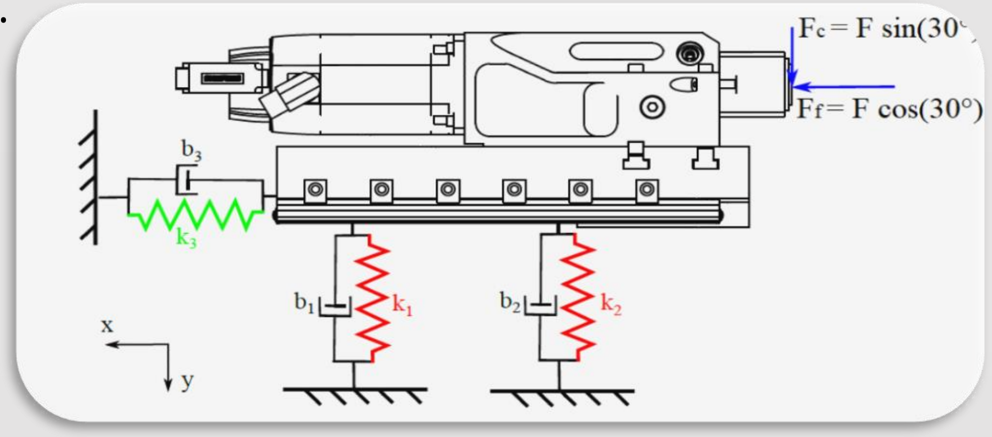
Introduction

The frequent problem of mechanical structure analysis is the uncertainty of input parameters. This is the main problem in the nonlinear structures where a small change of input values could cause a large change in the system response. Therefore, one must always keep in mind the uncertainty of a nonlinear system.

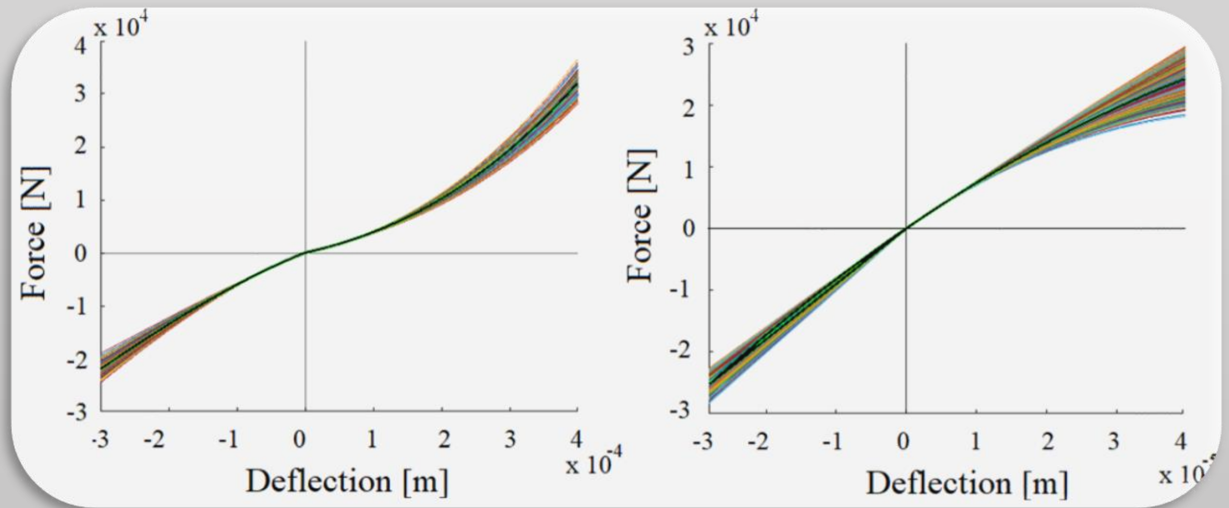
Our approach deals with a dynamical model of the machine-tool slide. In this structure, is used linear roll guideway, and ball screw which has nonlinear stiffness characteristic, also the second main part - the ball screw has nonlinear stiffness representation. The model of the stiffness takes account of uncertainties which influence the behavior of the structures. For the analysis were used two methods the Polynomial chaos expansion (PCE) and for validation were used Monte Carlo method (MC).



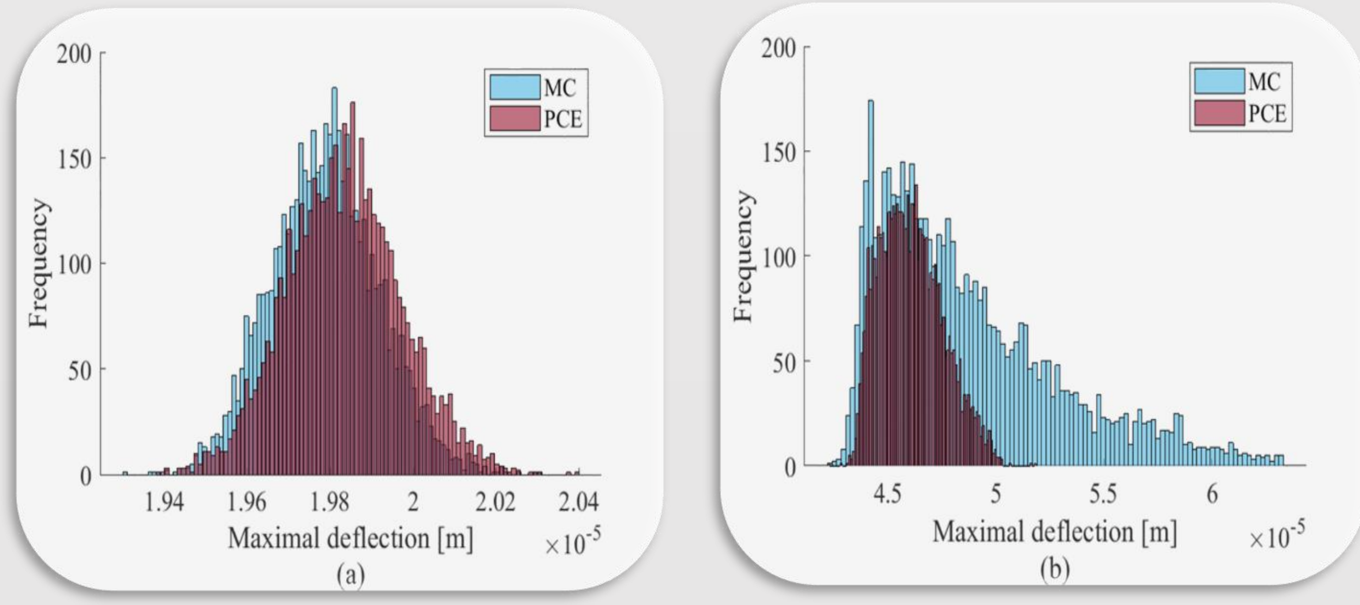
The scheme of modeled structure

Model

The model is based on a mass supported by 3 springs. The springs k1 and k2 represents the behaviour of linear guideway with nonlinear characteristics. The spring k3, which is representing the ball-screw, also has the nonlinear representation. The nonlinear coefficients were considered as uncertain. In the case of the linear guideway, it was the quadratic coefficient in the case of ball screw quadratic and cubic. In the end, there are four uncertain parameters with the normal distribution. The key part of this work is the time-domain simulation which represents the regenerative chatter model. The model is described by a Lagrange differential equation for three degrees of freedom. It was simulated in the MATLAB-Simulink and was used for both PCE and MC.



Characteristic under uncertainty, the left represents the ball screw, the right represents the linear guideway



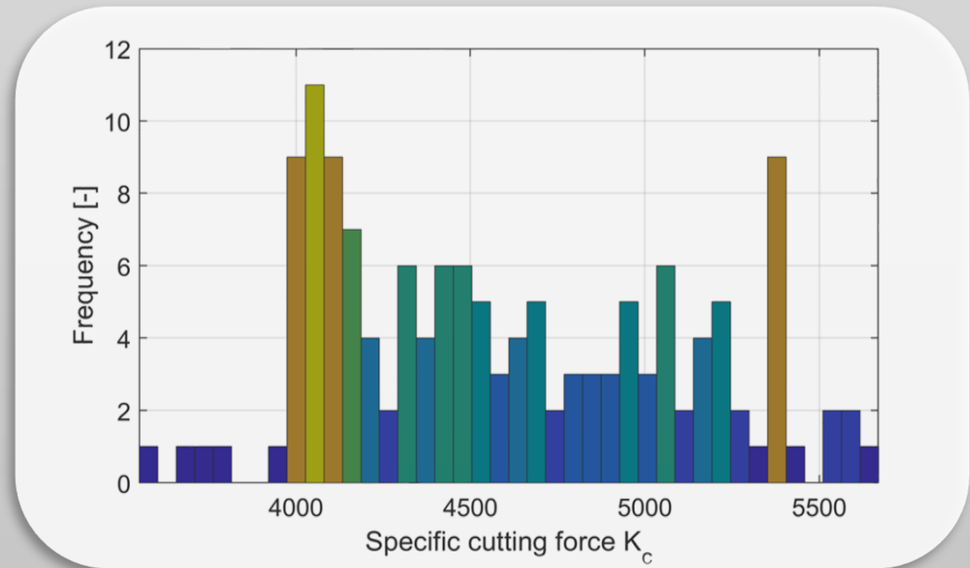
Machining in the stabile region (a) and on the boundary of the stabile machining condition

Results

The results of simulation in purely stable conditions are shown in part (a) and partially in (b). It is noticeable that for the edge of stability MC gives slightly different results comparing to PCE, where the distribution range is wider. On the other hand, in the stable conditions, where the character of deflection has mainly static nature, results are almost identical. The question is, if the time for the PCE model tuning does not consume more time than the whole MC, in the systems with changeable behavior.

Conclusion

This approach presents an example of the growing process analysis with structural uncertainties. Two methods have been presented PCE and MC, which was also used for PCS base coefficient calculation. The results show that the PCE method gives reliable results in the 80% shorter time comparing to MC. However, the weak point can be the preparation time of the metamodel, which can beat the time savings during the simulation. Mainly the base function computation and its validation must be considered during the planning of the simulation. The simulation was done for two machining conditions.

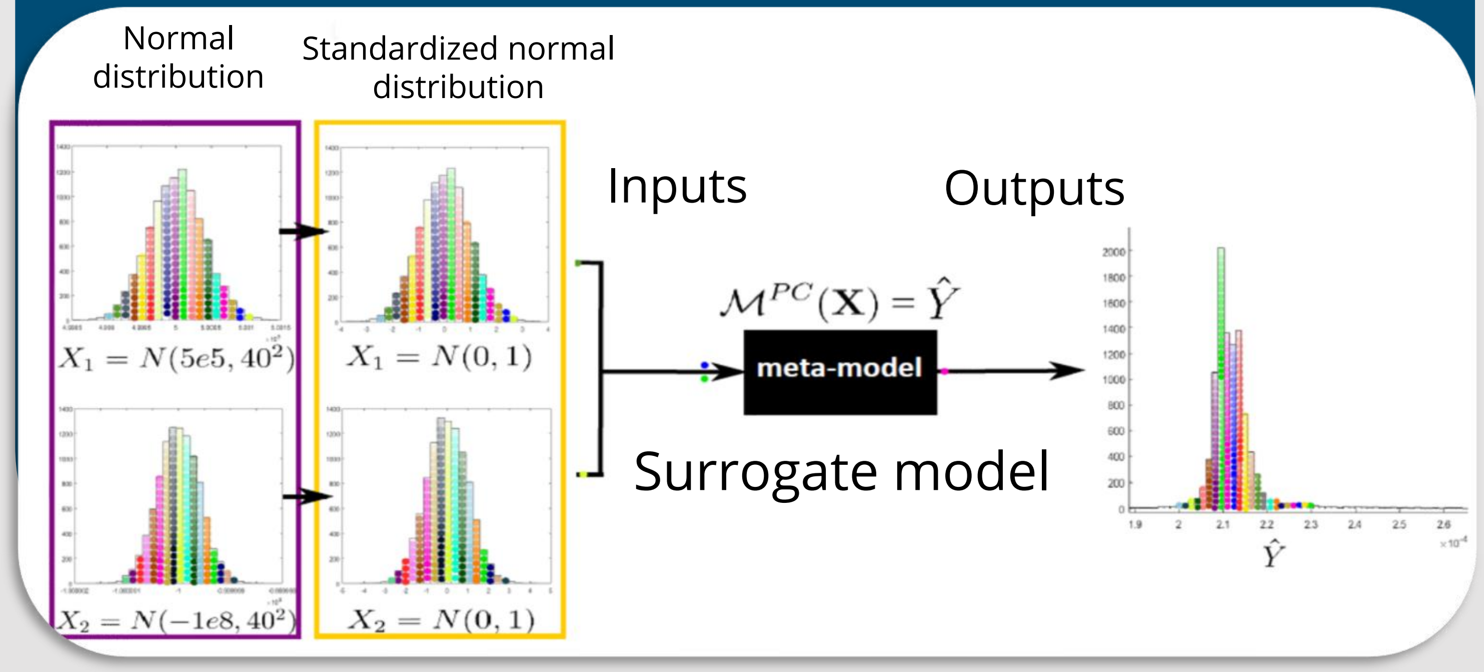


Distribution of specific cutting force turning medium carbon steel S45C measured

PCE Polynomial Chaos Expansion

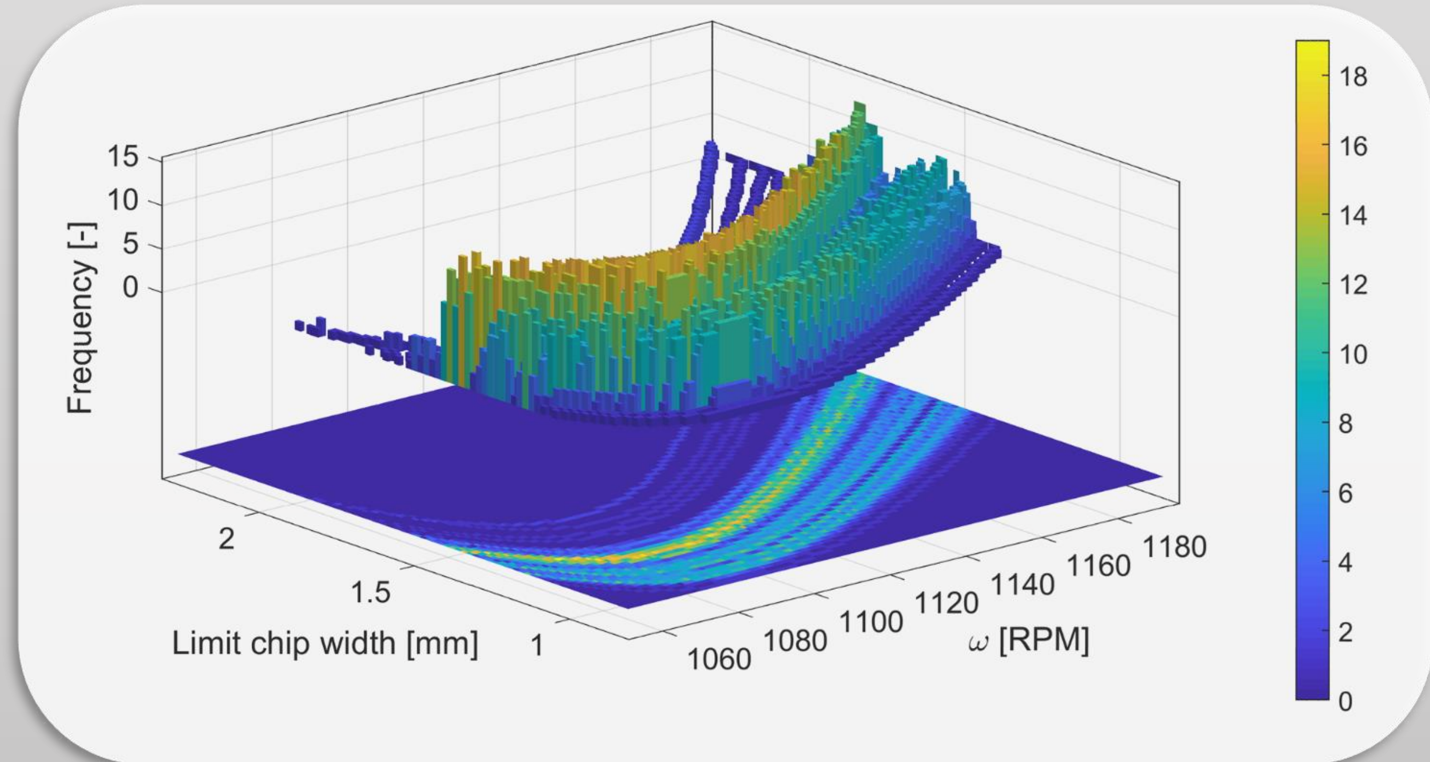
The main motivation for the use of PCE was the shortening of computational time. The main application is the situation where there are limited numbers of uncertain parameters with high uncertainty in a model of nonlinear behavior. In such cases, direct methods, such as MC, would be highly impractical.

The main principle is to build a surrogate model M^{PC} based on finite polynomials series which substitutes the original computation model M. Where X is the vector of inputs and Y is the vector of outputs.



Future development

Not only do the structural uncertainties influence the machine tool stability, but bud also the machining process parameters has an important role, which is also not deterministic. Due to this fact, future research must implement structural uncertainties as well as uncertainties of the machining processes..



The distribution of stability lobe diagram edge based on experimental measured specific cutting force

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