Towards an analytical prediction of chatter suppression using time-periodic modulation

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Short summary

Machine tool vibrations affect the wear, tool life and surface quality leading to an increase of production cost and time. A simple model for chatter is the regenerative effect that is summarised in [1, 2]. Chatter occurs typically within instability lobes in the spindle speed diagram and limits the maximum cut depth for stable material removal. Tools and methods for influencing (shift and distortion) these lobes are discussed in detail in the pioneering work [1]. Recently, a concept for increasing process stability during milling was introduced in [3, 4] which utilizes the time-periodic modulation of the tool support. The dynamics of such a system can be described by a simple time-delayed differential equation with time-periodic coefficients. However, this kind of parametric excitation is more general than the one occurring for varying spindle speed because its frequency is independent of the cutting frequency of the tool and therefore independent of the spindle speed and number of teeth.
Numerical results of stability charts in terms of spindle speed and cut depth show classic chatter lobes that are modified by the parametric excitation, see for example Fig. 1. In order to allow an efficient design and implementation of this concept, an analytical prediction of the stability boundary is sought. A first attempt using the harmonic balance method was investigated in [4] but leads to cumbersome expressions. Here we revisit different perturbation techniques as well as the homotopy analysis method in order to derive a compact form of the approximation of the stability boundary in the critical speed interval in the vicinity of n_{opt}.

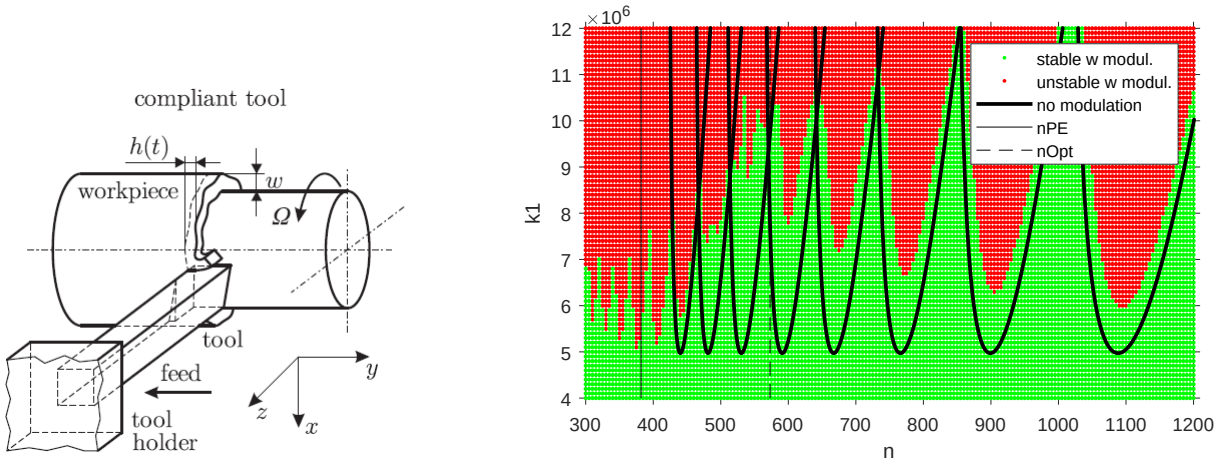

Bild 1 (Left) Mechanical system according to [2]. (Right) Stability chart of a chatter tool with constant support characteristic and a time-harmonically modulated support.

References

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