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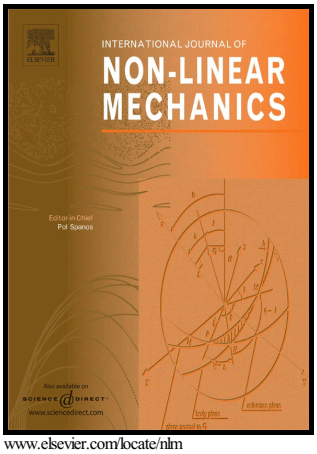

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Chatter mitigation using the nonlinear tuned vibration absorber

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Abstract
A passive vibration absorber, termed the nonlinear tuned vibration absorber (NLTVA), is designed for the suppression of chatter vibrations. Unlike most passive vibration absorbers proposed in the literature, the NLTVA comprises both a linear and a nonlinear restoring force. Its linear characteristics are tuned in order to optimize the stability properties of the machining operation, while its nonlinear properties are chosen in order to control the bifurcation behavior of the system and guarantee robustness of stable operation. In this study, the NLTVA is applied to turning machining.

1 Introduction

Machine tool vibrations represent a main concern in industry, as they result, for instance, in wavy machined surfaces and decrease in tool and spindle life [1, 2], significantly increasing production cost and time. The so-called regenerative effect (where the tool interacts with its delayed displacement via the surface profile that is cut one revolution earlier) is considered to be one of the main reasons for these vibrations [3, 4].

Active controllers are a possible solution to this problem [5, 6], but they have issues related to unpredictable instabilities and requirements of external energy source [5, 7]. They do not offer satisfactory vibration reduction, for instance, in case of long boring bars used for enlargement of deep holes, or in case of milling of thin-walled structures.

Several authors developed various kinds of passive vibration absorbers for the mitigation of such vibrations. These include conventional mechanical linear vibration absorbers [8], vibro-impact absorbers [9], friction damping absorbers [10], self-tunable absorbers [11], piezoelectric absorbers based on shunt circuits [12] and nonlinear energy sinks [13]. Numerical and experimental studies exhibited their promising performance in terms of stabilization of machining operations, allowing larger depth of cut in stable conditions, which enables to increase production speed. However, the intrinsic nonlinearity of machine tool vibrations, combined with the regenerative time delay effect, generates robust oscillatory motions, which exist also within the stable region of machining operation, causing dangerous bi-stabilities [4, 14]. These motions, generally related to subcritical bifurcations at the loss of stability, are overlooked by classical linear stability analysis, which makes them hardly predictable.

In this study, we propose a nonlinear passive vibration absorber, termed the nonlinear tuned vibration absorber (NLTVA), for the suppression of machine tool vibrations. It combines the beneficial effect of a linear absorber, able to enlarge the stable area of operation, with a nonlinear characteristic, which enables it to improve the robustness of the stable chatter-free motion and to avoid bi-stable conditions. It represents a nonlinear extension of the linear tuned vibration absorber (LTVA), as presented in [15] and, for instance, in [8].