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Dynamic Analysis of Mechatronic System with Ball Screw

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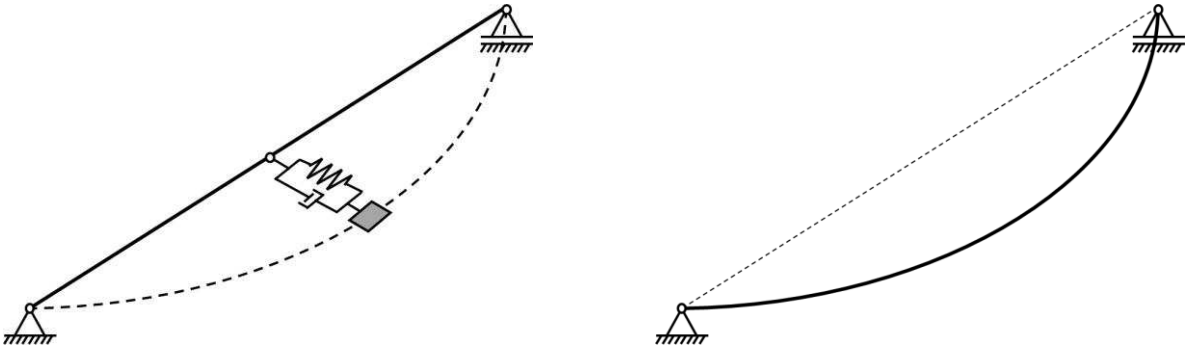
Abstract: This paper deals with dynamic modelling and analysis of a ball screw system for accurate machine tools. Ball screws are basic mechatronic subassemblies of accurate machine tools in the present time. Various mechanical parameters of ball screw affect dynamics of the whole mechatronic system and effects of individual parameters will be investigated. The screw of the ball screw system has flexible behaviour and it affects behaviour of the whole machine tool. There is length of the flexible screw determines natural frequency and it determine maximal speed of movement. The design of modern ball screw systems is focused on speed increasing of movement. The speed increasing of the ball screw systems is main aim of our development and the dynamic analysis of this system are presented in this paper.

Introduction

The main issue of machine tools are compensation of thermal influence for accuracy, machining technology and especially dynamic properties. The movement during machining and especially temporary rapid movement can cause significant vibrations. Increasing the speed is important to increase effectivity of production. Machining speed can be increased by definition of the correct machining technology and the most of production time is wasted during temporary rapid movements. Machine tool use linear actuators and ball screws. The linear actuators are very expensive and therefore the ball screws are commonly used in machine tools. The ball screw dynamic analyses and limitations are presented in this paper. Some methods of extending of ball screw operation range are mentioned.

This paper analyses the rapid moving of machine tools especially its modelling and control possibilities. The design of the screw, kinematic joints and the whole system assembly affects critical revolution of the ball screw; it means maximal revolutions without significant mechanical oscillation [1]. Diameter, length and material properties of ball screw determinate the critical revolution. Initial dynamic model of simple unbalanced mass-spring-damper model of ball screw is shown in Fig. 1a) and thereafter the FEM model will be analyzed – Fig. 1b). The basic dynamic analyses are presented.



a) mass-spring-damper model b) FEM model

Fig. 1: Dynamic models of rotating ball screw

Results

The recommended operation of ball screw and generally the shaft is under the critical revolutions [1]. The value of critical revolution depends on design parameters and it is shown in Fig. 2.

The value of critical revolutions for shafts with circular cross section is calculated from motion equation. The derived motion equation describes maximal revolutions per minute which depends on diameter and length of the ball screw.

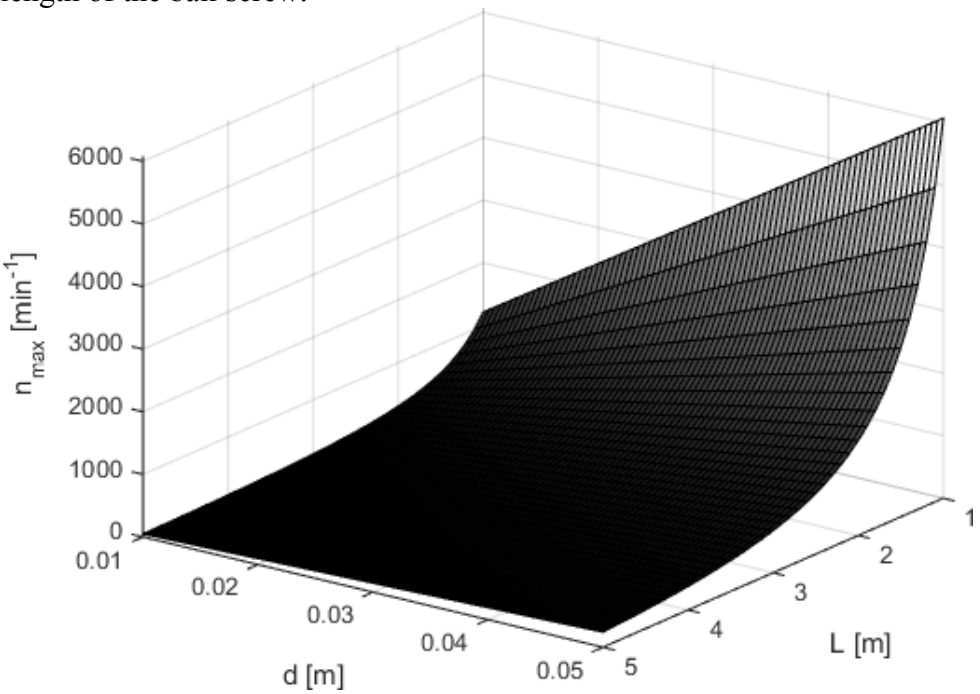


Fig. 2: Critical revolutions of ball screw depending on diameter and length

Summary

The main aim of this paper are dynamic analyses of ball screw simplified and FEM models, which will be used for design of new ball screws with high critical revolutions and control methods for avoiding of mechanical oscillation at critical revolutions.

Models of the dynamics systems are realized in MSC.Adams environment and these models can be co-simulated with Matlab control models [2]. It can provide very useful simulation tool for development of new mechatronic systems like adaptronic ball screws.

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