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Analysis of Machine Tool Spindles under Load

Michal Holub[1,a*], Jan Vetiska[1,b], Josef Knobloch[1,c], Petr Minar[2,d]

[1]Institute of Production Machines, Systems and Robotics, Brno University of Technology, Technicka 2896/2; 619 69, Brno; CZ

[2]Intemac Solutions s.r.o., Blanenska 1288/27, 664 34, Kurim, CZ

[a]holub@fme.vutbr.cz, [b]vetiska@fme.vutbr.cz, [c]knobloch@fme.vutbr.cz, [d]minar@intemac.cz

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Abstract: This paper deals with a new experimental approach to analyze radial, axial and tilt error motions of machine tool spindles under load. This work focuses on the identification error of the spindle movements under different machine operation conditions between 500 - 5000 rev / min and loads in range 50 - 500 N. Errors of the spindle movements are measured on cylindrical workpiece using capacitance sensors for different loads. The analysis of measurements of radial, axial and tilt error motions of machine tool spindle indicates dependence between loads and measured errors. The integration of the error measurements to novel multi-body dynamic models of machine tool spindles is very important for prediction of machine behavior during a cutting process.

Introduction

Spindles belong to the most important structural nodes of machine tools (MT). Running accuracy of the spindle of turning and milling machines has a major impact on resulting geometric and dimensional accuracy of a future workpiece. To these structural nodes of MT significant challenges are posed concerning parameters of performance, accuracy and service life [1]. In terms of the optimal spindle design for a cutting process, activities are performed in the area of static stiffness, dynamic behavior improvement, temperature stability and geometric accuracy of spindles. For simulation models of spindles and their verification various methods of measurement and identification of necessary parameters are introduced, such as the necessity to identify the external conditions entering the simulation models. Publications [2] deal with the proposal for temperature and static models of machine tool spindles. The models then provide information on rotation and displacement of axes, which are experimentally verified by laser and capacitance proximity sensors.

Another area of research is design of appropriate measurement methods and the use of various technologies to collect information about sought variables. Publication [3] describes the use of a magnetic load of a measurement artefact for causing a loading force on the spindle with a maximum load of 1.000 N. The observed deviation is only a radial one and describes spindle stiffness. Measurement of the radial deviation is described for high speed spindles in publication [4]. The paper presents test of running accuracy of spindles in the unloaded condition. The contemporary measuring procedures do not allow to assess the impact of the load on the running accuracy of the spindle.

Task formulation

Concerning precise MT, a great deal of emphasis is placed on running accuracy of machine tool spindles. One of the tasks is to control the accuracy of spindles by defined load conditions during the production stage. Another task is to increase the performance, reliability and accuracy of new machine tool spindles. This objective can be achieved at the spindle design stage by means of various computing devices. One of the tools that can be used for creating models and simulations is Multi-body system (MBS). On the basis of simulation runs optimal construction of machine tools spindles can be designed. This publication introduces the measurement of running accuracy of spindles at a defined speed and with radial static load. It also mentions the outputs of a model created in MBS. The load size of a spindle caused by operation conditions is chosen according to publication [5]. Concerning small milling machines, the cutting force ranges from 300 - 800 N depending on depreciation of the tool, passive force of 50 - 150 N, normal force of 250 - 500 N, with a cutting speed of 35 m/min and work piece material with a diameter of 1. 8159.

Multi-body dynamic model

MBS modelling is one of the possible approaches to creating complex models of parts and also whole MT. It enables to include compliant behavior in the models as well [6]. Creating a quality model requires its verification. For testing of behavior of new MT in development it is necessary to gain testing data by measurement. The model of a spindle is assembled according to V-model VDI 2206 and static and dynamic behaviour are both monitored there. The CAD data of MCV 754 QUICK machine were used as input and the complete model was designed for SW ADAMS. See Fig. 1 for the verification of static stiffness of the spindle without the change of rotation.

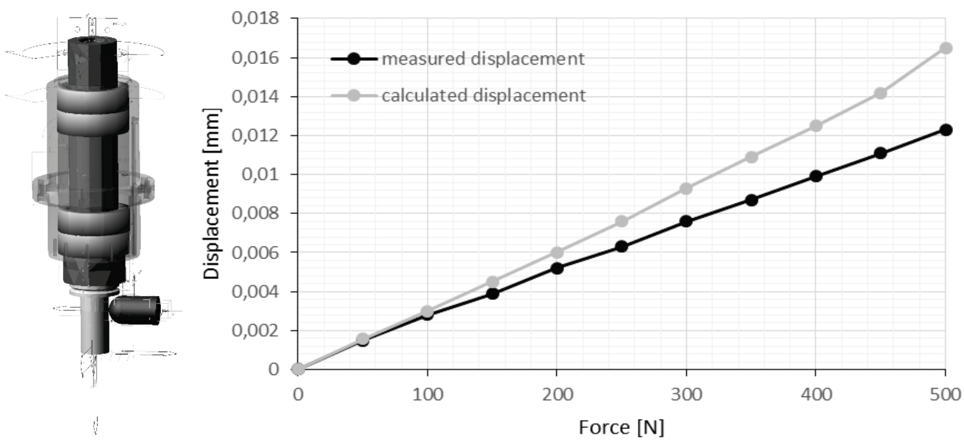

Fig. 1: Dependence of displacement of a spindle on radial load at rest

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