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Roman Szewczyk
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Anna Ostaszewska-Liżewska *Editors*

Mechatronics 2019: Recent Advances Towards Industry 4.0

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Editors

Mechatronics 2019: Recent Advances Towards Industry 4.0

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Foreword

During the last few years, global scientific and technological community observe dramatic changes in the industry. This revolution, called transformation towards Industry 4.0, determines new paradigms resulting in process optimisation tendencies and leading to increase the production volume with simultaneous reduction of involved resources. To achieve this goal, cyber-physical systems with artificial intelligence capabilities are commonly introduced to production lines, resulting in dramatic increase of processed and stored data, as well as subsequent development of completely new IT infrastructure, such as 5G mobile phone network standards.

Such radical transformation of industry is not a choice, but a necessity. Radical increase of number of people on the Earth together with natural expectations of increasing the quality of life around the world leads to unsustainable development and environmental burden. As a result, the forthcoming generations will be forced to consume less than us facing natural resources' depletion. The only way to avoid such scenario is wide implementation of optimised, adaptive cyber-physical production systems.

As a result, we observe intensive development of IT systems and artificial intelligence algorithms. On the other hand, efficient production line requires highly developed mechatronics systems, which truly determine its productivity. However, mechatronics seems to be neglected in changes of Industry 4.0, whereas it will play a decisive role in further success or defeat of our technical civilisation.

We hope that this book will be the first step to restoring mechatronics to the right rank. This book presents the results of intense discussions during the Mechatronics 2019 Conference held in Warsaw, 16–18 September 2019, gathering scientists from Poland, Czech Republic, Korea, Ukraine and France. Topics cover both modelling and experimental verification of performance of advanced mechatronics systems, system integration and its reliability, maintenance and development of robotics, automation and measurement systems as well as MEMS and biomedical applications focused on rapidly ageing population.

We strongly believe that solutions and guidelines presented in this book will be useful for both researchers of technical sciences and engineers solving problems in the world of mechatronics.

June 2019

Roman Szewczyk
Jiří Krejsa
Michał Nowicki
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Contents

Simulation, modelling and ICT

Time-Domain Regenerative Chatter Analysis of Non-linear Stiffness System 3
Petr Hadraba and Zdenek Hadas

The Method of Semantic Structuring of Virtual Community Content 11
Igor Korobiichuk, Yuriy Syerov, and Solomia Fedushko

Using Linear Matrix Inequalities for Synthesis of Modal Control of Multidimensional Linear Systems 19
Igor Korobiichuk, Oleksey Lobok, Boris Goncharenko, Natalya Savitskaya, Marina Sych, and Larisa Vihrova

Semi-automatic Spine Segmentation Method of CT Data 29
Malgorzata Mateusiak and Krzysztof Mikolajczyk

Stochastic Structure of Inciting Factors of Trivial Gyrostabilized Platform 36
Igor Korobiichuk, Volodimir Karachun, and Viktorij Mel'nick

Coupled Model of Solenoid 45
Filip Musil and Radek Vlach

Monte Carlo Based Detection of Parameter Correlation in Simulation Models 54
Jan Najman, Martin Brablc, Matej Rajchl, Michal Bastl, Tomáš Spáčil, and Martin Appel

Conductive ABS/Ni Composite Filaments for Fused Deposition Modeling of Structural Electronics 62
Bartłomiej Podsiadły, Andrzej Skalski, and Marcin Słoma

Selected Tests of a Control System for an Articulated Vehicle with Innovative Articulation 71
Mateusz Szumilas, Sergiusz Łuczak, and Błażej Kabziński

Sensors, Measurement and Diagnostics

System for Measuring Infrared Radiant Flux with Application of New Methods of Noise Detection and Reduction 81
Maciej Bodnicki and Piotr Sakowicz

Verification of Selected Gait Parameters Derived from Inertial Sensors Using Simple Smartphone Based Optical System 87
Aleksandra Budzyńska, Maciej Jagielski, Marek Żyliński, Gerard Cybulski, and Wiktor Niewiadomski

Distributed Collection of Environmental Data Using IoT Technology 95
Juraj Ďuďák, Peter Fabo, Gabriel Gašpar, Michal Kuba, and Anna Buchholcerová

Vibration Detection and Diagnosis for Civil Aircraft Improved Maintenance 104
Philippe Goupil

Automatic Mechatronic Test Stand Development for Embedded Electronics Using NI LabVIEW 113
Jan Hrbacek, Radek Hrbacek, and Jakub Lesinsky

Wavefront Sensor in Measurements of MEMS Vibrations 119
Michał Józwik and Dinesh Raja Nagarajan

Methods of Joint Stiffness Measurement Using a Manually Actuated Dynamometer 125
Patrik Kutilek, Petr Volf, Jan Hybl, Jan Hejda, Slavka Viteckova, Vaclav Krivanek, Radek Doskocil, and Pavel Smrcka

Electronic Filters Measurement Device 133
Maciej Martyński, Paweł Nowak, and Michał Nowicki

Mechatronics Solutions in Process of Transport Infrastructure Monitoring and Diagnostics 141
Stefan Sedivy, Lenka Micechova, and Pavel Scheber

Laboratory Stand for Fluxgate Level Measurement 149
Kamil Sowiński, Michał Nowicki, and Tomasz Charubin

Test Stand for Studying Flowmeter Performance in Presence of Pulsatile Flow 157
Maciej Szudarek, Mateusz Turkowski, and Grzegorz Twaróg

Pedestrian Indoor Localization Using IoT Sensors RSSI Signal Strength Measurement 164
Stanislav Vechet and Jiri Krejsa

Calibration of Bell Prover Test Stands with Critical Flow Venturi Nozzle 172
Jakub Wildner, Mateusz Turkowski, Maciej Szudarek, and Arkadiusz Zadworny

Magnetic Moment Measurement Stand 178
Weronika Ziarkowska, Michał Nowicki, and Tomasz Charubin

Robotics, Actuators and Control

Identification of Cyclic Changes in the Operation Mode of the Production Facility Based on the Monitoring Data 189
Nina Davydenko, Igor Korobiichuk, Liudmyla Davydenko, Michał Nowicki, and Volodymyr Davydenko

The Application of Hexagonal Grids in Mobile Robot Navigation 198
Piotr Duszak and Barbara Siemiątkowska

Development of Logical Control System for the Purification Department at Molasses Production 206
Igor Korobiichuk, Victor Tregub, Oleh Klymenko, Igor Elperin, Victor Sidletskyi, Yaroslav Smityuh, and Marina Chornovan

Features of Control for Multi-assortment Technological Process 214
Igor Korobiichuk, Anatolii Ladaniuk, and Viacheslav Ivashchuk

Simple and Low-Cost Analog Tactile Sensor for Robot 222
Jan Králík and Vojtěch Venglář

Evaluation of Visual Markers Detection Used for Autonomous Mobile Robot Docking Navigation 229
Jiri Krejsa and Stanislav Vechet

Design and Realization of a Performance and Reliability Evaluation Module for Commercialized Anti-lock Braking Systems 237
Jun-Hong Wu, Shu-Heng Guo, Kuo-Shen Chen, and Mi-Ching Tsai

Model Reference Control for SISO 2-D System with Input Delay 246
Jerzy E. Kurek

Mechatronic System for Weeding 255
Sergiusz Łuczak, Wojciech Credo, Karol Bagiński, Paweł Wnuk, Bartłomiej Fajdek, Krzysztof Bąk, and Michał Majewski

MEMS and Nanotechnology

Advantages of Using Piezoelectric Materials in the MEMS Construction on the Example of AlN and Sc Doped AlN Layers 265
Magdalena A. Ekwińska, Jerzy Zając, Dariusz Szmigiel, Michał Zaborowski, Cezariusz Jastrzębski, George Muscalu, Bogdan Firtat, Silvian Dinulescu, Adrian Anghelescu, and Carmen Moldovan

Monitoring Tilt of Elevated Loads Using MEMS Accelerometers 274
Sergiusz Łuczak and Maciej Zams

Design of Deterministic Model for Compensation of Acceleration Sensitivity in MEMS Gyroscope 285
Tomas Spacil, Matej Rajchl, Michal Bastl, Jan Najman, and Martin Appel

MEMS Accelerometers in Diagnostics of the Articulation of an Articulated Vehicle 292
Mateusz Szumilas, Sergiusz Łuczak, and Błażej Kabziński

Smart Materials and Structures

Design and Construction of System for Controlling Thermal Relaxation Process of Amorphous Ribbons in Liquid Metal Bath 303
Artur Górski, Piotr Gazda, and Michał Nowicki

Seebeck Coefficient Measurement in Amorphous Alloys 310
Dariusz T. Grudziński, Łukasz Jaśkowski, and Michał Nowicki

Electromagnetic Rolling Mass Energy Harvesting Device for Low Frequency Excitation 316
Zdenek Hadas and Ladislav Pincek

Marker Based Optical System for Parametric Rapid Design 324
Mateusz Janowski, Danuta Jasińska-Choromańska, and Marcin Zaczyk

Vision System for Acquiring Results from Analog Gauges 332
Grzegorz Kopeć and Paweł Nowak

Autocompensation Methods of Reducing the Influence of Penetrating Sound Radiation 340
Igor Korobiichuk, Viktorij Mel'nick, and Volodimir Karachun

The System of the Assessment of a Residual Resource of Complex Technical Structures 350
Igor Korobiichuk, Lyudmyla Kuzmych, and Volodymyr Kvasnikov

Homogenized Model of Piezoelectric Composite Structure for Sensing Purposes 358
Filip Ksica, Josef Behal, Ondrej Rubes, and Zdenek Hadas

Lower Limbs Orthosis for Experimental Motion Studies for Designing an Orthotic Robot's Turning Module 366
Dymitr Osiński and Danuta Jasińska-Choromańska

Heat Transfer Model of a Small Size Satellite on Geostationary Orbit in Cold Condition 374
Philippe Preumont, Roman Szewczyk, Pawel Wittels, and Filip Czubaczyński

Modelling the Mechanical Stress Dependence of 2D Magnetic Permeability in Soft Magnetic Materials 381
R. Szewczyk

Biomedical Applications

An Automated Lifting Device for Assisted Walk Physiotherapy 389
Maciej Grabowski and Artur Jędrusyna

Determining the Upper Limb's Intensity of Movement Using a Smart Orthosis for Rehabilitation at the Clinic and Home 397
Patrik Kutilek, Petr Volf, Jan Hejda, Slavka Viteckova, Vaclav Krivanek, Radek Doskocil, Veronika Kotolova, Pavel Smrcka, and Vojtech Havlas

The Influence of Screen-Printing Parameters on Properties of Conductive Layers for Application in Biomedical Electrodes 406
L. Kołodziej, S. Ostrowski, A. Maciejewski, M. Jakubowska, and G. Wróblewski

Anatomic Adaptability of Wearable Elbow Brace for Rehabilitation Applications 414
Patrik Kutilek, Kevin Bancud, Petr Volf, Jan Hybl, Jan Hejda, Slavka Viteckova, Vaclav Krivanek, and Radek Doskocil

Spectral VIS Measurements for Detection Changes Caused by of *Mycoplasma Synoviae* in Flock of Poultry 422
Zofia Lorenc, Sławomir Paśko, Anna Pakuła, Olimpia Kursa, and Leszek Sałbut

Development of Water Based Transient Resistive Screen-Printing Paste with Carbon Nanotubes for Biomedical Applications 430
S. Ostrowski, L. Kołodziej, A. Maciejewski, M. Jakubowska, and G. Wróblewski

Modeling of Sleep Disordered Breathing Using NARMAX Methodology 438
Piotr Piskulak and Krzysztof Lewenstein

Cooling Module for Orthosis 445
Petr Volf, Jan Hejda, Simona Hájková, and Patrik Kutílek

System for Measurement of the Mechanical Impedance of Human Body During Vibration Training 453
Marek Żyliński, Wiktor Niewiadomski, Anna Gąsiorowska, Anna Stępniewska, Adam Becmer, and Gerard Cybulski

Other Problems Connected with Advanced Mechatronics

Application of Dehumidified Air During Spray Drying for the Production of Food Powders 463
Alicja Barańska, Aleksandra Jedlińska, and Katarzyna Samborska

Design of an Antenna Pedestal Stabilization Controller Based on Cascade Topology 469
Michal Bastl, Jan Najman, and Tomáš Spáčil

The Influence of Geological and Anthropogenic Factors on the Change of the Water Quality Parameters in the Kamyanka River Within the City of Zhytomyr 476
Igor Korobiichuk, Iryna Davydova, Valentyn Korobiichuk, Volodymyr Shlapak, and Olena Herasymchuk

Identification of Technological Objects on the Basis of Intellectual Data Analysis 487
Igor Korobiichuk, Yaroslav Smityuh, Vasil Kishenko, Anatoliy Ladanyuk, Dmitriy Shevchuk, Viacheslav Ivashchuk, Regina Boyko, and Igor Elperin

Application of Industrial X-Ray Tomography in Paleontological Studies on the Example of Aurochs Tooth 496
Tomasz Kowaluk, Bartłomiej J. Bartyzel, Filip Rzepiński, and Sławomir Paśko

Use of Methods of Tensor Analysis in the Evaporator Plant Operating System 502
Igor Korobiichuk, Viktor Sidletskyi, Anatolii Ladaniuk, Ihor Elperin, and Mykhailo Hrama

Author Index 513

About the Editors

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Simulation, modelling and ICT

Time-Domain Regenerative Chatter Analysis of Non-linear Stiffness System

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Abstract. The phenomenon of self-excited vibration during machining still plays a key role in the productivity of a machine tool. The phenomenon was deeply analyzed by many works, but in the new prototype testing, unexpected behavior occurs. The hypothesis is that is caused by nonlinearity. This paper presents the approach of the time domain simulation of grooving cutting process for nonlinear analysis. The simulations compare linear stiffness model with two nonlinear, all these models were built by fitting measured static stiffness data by a regression model and also were built to have a similar response on modal hammer impulse, mainly the similar negative real part of the system response. The main idea for these simulations is to evaluate the effect of nonlinearity on system stability and primarily enables the description of vibration magnitude in the unstable region. The results showed that that nonlinear model has an influence on stability lobes and mainly on the magnitude of vibration in the unstable region which is significantly changed.

Keywords: Chatter · Machine tool · Nonlinear stiffness · Time-domain simulation · Lobe diagram

1 Introduction

One of the key factors for machine tools productivity is the chatter stability. Due to this fact, the chatter phenomenon was studied for decades. Nowadays the research is split into several branches. Some research works dealing with machine tool modeling based on the multibody system [1], another deal with the simplification of finite element model (FEM) and conversion to frequency response function (FRF) [2] the standard liner-based method for stability of the prediction system presented by Tlusty [3]. This method enables the analysis of stability in the whole machine tool position range [4]. A flexible model in ADAMS was used for this analysis [5]. In contrast to the analytical based stability assimilation, several works described the analysis based on the FEM simulation of the cutting process [6]. These simulations can be done due to their time-consuming only on small experimental systems. The effect of nonlinear stiffness on stability is described by [7], the nonlinear specific cutting force for lathe analysis was used [8], but most of the works deals for many reasons with linearized systems.

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Usage of linearization could cause a problem with real structure analysis. The main idea of this paper is to compare stability estimation done by simulated modal hammer measurement with the domain simulations; The difference between these two methods is the error of linearization. For comparison, there is also a linear system which is important for comparing time domain simulation. The main approach is that it shows that even non-linear ones could have an impact on stability. This method also enables the validation of the intensity of instability.

2 Simplified Machine Tool Stiffness Model

The key parts of this paper are the models of stiffness, these models used the estimation of measured data by several different models. Three of them are presented in this paper. The classical linear stiffness is used as a control model; its equation is:

$$F = k_1 x. \tag{1}$$

The piecewise linear function was also tested bud without significant change in results, so this model is not presented.

Cubic and quadratic equation were chosen for nonlinear models. To keep a negative value in the quadratic model form was used absolute value. The equations for cubic and quadratic are respectively:

$$F = k_1 x^3 + k_2 x. \tag{2}$$

$$F = k_1 x \cdot |x| + k_2 x. \tag{3}$$

The number of measured points is quite low, so the usage of the higher polynomial equation has no sense. The results of regression in Table 1 shows that the best match with measurement has the quadratic model, this could be also noticeable from Fig. 1.

Table 1. Regression results

	k1 (Nm^{-1})	k2	P-value	R-square	MSE
Linear	5.98e+06	-	3.31e−05	0.989	67.6
Quadratic	3.79e+09	4.95e+06 (Nm^{-2})	1.26 e−04	0.999	21.8
Cubic	7.58e+12	5.39e+06 (Nm^{-3})	2.47 e−04	0.999	30.5

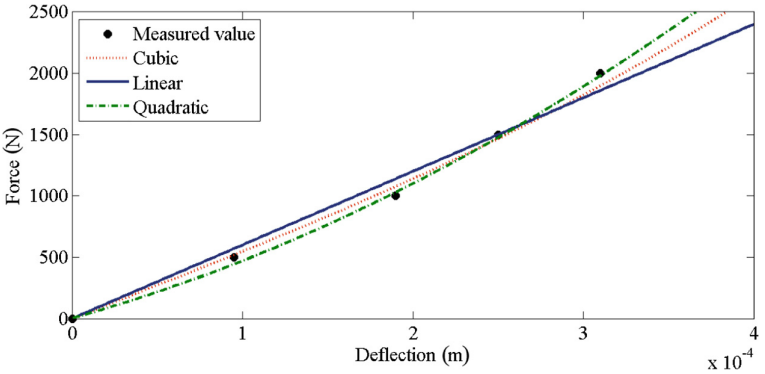

Fig. 1. The comparison between measured values and regression models

3 Simulated Modal Hammer Based Dynamic Model

One of the main ideas for all these analyses is to evaluate how precise is modal hammer stability estimation, with consideration of weak nonlinearity in the stiffness. The dynamic models were built to lead this expectation. The mass and damping coefficients were tuned to fit the similar simulated modal hammer as the linear model. The modal hammer simulation represents time domain simulation where the impulse signal corresponds to real impulses of modal hammer measurements. It should be mentioned that for different value of impulse force, the range 200–800 N, the output FRF does not noticeably change.

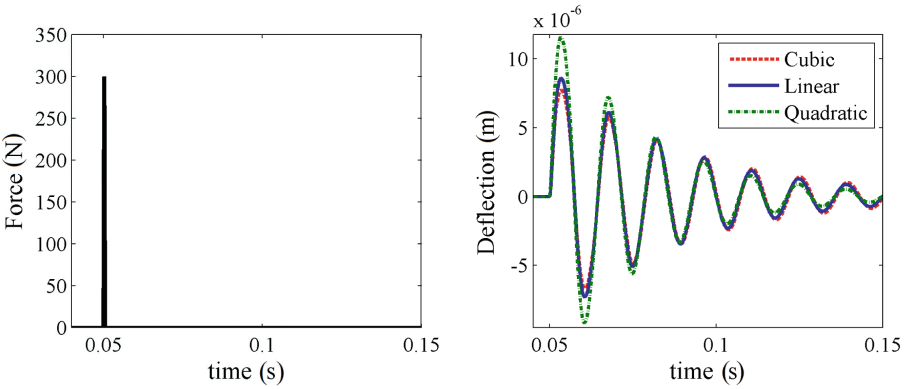

Fig. 2. The modal hammer simulation impulse force and the reaction of models

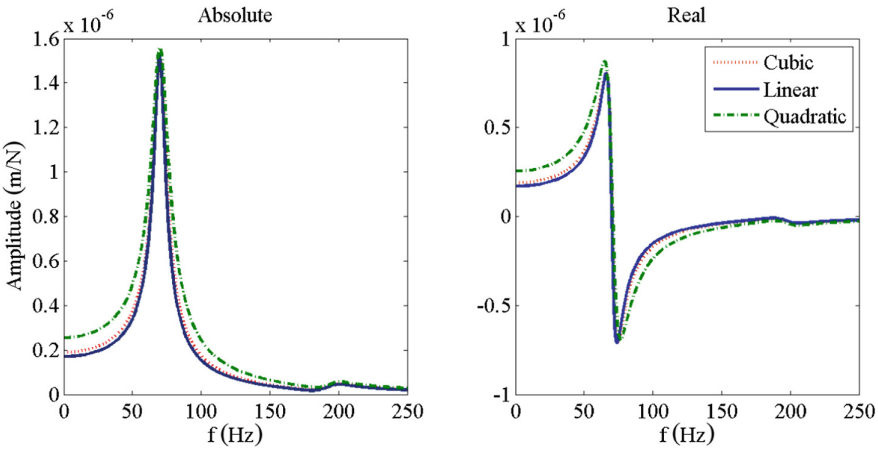

Fig. 3. The absolute and real frequency response for simulated modal hammer impulse

Figures 2 and 3 shows that the quadratic model has due to its characteristic lower higher deflection than both cubic and linear. This is caused by the lower function gradient for low displacement.

4 Simplified Growing Time-Domain Simulation Model

The basic model of regenerative chatter is in Fig. 4. The main idea is that the knife is connected to ground by a stiffness connection, due to this fact by the impulse thru the start of the cutting process the knife started oscillates on its natural frequency. These oscillations caused the pulsations of the cutting force Fc and also the waves on the surface of a machined part, these waves are returning to the cutting process and the phase shift between actual and previous cut plays the key role of the system stability.

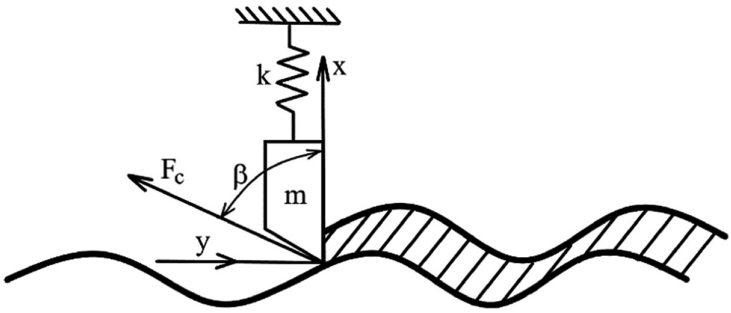

Fig. 4. The scheme of singe degree of freedom regenerative chatter

To model, this behavior is necessary to build several subsystems. The main part is the mechanical system model, in our case three different models. The output of this system is the knife deflection, which is used for further stability analysis. The actual deep of the cut is calculated from the required value and from the difference between actual deflection of the knife and from the wave on the material from cutting in the previous cut, this calculation also considers the possibility that the knife leaves the cut. In this situation, the negative deep of cut is set as zero and memory keeps its last waves value. The force is calculated from the actual deep of cut multiply by a specific cutting force, the value of this coefficient is dependence on the depth of cut. The behavior is nonlinear; the description could be found in the previous paper [9]. The last step of the model Fig. 5. The scheme of simulation model for regenerative chatter used for simulation is to calculate the force component for the x-axis.

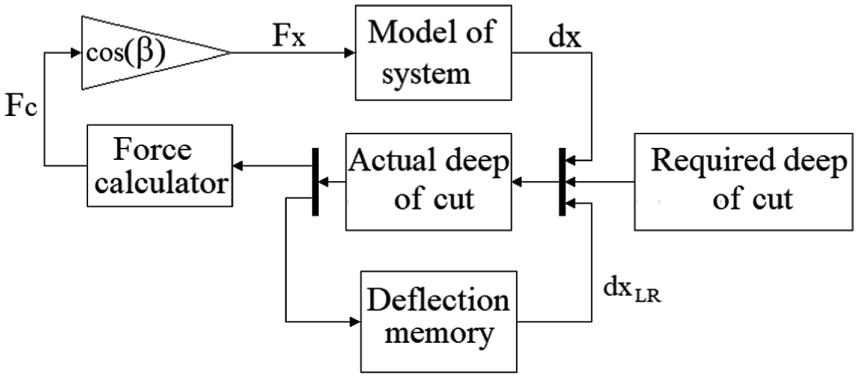

Fig. 5. The scheme of simulation model for regenerative chatter used for simulation

5 Comparison of Linearized Lobe Diagram and Results of Time Domain Simulations

Figure 6 shows the lobe diagram which is an assumption the system chatter stability. This lobe diagram was made from the real part of the simulated modal hammer measurement. The limit chip width changed slightly, also the spindle speed dependency. The biggest change is the quadratic motel which is caused by lower stiffness of low deflection region.

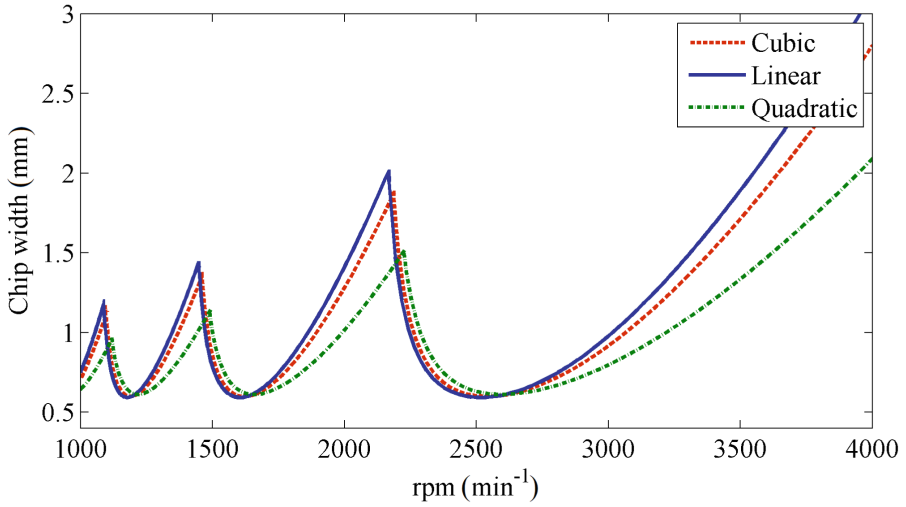

Fig. 6. Lobe diagram for system stability estimated from the negative real part of simulated modal hammer measurement.

This diagram is more interesting in the context of the time domain simulations Fig. 7. Where is the significant change of the spindle speed dependency, mainly in the quadratic model, there is a noticeable shift of the lobe to higher spindle speed. This fact could cause problem mainly for stability assumption in the region between un-sable lobes.

The simulation lobe diagrams were built from maximal deflection of each simulated conditions unique sequence. In these figures is noticeable that maximal deflection is in the linear system and lowest in the quadratic and the region of full stability (whole spindle speed range) does not change, so for these systems, we could use the term for the assumption of stability in whole spindle speed range:

$$b_{lim} = -\frac{1}{K_s \cdot \min(Re(G))}. \tag{4}$$

In this term, Ks represents the specific cutting force and the second component is the minimal value of the negative part of the system, this is according to Tlusty [3]. To summaries the classical method for chatter stability assumption is reliable for presented non-linear models, joust for the defining the limit width of the chip, the behavior above this line depends significantly on the form of the model.

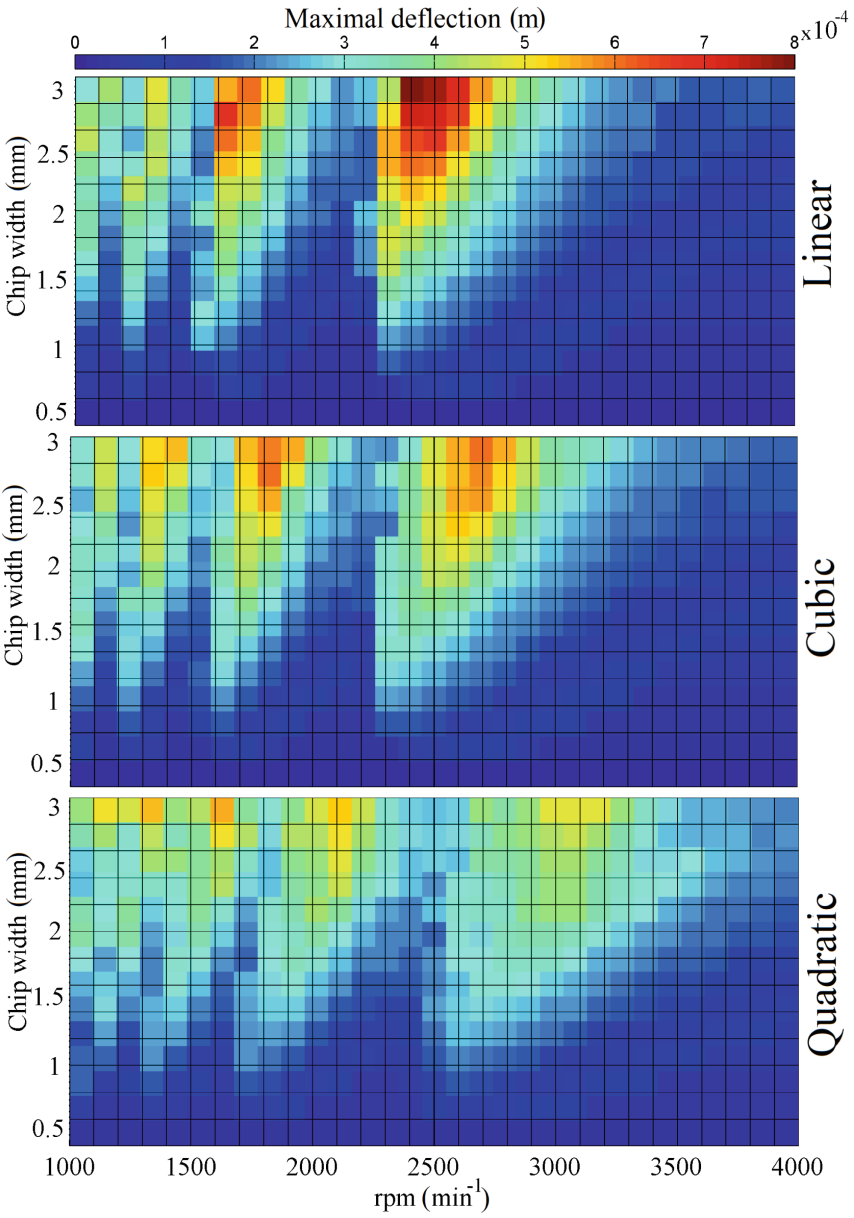

Fig. 7. Simulation lobe diagram for all stiffness models

6 Conclusion

The presented simulation of lobe diagrams shows the effect of the used nonlinear stiffness model. It should be noticed that these nonlinearities are not so strong, but the results of dynamic simulations show that its effect is not negligible. This fact shows how the stability estimation using modal hammer measurement could be inaccurate for linearized transfer function. Future development will focus on a more reliable estimation based on a combination of the measured FRF and static stiffness measurement. It could also provide a better understanding of nonlinearities impact on the machine tools stability. The better knowledge of this phenomena could be also applied in the process of new machine development.

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The Method of Semantic Structuring of Virtual Community Content

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Abstract. The method of semantic structuring of virtual community content has been developed in the paper on the example of web-forums. Virtual communities have been analyzed as an important means of communication on the internet for the purpose of scientific, educational and professional activities. Online communication web-forums are a convenient form of knowledge acquisition in communities. Semantic structuring of knowledge bases is an important and critical factor for easy navigation and search. However, the size of today's popular web forums does not allow doing this manually. For this purpose, it is necessary to develop automated tools of content restructuring. Application of the developed method of automated content restructuring by administrators has resulted in improvement of content structure. This method can be applied to modify the structure of sites, web forums and other forms of communities.

Keywords: Virtual community content · Automated content restructuring · Online communication · Web-forums · Correlation

1 Introduction

Virtual community/online community is a social group of people who communicate and interact via the Internet using special services and sites on the WWW.

Participants (Internet users who wish to participate in the community by registering and interact within the community creating content) and *content* (threads and posts created by participants) are the basis of virtual communities [1–5]. There are various types of virtual communities that differ in the way of arrangement, the audience (global, local) and the thematic direction.

Virtual communities operate on the basis of Internet. It should be noted that only a part of them are in a global environment of WWW.

According to the degree of integration in the WWW (Fig. 1) virtual communities are divided into the following types:

- social networks;
- discussion lists;
- public social networks;
- web communities.

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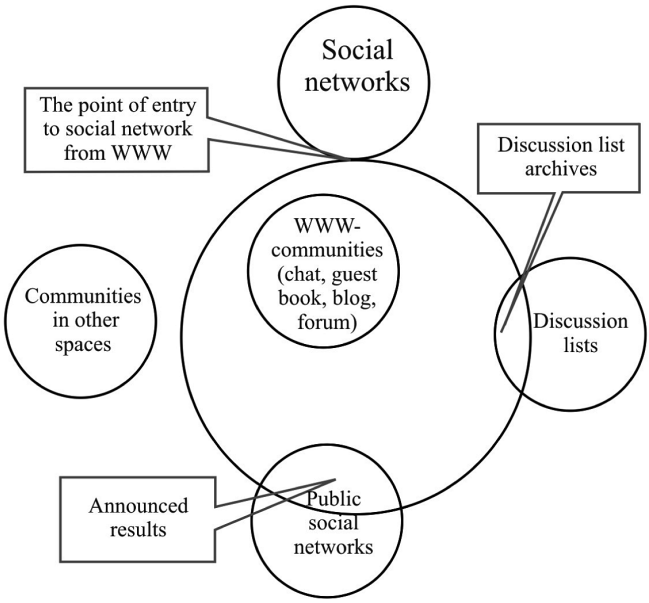

Fig. 1. Typology of virtual communities

With the advent of social networks, impact of web forums on development of Internet and information society has not generally decreased, despite the fact that web forums are not so popular in the global network as before. Therefore, at the current stage of development of the web such time-tested forms of communication as web forums occupy a significant part information of the Internet content. Feb forum is a convenient way of fixing threads in the form of post chains and developing knowledge bases by users of communities of different themes [6–9], which is an important factor for easy navigation and search.

Semantic structuring of information [10–12] in these knowledge bases is critical, because it defines accessibility of information for a user.

However, in practice, the content of virtual communities are formed by web users [13–16], and as a result, content of threads does not always correspond to titles and themes. It is therefore important to regularly update the structure of virtual community content [17–20] so that the theme of the thread is consistent with section themes.

The size of today's popular web forums is large and does not allow doing this manually. For this purpose, it is necessary to develop automated tools of content restructuring [21]. Application of the developed method of automated content restructuring by administrators is resulted in improvement of content structure [22]. This method can be applied to modify the structure of web forums, sites and other forms of communities.

2 Materials and Methods of Research

Let's provide formal description of a web forum in terms of its semantics. We shall consider the structure of the content of Web forum as a tree, each top of which is a section characterized by a set of such characteristics as a theme, thread and post.

Each section of the Web forum contains posts and threads related to one or several thematic areas.

Let the ***Theme*** be a set of forum themes:

$$\boldsymbol{Theme} = \{Theme_i\}_{i=1}^{N^{(Tm)}}, \tag{1}$$

where $N^{(Tm)}$ is the number of elements of the set ***Theme***; all the forum themes.

Each of the forum themes is described by the set of keywords:

$$\boldsymbol{Keyword} = \{Keyword_i\}_{i=1}^{N^{(Kw)}} \tag{2}$$

where $N^{(Kw)}$ is the number of elements of the set ***Keyword***, i.e. the number of keywords.

We define section themes of the Web forum as a set of keyword pairs and weighting factors that make a keyword important for this theme:

$$Theme_i = \left\{\left\langle Keyword_j, w_{ij}\right\rangle\right\}_{j=1}^{N^{(KwTheme_i)}} \tag{3}$$

where $Keyword_j \in \boldsymbol{Keyword}$ is a keyword from the set of keywords; w_{ij} is weight of the keyword $Keyword_j$ in the theme $Theme_i$; $N^{(KwTheme_i)}$ is the number of keywords in the theme $Theme_i$.

For each post the author identifies keywords from the set of keywords. Keywords assigned to a post form a set of post keywords, which we denote as

$$KeywordList(Post_i) \tag{4}$$

$$KeywordList(Post_i) \subseteq \boldsymbol{Keyword} \tag{5}$$

The set of all post keywords in the thread given their number creates a set of thread keywords, which we determine as

$$KeywordList(Thread_i) = \left\{\left\langle Keyword_j, n_{ij}\right\rangle\right\}_{j=1}^{N^{(KwThread_i)}} \tag{6}$$

where n_{ij} is the number of threads $Thread_i$, containing the keyword $Keyword_j$; $N^{(KwThread_i)}$ is the number of keywords in the thread $Thread_i$ and keywords that occur in thread posts $Thread_i$:

$$Keyword_j \in \bigcup_{Post_k \in Thread_i} KeywordList(Post_k) \tag{7}$$

Then, given (1–5), the degree of compliance of the thread $Thread_i$ with the theme $Theme_p$ is defined as:

$$\mu\left(Thread_i, Theme_p\right) = \frac{\sum_{j=1}^{N^{\left(KwThread_i\right)}} w_{pj} n_{ij}}{\sum_{j=1}^{N^{\left(KwTheme_p\right)}} w_{pj}} \tag{8}$$

where $w_{pj} = w\left(Theme_p, Keyword_j\right)$ is weight of the keyword $Keyword_j$ in the theme $Theme_p$; $n_{ij} = n\left(Thread_i, Keyword_j\right)$ is the number of threads, containing the keyword $Keyword_j$.

3 The Results of Research

Virtual community operates in the following way. The initial web forum content structure is created by administrator. Administrator creates section titles depending on the theme and web forum development scenario.

There are often situations of uneven growth of threads in different sections of a Web forum in the course of its operation. Certain sections become more popular and the number of threads maintained in them increase faster than in other sections.

This situation causes a decline in the quality of web forum content structure and complicates searching process. This requires changes in web forum content structure to evenly distribute threads between sections.

There is no need to restructure content too frequently, as it causes inconvenience to users seeking information in the ordinary section. Frequency of content tree restructuring is not fixed and depends on the dynamics of growth of web forum content volume.

The author has developed the method for organizational structuring of web forum content tree using tree diagrams. It is based on condition of balance of web forum content tree, i.e. each section should have not less than n and not more than $2n$ subsections (threads), starting from some point of time of its creation (at the time of creation of a web form its sections contain no content).

In this condition n is set by administrator, depending on content volume and ratio of sections and threads to web forum level at which they are.

Certain maximum number of subsections is allowed to be created in sections at each web forum level.

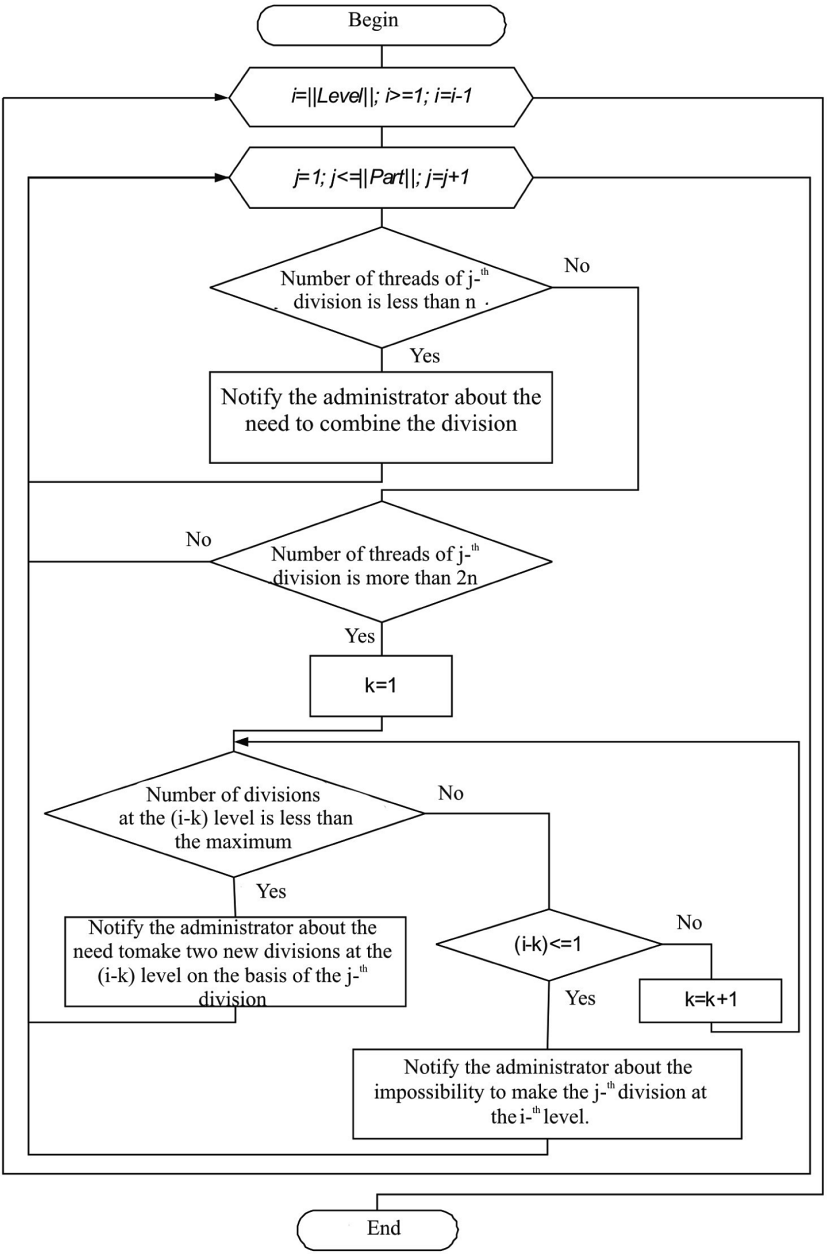

Fig. 2. Algorithm for organizational structuring of web forum content tree

Algorithm for organizational structuring of web forum is as follows:

1. Review of all web forum sections for compliance with the condition of balance.
2. If a section is too small, i.e. the number of threads in a section is less than n, the administrator is offered to create a new section at the same level and combine its threads with threads of another section, similar in themes. For this purpose, administrator should give a name to a new section and then combine sets of threads and thematic keywords of two sections.
3. If a section is too large, i.e. the number of threads in a section is more than $2n$, web forum administrator is offered to create two new sections one level higher, given that the number of sections available at this level does not exceed the maximum. If the number of sections available at the level higher exceeds the maximum, the division should be made at one of the higher levels at which this condition is met. Division of a section is made by dividing a set of thematic keywords of this section, and therefore the section itself, into two subsets.
4. Steps 1–3 should be applied as long as at least one section of the web forum violates a condition of balance.

Block diagram of the algorithm for organizational structuring of web forum content is given in Fig. 2.

As a result of the algorithm, all threads that are not relevant to the section theme are moved to the section which these threads are more consistent with (Fig. 3).

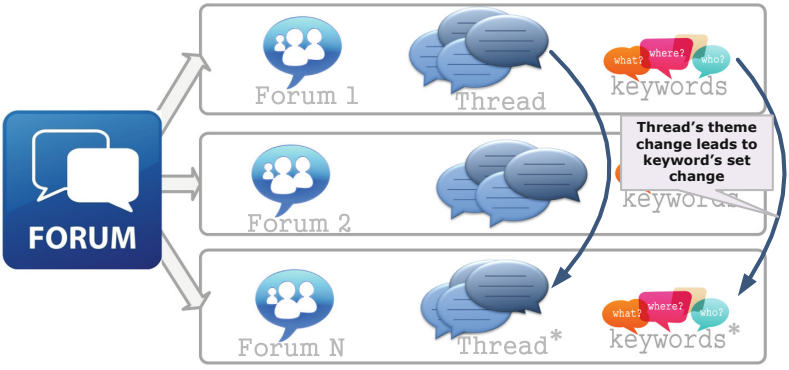

Fig. 3. Diagram of movement of threads between forum subsections

4 Conclusions

This article is about semantic content structuring of virtual communities. When community is created, an administrator builds a content skeleton, forming basic thematic subsections of forum and keyword sets with weighting factors that match the theme. Over time, users of a virtual community create new content that is distributed in the structure in a certain way. Experience has shown that there is a moment when it becomes apparent that community content requires reformatting in accordance with the