

Lecture Notes in Networks and Systems 128

Isak Karabegović *Editor*

# New Technologies, Development and Application III

 Springer

Isak Karabegović  
Editor

# New Technologies, Development and Application III

 Springer

*Editor*

Isak Karabegović  
Academy of Sciences and Arts  
of Bosnia and Herzegovina  
Sarajevo, Bosnia and Herzegovina

ISSN 2367-3370                      ISSN 2367-3389 (electronic)  
Lecture Notes in Networks and Systems  
ISBN 978-3-030-46816-3              ISBN 978-3-030-46817-0 (eBook)  
<https://doi.org/10.1007/978-3-030-46817-0>

© Springer Nature Switzerland AG 2020

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

<b>Conditions on Full Rotation of the Drive Member of the Four-Joint Mechanism</b> . . . . .	81
Avdo Voloder, Fikret Veljović, and Senad Burak	
<b>Achieving Crowning Contact of Spur Bevel Gears Through Deliberately Introduced Mounting Errors</b> . . . . .	89
Viktor Ivanov, Galyna Urum, and Svitlana Ivanova	
<b>Integrated Development and Design of Gears Reduction Drive</b> . . . . .	98
Isad Saric, Jasmin Smajic, and Adis J. Muminovic	
<b>Development of Linear Servo Hydraulic Drive for Material Testing</b> . . .	104
Vito Tič and Darko Lovrec	
<b>Structural Analysis of Direct Passive Pressure Reducing Valves Using Modified Kinematic Graphs</b> . . . . .	114
Yiheng Zhang, Ihor Sydorenko, Volodymyr Tonkonogyi, Liubov Bovnegra, and Predrag Dašić	
<b>The Study of the Elastic Characteristics of the Coupling with Nonlinear Feedback When Starting the Motor</b> . . . . .	122
Victor Kurgan, Igor Sydorenko, Ihor Prokopovich, Liubov Bovnegra, and Tetiana Lysenko	
<b>Finite Element Analysis (FEA) of Automotive Parts Design as Important Issue of Assembly Technology Designing of Passenger Vehicle</b> . . . . .	131
Ismar Alagić	
<b>Development of Aircraft Mechanical Systems and Mechatronics Modeling</b> . . . . .	147
Želimir Husnić	
<b>Chair Production and Robots Usage</b> . . . . .	154
Salah-Eldien Omer	
<b>Programming Robot KUKA KR 16-2 for a Palletizing Application</b> . . . .	164
Samir Vojić and Ramiz Sijamhodžić	
<b>Reinforcement Learning Based Human-Prosthetic Robot Interaction Control in Movement Therapy</b> . . . . .	172
Zlata Jelačić	
<b>Modeling, Analysis and Simulation of Work for the Punching and Cutting Operations on Inner Plate of the Front Car Door</b> . . . . .	182
Isad Saric, Enis Muratovic, and Harun Music	
<b>Intelligent CAD Systems for Generation G Code</b> . . . . .	190
Senad Rahimić and Anida Memić	



# The Study of the Elastic Characteristics of the Coupling with Nonlinear Feedback When Starting the Motor

Victor Kurgan<sup>(✉)</sup>, Igor Sydorenko, Ihor Prokopovich,  
Liubov Bovnegra, and Tetiana Lysenko

Odessa National Polytechnic University (ONPU), Institute of Industrial  
Technologies, Design and Management, Shevchenko Avenue 1,  
Odessa 65044, Ukraine  
kurgan@opu.ua, igs.ods@gmail.com,  
dlv5@ukr.net, tv112odessa@gmail.com

**Abstract.** The most difficult moment in the work with an asynchronous motor is the launch. And the more powerful drive is the more difficult launch. This is due to certain features of the asynchronous motors: a limited starting torque and starting throws of the current of the stator motor chain. The mathematical modeling of oscillating process of actuation of the actuator with an asynchronous motor, which includes an elastic coupling with nonlinear mechanical feedback, is carried out. The influence of the type of elastic characteristics of the coupling on the magnitude of the amplitude and frequency of the oscillation process and its time was studied. A single-mass rotational system model was used for the studies. According to the Runge-Kutta method, the oscillation processes of starting the transmission of a machine unit with an induction motor were investigated. To determine the coefficient of vibration isolation, a system with an elastic coupling having a linear elastic characteristic was calculated. A study was also conducted in the case where the coupling determines the elastic characteristics of the Duffing type “soft” and “hard” type. The results of the calculations show that it is advisable to use a nonlinear coupling with a combined characteristic. On the basis of this, a synthesis of the target elastic characteristic and the study of the oscillatory process in the application of the proposed elastic coupling.

**Keywords:** Elastic coupling · Mechanical feedback · Oscillation process · Rotational mass · Starting torque

## 1 Introduction

In modern machine-building, elastic couplings with metal elastic elements have become widespread. This is facilitated by the ability of these devices not only to transmit torque, but also to prevent negative oscillations in the technical system. This is achieved by introducing into the design an elastic coupling of mechanical feedback, which provides a wide range of elastic characteristics, including also nonlinear. Studies in this direction have shown that the nonlinearity of the elastic characteristics of one of

the components of the machine aggregate can significantly change the nature of the oscillating processes, which occur.

## 2 Scientific Research

Studies using mathematical model proved that elastic couplings with a nonlinear elastic characteristic show the most positive results [1]. However, already existing elastic couplings do not fully meet the stated requirements due to their narrow working range [2–4]. Up to now created potential designs of elastic couplings that implement a nonlinear elastic characteristic are not widely used due to the small number of their actual mechanical constructions.

### 2.1 Review of Modern Information Sources on the Subject of the Paper

At this stage, most of drives use asynchronous motors. The features of their operation, specifically the start-up of the engine, cause the considerable oscillatory load on the drive, this is due to the large and short-term starting torque. Because of this, there is a significant number of works devoted to oscillating processes in technical systems [5–9]. A mathematical modeling of the start of an asynchronous electric motor was carried out by using software packages [10, 11]. Developed the promising designs of nonlinear elastic couplings, which reduce the load on the drive and prevent negative oscillations [12–14]. The following studies show the feasibility of using elastic couplings with nonlinear mechanical feedback.

### 2.2 Objectives and Problems of Research

Mathematical modeling of oscillatory process of transmission starting of a machine assembly with an asynchronous electric motor, which consist of an elastic coupling with nonlinear mechanical feedback and studying the effect of elastic characteristics on the magnitude of the amplitude, frequency of the oscillatory process and its time.

### 2.3 Main Material Presentation

The chosen aim of the research is based on the fact that the results of the researches carried out in the field of nonlinear oscillation mechanics indicate that the nonlinearity of the elastic characteristics of one of the components of the machine assembly can significantly change the nature of oscillatory processes.

In the given research area it is believed that the starting torque  $M_{start}$  of the asynchronous motor shaft is a torque that advances on the shaft of an asynchronous electric motor under the following conditions: the speed of rotation is equal to 0, the current has a constant value, the electric motor windings are connected to rated supply frequency and voltage, the winding connection corresponds to the rated operating mode of the electric motor.

In mathematical modeling of the oscillatory processes of the machine assembly, the starting torque  $M_s(t)$  is modeled by a function of time characterized by two time

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

The first part of the text discusses the theoretical background of the study, focusing on the mechanical properties of the coupling and the experimental setup used to measure its elastic characteristics. It details the materials used, the testing procedures, and the data collection methods.

The second part of the text presents the experimental results, showing the relationship between the applied force and the resulting displacement of the coupling. This section includes a detailed analysis of the data, highlighting the linear and non-linear regions of the elastic behavior.

The third part of the text discusses the implications of the findings, comparing the experimental results with theoretical models and previous research in the field. It also addresses the limitations of the study and suggests directions for future research.

The fourth part of the text provides a summary of the key findings and conclusions of the study. It emphasizes the importance of understanding the elastic characteristics of the coupling for its proper design and application in various engineering contexts.

The fifth part of the text includes a detailed discussion of the experimental uncertainties and the accuracy of the measurements. It also provides a comprehensive list of references for further reading on the subject.

The sixth part of the text contains a list of figures and tables that illustrate the experimental results and the data analysis. These visual aids are essential for understanding the complex relationships between the variables studied in the experiment.

The seventh part of the text provides a final summary and a conclusion that reiterates the main findings and the significance of the study. It also includes a list of appendices that contain additional data and supporting information.

The eighth part of the text includes a list of symbols and abbreviations used throughout the document, as well as a list of the authors and their affiliations.



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[Redacted text block]

[Redacted text block]

[Redacted text block]

[Redacted text block]

[Redacted text]

[Redacted text]

[Redacted text]

[Redacted text]



3. Wang, L., Jia, Z., Zhang, L., Liu, H.: Analysis of the soft starting of adjustable speed asynchronous magnetic coupling used in belt conveyor. *Commun. Comput. Inf. Sci.* **923**, 382–393 (2018)
4. Zhang, Q., Lu, Q.: Analysis on rigid-elastic coupling characteristics of planar 3-RRR flexible parallel mechanisms. *Lect. Notes Comput. Sci.* **10463**, 394–404 (2017)
5. Piotr Serkie, S.: Comparison of the control methods of electrical drives with an elastic coupling allowing to limit the torsional torque amplitude. *Eksploatacja i Niezawodność* **19** (2), 203–210 (2017)
6. Olshanskiy, V., Burlaka, V., Slipchenko, M.: Free oscillations of an oscillator with nonlinear positional friction. *Ukrainian J. Mech. Eng. Mater. Sci.* **4**(2), 50–57 (2018)
7. Hmida, A., Hammami, A., Chaari, F., Khabou, M.T., Haddar, M.: Modal analysis of spur gearbox with an elastic coupling. *Appl. Cond. Monit.* **5**, 153–163 (2017)
8. Chen, X., Hu, J., Peng, Z., Yuan, C.: Bifurcation and chaos analysis of torsional vibration in a PMSM-based driven system considering electromechanically coupled effect. *Nonlinear Dyn.* **88**(1), 277–292 (2017)
9. Andrukhiv, A., Sokil, B., Sokil, M.: Asymptotic method in investigation of complex nonlinear oscillations of elastic bodies. *Ukrainian J. Mech. Eng. Mater. Sci.* **4**(2), 58–67 (2018)
10. Andrukhiv, A., Sokil, B., Sokil, M.: Resonant phenomena of elastic bodies that perform bending and torsion vibrations. *Ukrainian J. Mech. Eng. Mater. Sci.* **4**(1), 65–73 (2018)
11. Wang, C., Sun, Q., Cao, G., Zeng, J.: Analysis on asynchronous start permanent magnet synchronous motor cogging torque optimization based on equivalent magnetic motive force. *Lect. Notes Electr. Eng.* **423**, 977–987 (2018)
12. Sydorenko, I., Kurgan, V.: Synthesis of nonlinear elastic couplings on the basis of modified kinematic graphs. *Proc. Odessa Polytech. Univ.* **3**(53), 5–11 (2017)
13. Nitzan, S.H., Zega, V., Li, M., Ahn, C.H., Corigliano, A., Kenny, T.W., Horsley, D.A.: Self-induced parametric amplification arising from nonlinear elastic coupling in a micromechanical resonating disk gyroscope. *Sci. Rep.* **5**, 9036 (2015)
14. Arkhangelsk, G.: Efficiency of using an elastic coupling with an extended section of quasi-zero stiffness. *Mach. Parts* **51**, 17–22 (2015)