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Mechanical
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PROCEEDINGS

The 7th INTERNATIONAL SCIENTIFIC CONFERENCE
**RESEARCH AND DEVELOPMENT OF
MECHANICAL ELEMENTS AND SYSTEMS**

27th & 28th of April, 2011, Zlatibor, Serbia

Co-organisers:



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Publisher

Mechanical Engineering Faculty Niš
Prof. Dr.-Ing. Vlastimir Nikolić, dean

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Cover design

Tatjana Miltenović

Number of copies

180

Printing

SVEN, Niš

CIP – Каталогизacija u publikaciji
Народна библиотека Србије, Београд
621.01(082)

INTERNATIONAL Scientific Conference Research
and Development of Mechanical Elements and
Systems (7 : 2011 : Zlatibor)

Proceedings – The 7th International
Scientific Conference Research and
Development of Mechanical Elements and
Systems - IRMES 2011, 27th & 28th of April,
2011, Zlatibor, Serbia / [editor Vojislav
Miltenović]. - Beograd : Mechanical
Engineering Faculty, 2011 (Niš : Sven). - 638
str. : ilustr. ; 30 cm

Tiraž 180. - Bibliografija uz svaki rad

ISBN 978-86-6055-012-7

a) Машинство - Зборници
COBISS.SR-ID 183139340

ISBN 978-86-6055-012-7



Ministry of Education and Science of the Republic of Serbia has participated in printing costs of the proceedings of the 7th International Scientific Conference Research and Development of Mechanical Elements and Systems - IRMES 2011

All the publications in this Proceedings have the authorship, whereas the authors of the papers carry entire responsibility for originality and content.

Preface

New technologies, globalization and individualization of customer demands, as well as high quality of modern products, are forcing industrial enterprises to improve their processes of product development. This implies the support of enterprise processes throughout the product lifecycle, from the product idea through product development, manufacturing, improvement and quality assurance to maintenance during operation. Processes of product development are more than just usual engineering. A product portfolio must be analyzed and product concept must be examined from the aspect of its realization. This requires linking internal domain with external teams. New products must be introduced to market with high quality and low development costs. The prerequisite for development of high quality products and high productivity manufacturing is to master the knowledge, which is a result of research in science and technology.

The aim the 7th International Scientific Conference “Research and Development of Mechanical Elements and Systems” 2011 in Zlatibor is:

- to gather experts and researchers in the field of scientific research and industrial product development;
- to present new design solutions related to energy efficiency, application of available resources, product price reduction, ...
- to exchange knowledge and experience, through presentations of research results and expert information, with the aim of stimulating industrial activities in the region.



Participant countries

The best 114 abstracts were selected among 154 submitted by authors from Europe and Asia. The lectures came from Austria, Bosnia and Herzegovina, Belarus, Bulgaria, France, Germany, Greece, Croatia, Czech Republic, Hungary, Italy, Kazakhstan, Macedonia, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia and Spain. The presentations emphasize future trends in area research and development of mechanical elements and systems and cover the following topics:

- Industrial Product Development
- Computer Added Product Development - CAPD
- Mechatronics and Automatic Control
- Safety, Quality and Reliability
- Materials, Technology and Tribology
- Vibration and Noise, Testing and Monitoring
- Mechanical Systems and Components

The conference offers the possibility for participants to discuss the presented results in detail and share their experience.

Conference President

Prof.Dr.-Ing. Vojislav Miltenović, Full Professor, Machines Development and Construction Centre (CERP), University of Niš, Faculty of Mechanical Engineering, Niš, Serbia

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THE 7TH INTERNATIONAL CONFERENCE RESEARCH AND DEVELOPMENT OF MECHANICAL ELEMENTS AND SYSTEMS

SYNERGY OF EDUCATIONAL – SCIENTIFIC INSTITUTIONS WITH SMALL AND MEDIUM ENTERPRISES IN PRODUCT DEVELOPMENT TASKS

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Abstract: *Virtual Product Development (VPD) is the practice of developing and prototyping products in a completely digital 2D/3D environment. VPD has four main components: virtual product design, virtual product simulation, virtual product staging, digital manufacturing. VPD typically takes place in a collaborative, web-based environment that brings together designers, customers/consumers, and value chain partners around a single source of real-time product “truth.” VPD enables practitioners to arrive at the right idea more quickly, and to accurately predict its performance in both manufacturing and retail settings, ultimately minimizing time to value, market failure potential, and product development costs.*

Key words: *Product design, Virtual Product Development, Power Transmission, CAD/CAM/CAE*

1. INTRODUCTION

Product design is often misunderstood as a concept. It is commonly seen, as the process of making products look aesthetically pleasing or stylish. Most product designers understand product design to mean much more than this. Product design is a multi-disciplinary process which usually involves market and technological research, concept design, prototype development, final product development and testing as well as post production refinement. Product Design is defined by Walsh et al (1992: 18) as: *“The activity in which ideas and needs are given physical form, initially as solution concepts and then as a specific configuration or arrangement of elements, materials and components”.*

Rainey (2005) describes integrated product development (IPD) as “a strategy that integrates all activities from product concept through to production. IPD is a multidisciplinary management strategy that uses product teams and design tools such as modelling and simulation teams to develop products and processes to meet cost and performance objectives concurrently.

IPD involves understanding the customer’s needs and managing those requirements together with,

- suppliers as partners,
- integrating product development and research and development with the business strategy and business plans,
- integrating the design of manufacturing and product support processes and managing cost from the start by effective planning,
- low-risk development and managing project scope.

Companies that are able to bring new products, that satisfy the expectations of the customer fast and efficient to the market, will manage to succeed in the intense and

dynamic global environment in which it operates (Wheelwright and Clark, 1992). The US based Product Development & Management Association (PDMA) defines New Product Development as *“a disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts embryonic ideas into saleable products or services”*

The NPD process is driven by one or more of the following three factors:

1. **Technology:** Advances in technology (either in-house or outside) provide an opportunity for the improvements to an existing product.

2. **Market:** The firm has to improve its existing product in response to:

- (i) competitors’ actions (such as lowering of their price or an improvement to their product) and/or,
- (ii) feedback from customers through complaints about product performance.

3. **Management:** The motivation for improvement is:

- (i) internal (e.g., to increase market share, or improve profits by reducing warranty cost) and,
- (ii) external (e.g., new legislation with regards product performance).

The literature on NPD contains several alternative NPD process models (e.g., Wesner et al, 1995, Wind, 1982, Sounder, 1987, Pugh, 1991, Pahl and Beitz, 1988, Belliveau et al, 2002, and IEC 60300-1, 1991). It is possible to recognize the similarities between the different models. What they have in common is that the NPD process begins with an idea to build a product that meets specific needs (or create new needs for radically innovative products) defined by customers and/or the manufacturer, and ends when the product is launched on the market. This involves six phases as illustrated in Figure 1.

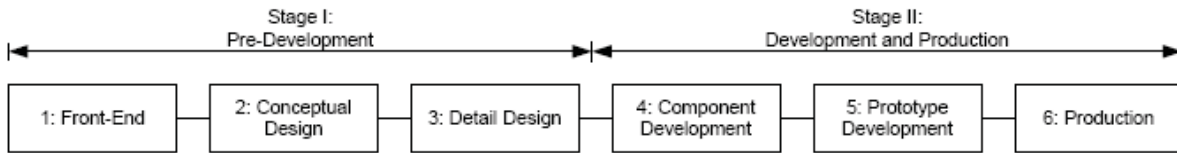


Fig. 1: Six phases of NPD

These six phases can be grouped into two stages (Stages I and II).

Stage I, the *predevelopment stage* consist of three first phases and is concerned with a *nonphysical* (or abstract) conceptualization of the product with increasing levels of detail.

Stage II, the *development and production stage*, consists of the next three phases and deals with the *physical* embodiment of the product resulting from the transformation of the conceptual product into a physical entity.

The high demand and competition of the market, caused by globalization and permanent technical innovation, exerts an enormous pressure on companies, especially in small and medium size enterprises (SME). These companies often do not have in their ranks enough personnel to dedicate to continuously develop new products, or to more fundamental research. For these companies, the most reasonable route to follow is to partner with an R&D institution (i.e. a University) and collaboratively develop new products. Both stand to gain from this type of collaboration. Nevertheless, this type of collaboration usually faces several barriers, namely related with communication, conceptual/abstract reasoning and time frames.

The R&D institution elements must be able to use a communication format that can be understandable by the SME's elements. The scientific terms and definitions must be adapted (or even misspelled) aiming to find a common language matrix, despite the level of engineering and/or technological skills existing in the company. Furthermore, an effort has to be made to achieve compatibility between the objectives of the researchers in the project (usually to produce thesis, papers, patents, etc.) with the SME's objectives (usually the design of competitive product/technology, the productivity increase, the better use of the resources, etc.). Also it is absolutely necessary to define early in the project the intellectual property rights of both parts. The day-by-day demands in a SME implies for a highly practical approach to solve the emerging problems and to develop the business. This behavior is also present when a SME is participating in a collaborative R&D project. There is a great pressure to find *the* solution and discuss the results of its impact. On the other hand, the research team believes that better results and a better knowledge of the process can be withdrawn if a scientific approach or method is followed. A balance must be found to merge these two concepts. It should be used a scientific approach or method that the SME can understand and be involved in. If not possible, the results of the scientific work should produce several alternatives solutions that can be analysed by the SME to support the decision process.

2. TOOLS AND METHODS FOR PRODUCT DEVELOPMENT

While design is a key of product development, it is subsidiary in inventing new values and functions or renovating existing ones, is related to their systematization or integration, or to organize its process. Since design is an inherent activity of mankind, discussion of frameworks and methods for improving or rationalizing design process had not been an explicit major issue in engineering. However, as the contents of artifacts, such as machines, products, have become more complicated and massive, allocation and enforcement of design knowledge and process have become unavoidable issues in manufacturing industry. Additionally, as various digital engineering tools such as CAD systems have becomes widely available under the progress of information technology, their utilization has become an important issue for enhancing product development performance.

Figure 2 roughly shows a map of tools and methods for product development over the design process and product life-cycle. While some of them originated in 1970s, others were formed in 1990s or later under the movement of concurrent engineering. The coverage of tools and methods has been gradually spread so as to support a series of phases and aspects more widely and in more integrated way. When considering that product development is an integrated activity, it should be an essentially important view not only to utilize respective ones, each of which was developed independently from the others, individually but also to systematically organize the overall process of product development by selectively utilizes ones, which are necessary and effective for a specific project, from available ones.

3. PRODUCT DEVELOPMENT AN THE FACULTY OF MECHANICAL ENGINEERING IN NIŠ

University of Niš, Faculty of Mechanical Engineering in Niš (UNFME) is je educational – scientific institution accredited to educate bachelor, master and doctoral students. UNFME does basic, applied and development researches in interdisciplinary areas of science.

Cooperation with SME is achieved over the Institute for Mechanical Engineering. Institute consists of several research centers:

- Centre for the applied mathematics,
- Centre for the nonlinear dynamics and active structures,
- Centre for logistics,

- Centre for machine design and product development,
- Centre for welding and welded structures and
- Centre for motors and motor vehicles.

Spectrum of competences and capabilities of UNFME are huge and local industrial complex relies on the UNFME as a knowledge Centrum in the region.

Centre for machine design and product development (CERP) is capable to develop various products from the

area of power transmissions and various designing challenges. Significant amount of the knowledge in product development is priceless basis for the knowledge sharing and further expansion.

Centre is one of the foundations of novel product development concept – virtual product development applied on power transmissions.

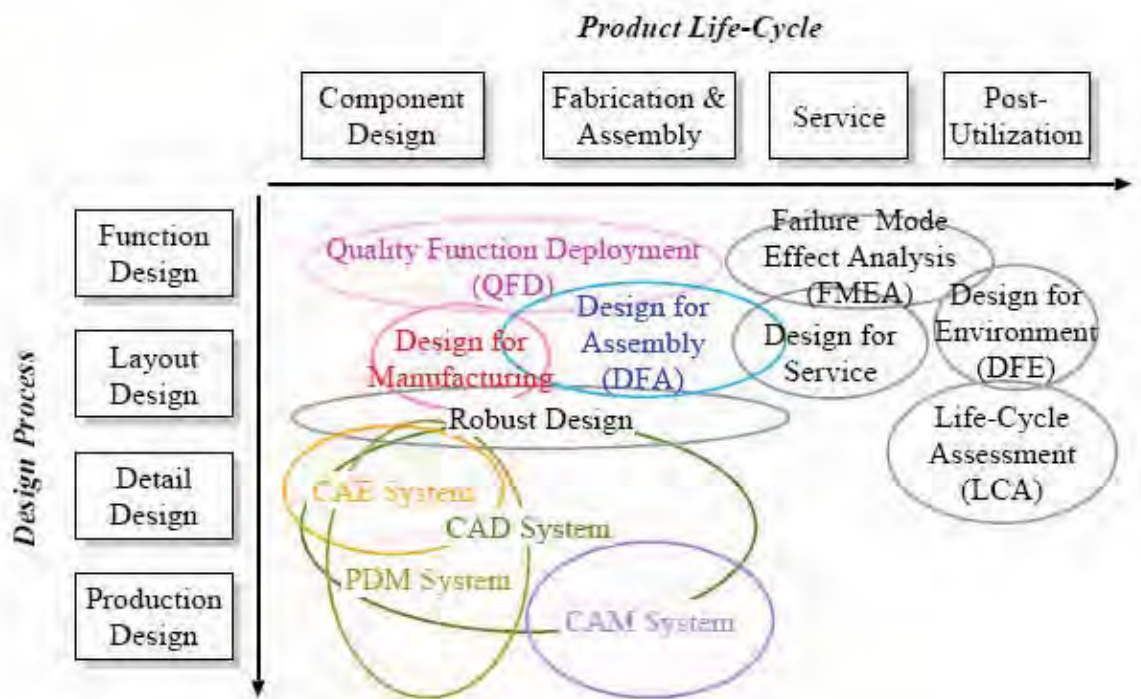


Fig. 2: Design process and Product Life - Cycle

4. VIRTUAL PRODUCT DESIGN ON EXAMPLE POWER TRANSMISSION AT FACULTY OF MECHANICAL ENGINEERING

New product development – NPD consist of 6 phases (Figure 1). Presently and a decade in the past, UNFME has numerous undergraduate / graduate subjects (Mechanical Parts, CAD, CAE, CAx, Design Theory, Industrial Design, Product Design, Systems for Design, Virtual Product Design etc.) which pay special attention on the phase no. 3 – Detailed design. Detailed design consists of:

- Product Shaping (modeling, documentation development etc.),
- Simulations and Calculations,
- Virtual Prototyping
- Computer Aided Visualization (CAV).

Product shaping is very important phase of product design process. Shaping theory is scientific discipline which studies methods and acts of parts, machine assemblies and machines shaping. Shaping tools, hardware and software for visualization of shapes by computer applications are parts of shaping theory, also.

Application of computers in product shaping process includes Computer Aided (CAx) technologies – Computer Aided Design (CAD), Computer Aided Manufacturing

(CAM), and Computer Aided Engineering (CAE). Software applications, used for shaping in this phase of design have to enable and ease:

- Static and dynamic calculations,
- Element modeling, including complex shapes and three dimensional (3D) curves or faces,
- Elements assembling into precisely defined relations and shapes,
- Application of standard elements, generated from adequate databases or part libraries (springs, bolts, bearings etc.),
- Automatic development of technical documentation as product of modeling and assembling,
- Automatic creation part lists,
- Simulation of movements and monitoring in working condition,
- CNC code generation, in order to automate manufacturing process,
- Sheet metal design support, mold base, for metals and plastics etc.,
- IGES i STEP database generation and usage in other CAD and CAM systems,
- Constructive optimization,
- Mechanism analysis,
- Analysis of experimental data derived from prototype testing,

- Marketing support – easy presentation making, realistic rendering, animation.
- Virtual product development enables high speed innovations and manufacturing, high quality products and economic production.
- Corporation's concurrence and quick accommodation to market requests require software for calculations of mechanical parts and tools which will enable easy 3D modeling and other automatization (CAD, CAD/CAM or CAD/CAM/CAE tools).

University of Niš, Faculty of Mechanical Engineering - UNFME is working long time period on development of integrated computer program for complete design of power transmitters – Power Transmitter Design Software (PTD). Integrated program system PTD, shown in Figure 3, has three main parts:

- Program modules for power transmission element's calculation,
- Program modules for calculation of rotation elements,
- Program modules for calculations of mechanical connections.

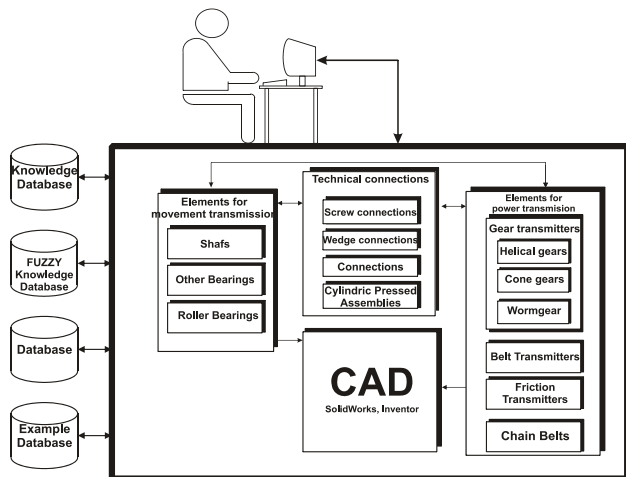


Fig. 3: Integrated system for power transmitters design PTD

PTD is developed by UNFME staff and undergraduate/graduate students of UNFME and it is used for further education of engineers or students and for projects realization – product development processes. Examples of projects realized by PTD are numerous: worm gear power transmissions, combined power transmission – worm gears and helical gears, helical gears and bevel gears, finite elements analyses – FEA, virtual prototyping, CAV etc (Figures 5 to 11). Developed product are mentioned for the students' education, as well as for the local small and medium enterprises of the Niš region.



Fig. 4: Worm gear power transmission, variant 1



Fig. 5: Worm gear power transmission, variant 2



Fig. 6: Combined power transmission - worm gear pair and bevel gear pair

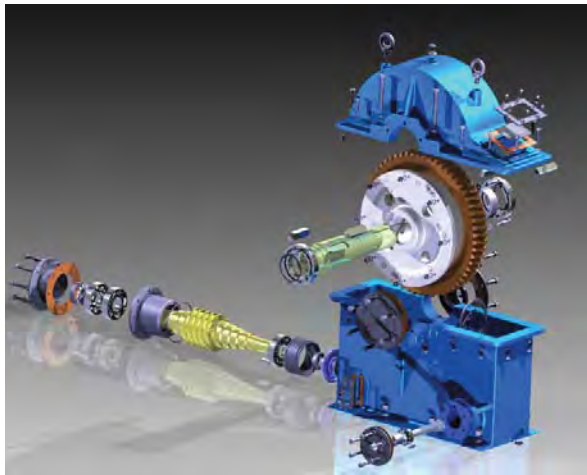


Fig. 7: Combined power transmission - worm gear pair and bevel gear pair (exploded view)

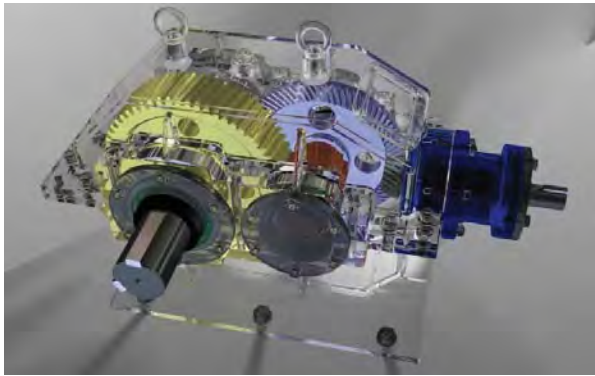


Fig. 8: Combined power transmission - helical gear pair and bevel gear pair ("Osa računarski inženjering" Company has awarded prestige prize "Petar Damjanović" to Marko Ristić for the best graduate thesis in Product Development)

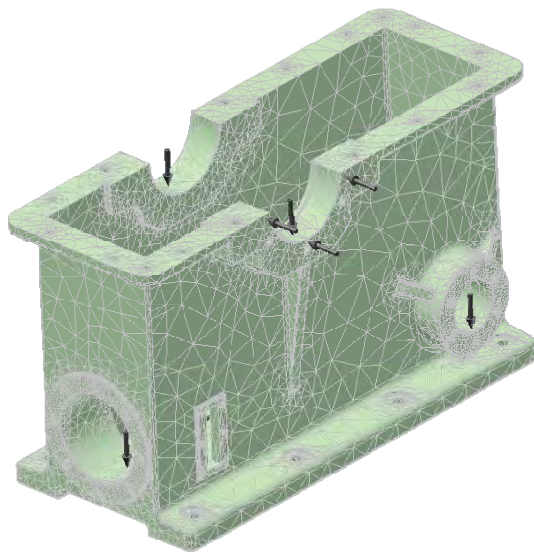


Fig. 9: Finite elements analysis –discrete model of the power reducer's case

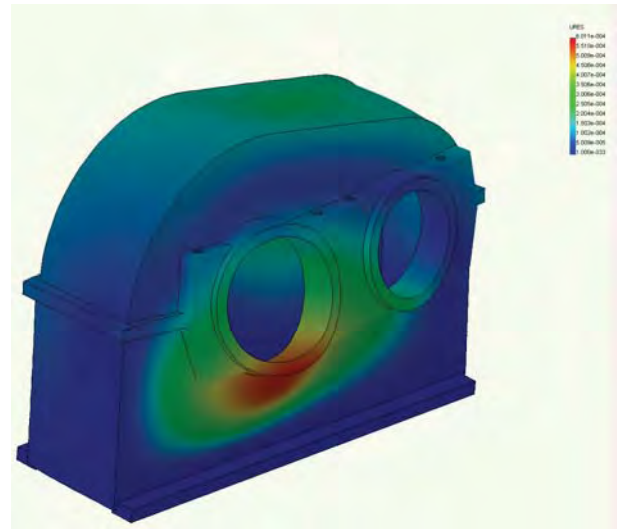


Fig. 10: Finite elements analysis –deformations on the power reducer's case

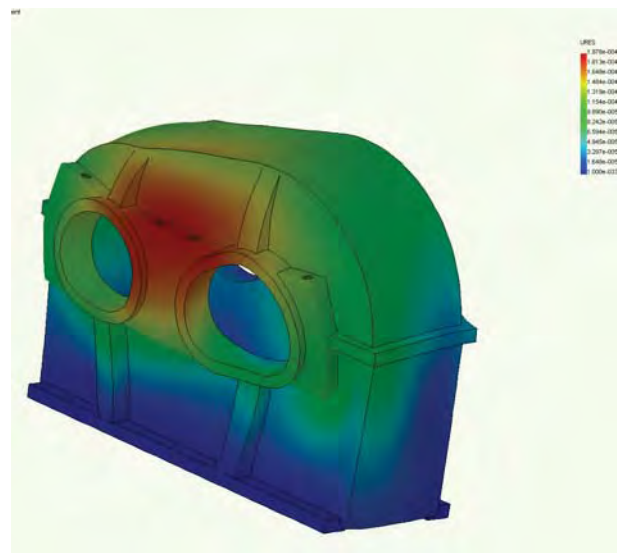


Fig. 11: Finite elements analysis –stress distribution on the power reducer's case

5. CONCLUSION

UNFME is creating an excellent bond with the small and medium enterprises in the region around the UNFME. Modern industrial age delivered new demands to the enterprises on product development:

- need for the fast product development,
- reduction of time and costs in order to stay competitive on the market, and
- increase of quality.

Developed systems for design at UNFME directly help these enterprises in achievement of several mentioned demands. Other demands can and are fulfilled in cooperation with the staff of the UNFME at Institute and Centres for various engineering tasks. Synergy of the University, as an example of science and knowledge centre, and the industrial complex is the only possible solution for modern challenges in engineering overcoming.

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27th & 28th of April, 2011, Zlatibor, Serbia

ISBN 978-86-6055-012-7