Application of ISO 80000-2:2009 in the Description of Technical Systems

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Abstract. Technical systems are inconceivable without documentation describing their implementation, use and maintenance. Documentation is usually based on three languages - the manufacturer's domicile language, English and mathematics. Mathematics is not only the first foreign language that we learn, but it is also the only foreign language that everyone learns. By mastering mathematics, we often focus on the result and over the years we may forget about proper notation. This can be overcome by means of the ISO 80000 standard. A standard is a document issued by one or more organizations whose goal is to bring order into a certain field. Standards are transferred to lower instances through a hierarchical structure. The ISO 80000 standard consists of fourteen documents under the general title Quantities and units. This paper provides an analysis of the requirements of Part 2 of the standard called "Mathematical signs and symbols to be used in the natural sciences and technology", and exemplifies its application in scientific journals and Master's theses at engineering faculties. The presence of the standard was assessed by analyzing the elements described by the standard in papers published in 2018 in the following five scientific journals: Tehnički vjesnik/Technical Gazette, Engineering Review, Acta Polytechnica Hungarica, the American Journal of Electrical Power and Energy Systems and the International Journal of Renewable Energy Research. In addition to these journals, the presence of the standard was also analyzed in Master's theses at two engineering faculties, i.e. the Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek and the Mechanical Engineering Faculty in Slavonski Brod, and the results are presented in a clear and concise graphical format. The conclusions of the performed analyses indicate that the standard is generally only partly implemented, with the exception of Tehnički vjesnik/Technical Gazette, where the standard is fully implemented, and the importance of adhering to normative documents is stressed in its Instructions for Authors.

Keywords: Standard · ISO 80000 · Technical systems · Maintenance · Mathematics

1 Introduction

Almost all systems are inconceivable without documentation containing their description. Technical systems are specific because numbers and mathematical expressions are

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used in their description. The basic rule stating that if something cannot be represented by means of numbers, then we do not know anything about it, imposes the need to write mathematical texts correctly. The importance of proper notation is reflected in the fact that part of the international ISO 80000 standard is entirely dedicated to mathematical writing. The aim of the paper is to explain the concept of standard, standardization and its application by using a practical example. The first part of the paper delineates a hierarchical structure of standardization through examples of international and local organizations and indicators of the number of the normative documents published. Standards at the level of the Republic of Croatia are available through the Croatian Standards Institute, so is the standard that regulates mathematical writing. The ISO 80000 standard consists of 14 normative parts that periodically undergo revision and change. The rules prescribed by the second part of *ISO 80000-2:2009 Quantities and units—Part 2: Mathematical signs and symbols to be used in the natural sciences and technology* are presented partially in textual and tabular form. In order to show the application of the standard, papers and Master's theses were analyzed that were published during 2018 in five scientific journals and at two engineering faculties, respectively. The results of the analysis are presented graphically, and based on them, conclusions are drawn about the application of the standard in everyday practice.

2 Standardization and Standards

2.1 Standardization

Standardization is the activity of establishing an optimum degree of order for common and repeated use in a given context with regard to potential problems or actual problems, [1]. Standard refers to a document approved by a recognized body that provides guidelines whose compliance is not mandatory and may apply to a process or a production method, [1]. The function of a standard is to efficiently connect systems, provide quality of service and reduce a variety of different systems, as well as to describe processes and products. The application of the standard is mainly related to technical systems and system organization, but in the past decade, it has also related to the field of energy, where the advantage of standardization has been recognized and applied when defining the guidelines of energy policy, [2].

Standardization is based on the principles of consensus, involvement of all stakeholders, operational transparency, state-of-the-art technology and the coherence of the set of standards, [3]:

- Consensus is a "general agreement characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments".
- All stakeholders must be involved in the preparatory stage of the standard and in the drafting stage of the standard.
- Operational transparency during the entire standard development process is important because the public must have access to documents, information about the body

preparing the standard, and information about the stages of standard preparation and development. The public must be informed in a timely and appropriate manner.
- State-of-the-art technology at a particular time is based on proven scientific, technical and experiential knowledge defining current standards.
- The coherence of the set of standards implies that two standards must not be contradictory, i.e. when adopting a new standard for something for which there already exists a standard, the old standard must be withdrawn in order for the new standard to be published and enter into force.

2.2 Standardization Organizations

Standardization organizations can be divided into local and international. At the European level (i.e. local in relation to the authors), these organizations are the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI).

European Committee for Standardization (CEN) [4] brings together 34 European countries. With regard to its level of activity, CEN is below the ISO organization. There were 1,198 documents produced during 2018 (technical specifications, European standards, technical reports, CEN workshop agreements, and CEN guides), of which 1,076 were European standards. At the end of 2018, there were 3,498 documents in preparation. At the same time, there were 16,979 active documents, of which 15,305 were European standards. The Committee consists of 2,134 technical bodies, which are partly joint committees with the European Committee for Electrotechnical Standardization (CENELEC), [5].

European Committee for Electrotechnical Standardization (CENELEC) [6] is a European committee responsible for standardization in the field of electrical engineering, which prepares voluntary standards for trade between countries and supports the unity of the European Common Market. This Committee actively participates in 34 European countries and consists of 383 different technical bodies. In 2018, the Committee developed 383 standards. At the end of 2018, there were 7,085 active standards, while 97 standards are awaiting publication, [5].

European Telecommunications Standards Institute (ETSI) [7] is an institute in Europe responsible for standards in systems, applications and services in information and communication technologies, which later began to be applied all over the world. It has 64 member countries and 872 members. The Institute has published 46,765 standards since its establishment, and more than 17 million standards have been downloaded. It is currently a partner in a global project aimed at developing 4G and 5G mobile communications, [5].

Local organizations act not only in Europe but also internationally, and work on standards with organizations around the world.

International standards and standardization organizations are organizations that operate throughout the world. They are headquartered in one country with multiple branches around the world. Standards are adopted independently or in collaboration with other organizations operating either globally or only in a small geographical area. The standards adopted in most cases solve problems that concern the whole world, so the final

solution is a compromise made up of several possible solutions. The largest organizations are the International Organization for Standardization - ISO [8], Deutsches Institut für Normung - DIN [9], and the British Standards Institution - BSI, [10].

International Organization for Standardization (ISO) is an organization that started to operate in 1946, when 25 delegates met at the Institute of Civil Engineers in London to facilitate the international coordination and unification of industrial standards. The International Organization for Standardization (ISO), which currently has 164 member countries and 3,573 technical bodies in charge of developing standards, officially began operating in February 1947. The organization is headquartered in Geneva, Switzerland. Since it was founded, 23,163 international standards have been published covering almost all aspects of technology and manufacturing. During 2018, as many as 1,637 standards were published.

Deutsches Institut für Normung (DIN), i.e. the German Institute for Standardization, was founded in 1917. This Institute is an independent platform for standardization in Germany and worldwide that supports innovative solutions related to business digitization and research projects, which has 3,575 working committees. It has published 40,352 standards.

British Standards Institution (BSI) is a company that takes care of other organizations achieving excellence around the world. It has 193 member countries and 84,000 customer clients. BSI has published a total of 50,529 British standards.

The increase of knowledge and activities inevitably leads to a greater number of necessary compromises in solving the identified challenges and consequently the number of new standards. Figure 1 shows a trend referring to the number of ISO and DIN standards in the last couple of decades.

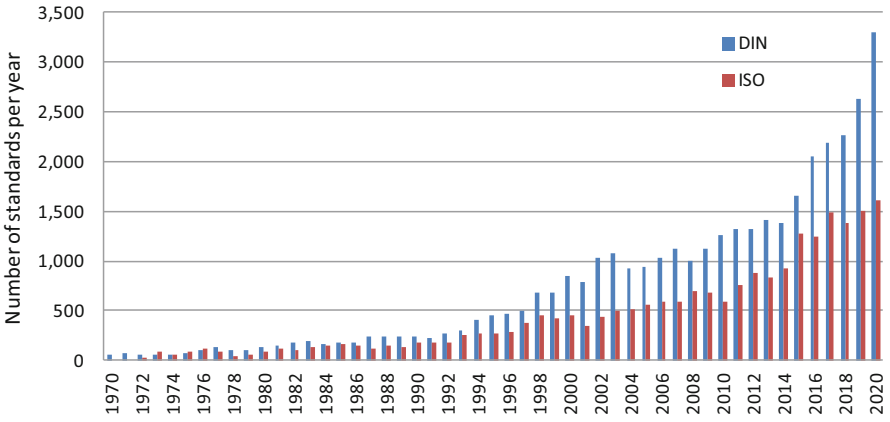

Fig. 1. Number of ISO and DIN standards published by year

Croatian Standards Institute (Hrvatski zavod za norme – HZN). The standards are accessed through the national standards organization of the Republic of Croatia. The Croatian Standards Institute is an independent, public and non-profit institution whose

goals are as follows: to increase the safety level of products and processes, to protect human health and the environment, to promote the quality of products, services and processes, as well as appropriate use of materials and energy, to improve product efficiency, to control variety, to ensure compatibility and interchangeability, and finally, to remove technical barriers to international trade. The Croatian Standards Institute is a member of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI), [3].

2.3 Standards

ISO 80000 Standard. The ISO 80000 standard was completed in 2009 and it replaced the IS 31 standard, which provided guidelines in scientific and educational documents on how to use the units of measurement, physical quantities, and formulas containing the aforementioned. This standard is also known as ISO/IEC 80000, because ISO is not the only standards developing organization. The International Electrotechnical Commission (IEC) played a great role in adopting Part 6 - Electromagnetism, Part 13 - Information science and technology, and Part 14 - Telebiometrics related to human physiology.

Under the general title Quantities and units, the ISO 80000 standard consists of the following parts:

– Part 1: General
– Part 2: Mathematical signs and symbols to be used in the natural sciences and technology
– Part 3: Space and time
– Part 4: Mechanics
– Part 5: Thermodynamics
– Part 6: Electromagnetism
– Part 7: Light
– Part 8: Acoustics
– Part 9: Physical chemistry and molecular physics
– Part 10: Atomic and nuclear physics
– Part 11: Characteristic numbers
– Part 12: Solid state physics
– Part 13: Information science and technology
– Part 14: Telebiometrics related to human physiology.

In 2017, Part 14 was withdrawn from the standard in line with the votes cast by international organization board members, and the standard currently has 13 parts. Parts 2, 3, 4, 5, 7, 9, 10, 11 and 12 were revised in 2019. Part 8 of the standard was changed in 2020. Part 1 of the standard is awaiting revision and will be replaced by ISO/CD 80000-1.2.

ISO 80000-2:2009 Standard - Mathematical Signs and Symbols to be Used in the Natural Sciences and Technology. A standard which gives general information about mathematical signs and symbols, their meanings, verbal equivalents and applications is known as ISO 80000-2:2009 Quantities and units—Part 2: Mathematical signs and symbols to be used in the natural sciences and technology. The recommendations in ISO 80000-2:2009 are intended mainly for use in the natural sciences and technology, but they also apply to other areas where mathematics is used, [11]. The research described in this paper is based on the given standard.

Variables, Functions and Operators. Variables such as x, y, etc., and running numbers, such as i in $\Sigma_i x_i$ are printed in italic (sloping) type. Mathematical constants, whose values never change, are printed in Roman (upright) type, e.g., e = 2,718 218 8…; π = 3,141 592…; $\mathrm{i}^2 = -1$. A comma, semicolon or some other appropriate symbol can be used as a separator between numbers or expressions. The comma is generally preferred, with the exception of numbers with the comma as a decimal separator. In individual tables, for each individual field of mathematical notation, the standard provides a handful of examples by linking symbols, the meaning of the symbols, verbal equivalents, and remarks and examples. Table 1 shows examples from four fields.

Table 1. Examples of mathematical notation

Field	Sign, symbol, expression	Meaning, verbal equivalent	Remarks and examples
Mathematical logic	$p \Rightarrow q$	p implies q, if p, then q	$q \Leftarrow p$ has the same meaning as $p \Rightarrow q$ $\Rightarrow$ is the implication symbol
Sets	$B \subseteq A$	B is included in A, B is a subset of A	Every element of B belongs to A $A \supseteq B$ has the same meaning as $B \subseteq A$
Standard number sets and intervals	$(a, b]$	Left half-open interval from a excluded to b included	$(a, b] = \{x \in \mathrm{R} \mid a < x \leq b\}$ The notation $]a, b]$ is also used
Miscellaneous signs and symbols	$a \triangleq b$	a corresponds to b	When $E = kT$, then 1 eV $\triangleq$ 11 604,5 K When 1 cm on a map corresponds to a length of 10 km, one may write 1 cm $\triangleq$ 10 km

In addition to examples given in Table 1, the standard also provides examples in the fields of elementary geometry (e.g. AB∥CD, whose verbal equivalent is: the straight line AB is parallel to the straight line CD), operations (e.g. $a \cdot b$, $a \times b$, $a\,b$, ab, whose verbal equivalents are: a multiplied by b, a times b), combinatorics (e.g. $n!$, whose verbal equivalent is: factorial), functions (e.g. f, g, h, etc.), exponential and logarithmic functions (e.g. a^x, whose verbal equivalents are: a to the power of x, exponential function to the base a of argument x), circular and hyperbolic functions (e.g. arccos x, whose verbal equivalent is: arc cosine of x), complex numbers (e.g. $|z|$, whose verbal equivalent is: modulus of z), matrices, coordinate systems, scalars, vectors and tensors, transforms and special functions.

3 Application of ISO 80000-2:2009 in Scientific Journals and Master's Theses

By adopting the way of writing mathematics related expressions proposed by the standard, it is possible to unambiguously analyze all types of mathematical notation and identify deviations from normative recommendations. In order to determine the application of the standard in everyday practice, we selected five scientific journals and two engineering faculties, where we conducted an analysis of Master's theses published in 2018.

3.1 Scientific Journals

The application of the standard in everyday practice was analyzed in the following five different journals: Tehnički vjesnik/Technical Gazette, Engineering Review, Acta Polytechnica Hungarica, the American Journal of Electrical Power and Energy Systems and the International Journal of Renewable Energy Research.

Tehnički vjesnik/Technical Gazette (ISSN 1330-3651) is a journal that has been published since 1994 at Josip Juraj Strossmayer University of Osijek. The publishers are the Mechanical Engineering Faculty in Slavonski Brod, the Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek and the Faculty of Civil Engineering and Architecture in Osijek. The editorial board of the journal requires all authors to comply with the ISO 80000 standard. The impact factor of the journal is 0.644. The journal publishes 6 issues per year, [12]. All manuscripts must undergo an external, mostly international, double-blind review process and, when accepted for publication, they are made freely available for access for all users to read and download.

Engineering Review (ISSN 1330-9587) is an international journal that publishes original research papers related to the analysis of structures, materials and new technologies in the field of mechanical engineering, shipbuilding, basic engineering sciences, electrical engineering, computer science and construction. The journal has been published since 1970 by the University of Rijeka and it is the successor of the Proceedings of Engineering Faculties in Rijeka. As of 2012, the journal publishes 3 issues per year; before that, it published 2 issues per year, [13]. The impact factor of the journal is 0.627. Only scientific papers are published. Before publication, all manuscripts must undergo external, mostly international, peer review.

Acta Polytechnica Hungarica - Journal of Applied Sciences (ISSN 1785-8860) is an international peer-reviewed scientific journal of Óbuda University, the Hungarian Academy of Engineering and the IEEE Hungary Section. The journal has been published since 2004. Depending on the number of papers, it publishes 7 to 8 issues per year, and in the last two years it published 10 issues each year, [14]. The impact factor of the journal is 1.806.

American Journal of Electrical Power and Energy Systems (ISSN 2326-912X) is an American journal of energy and energy systems but the topics of the papers published in the journal are not exclusively related to these areas. The first volume was published in 2012, and the journal publishes 2 issues per year (with the exception of the first year), [15].

International Journal of Renewable Energy Research (ISSN 1309-012) is an international journal dedicated to renewable energy research. The journal has 9 volumes (i.e. the first volume was published in 2011) and it publishes 4 issues per year. The impact factor of the journal is 5.127, [16].

In order to analyze the application of the standard, the year 2018 was selected for two reasons. The first and most important reason is that it is the last year for which there exist complete records required for the preparation of the final paper [5], and the second reason is that we have a local maximum in the publication of papers at the national level. The second reason is not relevant because the journals covered in our analysis publish papers by foreign authors whose number does not correspond to the national trend. According to the Croatian scientific bibliography (CROSBI), 2018 is the year of the local maximum after 2011, when we recorded the largest number of papers published in journals by Croatian scientists, Fig. 2.

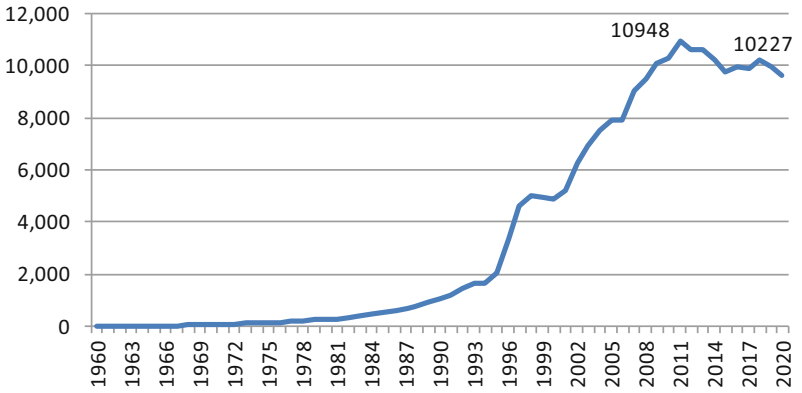

Fig. 2. Number of papers published in journals by Croatian scientists (CROSBI data)

The number of papers published in selected journals during 2018 can be seen in Fig. 3.

All papers published in 2018 were taken into consideration such that they were classified into five categories in accordance with the content in which the elements were observed that are regulated by ISO 80000-2:2009. In doing so, the first category contains

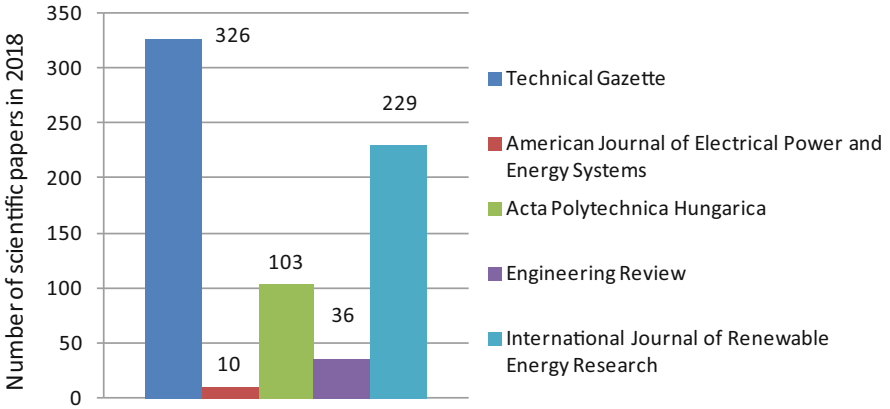

Fig. 3. Number of papers published in analyzed journals during 2018

papers whose 80% to 100% content can be regulated by the standard. Each subsequent category contains 20% less mathematical text. The second category encompasses papers in which there is from 60% to 80% of mathematical text, the third category presents papers with mathematical text in the papers ranging between 40% and 60%, while in the fourth and the fifth category there is from 20% to 40% and from 0% to 20% of mathematical text in the papers, respectively. The analysis was conducted by the first author, it is a subjective review and there is a possibility of deviation from the actual situation. Figure 4 shows the ratio of the number of pages by issues for 2018, i.e. by papers published in issues depending on the field in which the standard is applied. The number of pages containing elements of the standard is expressed as a percentage for each of the five categories with mathematical text.

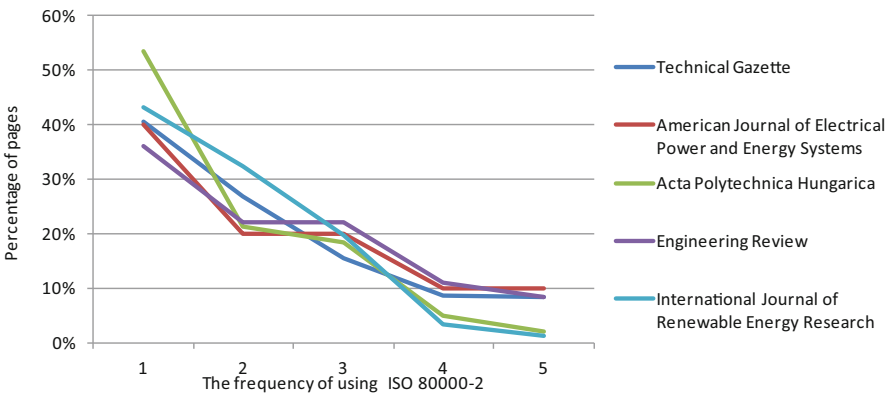

Fig. 4. Ratio of the number of pages to the frequency of using ISO 80000-2:2009

Correct application of ISO 80000-2:2009 in the aforementioned journals was also evaluated in the analysis (i.e. a degree to which the rules were observed) within a range of grades between 1 (worst) and 5 (best) (Table 2).

Table 2. Evaluation of the application of ISO 80000-2:2009

Journal	Grade
Tehnički vjesnik/Technical Gazette	5
Engineering Review	4
Acta Polytechnica Hungarica	4
American Journal of Electrical Power and Energy Systems	5
International Journal of Renewable Energy Research	3

3.2 Master's Theses

The analysis of Master's theses included theses defended during 2018 at two engineering faculties in Croatia, i.e. the Faculty of Electrical Engineering, Computer Science and Information Technology (FERIT) in Osijek and the Mechanical Engineering Faculty in Slavonski Brod. The scope of application of ISO 80000-2:2009 and its presence expressed as a percentage was analyzed, as well as a degree to which standard-related guidelines were followed. Figure 5 shows the number of papers classified into five categories. The first category consists of papers containing 80% to 100% of mathematical text, the second category encompasses papers in which there is from 60% to 80% of mathematical text, and in the third category there is from 40% to 60% of mathematical text in the papers, while in the fourth and the fifth category, there is from 20% to 40% and from 0% to 20% of mathematical text in the papers, respectively.

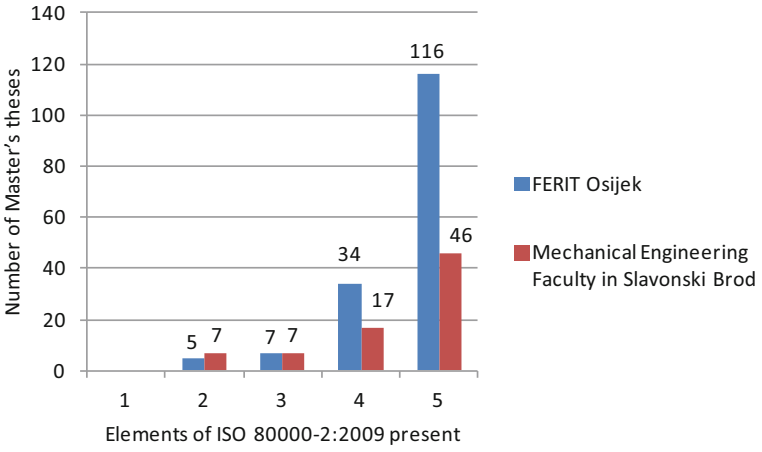

Fig. 5. Dependence of the presence of ISO 80000-2:2009 elements on the number of Master's theses

As can be seen in Fig. 5, 60% of Master's theses defended at FERIT contain up to 20% of mathematical text, while this number amounts to 48% at the Mechanical Engineering Faculty. There are no theses composed of 80% to 100% of mathematical text. Correct applications of the standard in individual Master's theses were analyzed and evaluated. The graph in Fig. 6 compares the total number of Master's theses and the number of Master's theses that are fully compliant with the standard.

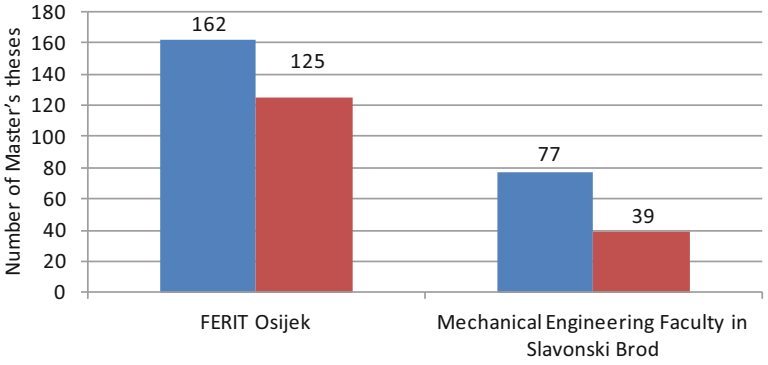

Fig. 6. Number of Master's theses marked in blue and Master's theses that achieved full compliance with ISO 80000-2:2009 marked in red

4 Conclusion

Technical systems are inconceivable without documentation describing their implementation, use and maintenance. Mathematics is a language used in the description of technical systems. In order to write mathematical text correctly, we must respect the rules, i.e. the standards. A standard is a document issued by one or more organizations whose goal is to bring order into a certain field. The ISO 80000 standard brings order into the field of mathematical writing. The ISO 80000 standard consists of fourteen documents under the general title Quantities and units. ISO 80000-2:2009 Quantities and units - Part 2: Mathematical signs and symbols to be used in the natural sciences and technology provides recommendations for writing mathematical texts. Scientific journals in the field of technical sciences publish papers that mostly contain mathematical signs and symbols. The share of papers based on mathematics as a whole is up to a maximum of 10%. The application of the ISO 80000-2:2009 standard is at a high level. Master's theses analyzed as part of our research follow the guidelines stipulated by ISO 80000-2:2009 in the range of 20 to 70%. The results of this research also indicate that the standard is significantly more frequently present in Master's theses in the field of mechanical engineering.

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