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Research on Tribology in Southeastern Europe: A Bibliometric Study

In recent years there is a small but increasing number of articles presenting and/or analyzing the scientific production from discrete geographical regions on a certain scientific topic. These articles applied the so-called bibliometric methods in order to evaluate the contribution of different countries in a scientific research field. In the present work, the research output of all countries in Southeastern Europe (SEE) on the scientific field of tribology is presented by using bibliometric indices such as the total number of publications and citations as well as the h-index and the average number of citations per publication. Such a study is attempted, to the authors' knowledge, for the first time.

Keywords: tribology, Southeastern Europe, bibliometric indices, scientific publications, Scopus database.

1. INTRODUCTION

The quantitative study of science is mostly referred to as scientometrics. Within scientometrics, the research on scientific communication, particularly with data from publications, citations and journals is called bibliometrics [1]. Nowadays, this discipline has grown dynamically and rapidly and has its own journals, conferences, and academic departments.

Bibliometric methods are quantitative by nature, but are used to make pronouncements about qualitative features. Compared to peer review, which has a limited area of investigation, it is easy to use bibliometric methods to examine unlimited quantities of publications. Bibliometrics has given us a tool that can easily be scaled from micro (faculty member/individual researcher) to macro (world) level [2].

Bibliometric analysis is a useful tool to obtain information about the current state of research in particular areas and allows researchers to identify and undertake new lines of research [3]. This type of analysis is a research method used in library and information sciences and utilizes quantitative analysis and statistics to obtain the bibliographical works within a given field, topic, institute, or country [4].

In Greece, a handful of studies have been conducted regarding the research performance of Greek University departments using bibliometrics. These studies refer mainly to engineering and computer science departments [5-9] and to medical ones [10]. Moreover, 93 Greek university departments from the fields of social sciences and humanities, sciences, engineering, pharmacy and economics were evaluated according to their academics' h-index [11].

In Serbia, studies concerning either a specific discipline [12] or the evaluation of scientific journals [13,14] have been recently published. Worth mentioning

also is an early publication from Turkey analyzing physics publications from Middle Eastern countries [15], whilst in [16] the international collaboration of East European scholarly communities is presented.

In general, studies concerning the scientific performance of researchers from discrete geographical regions to a specific scientific discipline are rather limited. Besides [4,15], in [17] the contribution of Iberian-American countries in food science and technology is presented and in [18] the scientific output of Scandinavia is outlined. Recently, a combined analysis of publications and patents of European researchers in the field of production technology and manufacturing systems was published [19], as well as an overall presentation of the research performance of all European countries; see [20]; moreover, a comparison of the scientific performance of the US and the European Union was reported in [21].

The viability of the bibliometric methods for measuring the scientific performance, in general, is accepted to be quite high. To the best of our knowledge, there is a lack of data concerning the evaluation of research productivity in tribology originating from the Southeastern European countries. Such a presentation is attempted in the present work by using bibliometric indices as the total and average publications and citations and the mean *h*-index.

Even though it is not the topic of the present work, it must be noted that the process of evaluation of scientific research performed by Higher Education Institutions (HEIs) is now obligatory in a number of SEE countries following the European initiatives for a European Higher Education Area (Bologna process and Bergen report) [22]. For this evaluation, nowadays, there seems to be a movement towards bibliometric measures and indices [8,11].

2. BIBLIOMETRIC INDICES

The selection of the appropriate bibliometric indices is of crucial importance for the effective and robust presentation and evaluation of research by bibliometrics. It has been indicated that "...at all levels of evaluation no indicator should be taken in isolation.

A series of indicators representing the different facets of scientific activity should be employed…" [23]. The indices selected in the present work correspond to four axes of research output: productivity, impact, efficiency and hybrid (productivity + impact). The same scheme was used in a number of recent publications [7-9]. In this respect, the following bibliometric indices were initially monitored:

Productivity

- P: Total number of publications (on country level) in the given time-period.
- P_y: Total number of publications (on country level) during a year.
- P_{av}: Average number of publications per year (on country level) in the given time-period.

Impact

- C: Total number of citations excluding self-citations (on country level) in the given time-period.
- C_s: Total number of citations with self-citations (on country level) in the given time-period.

Efficiency

- c_{av}: Average number of citations per publication on country level, excluding self-citations (C/P).
- c_{avs}: Average number of citations per publication on country level, including self-citations (C_s/P).

Hybrid (productivity + impact)

- *h*-index (on country level excluding self-citations, i.e., considering P and C of a country as the outcome of a sole researcher).
- h_s-index (*h*-index on country level, taking into account self-citations).

Indices P and P_y can be seen as a measure of the scientific size of a country. Scientific size, however, is not the same as scientific strength as it is indicated in [20]. Another standard indicator is the total number of citations (C) received by these P publications in the examined period.

The average number of citations per publication is calculated on the basis of the total number of publications (P) and citations within the given time-period. This measure, citations per publication, is used as an indicator of efficiency [7,8] or as an impact index [20]. This measure may be calculated twice; without self-citations and including self-citations in order to examine the effect of self-citations on the publication profile of national research.

The *h*-index was introduced in 2005 by J.E. Hirsch [24], combining in a single indicator a measure of quantity and impact of the scientific output of a researcher. According to Hirsch, "a scientist has index *h* if *h* of his or her N_p papers have at least *h* citations each and the other ($N_p - h$) papers have $\leq h$ citations each". The scientific community has shown a huge interest in this indicator, as shown by the high number of publications on the topic and its adoption by *Nature* and *Science* [7]. A detailed analysis of the *h*-index and the *h*-type indices for assessing scientific research performance is presented in [25].

A crucial problem arisen after monitoring measures such as P and/or c_{av} is how a certain number of publications or citations per publication can be considered low or high. On the basis of experience and the already published relevant research articles it is believed that the most appropriate method is the field-based normalization; for details see [20].

3. METHODOLOGY

Traditionally, bibliometric studies were based on the number of publications and citations, using the well-known Web of Science (WoS) distributed (now) by Thomson-Reuters, which has dominated the world of multidisciplinary citation indexes. However, in 2004, two alternatives have become available. One of them is Scopus® (http://www.scopus.com/) developed by Elsevier and the other is the freely available Google Scholar® (http://scholar.google.com/). The comparison of these three databases is beyond the scope of the present study; this topic is addressed in [7,26].

The required scientific data of each country necessary to calculate the bibliometric indices were retrieved using the Scopus® scientific database. Selection of Scopus as a suitable tool for the scientific field studied in the present work (tribology) was based on preliminary case studies and on previous suggestions; see for example [10,26]. Scopus® possesses certain characteristics which allow for enhanced service for educational and academic needs, engineering literature research and bibliometric analysis. Scopus® offers a basic search or an advanced search options. In the basic search, the results for the chosen keywords can be limited by the date of publication, subject area, and document type. The results can be refined by document type, author name, source title, publications per year, and/or subject area, and a new search can be initiated within the results [4]. Last but not least, Scopus provides almost 100 % "engineering" coverage. The key words entered in Scopus® as source titles to accomplish the objective of this study are presented in Figure 1. Then, all 13 SE European countries were entered as country affiliation. The subject area selected for this research was "physical sciences".

It must be noted that each country search was performed twice by: (i) considering the complete research profile of each country with no time limit and (ii) taking into account only the documents and corresponding citations for the last decade (period 2005 – 2014) to make comparisons using the same time basis. In this case, the index ''10'' is added to the symbol of each bibliometric index, indicating that it corresponds to the last ten years. For comparison purposes search with no time limit was expanded to include some Mediterranean and nearby countries; see Table 1. For historical reasons in Table 1 "Yugoslavia" was also entered as country affiliation.

The search results were as follows: (TITLE (tribo***) OR TITLE (friction) OR TITLE (wear) OR TITLE (lubrication) AND AFFILCOUNTRY (each one of 13 WE Europe countries)) AND SUBAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys); DOCUMENT TYPE (ALL); see Fig. 2.

Figure 1. Keywords entered during the present bibliometric study

Figure 2. Typical search results for a country

The selection of keywords in Figure 1 is, actually, the result of an optimization based on a number of trials. Term "tribo***" was preferred from "tribolo***" in order to include articles referred to tribosystem or to tribocorrosion. On the other hand, articles referred to as "tribocharging" were introduced. The addition OR TITLE (coat***) increases the results over two times and returns many titles from chemistry and biology which are not closely related with (engineering) tribology. In general, keywords in Figure 1 were considered as a good representation of tribological concept in scientific papers. Perhaps, it is not the best solution; however, it is definitely a starting point. All data presented in this work were collected from 28th to 31st March 2015 and concerned scientific work published until the end of 2014. Note also that in some Tables and figures countries' name was abbreviated by the three letters UN codes.

4. RESULTS AND DISCUSSION

4.1 Trends in publication

Thirty five (35) searches were performed in total; each search was run twice. There was no refinement of the results besides some evident irrelevant entries, e.g., quantum friction, for 2014 year. Search results obtained; see Fig. 2 for a typical output, are summarized in Table 1 and Table 2 for indices with no time limit and for the last decade's indices, respectively.

Table 1 presents the "timeless whole picture" of scientific production from the discrete geographical region to the scientific discipline of tribology. Discussion which follows refers to the last decade bibliometric data; see Table 2, in order to comment on the basis of a defined time-window. Note, also, that for the internationally co-authored publications the "whole

Table 1. Cumulative bibliometric indices with no time limit

Country	Number of articles	Citations (incl. self-citations)	Citations (excl. self-citations)	h-index (incl. self-citations)	h-index (excl. self-citations)	Year of 1st publication
	P	C_s	C	h_s	h	
Albania	2	9	8	2	2	1991
Bosnia and Herzegovina	22	14	5	2	1	2002
Bulgaria	142	974	774	18	18	1986
Croatia	142	546	380	11	9	1993
Cyprus	18	138	107	5	5	2000
FYROM	10	41	19	4	3	2005
Greece	392	3850	3125	31	27	1975
Moldova[1]	34	172	112	5	4	1994
Montenegro	13	28	15	3	3	2005
Romania	694	2436	1716	25	22	1963
Serbia	258	775	438	13	9	1998
Slovenia	336	3994	3129	35	30	1994
Turkey	1536	13117	n/a	48	n/a	1971
Yugoslavia[1,2]	65	469	367	12	11	1973
For comparison						
Austria	755	5243	n/a	34	n/a	1974
Egypt	419	2441	2080	24	22	1949
France	4388	n/a	n/a	n/a	n/a	1959
Italy	2111	n/a	n/a	n/a	n/a	1951
Spain	1477	15420	n/a	52	n/a	1978
Israel	547	12202	10271	53	49	1967
World total	135404	n/a	n/a	n/a	n/a	1828

n/a – not available.

[1]Historical notes: The "Breakup of Yugoslavia", having occurred as a result of a series of political upheavals and conflicts during the early 1990s, should be taken into account. After April 1992 Slovenia, Croatia and Bosnia and Herzegovina were internationally recognized. In 28 April 1992 the Federal Republic of Yugoslavia (from February 2003 State Union of Serbia and Montenegro) was formed whilst in June 2006 Serbia and Montenegro became an independent states. Moldova declared its independence on 27 August 1991 and on March 2, 1992 gained formal recognition as an independent state at the United Nations.

[2]Last publication with affiliation "Yugoslavia" was in 2006.

Table 2. Cumulative bibliometric indices for the last decade (2005 – 2014)

Country	Number of articles	Citations (incl. self-citations)	Citations (excl. self-citations)	h-index (incl. self-citations)	h-index (excl. self-citations)	Average number of articles	Average number of citations	
	P_{10}	C_{s10}	C_{10}	h_{s10}	h_{10}	P_{av10}	c_{avs10}	c_{av10}
Albania	0	0	0	0	0	0.0	0.00	0.00
Bosnia and Herzegovina	16	9	4	2	1	1.6	0.56	0.25
Bulgaria	75	340	270	9	8	7.5	4.53	3.60
Croatia	81	208	206	7	7	8.1	2.57	2.54
Cyprus	11	56	47	4	3	1.1	5.09	4.27
FYROM	8	20	10	2	2	0.8	2.50	1.25
Greece	191	1202	964	16	15	19.1	6.29	5.05
Moldova	21	62	25	4	2	2.1	2.95	1.19
Montenegro	11	23	12	3	2	1.1	2.09	1.09
Romania	457	1055	649	17	12	45.7	2.31	1.42
Serbia	200	649	383	12	8	20.0	3.24	1.91
Slovenia	195	1924	1544	26	23	19.5	9.87	7.92
Turkey	1084	6911	n/a	35	n/a	108.4	6.38	n/a
World total	52296	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a – not available.

counting" method was applied, i.e., every country gets full credit for internationally co-authored papers.

The first four columns of Table 2 comprise the absolute values of bibliometric data for all SE European countries as they were retrieved from Scopus database. Comparison of the sum of publication totals of the first column with the world total indicate the fact that these countries account for only 4.5 % of the tribology literature published worldwide.

The number of scientific articles published by SE Europe researchers has increased markedly in the recent ten years. Turkey has by far the largest publication output of the SE European countries, followed by Romania. Then, with almost equal P_{10} comes Serbia Slovenia and Greece. Moreover, in descending order, Turkey, Romania, Serbia, Greece and Slovenia contribute more than 90 % of the total SEE production on the topic in the analyzed period.

The analysis of publication activity shows in general, a significant year-by-year increase in the number of scientific articles published by SE Europe researchers with only one exception for year 2012. The variation of paper with year for countries with $P_{av10} > 5$ is presented in Figure 3. Growth trends and stable rates for various countries can be identified in this figure.
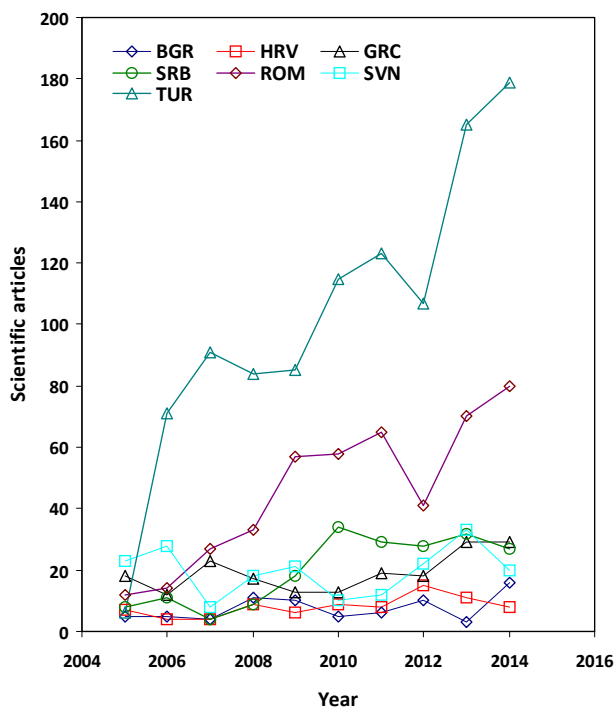

Figure 3. Annual variation of tribological papers (P_y) from SE Europe countries with $P_{av10} > 5$ published from 2005 to 2014

Besides the number of publications P, the total number of citations C which a scientific body of P articles has received is usually used as a criterion of the impact of the research under consideration. From Table 2 it is evident that Turkey possesses the highest C_{s10} followed in descending order by Slovenia, Greece, Romania and Serbia. These five countries account for 92 % approx. of all citations received.

The average number of citations per publication on country level is considered as an index of the efficiency of scientific research. Slovenia possesses the highest index ($c_{avs10} = 9.87$) followed by Turkey ($c_{avs10} = 6.38$)

and Greece ($c_{avs10} = 6.29$). Only these three countries are above the average value of 5.30 calculated for the whole region.

The *h*-index as it was originally introduced [24] combined in a single, synthetic indicator a measure of quantity and impact of the scientific output of a researcher. Despite being originally designed to assess individual scientific outcomes, the *h*-index can also be applied to other units of analysis, such as groups of researchers, university departments, scientific facilities, journals and countries [6,8,27,28].

During present research h-index was estimated on country level, by considering P and C values of a country as the outcome of a sole researcher; results obtained are summarized in the fourth and fifth columns of Table 2. It is evident that Turkey possesses the highest h_{s10} followed in descending order by Slovenia, Romania, Greece and Serbia.

A comparison of the results discussed above with similar results concerning other geographical regions, e.g. Scandinavia or EU countries would be of utmost interest; however such a comparison is not possible yet since relative data are not available. Research profiles for a number of countries including Greece and Turkey are discussed in [20]; the scientific size (publications) and the scientific strength (standardized citations per publication) of EU-27 member states are also presented there. Worth mentioning also that no international data are available to reliably compare output in terms of publications to input in terms of number of researchers. Instead, publication output is usually compared to the size of the population in the different countries – although differences in population do not necessarily reflect differences in research efforts [29].

Much of the difference among countries in publication output shown in Tables 1 and 2 can be attributed to differences in country size and investments in research. For a better insight into research production and impact one should correlate bibliometric indices with social-economic indices such as population, number of engineering departments in universities, gross domestic product (GDP) and gross domestic expenditure on R & D (GERD). In general, a gross positive relationship between the economic potential of a country and its scientific production is displayed [17]. On the other hand, most of the SEE countries are far from reaching the investment levels of scientifically developed countries in terms of GERD and efforts must be directed towards the increase of this indicator.

4.2 Authorship characteristics

As indicated from Table 2, present analysis is based on a total output of more than 2300 papers (articles, notes, letters chapters and reviews) published in the journals indexed by the Scopus® for the period 2005 – 2014. These are the papers that include at least one author listing an affiliation in one of the SEE countries. While counting the papers it is observed that, on average, more than 85 % of the total number of the papers comes from universities. This simply implies that tribology research in SEE countries is carried out mainly in universities and public research institutions associated with higher

education organizations; private research centers and industry seem to have little contribution and participation.

As it is expected for a multi-disciplinary scientific field such as tribology, the majority of the published articles are multiple authored. Single authored contributions account for about 8.5 – 10 % for Serbia Bulgaria and Romania, 5.2 % for Greece, 3.5 % for Slovenia and reduced to zero for Croatia.

In Table 3 the most prolific authors in the field of tribology in each of SEE counties are presented. A threshold of $P_{10} \geq 10$ resulted in a number of 16 scientists from 7 different countries. Note that P_{10} values in Table 3 refer to tribology papers only; the overall output of an author may be far greater.

In Table 4 the most cited articles in the field of tribology in each of SEE counties are presented. Three articles at maximum from each country were included provided that the article received at least 10 citations.

Another important topic to be examined is the "journal preference". Scientists' selection of journals for publication has always been an important aspect of their publication activity. In tribology, as in most other fields such as engineering and/or materials science, hundreds of journals of different levels of readership are available in the Scopus® data base. These journals are ranked according to their readership and scientific influence levels as measured by their IPP (impact per publication) [1] and SJR (SCImago Journal Rank) indicators. Note, that the SJR indicator is a free journal metric and provides an alternative to the impact factor (IF) which is based on data from the Science Citation Index; see for details [30].

Table 5 presents information about the most preferred journals for publication by tribologists from SEE countries. Three journals, at maximum, for each country were included, provided that more than one article was published in the journal. Different patterns of preference are identified from different countries; in some cases preference is strongly influenced by the nationality of the editing company of a journal.

4.3 International scientific collaboration

It has been indicated in a number of publications; see for example [18,20] that there is an increasing international scientific collaboration in many disciplines. Moreover, the growing share of internationally co-authored papers involves an increasing number of countries.

Table 6 refers to international collaboration within the SEE counties. For each country the three countries with the highest number of common papers are presented. The percentage of international publications is almost 100 % for Cyprus and Montenegro and 75 % for FUROM. The share of international publications is in the 20 – 30 % range for Croatia and Greece; slightly lower (15 – 18 %) for Slovenia and Serbia and somehow higher (34 %) for Bulgaria. Turkey, which possesses the highest P_{10} value, has the lowest percentage of international collaboration. Besides from the common research among Serbia – Montenegro – Bosnia and Herzegovina there is no other considerable "internal" collaboration among the other SE European countries.

Table 3. The most prolific authors in the field of tribology in SE Europe

Country	Author	P_{10}	Affiliation
Bulgaria	M. Kandeva	15	Tribology Center, Technical University of Sofia, Sofia
Croatia	J. Deur	10	Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb
Greece	K.D. Bouzakis	14	Mechanical Engineering Department, Aristoteles University of Thessaloniki
	P.G. Nikolakopoulos	10	Department of Mechanical and Aerospace Engineering, Panepistimion Patron, Patra
Romania	A. Tudor	18	Department of Machine Elements and Tribology, University Politehnica of Bucharest, Bucharest
	A. Samuila	14	High Intensity Electric Fields Laboratory, Technical University of Cluj-Napoca, Cluj Napoca
	L. Deleanu	12	Faculty of Mechanical Engineering, Universitatea Dunarea de Jos din Galati, Galati
Serbia	M. Babić	31	Faculty of Engineering, University of Kragujevac, Kragujevac
	S. Mitrović	28	Faculty of Engineering, University of Kragujevac, Kragujevac
	A. Vencl	22	Faculty of Mechanical Engineering, University of Belgrade, Belgrade
Slovenia	M. Kalin	56	Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana
	J. Vižintin	48	Centre for Tribology and Interface Nanotechnology, University of Ljubljana, Ljubljana
	B. Podgornik	34	Institute of Metals and Technology Ljubljana, Ljubljana
Turkey	U. Sen	23	Department of Metallurgy and Material Engineering, Sakarya Universitesi, Sakarya
	H. Unal	22	Faculty of Technology, Sakarya Universitesi, Sakarya
	Y.G. Şahin	22	Department of Physics, Ataturk Universitesi, Erzurum

Table 4. The most cited articles in the field of tribology for each SE Europe country

Country	Authors and article	C_s
Bulgaria (BGR)	Kelly P.J., Li H., Whitehead K.A., Verran J., Arnell R.D., Iordanova I., A study of the antimicrobial and tribological properties of TiN/Ag nanocomposite coatings, *Surface and Coatings Technology*, 204 (6-7), 1137-1140, 2009	49
	Denkov N.D., Tcholakova S., Golemanov K., Ananthapadmanabhan K.P., Lips A., Viscous friction in foams and concentrated emulsions under steady shear, *Physical Review Letters*, 100 (13), 138301, 2008	47
	Kelly P.J., Li H., Benson P.S., Whitehead K.A., Verran J., Arnell R.D., Iordanova I., Comparison of the tribological and antimicrobial properties of CrN/Ag, ZrN/Ag, TiN/Ag, and TiN/Cu nanocomposite coatings, *Surface and Coatings Technology*, 205 (5), 1606-1610, 2010	39
Croatia (HRV)	Matuško J., Petrović I., Perić N., Neural network based tire/road friction force estimation, *Engineering Applications of Artificial Intelligence*, 21 (3), 442-456, 2008	26
	Królczyk G., Legutko S., Raos P., Cutting wedge wear examination during turning of duplex stainless steel, *Tehnički vjesnik – Technical Gazette*, 20 (3), 413-418, 2013	15
	Horvat Z., Filipovic D., Kosutic S., Emert R., Reduction of mouldboard plough share wear by a combination technique of hardfacing, *Tribology International*, 41 (8), 778-782, 2008	14
Cyprus (CYP)	Polychronopoulou K., Rebholz C., Baker M.A., Theodorou L., Demas N.G., Hinder S.J., Polycarpou A.A., Doumanidis C.C., Böbel K., Nanostructure, mechanical and tribological properties of reactive magnetron sputtered TiC$_x$ coatings, *Diamond and Related Materials*, 17 (12), 2054-2061, 2008	29
	Polychronopoulou K., Baker M.A., Rebholz C., Neidhardt J., O'Sullivan M., Reiter A.E., Kanakis K., Leyland A., Matthews A., Mitterer C., The nanostructure, wear and corrosion performance of arc-evaporated CrB$_x$N$_y$ nanocomposite coatings, *Surface and Coatings Technology*, 204 (3), 246-255, 2009	15
Greece (CRC)	Gyftou P., Stroumbouli M., Pavlatou E.A., Asimidis P., Spyrellis N., Tribological study of Ni matrix composite coatings containing nano and micro SiC particles, *Electrochimica Acta*, 50 (23), 4544-4550, 2005	92
	Gertzos K.P., Nikolakopoulos P.G., Papadopoulos C.A., CFD analysis of journal bearing hydrodynamic lubrication by Bingham lubricant, *Tribology International*, 41 (12), 1190-1204, 2008	70
	Lekka M., Kouloumbi N., Gajo M., Bonora P.L., Corrosion and wear resistant electrodeposited composite coatings, *Electrochimica Acta*, 50 (23), 4551-4556, 2005	62
Romania (ROM)	Márton L., Lantos B., Modeling, identification, and compensation of stick-slip friction, *IEEE Transactions on Industrial Electronics*, 54 (1), 511-521, 2007	72
	Berradja A., Bratu F., Benea L., Willems G., Celis J.-P., Effect of sliding wear on tribocorrosion behaviour of stainless steels in a Ringer's solution, *Wear*, 261 (9), 987-993, 2006	45
	Benea L., Wenger F., Ponthiaux P., Celis J.P., Tribocorrosion behaviour of Ni-SiC nano-structured composite coatings obtained by electrodeposition, *Wear*, 266 (3-4), 398-405, 2009	36
Serbia (SRB)	Cvijović-Alagić I., Cvijović Z., Mitrović S., Panić V., Rakin M., Wear and corrosion behaviour of Ti-13Nb-13Zr and Ti-6Al-4V alloys in simulated physiological solution, *Corrosion Science*, 53 (2), 796-808, 2011	57
	Vencl A., Bobic I., Arostegui S., Bobic B., Marinković A., Babić M., Structural, mechanical and tribological properties of A356 aluminium alloy reinforced with Al$_2$O$_3$, SiC and SiC + graphite particles, *Journal of Alloys and Compounds*, 506 (2), 631-639, 2010	27
	Aleksendrić D., Neural network prediction of brake friction materials wear, *Wear*, 268 (1-2), 117-125, 2010	23
Slovenia (SVN)	Jurkovic J., Korosec M., Kopac J., New approach in tool wear measuring technique using CCD vision system, *International Journal of Machine Tools and Manufacture*, 45 (9), 1023-1030, 2005	67
	Leskovšek V., Kalin M., Vižintin J., Influence of deep-cryogenic treatment on wear resistance of vacuum heat-treated HSS, *Vacuum*, 80 (6), 507-518, 2006	61
	Nolan D., Huang S.W., Leskovsek V., Braun S., Sliding wear of titanium nitride thin films deposited on Ti-6Al-4V alloy by PVD and plasma nitriding processes, *Surface and Coatings Technology*, 200 (20-21), 5698-5705, 2006	57
Turkey (TUR)	Ocak H., Loparo K.A., Discenzo F.M., Online tracking of bearing wear using wavelet packet decomposition and probabilistic modeling: A method for bearing prognostics, *Journal of Sound and Vibration*, 302 (4-5), 951-961, 2007	116
	Kılıçkap E., Çakır O., Aksoy M., İnan A., Study of tool wear and surface roughness in machining of homogenised SiC-p reinforced aluminium metal matrix composite, *Journal of Materials Processing Technology*, 164-165, 862-867, 2005	72
	Kök M., Özdin K., Wear resistance of aluminium alloy and its composites reinforced by Al$_2$O$_3$ particles, *Journal of Materials Processing Technology*, 183 (2-3), 301-309, 2007	63

Table 5. The most preferred journals for publication by tribologists from SEE countries

Country (P$_{10}$)	Journal	Number of articles
BIH (16)	Journal of the Balkan Tribological Association	3
	Tribology in Industry	3
	Procedia Engineering	2
BGR (75)	Journal of the Balkan Tribological Association	17
	Tribology in Industry	4
	Aip Conference Proceedings	4
HRV (81)	Tehnički vjesnik – Technical Gazette	10
	Metalurgija (Metallurgy)	7
	Vehicle System Dynamics	5
CYP (11)	Diamond and Related Materials	2
GRC (191)	Surface and Coatings Technology	10
	Tribology International	10
	Wear	10
MDA (21)	Surface Engineering and Applied Electrochemistry	9
MNE (11)	Thermal Science	4
ROM (457)	Applied Mechanics and Materials	37
	Metalurgia International	36
	Journal of the Balkan Tribological Association	27
SRB (200)	Tribology in Industry	47
	Journal of the Balkan Tribological Association	33
	Tehnički vjesnik – Technical Gazette	8
SVN (195)	Wear	18
	Tribology International	13
	Strojniški vestnik – Journal of Mechanical Engineering	10
TUR (1084)	Materials and Design	90
	Wear	54
	Industrial Lubrication and Tribology	37

Table 6. Collaborations between SEE countries with other countries in the field of tribology

Country	Collaboration Country*		
Bosnia and Herzegovina (16)	Serbia (8)	Croatia (2)	Slovenia (1)
Bulgaria (75)	Germany (15)	FYROM (5)	USA (5)
Croatia (81)	Serbia (14)	USA (13)	Germany (7)
Cyprus (11)	USA (10)	Greece (4)	UK (3)
FYROM (8)	Bulgaria (5)	Poland (1)	–
Greece (191)	Germany (20)	UK (14)	USA (14)
Moldova (21)	Belgium (5)	Lithuania (5)	France (1) Israel (1)
Montenegro (11)	Serbia (9)	Croatia (1)	USA (1)
Romania (457)	France (47)	Germany (15)	Portugal (15)
Serbia (200)	Croatia (14)	Montenegro (9)	Bosnia and Herzegovina (8)
Slovenia (195)	Spain (15)	Austria (13)	France (8)
Turkey (1084)	USA (57)	Germany (16)	Iran (12)

*Numbers in brackets indicate number of publications

4.4 General remarks and limitations

Bibliometric indicators are increasingly being used as a tool for research performance monitoring and/or evaluation. Bibliometric methods are quantitative by nature, but are used to make pronouncements about qualitative features [2]. The authors are aware of the fact that the use of bibliometric techniques to assess the publication efforts of scholars is far from not being controversial. They know that there is a burgeoning debate about the convenience of the use of citation indicators; for the limitations and undesirable effects of the citation system see [31]. Moreover, they wish to emphasize the fact that publication-related activities is only one output in the knowledge transfer process of Higher Education Institutions (HEIs) [32]. However, they do believe that, in spite of the inherent limitations of bibliometrics, the viability of the adopted method for monitoring the scientific performance is quite effective, especially when limited resources are available.

5. CONCLUSIONS

In the present study, bibliometric indices were used to describe scientific activity in the field of tribology in the

It should be noted that the share of internationally collaborative publications in the total scientific output of a country can be considered as first indication of the extent to which researchers in a country cooperate with colleagues outside their own country. This indicator can be seen as a measure of the international orientation of a country. On the other hand the complementary percentage, i.e. the share of non-internationally collaborative publications, is an indicator of the size of a country's own scientific basis and of its scientific independence; see for details [20].

13 Southeastern Europe countries during the last decade. Based on the authors' knowledge, this is the first article to analyze the quantity and quality of tribology-based research from this region. The research output is presented by using indices such as the total number of publications and citations as well as the *h*-index and the average number of citations per publication.

The total publications found in Scopus® between 2005 and 2014 showed a yearly increase. Most countries experienced increases in the absolute number of documents produced in the field of tribology over time. Furthermore, the current study showed low research output in some countries. Turkey has by far the largest publication output of the SE European countries, followed by Romania. Then, with almost equal P_{10} comes Serbia and Greece.

As far as the efficiency and the impact of research is concerned Slovenia is first with an index value "citations per publication" $c_{avs10} = 9.9$. Greece and Turkey follows with values in the range of 6.3. The average citation rate for publications from SEE countries was 5.3 citations per article.

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ТРИБОЛОГИЈА У ЈУГОИСТОЧНОЈ ЕВРОПИ: БИБЛИОМЕТРИЈСКА СТУДИЈА

Николаос М. Ваксеванидис, Александар Венцл, Пандора Псилаки

У последњих неколико година се појавио известан, али растући, број радова који приказују и/или анализирају научно-истраживачки рад у оквиру појединих географских региона, у одређеној научној области. У овим радовима се примењују тзв. библиометријске методе на основу којих се врши процена научно-истраживачког доприноса појединачних земаља региона. У овом раду су приказани резултати научно-истраживачког рада у земљама југоисточне Европе, у области трибологије. Резултати су приказани помоћу следећих библиометријских параметара: укупан број публикација и цитата, *h*-индекс и просечан број цитата по публикацији. Овакво истраживање, према сазнањима аутора, до сада није спроведено.