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**SEARCHING FOR THEORETICAL CONCEPTS IN A SPECIFIC SCIENTIFIC  
DISCIPLINE: AN APPROACH BASED ON TERMINOLOGICAL FLOWS**

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Abstract: Tribology is a very interdisciplinary field. Tribology, lubrication and surface technology are key technologies and with utmost importance for all branches in industrial production. Innovations in these technologies require the best possible fundamental understanding of the complex processes taking place at the interfaces of a tribological system. Therefore the XTribology centre in AC<sup>2</sup>T Research GmbH is confronted with the challenges of a highly interdisciplinary field. In previous works, we developed an approach based on the analysis of the evolution of a specific scientific discipline by means of studying its terminology extracted from related specialized international literature. In this work we investigate the very important subfield of Tribology “the mechanism of wear”. The scientific basis is still explored. Besides general bibliometric aspects the “theories” and its connection to experiments are of specific interest.

Keywords: Tribology; Mechanism of wear; Friction; Lubrication; Bibliometrics; Theory; Experiments

## Introduction

Tribology is the science and engineering of interacting surfaces in relative motion, including the study and application of the principles of friction, lubrication and wear. Tribology, lubrication and surface technology are key technologies and with utmost importance for all branches in industrial production. Innovations in these technologies require the best possible fundamental understanding of the complex processes taking place at the interfaces of a tribological system. Therefore the XTribology centre in AC<sup>2</sup>T Research GmbH is confronted with the challenges of a highly interdisciplinary field.

In previous works, we developed an approach based on the analysis of the evolution of a specific scientific discipline by means of studying its terminology extracted from related specialized international literature. After the identification of the constituent sub-fields of the discipline, our methodology operates a global characterisation of their related terminology allowing comparing their evolution and studying their relationships defined in terms of terminology exchanges. The results are presented under the shape of a web server to facilitate their assessment by scientific experts.

In this work we investigate the very important subfield of Tribology “the mechanism of wear”. The scientific basis is still explored. There is still to be done much in the research for wear and its bridges to its applications, which entails a high potential of innovation. The work is guided by the following research questions:

- Where is the focus of research in “mechanism of wear” currently on?
- What are the contemporary and established theories for describing the “mechanism of wear”?
- Which bridges can be identified between the experimental methods and the theories?

From the methodology point of view, the in-depth analysis of the results made available on a Tribology-devoted web server was able, in a general way, to contribute to a better understanding of the evolution of the studied core discipline and its relationships in a multidisciplinary context. In this work, we are particularly interested on the development of an analytical approach allowing identifying the links privileged between the Tribology and the sub-fields supplying its needed theoretical background.

In the first part of this contribution a bibliometric analysis of the field “Machine components. Friction, wear, lubrication” is presented, where the search strategy, general aspects of the publication activities, and connections to the activities in Austria and AC<sup>2</sup>T Research GmbH is discussed.

The second part deals with a detailed investigation of the content of the data set with a specific focus on theories and its connection to experiments.

### **Bibliometric analysis of the “Machine components. Friction, wear, lubrication” field**

We focus on the international scientific literature published from 2001 to nowadays, dealing with the field “Machine components. Friction, wear, lubrication” and indexed in the PASCAL bibliographic database.

This information source provides broad multidisciplinary coverage of scientific publications and contains at the present time about 20 million of bibliographic records from the analysis of the scientific and technical international literature published predominantly in journals and conference proceedings.

The corpus is obtained from the following query:

*(tribolog\* ou nanotribolog\* ou microtribolog\* ou tribofilm\* ou tribocorrosi\* ou triboelectricit\* ou mechanoluminescen\* ou triboluminescen\* ou triboch?mi\* ou tribomet\* ou tribosens\* ou nanolubrifcation ou cc=001d11g06 ou cc=001d12d02 ou cc=001b80a40p ou (mc="usure" et (wear\* ou friction ou orthop\* ou biomec\*)) ou mc=lubrification ou (mc="contact mecanique" et mc=frottement) ou sn="1545-858x" ou sn="0301-679x" ou sn="0036-8792" ou sn="0724-3472" ou sn="1045-7828" ou sn="0742-4787" ou sn="0024-7154" ou sn="0043-1648" ou sn="1040-2004") et (dp=2001 ou dp=2002 ou dp=2003 ou dp=2004 ou dp=2005 ou dp=2006 ou dp=2007 ou dp=2008 ou dp=2009 ou dp=2010 ou dp=2011)et(cc=001d12d\*)*

The obtained result is a corpus of 9,454 records representing the worldwide production of the field “Machine components. Friction, wear, lubrication” in the PASCAL database for the considered period.

This corpus is analysed by means of bibliometric analysis tools in order to highlight some characteristics of the worldwide production: annual productivity, journals, authors, affiliation.

In parallel, we examine the position of the Austrian production in the international scientific landscape and, more finely, we focus on the AC<sup>2</sup>T literature characteristics in the Austrian context. In this study, the Austrian production is determined from the worldwide corpus by searching for the bibliographic references containing at least one author whose country of affiliation is Austria. Also, the AC<sup>2</sup>T production is identified by a second filtering retaining exclusively the bibliographic references having at least one occurrence of this institute in their list of affiliation addresses.

#### **Annual productivity**

In the considered period (2001-2011), the international production is represented by 9,454 records, the Austrian one by 87 records and the AC<sup>2</sup>T one by 34 records. The Austrian production represents 1% of the worldwide one. The AC<sup>2</sup>T production corresponds to 0.4% of the international one and 39% of the national production.

In the figures 1, 2 and 3, we present the annual distribution of, respectively, the worldwide, the Austrian, and the AC<sup>2</sup>T productions.

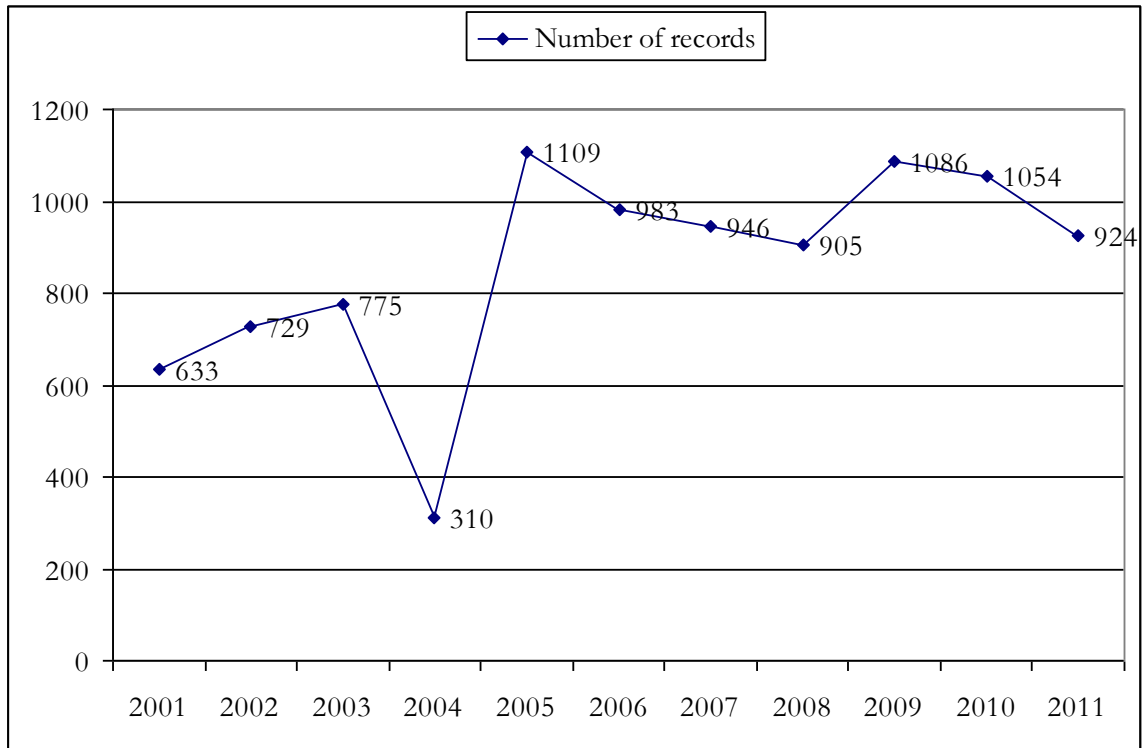


Figure 1. Distribution by year (2001-2011) of the international production in the field “Machine components. Friction, wear, lubrication”

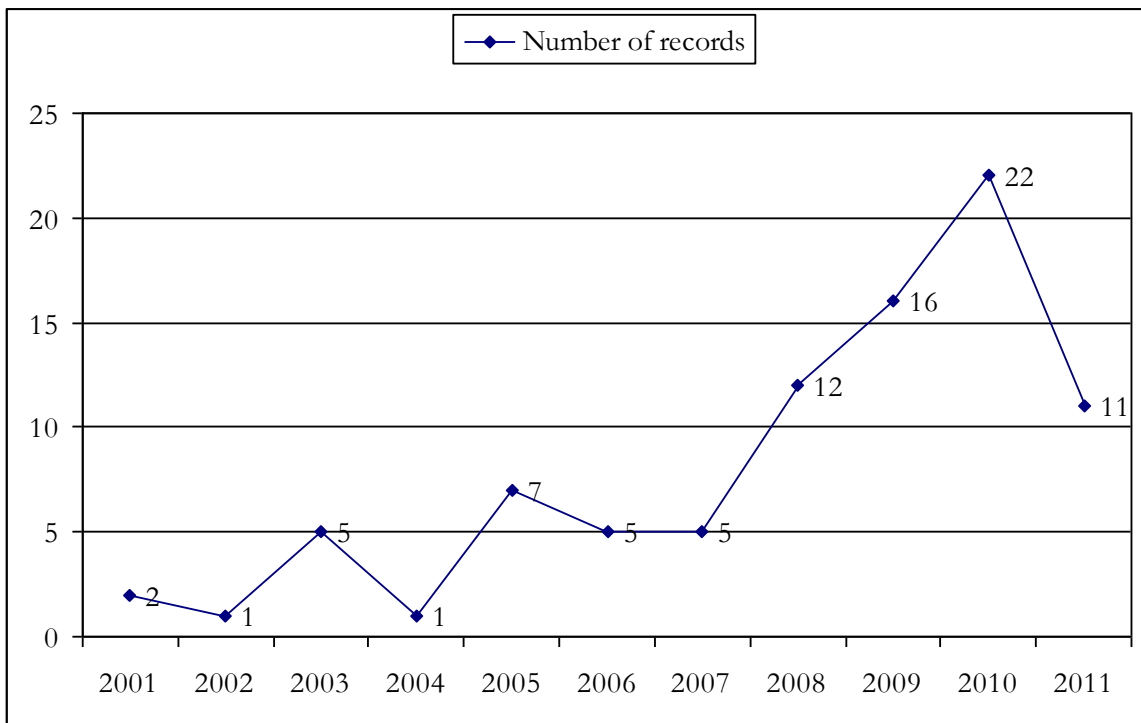


Figure 2. Distribution by year (2001-2011) of the Austrian production in the field “Machine components. Friction, wear, lubrication”

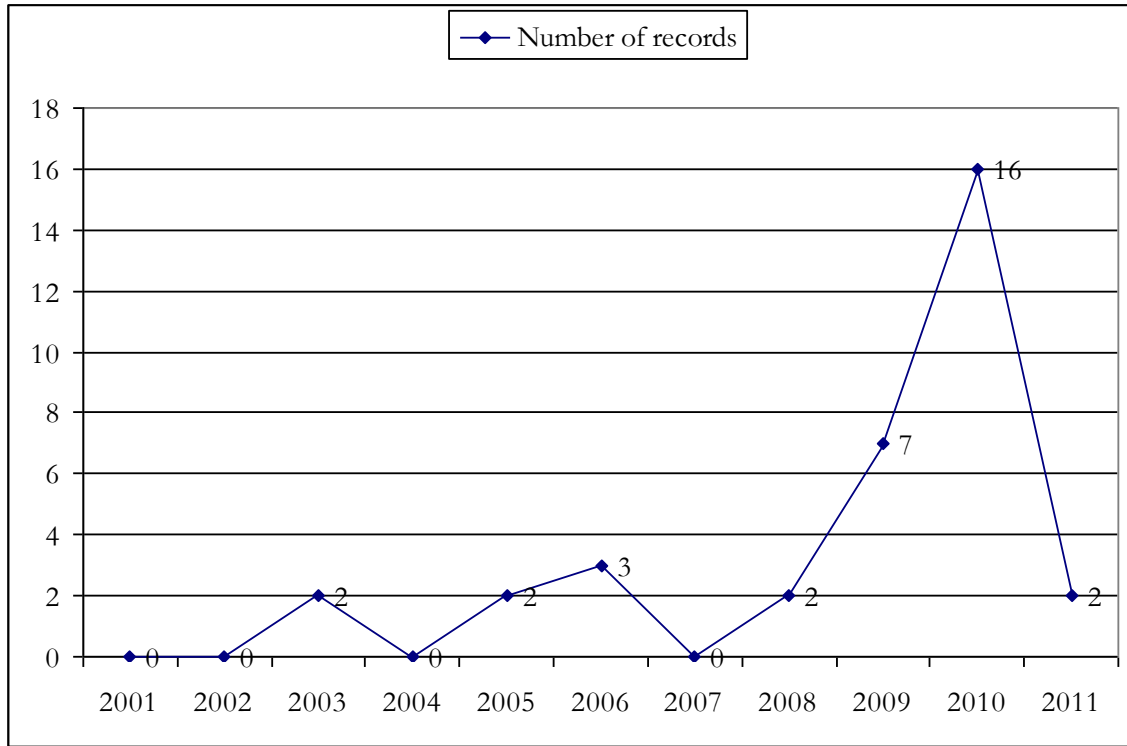


Figure 3. Distribution by year (2001-2011) of the AC<sup>2</sup>T production in the field “Machine components. Friction, wear, lubrication”

A first observation of the Figures 1, 2 and 3 shows a significant decrease of the production in 2004. This artefact is due to a modification of the PASCAL database coverage and not to a real drop off of the field production. On the other hand, let us remark that the annual production of the 2011 year is not yet complete and, by consequence, it looks anormally weak in Figures 1, 2 and 3.

This is the reason we do not take into account the values of these years in the following analysis of the annual productivity of the field “Machine components. Friction, wear, lubrication”.

While international literature presents a quite regular production since 2005, we can observe a clear progress of the Austrian production since 2007. The same observation can be made for the AC<sup>2</sup>T which shows a spectacular progression since 2008. Particularly, we can also notice that in 2010 the AC<sup>2</sup>T production represents more than the half of the Austrian one.

### Publishing types

Classically, the diffusion of research results is made either by their publication in journals or by their presentation to peers in conferences. In the field “Machine components. Friction, wear, lubrication” the part of communications presented in conferences is quite high: 27%, 43% and 53 %, respectively, for international, Austrian and AC<sup>2</sup>T productions. This would lead us to affirm that this scientific community considers very important to exchange on their outcomes in the

direct interactive context that conferences bring. The particularly high rate of AC<sup>2</sup>T could be the sign of the important attachment of this institute to this type of exchanges.

### Interdisciplinarity of the field

The data set is extracted from the PASCAL database that is specifically adapted to point out the interdisciplinarity of a field. Indeed, its records benefit from an indexing by both keywords and multiple thematic categories of a disciplinary classification scheme assigned to each individual publication, either manually by scientific experts or automatically, based on a content analysis. This category multiplicity allows us to identify the interactions between different disciplines by considering that, if a reference gets different thematic categories, this means that the content of the related document deals with different disciplines.

In the figures 4, 5 and 6, we present respectively the repartition of the international, the Austrian, and the AC<sup>2</sup>T productions in the field “Machine components. Friction, wear, lubrication” by considering their bibliographic references dealing also with other disciplines. They are, in order to facilitate the reading, organized in 13 different disciplinary sets that we detail in table 1.

**Table 1. List of the 13 disciplines in relation with “Machine components. Friction, wear, lubrication”**

ID number	Discipline	Percentage of records		
		International	Austria	AC <sup>2</sup> T
1	Mathematics	0.36	0.00	0.00
2	General physics. Condensed matter. Materials science	5.89	0.00	0.00
3	Mechanics of solids	<b>17.54</b>	<b>22.99</b>	<b>14.71</b>
4	Surfaces and interfaces	0.60	2.30	0.00
5	Chemistry	0.75	0.00	0.00
6	Energy. Electronics. Polymers	<b>14.45</b>	4.60	2.94
7	Metals, metallurgy	<b>13.08</b>	<b>11.49</b>	<b>20.59</b>
8	General mechanical engineering. Industrial metrology	5.03	3.45	5.88
9	Drives	<b>11.55</b>	<b>10.34</b>	<b>8.82</b>
10	Engines. Pumps. Steel design	2.51	3.45	2.94
11	Precision engineering	1.11	0.00	0.00
12	Universe science	0.12	0.00	0.00
13	Life science	2.48	2.30	5.88

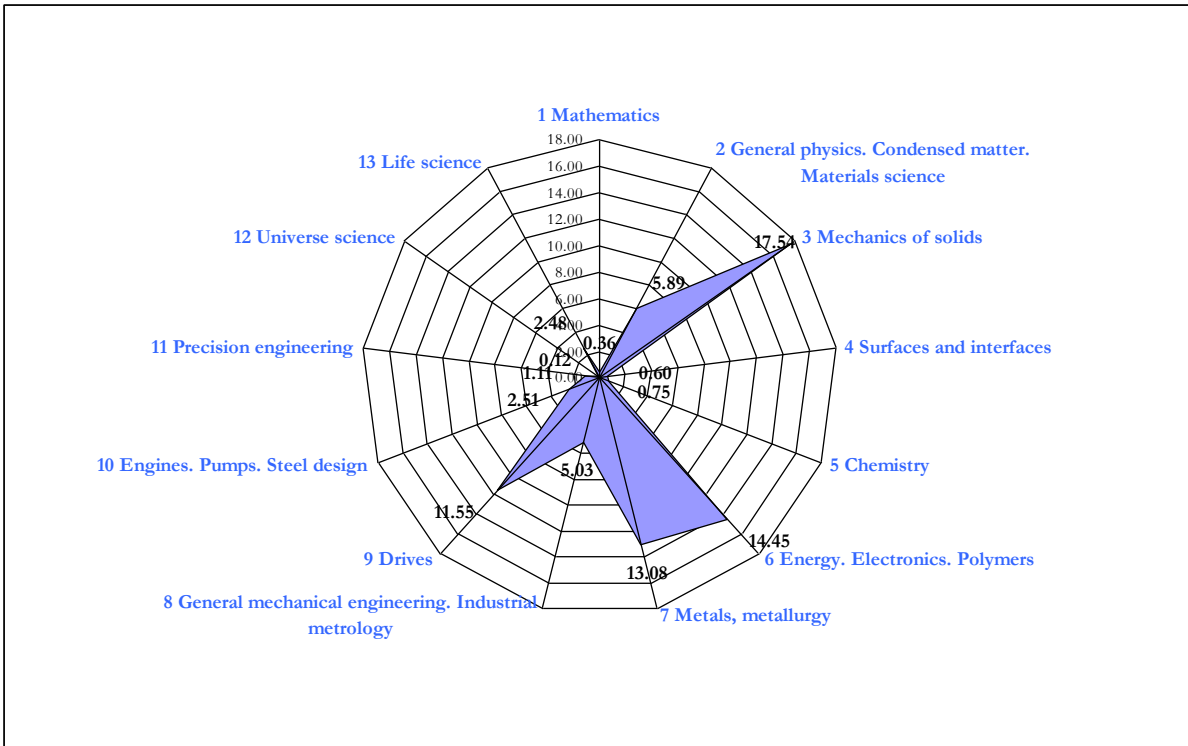


Figure 4. Repartition of the international production in the 13 disciplines in relation with the field “Machine components. Friction, wear, lubrication”

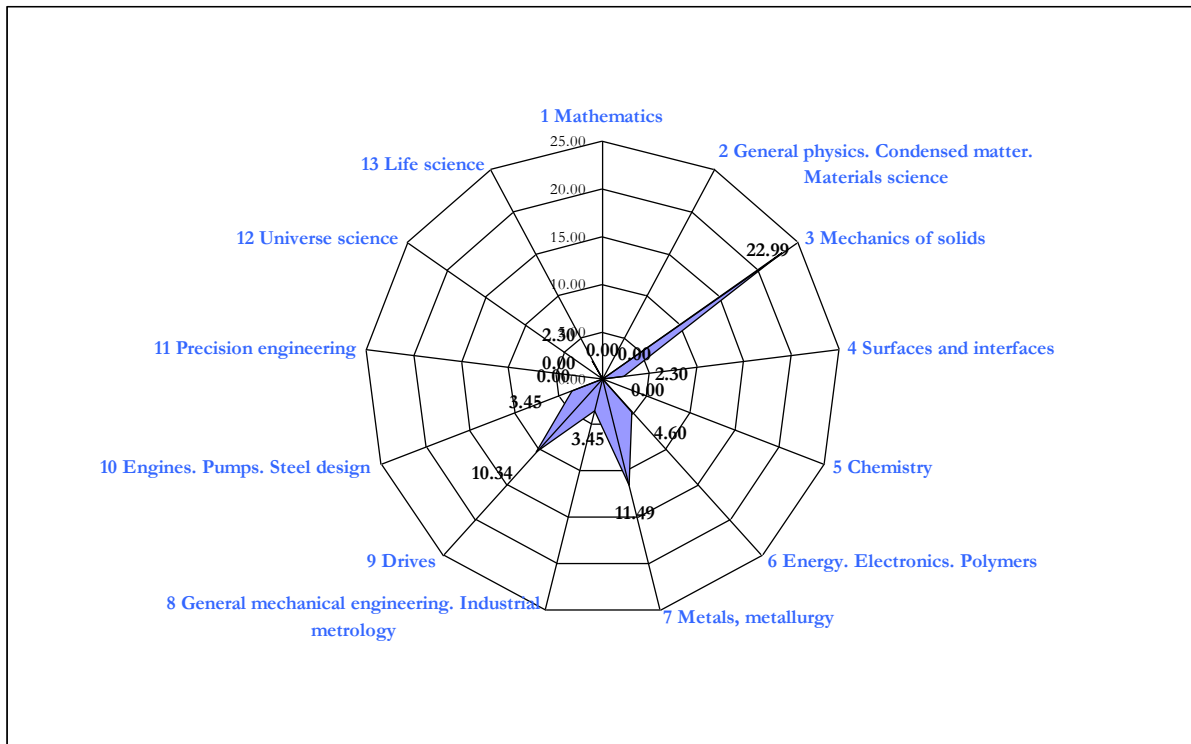


Figure 5. Repartition of the Austrian production in the 13 disciplines in relation with the field “Machine components. Friction, wear, lubrication”



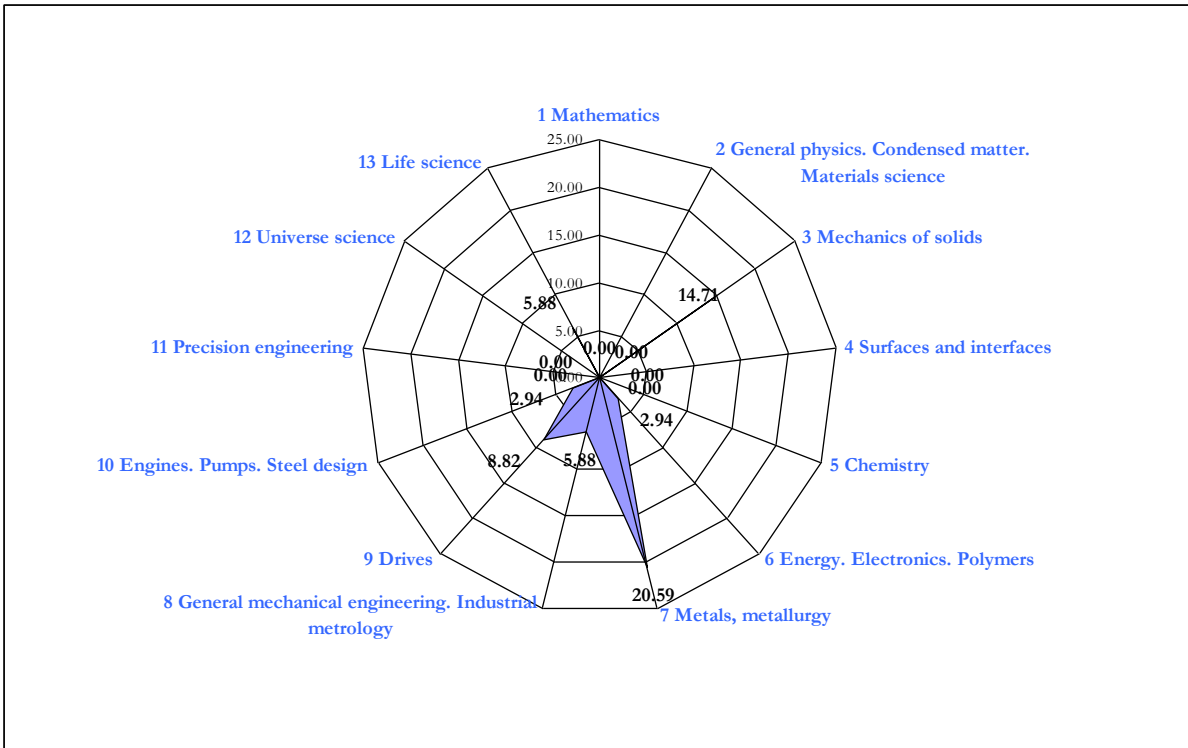


Figure 6. Repartition of the AC<sup>2</sup>T production in the 13 disciplines in relation with the field “Machine components. Friction, wear, lubrication”

We can observe that the international literature in the field “Machine components. Friction, wear, lubrication” deals especially with “Mechanics of solids”, as well as with Engineering sciences like “Energy, Electronics and Polymers”, and finally with “Metals, metallurgy” and “Drives”.

Austrian production focuses for a great part on “Mechanics of solids”, and then on “Metals, metallurgy” and “Drives”, showing that studies are conducted in the field of fundamental sciences as well as in more applied sciences. The AC<sup>2</sup>T publications concentrate mainly on “Metals, metallurgy”, and to a lesser extent on “Mechanics of solids” and on “Drives”, pointing out a more applied research oriented toward Engineering sciences.

### Affiliations

Bibliometric analyses launched on countries of affiliation appearing in publications of both Austria and the AC<sup>2</sup>T in the field “Machine components. Friction, wear, lubrication” show important scientific collaborations with Germany and with India. On the national level, 18.4 % of publications are written together with German scientists while 6.9 % of the analysed records concern collaborations with India. For the AC<sup>2</sup>T, the trend is inverted in the sense that its largest number of collaborations occurs with Indian laboratories in 17.6 % of records. Germany follows with 11.8 % of publications.

Furthermore, a detailed analysis of the Austrian affiliations in the obtained corpus, confirms the very important position of the Austrian Center of Competence for Tribology in the “Machine components. Friction, wear, lubrication” field. Another important actor is the Department of Physical Metallurgy and Materials Testing in the University of Leoben, showing that metallurgy

seems to be a significant area of tribology application fields in Austria. This confirms the precedent observation made in the interdisciplinarity study.

### Journals

In the tables 2, 3 and 4, we present the top journals of, respectively, the worldwide, the Austrian, and the AC<sup>2</sup>T productions.

**Table 2. The six top journals of the worldwide production in the field “Machine components. Friction, wear, lubrication”**

Title	Percentage of records
Wear	36.67
Tribology international	15.98
Journal of tribology	10.17
Tribology transactions	7.20
Tribologie und Schmierungstechnik	5.13
Tribology & lubrication technology	4.20

**Table 3. The six top journals of the Austrian production in the field “Machine components. Friction, wear, lubrication”**

Title	Percentage of records
Wear	32.18
Tribologie und Schmierungstechnik	31.03
Tribology international	24.14
Vehicle System Dynamics	3.45
Journal of tribology	2.30
Thin solid films	2.30

**Table 4. The four journals of the AC<sup>2</sup>T production in the field “Machine components. Friction, wear, lubrication”**

Title	Percentage of records
Tribology international	47.06
Tribologie und Schmierungstechnik	38.24
Wear	11.77
Tribology transactions	2.94

The first thing which we can bring to light when analysing the three tables is the important position of the journal in German language, Tribologie und Schmierungstechnik, in both the Austrian and the AC<sup>2</sup>T corpus. Indeed, in these two cases, it ranks second while it is in fifth place in the international literature.

The other observation we can make about the national production is that Austrian researchers, although being interested in the fundamental aspects of the field “Machine components. Friction, wear, lubrication”, also focuses on particular applications, as evidenced by the presence of the periodicals “Vehicle System Dynamics” and “Thin Solid films”.

## Paper language

In the tables 5, 6 and 7, we present the most frequent languages used in scientific publications in the field “Machine components. Friction, wear, lubrication” of, respectively, the worldwide, the Austrian, and the AC<sup>2</sup>T productions.

**Table 5. The most frequent paper languages of the worldwide production in the field “Machine components. Friction, wear, lubrication”**

Language	Number of records	Percent
English	8887	94,003
German	456	4,823
French	101	1,068
Spanisch	8	0,085
Japanese	3	0,032

**Table 6. The most frequent paper languages of the Austrian production in the field “Machine components. Friction, wear, lubrication”**

Language	Number of records	Percent
English	69	79,31
German	18	20,69

**Table 7. The most frequent paper languages of the AC<sup>2</sup>T production in the field “Machine components. Friction, wear, lubrication”**

Language	Number of records	Percent
English	26	76,471
German	8	23,529

At a first glance, the more the geographic zone is limited, the more the percent of German language in tribology scientific publications becomes important.

For comparison, if we consider the global scientific literature in the same period, we notice that English represents 93% of the paper languages, followed by French with 6%. German comes third with 0.7%.

This analysis confirms the trend observed in the journal ranking.

Can we therefore deduce that the tribology scientific field is an important research area in German speaker countries?

The results obtained in this work by means of bibliometric tools in the field “Machine components. Friction, wear, lubrication” show an increase of the Austrian research activity in this domain.

The interest of Austria for applied fields of tribology, in particular for metallurgy, is highlighted by the analysis of the interdisciplinarity of the field “Machine components. Friction, wear, lubrication” as well as the journal distributions.

Moreover, we evidenced the growing proportion of the AC<sup>2</sup>T annual production in the Austrian landscape in the last years. This point was confirmed by the study of the Austrian affiliations and trends to suggest that the Austrian Center of Competence for Tribology is at the forefront of Austrian research in the field “Machine components. Friction, wear, lubrication”.

**The content in connection to the term “theory”**

For a more detailed analysis we consider all terms<sup>1</sup> in the frequency interval of [20; 999]. The frequency of a term is given by its occurrence in an article. It is counted once if it occurs at least once in an article. The interval [20; 999].was chosen because of the following considerations. Terms with a higher frequency are much more general such as “tribology” with a frequency of 8,006, or “experimental study” of a frequency of 4,276, or “wear” with a frequency of 1,527 for example. Terms with a low frequency deal possibly with new ideas or aspects far away from an established research topic, or are spelling mistakes.

The most visible terms of the considered field “Machine components. Friction, wear, lubrication” are presented in the following Table 8 (12 terms with the highest frequency in the considered interval):

**Table 8. Most visible terms in the considered field.**

<b>Keyword</b>	<b>Frequency</b>
Rough surface	992
Lubrication	947
Scanning electron microscopy	923
Lubricating oil	914
Roughness	908
Dry friction	889
Metal	823
Abrasive wear	813
Wear rate	792
Sliding friction	727
Sliding wear	704
Contact stress	700

Which terms occur the first time in 2011? These terms indicate the current research topics or emerging topics.

**Table 9. Terms with a frequency higher than 1 and the first time in 2011.**

Documentation
Extract
Lead sulfide
Railway industry
Recovery
Springback

<sup>1</sup> Term or keyword or descriptor denote main aspects of an article, and describe the matter of the article very generally.

The following titles (all from 2011 as in Table 9 shown) deal with the terms in table 9:

- Documentation
  - *Documentation of tool wear progress in the machining of nodular ductile iron with silicon nitride-based ceramic tools*
  - *Experimental surface contact fatigue failure analysis of a hypoid pinion used in differential system of a truck*
- Extract
  - *Harmonic Wavelet Packet Analysis of Friction-Induced Vibration*
  - *A review: plant extracts and oils as corrosion inhibitors in aggressive media*
- Lead sulfide
  - *Friction and wear behaviour of bacterial cellulose against articular cartilage*
  - *Tribocorrosion behavior of CoCrMo alloy for hip prosthesis as a function of loads: A comparison between two testing systems*
- Railway industry
  - *Influence of track conditions and wheel wear state on the loads imposed on the infrastructure by railway vehicles*
  - *A study of rolling contact fatigue crack growth in U75V and U71 Mn rails*
- Recovery
  - *Surface Defect Generation and Recovery in Cold Rolling of Stainless Steel Strips*
  - *Gap control for near-dry EDM milling with lead angle*
- Springback
  - *Elastoplastic Stress Analysis and Residual Stresses in Cylindrical Bar Under Combined Bending and Torsion*
  - *Evaluation of lubricants for electrically-assisted forming*

### **The term “theory”**

Now we investigate especially the term “theory” and its co-terms.

The term “theory” occurs in 588 articles (either in the title, in the abstract, or as a descriptor/keyword), which means in 6.22% of the data set. If we consider only the descriptor field, we get 154 articles with “theory” as a descriptor/keyword, which is approximately 1.63% of the considered data set. Hence we can say that “theory” seems to play a subordinate role in this technology field.

Remarkable is the fact that the term “theory” occurs only till 2004 in this data set (see figure 7), whereas “theoretical study” also can be found in 2011.

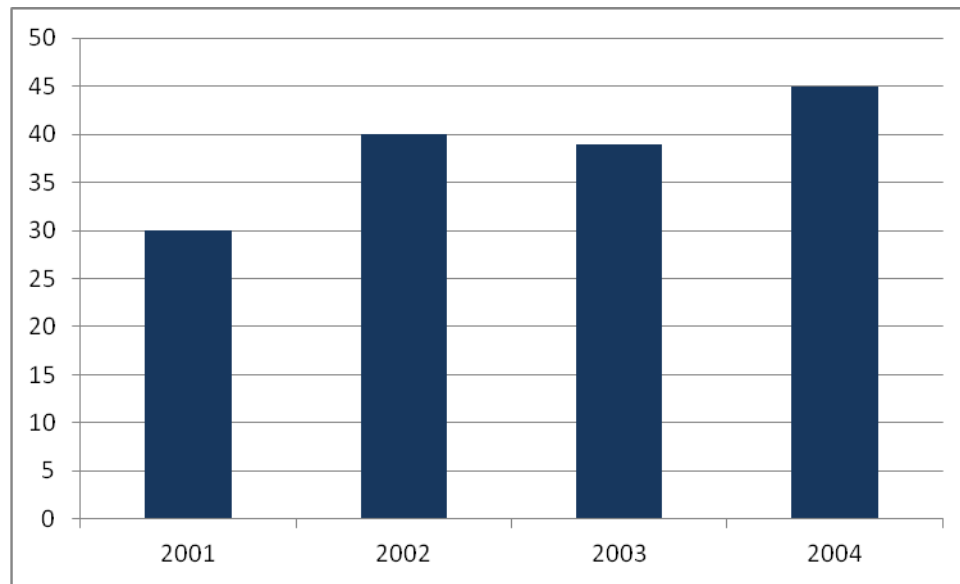


Figure 7. Number of articles with the keyword “theory” over all considered years.

Looking for specific theories in this data set (with “theory” in the descriptor field) we get the following theories and titles:

- A simple elastic model is used to describe the elastic deformation of the bearing liner in the article *The effects of surface irregularities on the performance characteristics of flexible finite journal bearings lubricated with couple stress fluids* (2002)
- Approximation theory in
  - *Soot Characterisation and Diesel Engine Wear* (2004)
  - *Steady motion of a drop along a liquid interface* (2003)
  - *Efficient parallel numerical solver for the elastohydrodynamic Reynolds-Hertz problem* (2001)
- Constraint theory in
  - *Optimization of set-up conditions for stability of the centerless grinding process* (2004)
  - *Multidirectional compliance and constraint for improved robotic deburring. Part 1: Improved positioning* (2001)
- Control Theory in *Design and implementation of command and friction feedforward control for CNC motion controllers* (2004)
  - *Designing automotive gear oils for the new millennium* (2002)
- Drainage theory in *A review of drainage and spontaneous rupture in free standing thin films with tangentially immobile interfaces* (2003)
- Fuzzy theory in *Fuzzy synthetic method for life assessment of power transformer* (2004)
- Graph theory in *Analysis of tool and workpiece interaction in diamond turning using graphical analysis of acoustic emission* (2003)
- In the article *The thickness of a marangoni-driven thin liquid film emerging from a meniscus* (2002) the resulting reduced model ... recovers the result of the older theory.

- Kabalnov-Wennerstrom theory (from 1996) in the article *Lubrication in aqueous solutions using cationic surfactants - A study of static and dynamic forces* (2002)
- Lubrication theory in
  - *Friction reduction in low-load hydrodynamic lubrication with a hydrophobic surface* (2007)
  - *Lubrication in aqueous solutions using cationic surfactants - A study of static and dynamic forces* (2002)
  - *Tribology properties of TiCp/ZA43 composite under continuously lubricated sliding condition* (2002)
  - *The effects of surface irregularities on the performance characteristics of flexible finite journal bearings lubricated with couple stress fluids* (2003)
  - *Multidirectional compliance and constraint for improved robotic deburring. Part 2: Improved bracing* (2001)
  - *Particle convection in an evaporating colloidal droplet* (2002)
  - *Particulate flow simulations using lubrication theory solution enrichment* (2002)
  - *Lateral drying in thick films of waterborne colloidal particles* (2011)
  - *Thermal effects in cylindrical journal bearings of high-speed gearboxes* (2003)

The articles with the following titles deal with “theoretical study” (three articles are published in 2011, Four are published before 2008):

- *Hydrodynamic interactions for the measurement of thin film elastic properties, 2011*
- *Terraced spreading of nanofilms under a nonmonotonic disjoining pressure, 2011*
- *Direct verification of the lubrication force on a sphere travelling through a viscous film upon approach to a solid wall, 2011*
- *MODELING OF AN ELASTOMERIC FRICTION DAMPER, 2009*
- *An application of contact melting theory to skates sliding on ice, 2008*

The term “theory” concurs with 138 different terms (out of 1,149 descriptors in the considered data set).

For a detailed analysis the software BibTechMon (Bibliometric Technology Monitoring developed in the department Technology Management of the AIT Austrian Institute of Technology) is applied. This software is based on co-object analysis. In case we consider for instance the keywords because of their common occurrence in articles a node stands for a keyword. Two nodes (keywords) share an edge if they occur in the same article. The strength of an edge is given by a similarity coefficient like the Jaccard coefficient. The “size” of a node is given by the frequency of a keyword, which means the number of articles a considered keyword occurs at least once. This software helps especially in the analysis of the data. Furthermore it presents the network graphs of e.g. keywords.

Figure shows the term “theory” and its co-terms (the coloured ones). The term “theory” is more on the edge of the network in the north east part. This means that this term does not play a

central role in the considered data set. Terms in the centre of the network have often a connection to many other terms and therefore articles. Terms more in the centre occurs in many articles of the considered data set and deal with the main aspects of the investigated data. In our case the term “theory” is on the edge, but it is obvious that “theory” is connected to terms in the centre, as figure 7 shows.

Table 10. Co-terms to « theory » with the highest co-frequency.

co-term	co-occurrence
Experiments	72
Lubrication	49
Lubricants	41
Wear of materials	19
Viscosity	18
Additives	17
Insulating oil	17
Lubricating oils	16
Oxidation	12
Abrasives	11

The term with the highest co-frequency to “theory” is “experiments”, as Table shows. This fact is remarkable, because experts working in this field and familiar with “experiments” think that there are not so many theories which could support the experimental results. We will investigate this problem in more details.

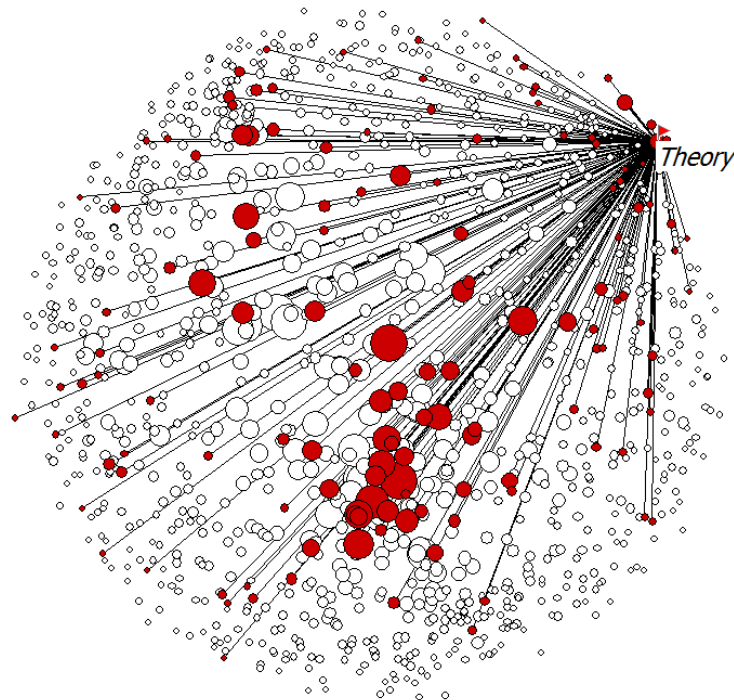


Figure 8. The term “theory” and its co-terms in colour in the network graph.



## Experiment – Theory

In the network graph the terms “experiment” and “theory” connected 228 times, what means that the two terms occurs together in 228 articles out of 9,454, only in 2.41%, a very low percentage. Furthermore the articles are old; the youngest ones are published in 2004.

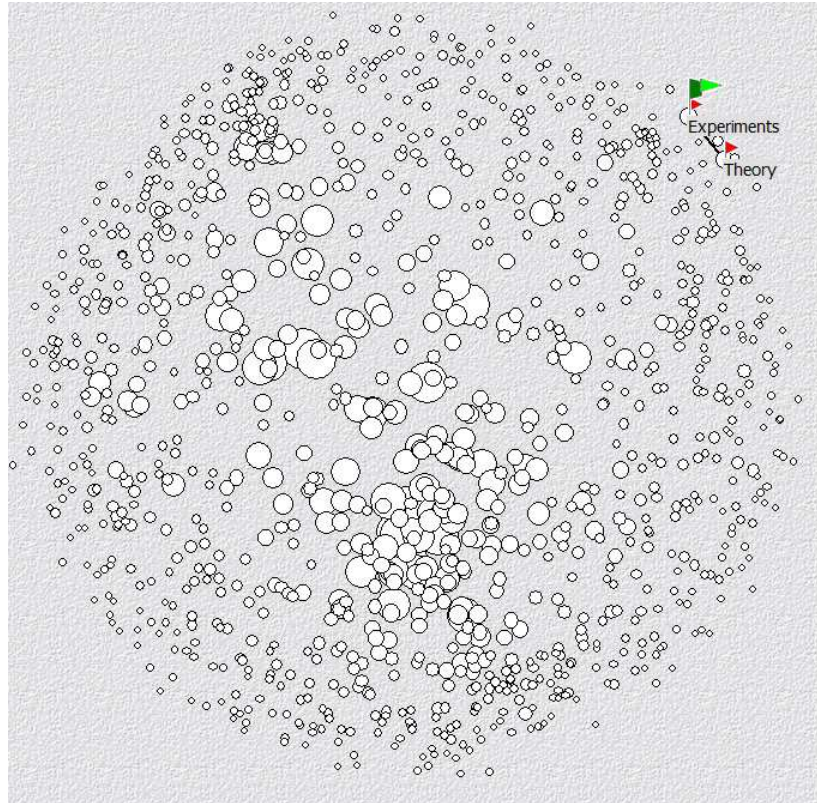


Figure 9. The term “theory” and “experiments” in the network graph at the edge at north east.

Few examples of titles published in 2004 (there are 32 articles in 2004, and these are the youngest ones) which connect experiments and theory are the following once:

- *Mechanism of Boundary Film Formation from n-Hexadecane*
- *Coated gears and bearings optimised for environmentally acceptable lubricants*
- *High-pressure rheology of eight synthetic lubricants based on phase diagrams*
- *The tribological properties of several silahydrocarbons for use in space mechanisms*

### The term “theory” in titles and abstracts

If we search for the term “theory” in titles or abstracts we 389 articles or 4.11% of the publications. That means that it is not necessary also in the field “descriptor”. 30 articles with these conditions are published in 2011. They deal with the following kinds of theories:

- *cyclic plasticity theory;*
- *density functional theory;*
- *dynamics theory of the vehicle;*
- *Erigen s micropolar theory;*
- *Euler s belt theory;*

- *extreme-value theory*;
- *FASTSIM (simplified theory of rolling contact)*;
- *fractal theory*;
- *Group theory*;
- *Hertz Contact Theory*;
- *Hertz theory*;
- *Hopf bifurcation theory*;
- *Irreversible thermodynamic theory*;
- *isomorphic replacement theory in mineralogy and petrology*;
- *Jakobsson-Floberg-Olsson cavitation theory*;
- *Johnson-Kendall-Roberts (JKR) theory*;
- *Kalker's non-Hertzian rolling contact theory*;
- *linear wear theory*;
- *lubrication theory*;
- *M-estimation theory*;
- *rolling contact theory*;
- *rubber friction theory*;
- *Stokes microcontinuum theory*;
- *theory of scale*;
- *three-dimensional theory of elasticity in conjunction with Archard's generalized wear equation*;

These theories are either applied, or the described methodologies are based on these theories.

There are six articles with the term “theory” in the titles in 2011:

- *Development of a Centrifugal Oil Lubricator for Long-Term Lubrication of Spacecraft Attitude Control Systems-Design and Theory (University of South Australia Mawsonlakes Campus)*
- *RCF and wear in theory and practice-The influence of rail grade on wear and RCF (Voestalpine Schienen GmbH, Austria; Austrian Academy of Sciences, Austria; University of Leoben, Austria; RailMeasurement Ltd, Germany; National Research Council Ottawa, Canada; University Clayton, Australia)*
- *A Review of Elasto-Hydrodynamic Lubrication Theory (SKF Engineering & Research Centre Nieuwegein; Universite de Lyon, France)*
- *Thermal Fly-Height Control Slider Instability and Dynamics at Touchdown: Explanations Using Nonlinear Systems Theory (University of California, Berkeley, CA, USA)*
- *Characteristics of micro-gas journal bearings based on kinetic theory (National Cheng Kung University, Taiwan; National Kaohsiung University of Applied Sciences, Taiwan)*
- *A Greenwood & Williamson theory for line contact (University Cambridge, UK; Politecnico di Bari, Italy)*

Experts in this field will observe that these articles and also the mentioned theories above connect experiments and theories. Nevertheless the question is if there is a specific theory / model for describing a rounded technological problem.

Compared with the whole corpus of the data (9,454 records all in all) we see that “theory” is not covered well, is not discussed or developed in this field of investigation. Either there are fewer theories in this field or they are covered with another terminology. Therefore we touch briefly a further term.

### The term “modelling”

“Modelling” occurs in 51 articles. Figure 10 shows that this term occurs each year of the time span in our data set. The frequency alternates firstly and increases slightly finally.

The following titles are examples of the latest research (2011):

- *The Effect of Nonuniform Viscosity on Stagnation Point Pressure*
- *Electrothermomechanical Finite-Element Modeling of Metal Microcontacts in MEMS*
- *Analytical modelling of the three-dimensional steady-state temperature in a bearing ring*
- *Entry, start up and stability effects in visco-plastically lubricated pipe flows*
- *Investigation of the temperature field induced in the process of friction of a composite pad and a homogeneous disc*

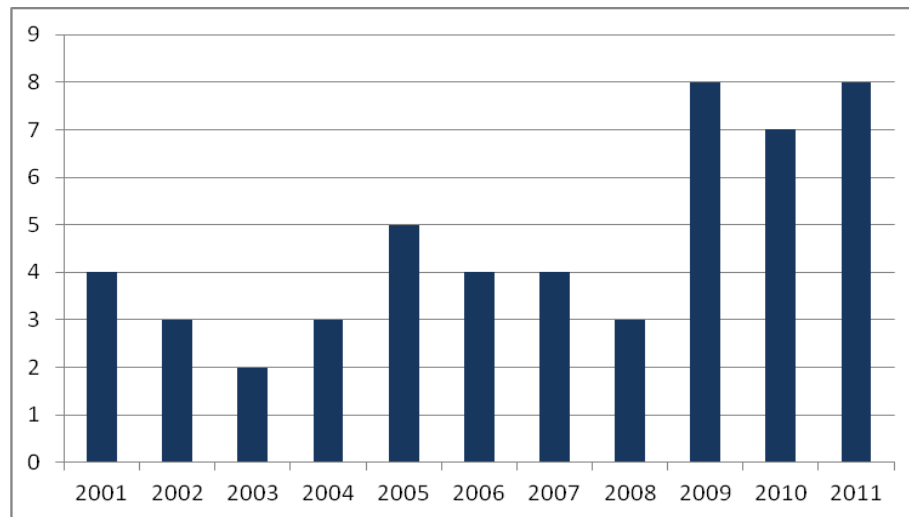


Figure 10. The term “modelling” in the data set over the considered time span.

But as well as “modelling” and “empirical model” are on the edge of the network graph. Hence these topics are side issues. (empirical model has a frequency of 26).

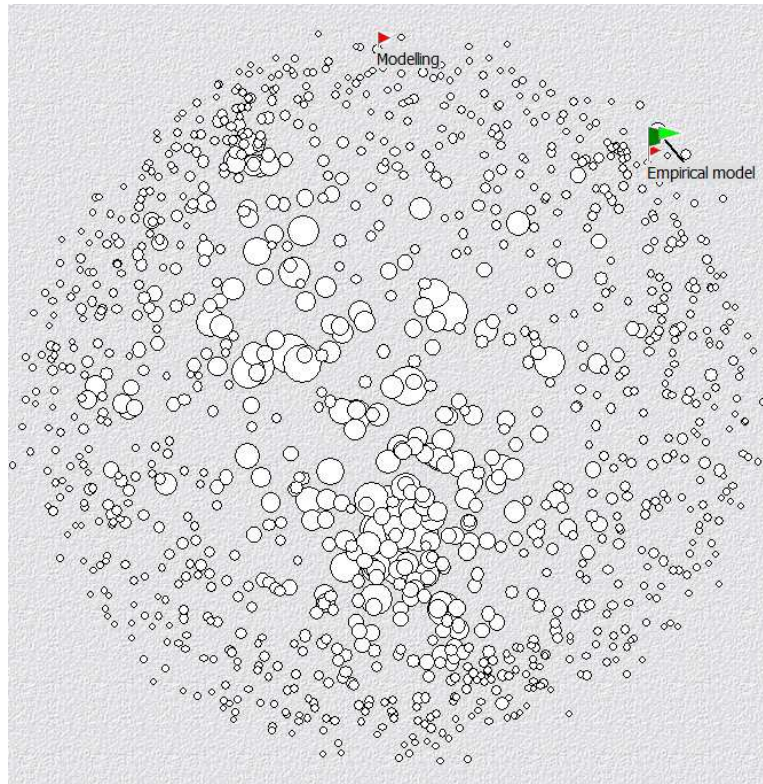


Figure 11. The term “modelling” and “empirical model” in the data set over the considered time span.

## Conclusions

We learn from this study that there is a slight decrease in the productivity worldwide, whereas Austria and especially AC<sup>2</sup>T show an increase in the publication activities in the field of “Machine components. Friction, wear, lubrication“.

The international literature in the field “Machine components. Friction, wear, lubrication” deals especially with “Mechanics of solids”, as well as with Engineering sciences like “Energy, Electronics and Polymers”, and finally with “Metals, metallurgy” and “Drives”.

Austrian production focuses for a great part on “Mechanics of solids”, and then on “Metals, metallurgy” and “Drives”, showing that studies are conducted in the field of fundamental sciences as well as in more applied sciences. The AC<sup>2</sup>T publications concentrate mainly on “Metals, metallurgy”, and to a lesser extent on “Mechanics of solids” and on “Drives”, pointing out a more applied research oriented toward Engineering sciences.

Which role does “theory” play in this field? The analysis concerning “theory” is poor. The term “theory” occurs in 588 articles (either in the title, in the abstract, or as a descriptor/keyword), which means in 6.22% of the data set. If we consider only the descriptor field, we get 154 articles with “theory” as a descriptor/keyword, which is approximately 1.63% of the considered data set. Hence we can say that “theory” seems to play a subordinate role in this technology

field. The experts in Tribology will give their comments till the conference is running so that the benefit of such an analysis can be assessed.

Bibliometric methods give a good overview to a specific field generally. But if you would like to know specific details it is necessary to read the article, what is evident. However bibliometric methods help to go into details easily.

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