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Terotechnology versus Exploitation Theory – some remarks

Key words

Terotechnology, exploitation theory, process of exploitation, operation, life cycle cost, assets.

Słowa kluczowe

Terotechnologia, teoria eksploatacji, proces eksploatacji, działanie, koszt czasu życia, aktywa.

Summary

The considerations in this paper are orientated towards the relationship between terotechnology and the theory of exploitation. First, the history of the birth and development of exploitation theory in Poland is described, citing the definition of this field of science as well as formulating basic problems considered in the framework of its area. A definition of the term *exploitation process* is given, along with a comprehensive description. The second scope of consideration is terotechnology, of which definitions are specified and the history of its development is described. Additionally, the meaning of the term *operation* is explained in relation to the term *exploitation*. The last chapter offers a general summary, indicating clearly what the actual mutual relationship of terotechnology and the theory of exploitation is and what the main differences are.

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1. Introduction

The theory of the exploitation of technical objects is presently well developed in Central and Eastern Europe, and in Poland especially. The scope of considerations, definitions of basic terms, principles, methods of investigations, rules and methods of description are clearly defined, but we have problems in communicating this with the English-speaking world. Direct translation of the term *Teoria eksploatacji* as *exploitation theory* almost fails to work in practice. And *vice versa*. The term 'terotechnology' is not very popular in the engineering world in this part of Europe. A similar situation can be noticed with the term *proces eksploatacji*, which is directly translated as *exploitation process*. There are also some problems with the English term *operation*. Generally, this is a peculiar situation.

Let us try to sort out this state of affairs.

The purpose of this paper is to provide a description of the situation in this regard, with a clear indication of the differences and similarities existing in the corresponding expressions.

2. Exploitation theory (*Teoria eksploatacji*)

Let us commence our considerations from the history of the development of this theory in Poland.

The first papers examining exploitation problems of machines were published in the 1960s (cf. Ziemba [1]). The term *exploitation theory* was at first associated with machinery, and later enlarged to consider more general application – the exploitation of technical objects. At this time, rapid progress was observed in the field of tribology, and the theory of reliability was coming into being. At the end of the 1960s, the Polish Academy of Sciences, Mechanical Engineering Committee, formulated a Section of Exploitation of Machines, with three theme groups: Tribology, Reliability and Exploitation. Later came the occurrence of 'Technical Diagnostics' (1980). A relatively new arrival is 'Safety', and this theme – together with the previous three – has now existed for almost ten years. At the end of the 1960s and beginning of the 1970s, the quarterly *Exploitation Problems of Machines* of the Polish Academy of Science was established. Subsequently, some further technical periodicals focused on exploitation have been founded.

Generally, the fast growth of the theory of reliability noted in the 1970s made for a rapid acceleration in the theory of exploitation. Researchers involved in penetrative reliability considerations quickly came to the conclusion that many problems associated with the usage of an object (element or system according to the theory of reliability) in real conditions need to be considered within a wider scope. It was necessary to take into account some properties of

the object not connected with reliability in a direct way but connected with object properties associated with the process of its application in particular operation conditions. Researchers were interested in what was going on with many object properties during the utilisation of the object and during maintenance. A great part of reliability considerations belongs, therefore, to the scope of the consideration of the theory of exploitation, but the scope of consideration of the theory of exploitation is much wider than that of reliability.

Apart from this, pure theoretical investigations connected with the theory of object utilisation and maintenance (that is exploitation of this object) were made, resulting in some significant books at the time, such as: Koźniewska [2], Bojarski [3], Konieczny et al. [4], Konieczny [5], Olearczuk [6]. In the second half of the 1960s, the first National Symposia on Exploitation of Technical Objects were held. In 1973, a study of exploitation for a doctoral degree was offered (Konieczny [7]) for the first time. Generally, the theory of exploitation proved very useful. Evidence for this statement can be found by considering the problems of the operation of mine machinery systems (e.g., Sajkiewicz [8,9], Czaplicki and Lutyński [10]).

The term exploitation comes from the French word *exploitation*, which means, first of all, *usage*. In connection with engineering problems, exploitation is based on the statement that it is *usage of something in a rational way*.

In the 1970s, much was published on this topic in Central and Eastern Europe, and after several years of intensive development this theory was well stabilised. Researchers involved in this kind of investigations came to the conclusion that *the exploitation of a technical object is a set of intentional actions running in time of a technical, economical and organisational nature directed at this object, as well as mutual relationships existing between them (people co-operating and the object) from the moment of the object's first usage until its withdrawal and disposal* (Polish Standard PN-82/N-04001 [11]). Similar definitions can be found in the standards of neighbouring countries.

For more than twenty years, in a number of technical universities, the theory of exploitation has been offered as a separate lecture subject in connection with the utilisation of various classes of technical objects, e.g. Warsaw University of Technology, Wrocław University of Technology. Many books and textbooks have been issued (e.g., Adamkiewicz [12], Downarowicz [13], Kaźmierczak [14], Będkowski and Dąbrowski [15]). The theory of exploitation has proved essential and useful.

The general problem of exploitation theory is the following:

(G): What to do or how to arrange the path of the exploitation process of an object in order to obtain its most convenient course?

Other points of interest are the answers to many particular questions like the following:

- What are the components of the exploitation process? How can we identify them?
- What kind of influence does the object's environment have on the course of its exploitation process?
- What are the technical and economic possibilities for changing the course of the process?
- What kind of changes in the process will be the most profitable?
- What kind of changes in the construction of the object or system structure should be carried out to improve its achievements?
- How should the course of the process be arranged to assure an appropriate level of safety?
- How can a system of backup facilities be arranged for the object to obtain its defined level of efficiency?

and many, many others (Piasecki [16], Kaźmierczak [14] for instance).

Statement (G) contains three important components. They are *the arrangement of the path, the exploitation process*, and *the convenient course of the process*. Let us discuss their significance.

Note that the main point of interest here is a certain course of action called the *exploitation process*. This is a process of the changes of the properties of an object during its utilisation and maintenance. Utilisation and maintenance – component processes – interlace each other. The exploitation process is running in time; however, the time alone may not be so important. Very often in engineering practice more rational is a different parameter of the process, such as the number of tonnes of mass transported, the number of tonnes of rock excavated or dumped, the number of executed cycles of the machine, etc.

Let us consider the problem of the exploitation process a little more.

Very often investigation of the properties of the exploitation process of the machinery system concerns properties that can be identified immediately with regard to measure, and it is enough to observe symptoms occurring during the process of exploitation. However, there are several further properties that can be identified, and measures can be attributed only when handling appropriate data. Sometimes modelling is very useful here, because working with the model allows interesting measures of the process to be constructed. The term *exploitation process* will be understood here in a slightly wider sense than that usually identified in the theory of exploitation. According to the classical definition, the exploitation process of an object is the process of the changes of its properties from the moment when utilisation is commenced until the moment of definite withdrawal from the object's utilisation, i.e. during the object life cycle. Kaźmierczak [14 p. 156] formulated the following definition: *an exploitation process is everything that happens with the object from the moment of the end of its production till the moment of its final withdrawal from utilisation.*

In many cases, an exploitation process of machinery systems is understood as a two-dimensional process, namely:

- The process of changes of reliability properties of machines that the system consists of.
- The process of the changes of functions executed by these machines.

These unit processes are not equivalent to each other.

The course of the process of changes in reliability properties does arise from the process of functioning, but not exclusively. Two other factors have an influence here – exploitation conditions (surroundings in the meaning of theory of systems) and object properties given during stages of its design and production. The process of changes of reliability properties is superior to the process of functioning.

There are two basic terms of exploitation theory associated with the term *exploitation process*. These are *the state of object* and *exploitation event*.

As we know, during the object exploitation process, the properties of an object change. For some features these changes will be of a continuous type, sometimes slow, sometimes transitional, sometimes drastic. Therefore, an object at a given moment in time is not identical to the object at a different moment in terms of its properties. In order to describe the process of these changes, the term *state* is applied.

Defining a set of object properties $\mathfrak{G}$, $\mathfrak{G} = \{g_1, g_2, \ldots, g_m\}$, we can say that the state of the object in a time t is determined by a certain function:

$$\mathfrak{S}(t) = f[\mathfrak{G}(t)] = f[g_1(t), g_2(t), \ldots, g_m(t)].$$

Kaźmierczak [14 p. 119] gave a similar assessment of the term state: under the term 'state of object' we are going to understand here a 'photography' of values of object properties in a given moment of time.

In practical applications this function is not considered to be a continuous one. Discrete divisions are usually made and states are named. These names are usually associated with the physical side of the state, e.g. repair state, work state, stationary state, etc. Notice that a simple conclusion can be made here: The exploitation process of an object is the sequence of states of this object or – the usual formulation – this is the process of the changes of states.

As a result of this process of discrete division at each moment when a change of state appears, an exploitation event has taken place. Sometimes these events are visible and to some extent perceptible, e.g. a certain element of the object failed and the machine ceases operation. Sometimes events are conventional ones – nothing physically happened apart from the fact that a certain object parameter exceeded its limited value, e.g. brake lining worn excessively. At this moment, we assume that the object is in a different state. All these considerations are valid for objects that can be repaired, i.e. all machines and their systems. However, there are technical devices that cannot be

repaired, called objects working till first failure in reliability theory, but sometimes the engineering world is more complicated. For example, the head rope in a hoisting installation is a non-repairable object and does not work after the first failure occurrence (if we have in mind rope rupture); however, it is considered no longer working the moment when the defined rope parameter exceeds its limited value. The hoisting rope has its own failures if wire breaks are taken into account. These failures can be many.

Having an idea of what exploitation process means, it is easier to understand the remaining two elements in statement (G).

The expression convenient course of the process contains a subjective component, because convenience needs the formulation of a criterion that will measure this expediency. This criterion can be purely economic (the maximum profit), can be connected with safety, and can be connected with other factors such as social ones, for instance (production should be maintained, otherwise many people will lose their jobs). What kind of criterion will be applied depends entirely on the people controlling the exploitation process of the object of interest.

The last expression that should briefly be described is arrangement of the path of the process. This short statement contains a great deal. For a large machinery system, for example, it will concern the preparation and later current control of the whole back-up system, i.e. repair shop fully equipped, maintenance facility, spare parts warehouse and its current supply, the people involved in servicing the system, fuel and lubrication tanks, etc. We may term this part hardware. Equally important will be software, containing all procedures associated with the maintenance of the system in such a condition that it can fulfil the task of its existence. All procedures are running in time. Some of them remain without change, and some of them will be different for different stages of exploitation of the system.

3. Terotechnology

Let us start our considerations from the approach of the English-speaking world to the term *exploitation*. In the English language, this word possesses many negative connotations. Looking at Thesaurus.com (2008) one finds synonyms such as: ‘corruption’, ‘wrong’, ‘dishonesty’, ‘crime’, ‘barbarism’, ‘misuse’, ‘cheat’, etc., and even ‘unwanted sexual advance’, and Wikipedia (2008) gives an association with Marxist theory. Generally, many unpleasant associations[1)]. For this reason, acceptance of the term *exploitation* is extremely difficult in this part of the world.

[1)] If English-speakers have a good connotation with a given word they have no objections to using it. In mining science we have a type of mine called a ‘glory hole’.

In common opinion, an interchangeable term for *exploitation theory* is *terotechnology*. Both terms mean roughly the same, but they are not identical in their meaning. There are differences in how a particular problem should be approached, as well as what the scope of consideration and the main points of interest are.

The history of early development was different in the United Kingdom, where terotechnology was born, than in Central Europe. However, the period of delivery is roughly the same – the end of the 1960s. In the United Kingdom, the problem of the maintenance of objects has its own life, and it separated partly from reliability when national conferences were held on this topic in the 1960s. In 1967, the British Council of Maintenance Associations was founded. After several years of the vast development of both an empirical and a theoretical nature, the Committee for Terotechnology was formed. It took two years to come up with a definition of terotechnology.

This is a combination of management, financial, engineering, and other practices applied to physical assets in pursuit of economic life cycle costs. The practice of terotechnology is concerned with the specification and design for reliability and maintainability of plant, machinery equipment, building and structure with their installation, commissioning, maintenance, modification and replacement, and with feedback of information, performance and cost (Hewgill and Parkes [17].

In the future terotechnology will be an essential element of good husbandry, of quality and of the ability to understand that an artefact commits resources both in its making and in its subsequent use … the outcome of such an approach may result in a product which has high initial cost and long reliable life, or which is cheap with a short life and anticipated replacement or breakdown … Terotechnology has a simple objective – that of minimizing the whole life cost of ownership – but its practice can be complex, involving interdependencies and relationships of a diversity of resources – people, money, material, ideas and techniques. (Darnell [18])

It was presumed that the papers by Finniston [19], Rappini [20] and Wiegel [21] could be taken as reports of pioneering work in the area of terotechnology. All the authors belonged to integrated iron and steelworks. Therefore, terotechnology is a recent thought, with a formal definition developed in 1972, and its beginning came as a practical method for efficient and timely maintenance in an integrated iron and steelworks. One of the pioneers was Evans, whose paper was presented at a conference in Durham, UK in 1974 [22]. The first International Congress on Terotechnology was held in London in May 1979.

In 1981, Tamaki [23] formulated a term: Total Productive Maintenance (TPM). It has been stated that this is the application of terotechnology by the Japanese in their own way. In its pursuit of economy in life cycle costs, TPM has an identical purpose to terotechnology, but in its approach it is different.

TPM is based on the assumption that causes of equipment failure and poor quality are interdisciplinary and that it is necessary to have plant-orientated management organisation, and stresses the total participation of the workforce. Following this line of reasoning, Takahashi [24] identified specific motives for advocating the subsequent adoption of TPM in Japan.

Finally, in 1993 BS3811, *Glossary of terms used in Terotechnology* was published [23].

To get an idea about terotechnology today some quotations should be taken into account.

The British standard cited above gives the following definition:

a combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle cost.

Bhandury and Basu's [26] book on terotechnology – probably the first example of such a comprehensive elaboration in English – stated succinctly:

Terotechnology – a concept, nay, a philosophy.

According to the online MSN dictionary (2007) [27] it is

a branch of technology that uses managerial and financial expertise as well as engineering skills when installing and running machinery.

Investopedia (2007) [28] informs:

A word derived from the Greek root word 'tero', or 'I care', that is now used with the term "technology" to refer to the study of the costs associated with an asset throughout its life cycle - from acquisition to disposal. The goals of this approach are to reduce the different costs incurred at the various stages of the asset's life and to derive methods that will help extend the asset's life span. Terotechnology uses tools such as net present value, internal rate of return and discounted cash flow in an attempt to minimize the costs associated with the asset in the future. These costs can include engineering, maintenance, and wages payable to operate the equipment, operating costs and even disposal costs. Also known as 'life-cycle costing'.

For example, let's say an oil company is attempting to map out the costs of an offshore oil platform. They would use terotechnology to map out the exact costs associated with assembly, transportation, maintenance and dismantling of the platform, and finally a calculation of salvage value. This study is not an exact science: there are many different variables that need to be estimated and approximated. However, a company that does not use this kind of study may be worse off than one that approaches an asset's life cycle in a more ad hoc manner.

At en.wikipedia.org [29] we can find the following statements:

Terotechnology is the economic management of assets. It is a combination of management, financial, engineering, and other practices applied to physical assets such as plant, machinery, equipment, buildings and structures in pursuit of economic life cycle costs. It is concerned with the reliability and maintainability of physical assets and also takes into account the processes of installation, commissioning, operation, maintenance, modification and replacement. Decisions are influenced by feedback on design, performance and costs information throughout the life cycle of a project. It can be applied equally to products, as the product of one organization often becomes the asset of another.

The term terotechnology can also be found in an online business dictionary, where the following statement is given (www.businessdictionary.com) [30]:

Multidisciplinary approach to obtaining maximum economic benefit from physical assets. Developed in the UK in the early 1970s, it involves systematic application of engineering, financial, and management expertise in the assessment of the lifecycle impact of an acquisition (buildings, equipment, machines, plants, structures) on the revenues and expenses of the acquiring organization. Practice of terotechnology is a continuous cycle that begins with the design and selection of the required item, follows through with its installation, commissioning, operation, and maintenance—until the item's removal and disposal—and then restarts with its replacement. From the Greek word 'terein,' to guard or to care for. Terotechnology is in the Accounting & Auditing, Industries, Manufacturing, & Technology and Purchasing & Procurement subjects.

Terotechnology has become a separate academic subject or even a specialisation of study.

The School of Oil and Gas Engineering of University of Western Australia, for instance, offers the ‘ASST8577 – Terotechnology’ course, though the recommended course reading comprises books on Maintenance, Replacement and Reliability exclusively.

Monash University**,** Australia proposes the excellent course ‘GEG7014 – Terotechnology and life cycle costs’ in the Postgraduate Faculty of Engineering. Course duration: 150 hours. The first information sentence reads: ‘Introduction to asset management and terotechnology’, suggesting that these two matters are different.

The Växjö University, Sweden offers a Masters programme in Terotechnology in which a student can have a profile in Production Systems, that is Production Manager, Creative Quality Developer and Maintenance

Designer. In the leaflet one can find the statement: ‘Terotechnology is about how to optimise the manufacturing part of an organisation’.

To conclude our discussion of the problem of terotechnology two remarks must be mentioned.

In 2004 and 2005, Belak from Croatia published two papers [31, 32] considering the problem of terotechnology.

In his 2004 work, he analysed the position of terotechnology in the overall approach to the planning, design, manufacturing, installation, service, maintenance, decommission and recycling of a technical system. He indicated that terotechnology is also related to the economics, life cycle cost and maintenance. According to this author, terotechnology should be treated as an optimisation process of the ratio between the total effective or potential production of the system and the cumulative cost in its lifetime. As a static phenomenon, the ratio can be optimised apart from the market influence and business strategy and policy. The optimisation process must indispensably include reliability, adaptability and availability of the system.

In the 2005 paper he made – together with his co-author Čičin-Šain – a review of the definitions of terotechnology, they indicated some differences in definitions that are the source of misunderstandings. According to the authors, all the definitions quoted have in common the aspect of costs examined throughout the life cycle of business operation systems; however, the concept of terotechnology also includes earnings produced by the activity of the business operation system, a fact that most terotechnology definitions disregard.

A second remark should be made in association with the paper written by Ibrahim and Brak [33]. They presented a new concept and the implementation of inter-continental flexible training of terotechnology and life cycle costs, based on experience obtained in Australia and the USA.

4. Operation vs. exploitation

In connection with the relationship between terotechnology and the theory of exploitation, one more disagreement is often noticed. In Central and Eastern Europe, we usually apply the statement ‘during exploitation’. English-speaking researchers tend to say ‘during the operation’, indicating that this is a more appropriate statement. Is it so?

There is no doubt that, in common English, such a statement is easily understood and communicative. However, living among English-speakers, it is easy to perceive that this word is used frequently and has a great number of synonyms. One impression arises irresistibly – this word is *over-used.* For common usage, everyday language – there is no objection. Nevertheless, if strict, precise scientific language should be employed this word looks like a *picklock.* Thesaurus.com (2008) gives 48 meanings of the expression *operation*, from service,

progression, force, happening, movement, affair, deal, enterprise, achievement, deed, stroke etc. up to space, size and surgery. This is an extremely wide range.

BS3811 gives the following definition of the term *operation*: 'the combination of all technical and administrative actions intended to enable an item to perform a required function, recognising necessary adaptation to changes in external condition'. Nevertheless, the impression remains that this word has too many denotations. In science we need precise terms.

5. Summary and remarks

Let us now make a short summary.

Terotechnology is a *concept, combination of practices, kind of technology, economic management of assets, multidisciplinary approach, philosophy*.

Terotechnology has the objective:

to minimise the whole cost of ownership of the object life,

to obtain maximum economic benefit from physical assets,

to reduce the different costs incurred at the various stages of the asset's life and to derive methods that will help extend the asset's life span,

to optimise the ratio between the total effective or potential production of the system and the cumulative cost in the lifetime of the system.

The theory of exploitation is the strictly defined *field of science* determining the fundamentals of exploitation of objects in a rational way.

The theory of exploitation has two objectives: theoretical and practical. The theoretical goal comprehends the mechanisms governing the course of the changes of an object's properties during its utilisation and maintenance. The practical aim is to maximise economic benefit from object exploitation during the object life, provided that the safety requirements are fulfilled.

Terotechnology has existed for almost forty years now, and there is no statement that it is a field of science! Until now, it has been the focus of many different definitions and different approaches. The main points of interest are located in different areas. Some statements are opposite to each other. The only precise statement that can be formulated in this scope is that 'we roughly know what it is all about'. And almost that is all. There are no spectacular theoretical achievements. Many quite good developments have a partly scientific, partly technical character, but they do not solve the formulated problems in the way

they should according to the high requirements formulated by terotechnology *sensu stricto*. What causes such a situation?

Analysing this variety of definitions, we can find that the point of interest is connected with the whole life cycle cost of the object. And this 'object' in terotechnology is a system – a complicated structure. For a person who is familiar with the theory of exploitation, it is obvious that statements such as 'achievement of maximum profit of object exploitation during the object's life cycle' or 'achievement of minimum of costs spent on the object during its whole life', or 'to find the optimum… during the object's life cycle' are too ambitious! From a theoretical point of view, we can construct many mathematical patterns describing the relationships between different variables that have an influence on the 'object costs'. But is it necessary to take into consideration a lot of such variables, many of them random, some of them on unidentified distributions, some of them with great dispersion? Frequently, we have the functions of many variables. If we add that a great part of our considerations should be located in the theory of prediction (we made our terotechnology considerations when the object still exists), many components of the patterns mentioned here are estimated with different accuracy and a lot of cost pieces vary in time, it will be obvious that from a practical point of view the usefulness of such divagations is low, especially if we have the whole object life in mind.

The theory of exploitation has also existed for almost forty years. It is a field (discipline) of science with its own well-defined nomenclature, determined field of interest, verified mathematical methods and laws and principles. In many areas, the theory of exploitation has occurred very useful, both from theoretical and practical points of view. It is worth noticing that, in exploitation theory, we are not interested in the maximum of a certain function describing a certain object property during the whole object life; we are interested in 'maximising', i.e. 'going towards the maximum'. It is more practical, easier to attain. We have positive effects in this way.

At the end of this paper, it seems that the best suggestion that can be formulated – towards our colleagues from terotechnology – is to break prejudices against the term *exploitation* and derive from this a field of science. For your purposes this will be spot on and very useful. We have to confess also that our colleagues are more ambitious than we are, being involved in exploitation theory.

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Terotechnologia a teoria eksploatacji – kilka uwag

S t r e s z c z e n i e

Rozważania przedstawione w artykule poświęcone są omówieniu pojęć terotechnologii i teorii eksploatacji. Zarysowano w skrócie historię powstania teorii eksploatacji w Polsce odnotowując pionierskie prace w tym zakresie. Zdefiniowano pojęcie eksploatyki jak i – w nieco szerszym ujęciu – pojęcie procesu eksploatacji. Wymieniono kilka podstawowych zagadnień charakterystycznych dla tej teorii. W trzecim punkcie rozważań podano kilka obowiązujących definicji terotechnologii, a także przedstawiono historię powstania i rozwoju terotechnologii przedstawiając prekursorskie opracowania z tej dziedziny. Odniesiono się również do pojęcia ‘operation’ jako potocznego odpowiednika określeń takich jak działanie, użytkowanie, eksploatowanie. Wskazano, że pojęcie ‘operation’ w języku angielskim jest używane powszechnie a zarazem nadmiernie. Słowo to ma w języku angielskim 48 znaczeń, co w zastosowaniach naukowych – w których potrzebujemy się posługiwać precyzyjnymi terminami – stawia pod znakiem zapytania racjonalność tego określenia. Dokonując podsumowania wskazano, dlaczego istnieją „opory” w stosowaniu terminu „eksploatacja” przez angielskojęzycznych badaczy świata techniki. Stwierdzono również, że istniejące definicje terotechnologii nie są ze sobą spójne, a główne zagadnienia terotechnologii bywają różnie określane. Niektóre z zadań terotechnologii bywają formułowane zbyt ambitnie, co uniemożliwia osiągnięcie wymiernej, praktycznej użyteczności.