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NEW MECHANISMS FOR THE TRANSFORMATION OF INNOVATIVE KNOWLEDGE
on the example of surface engineering

Keywords

Knowledge transformation, technology transfer, surface engineering.

Abstract

The paper presents new mechanisms and structures for the transformation of knowledge into practical solutions on the example of surface engineering. Specific characteristics of plasma technologies of surface engineering imply that they should be developed and used in specialized technology centres interrelated with research and industry sector. It causes a need to establish new mechanisms of the acquisition of knowledge from various sources simultaneously, transformation of knowledge into industrial technologies and transfer of research results into industry. Apart from the development of new mechanisms it is very often necessary to create special networks or virtual structures enabling effective access to researchers, practitioners, laboratories and devices.

The paper presents different mechanisms and structures adjusted to the nature of executed research – either incremental or breakthrough.

Introduction

The demand of Polish economy for advanced technologies has been growing very rapidly. This concerns in particular plasma technologies related to surface engineering. These technologies are more and more commonly used for increasing the durability of tools and important elements of machines, including the elements working in extreme conditions, as well as for increasing the quality, for instance corrosion durability or the aesthetics of products manufactured on a mass scale. Problems concerning the implementation of these technologies are connected with their specificity. Nearly every successive implementation requires the development of a specialised technological process depending on: the type of the product, its size, material used, working conditions etc. Technological apparatus used for elaborating and applying new technologies is very complicated and expensive and requires highly specialised personnel for operation. Moreover, its processing capacity usually exceeds the current production needs. The characteristics of plasma technologies of surface engineering mentioned above prove that these technologies should be developed and used in specialised technology centres, closely interrelated both with research and industry sector. Such a situation requires the establishment of new mechanisms of the acquisition of knowledge simultaneously from many research centres, transformation of this knowledge into professional industrial technologies and, in the final stage, transfer of obtained solutions into industry. Very often, because of a breakthrough nature of the developed research and technological solutions it is necessary to create a special network and virtual structures which would give a direct access to specialisted laboratories, devices and most of all to researchers and practitioners. It is also essential to secure an appropriate financing for such undertakings - usually very expensive and at the same time associated with high risk - in the framework of strategic governmental programmes or international projects, which besides the scientific and technical studies, additionally requires the application of innovative organisation methods. The process of the creation of new mechanisms and structures of the transformation of knowledge and transfer of advanced technologies is presented on the example of the deposition processes of specialised coatings with the use of PVD/CVD methods and design of technological devices and organisational structures essential for their application.

1. Mechanisms and structures of knowledge transformation

The transformation of knowledge into practical solutions was described by [1] as a process of the adaptation and change of the results of scientific research leading to the achievement of a precisely formulated objective which is to obtain a product that satisfies a given need in particular conditions.

However, as shown in Fig. 1, the term transformation has been differentiated between the transformation the result of which is a verified prototype solution and the transfer associated with the activities consisting in the dissemination of transformation results that have a commercial market potential in economy.

The term of knowledge transformation was defined in a very simple and unambiguous way in the documents of the European Union [2] as: a process of transforming the scientific research results into commercial products/services. In the reality knowledge transformation and the transfer of advanced technologies and products into economy are very complex processes that require the creation of special mechanisms and structures for generating aims and realisation of procedures for research and application.

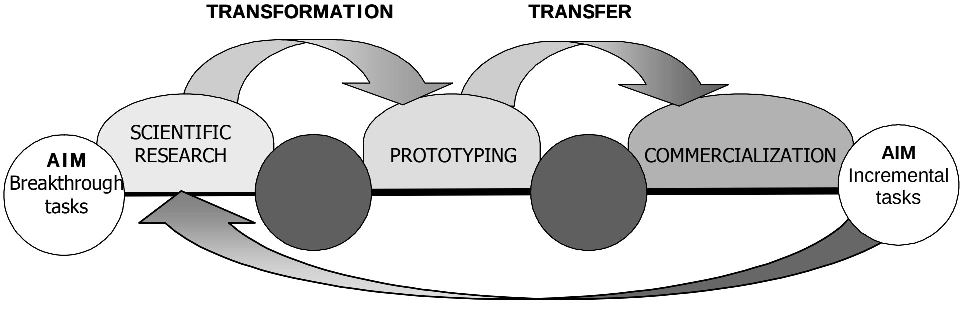

Fig. 1. Processes of knowledge transformation and transfer to practical applications

A particular difficulty lies in the fact that the sectors of science and industry do not have well developed mechanisms of cooperation and strategic support for the development of innovativeness at the country level is insufficient or inappropriately organised.

The lack of such mechanisms and cooperation structures on a large scale results in low participation rates of Polish scientific, economic and governmental units in the framework programmes of the European Union, particularly in the 6th Framework Programme.

The attempt to change the situation in the subject area connected with sustainable development in the field of machines construction and maintenance, on the country scale, constitutes the Multi-Year Programme PW-004: “Development of innovativeness systems of manufacturing and maintenance 2004-2008” (Fig. 2). The aim of the programme is to create both mechanisms and innovative structures of knowledge transformation and to verify the proposed system solutions on the example of specific products and technologies in particular fields of knowledge and practice, including the field of surface engineering.

The content-related basis of the PW-004 Programme is the identification of strategic research area, including niche issues in which the Polish scientific milieu has creative potential, appropriate laboratory and experimental infrastructures, the possibility of international cooperation and also testing ground for innovative solutions that is consistent with world standards. The precisely identified research required the specification of detailed tasks and making the scientific environment realise them. The proposed new mechanism

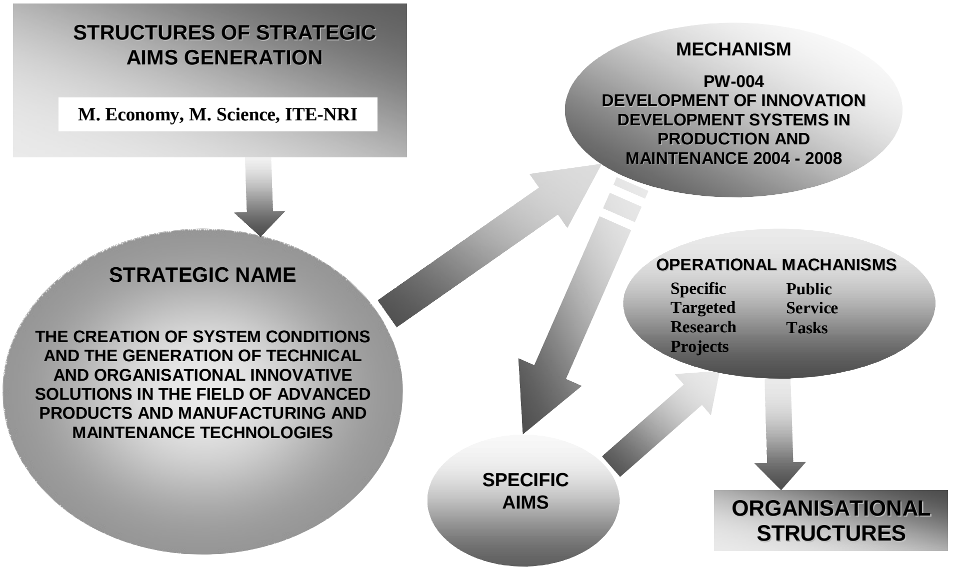

Fig. 2. Interrelations of aims, mechanisms and structures in the Multi-Year Programme PW-004. *On the basis of [4], author: M. Trzos*

for generating the research tasks was and is untypical to the extent that, unlike the so far practice no proposals of research tasks in a given thematic area were expected, but the proposed tasks were precisely formulated, together with specific parameters of the expected final solutions and were integrated in the form of a complex project, the results of which should lead to the achievement of the assumed strategic aim. In other words, the potential project participants declare to develop research task planed in detail and at the required scientific and technical level, according to the established functional and quality assumptions. Such approach determines the success of the whole scientific and application undertaking. A very significant factor in this mechanism is the possibility to combine several teams that have been realising similar or equal tasks so far in one common undertaking. It is also important to make the teams aware of the importance of their work for the final strategic result of the whole project. Thanks to such a mechanism there is a greater chance for a successful completion of the breakthrough research tasks that introduce a completely new research and application issue requiring the creation of new knowledge. Also more probable is the achievement of the synergy effect for solving tasks aimed at the subsequent improvement of present solutions through the systematic implementation of innovative solutions, based on the current knowledge, the so called incremental research. Another result of the implementation of new mechanisms for conducting applied research directed to the increase of innovativeness in the production and maintenance, implemented within the Multi-Year Programme PW-004, are the changes of the current structures of research and implementation systems, as well as the creation of network structures (virtual) enabling a successful application of cooperation mechanisms, and the reconstruction of standard structures, necessary for the adaptation to new mechanisms of the internal and external cooperation.

2. System of research and applications of hybrid technologies of surface engineering

General principles of the application of new mechanisms and the process of creating new knowledge transformation structures within the Multi-Year Programme PW-004 will be presented on a concrete example of the development of a system that enables the creation of the new generation of hybrid technologies in surface layer.

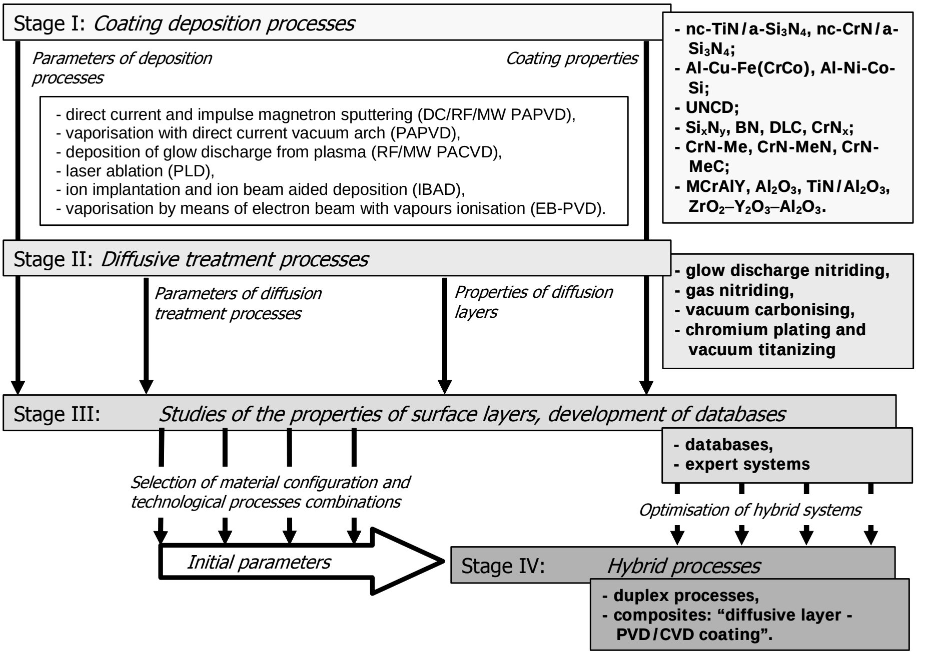

Fig. 3. Mechanism for the development of highly technologically advanced hybrid samples of surface layer
On the basis of [5], author: J. Walkowicz

The first stage of the project realisation constituted in the identification of national academic and research units in the field of technologies considered as the advanced technologies in the scope of incremental technologies. Based on this knowledge, the aim of the project was formulated as follows: “Development of hybrid methods meant for the creation of nanocomposite protective layers with the use of special structural variations of functional gradient materials that combine the physical and chemical deposition methods from the ionised gas phase with the selected diffusion treatment methods”.

Both the deposition methods, coating materials and diffusion treatment methods were proposed. By means of these methods new generations of surface layers with known parameters and composition were to be obtained. The mechanism and the realisation procedures concerning the creation of research system and the application of new generation hybrid technologies of surface layers were shown in Fig. 3. The system’s characteristic is the verification of micro-mechanical and tribological properties of surface layers and coatings created in different research units of the country in one specialised laboratory. Thanks to such approach it is possible to compare the achieved values of physic-chemical parameters of the new surface layers compositions. The compositions which obtained satisfactory values in the laboratory tests undergo application procedures in a specialised centre of advanced plasma technologies. The centres are equipped with technological devices specially developed, manufactured and adjusted for this purpose, thanks to which it is possible to implement the developed model technologies into industry and conduct appropriate maintenance tests. The scheme of the organisational structure carrying out the application of model solutions, both technological and equipment, was shown in Fig. 4.

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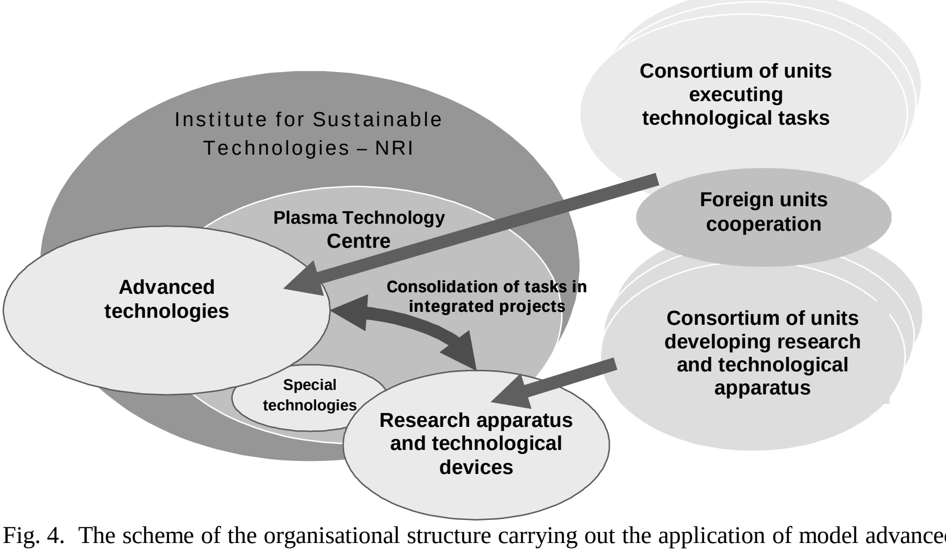

Fig. 4. The scheme of the organisational structure carrying out the application of model advanced solutions, hybrid technologies of surface layer

The original technological device meant for the deposition of surface layers executed within the project was shown in Fig. 5a and the results of an exemplary successful implementation of one of the hybrid technologies on hot forging tools were shown in Fig. 5b.

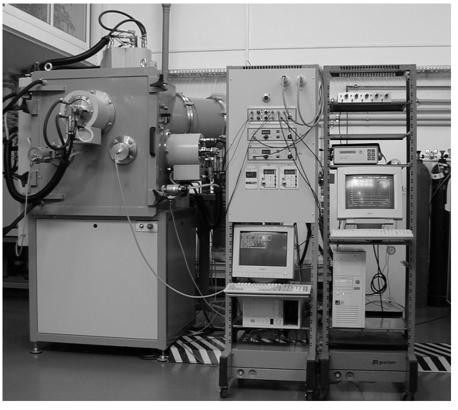

Fig. 5a. Devices for the application of "duplex" technology

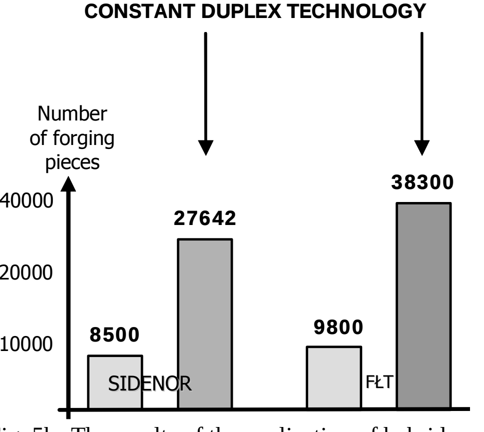

Fig. 5b. The results of the application of hybrid technologies for hot forging tools *On the basis of [5]*

3. The role of ICT systems in surface treatment

A very significant mechanism for the realisation of a complex task consisting in the creation of hybrid treatment pack of surface layer in the network system of the realisation units is the possibility of a unified documentation of the results of model investigations of layers, technological parameters of processes and maintenance experiments [6].

The scheme of obtaining data and information flow in the system aiming at the development of pack of highly technologically advanced hybrid treatment of surface layer was presented in Fig. 6.

The structure of the database destined for the collection of information on the processes of constituting surface layers is presented in Fig. 7. Certainly, the information collected in such a specialised base is very useful for the optimisation of the parameters of the particular hybrid compositions, for the selection of settings and signals steering technological operations.

The processes of the creation of next generations of better quality surface layers and coating materials run, in case of incremental research, in a closed circle (Fig. 8). Products for which innovative technological solutions were applied (e.g. tools for forging, pressing, machining, pressure casting with duplex coating: layer nitrided coating from titanium nitride), they are subjected to the exploitation investigations during the industrial exploitation.

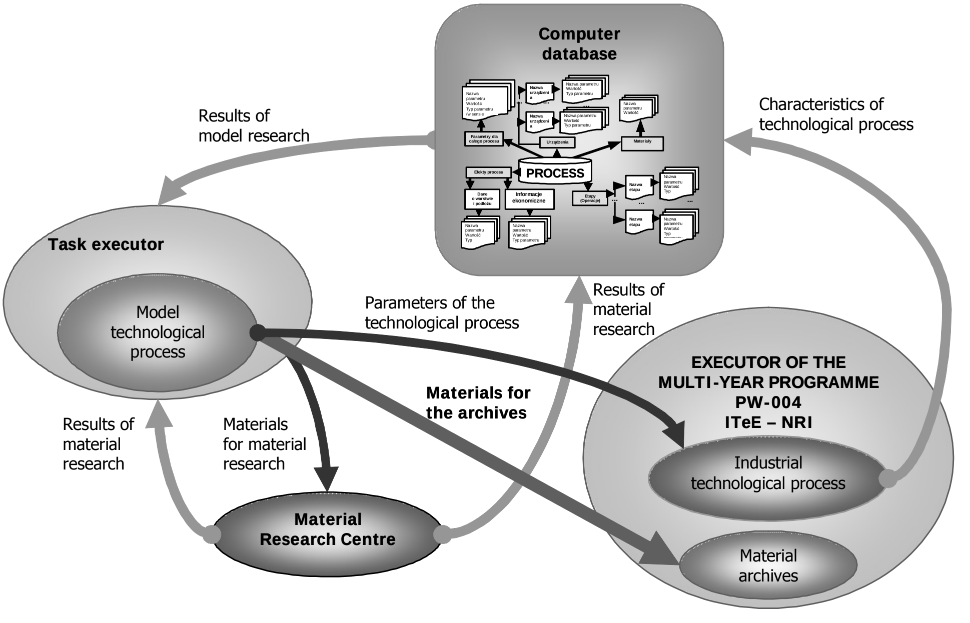

Fig. 6. Scheme for the documentation of material investigations in the hybrid processes of the development of surface layers

The results of these investigations, collected in knowledge bases, are used in the development of next generations of surface layers with better parameters that, as a result of transformation, usually conducted by means of trial and error method, are converted into model and prototype solutions – later implemented into industry – and the cycle is repeated by generating solutions admittedly of better quality. However some properties cannot be envisaged *a priori*, and what is more, they cannot be programmed in accordance with the requirements of a potential user. The enrichment of the databases encompassing the parameters and characteristics of products and processes of hybrid treatment of surface layers and the creation of knowledge and expert systems constitute the basis for the initiation of a break through task in the field of surface plasma technologies. The new task consists in the development of intelligent tools for surface treatment processes.

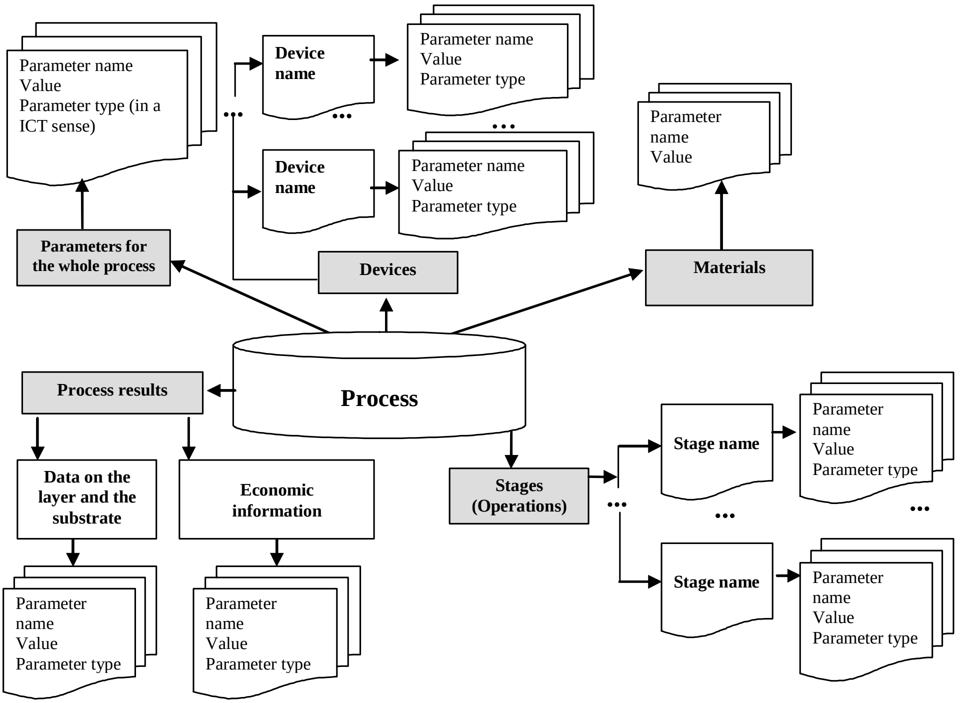

Fig. 7. Database for the collection of information processes for the creation of hybrid surface layers
On the basis of [7], author: J. Dobrodziej

New network and virtual cooperation mechanisms in the programme concerning the development of hybrid technology package of surface layer created a unique opportunity to generate a database comprising historical information collected by individual project partners during their usually multi-year studies in the particular field of knowledge and practice.

Huge databases that are created as a result of this cooperation enable, by means of artificial intelligence methods, the search of trends and regularities in the processes of constituting surface layers, as well as the relations and function dependencies of the structure and properties of designing the layers, both with process parameters and the treated substrate. Complex databases including the process parameters and the properties of the created surface layers and coatings, integrated in the large network of scientific and R&D units that deal with these technologies, enable (promising works in this subject area have already been undertaken [7], [8]) mathematic modelling of surface layer, including: the development of simulation models of technological processes, the designing of ”duplex” and ”multiplex” technological processes with the application of neuron networks and fuzzy logic, the development of computer systems for the control of “on-line” processes.

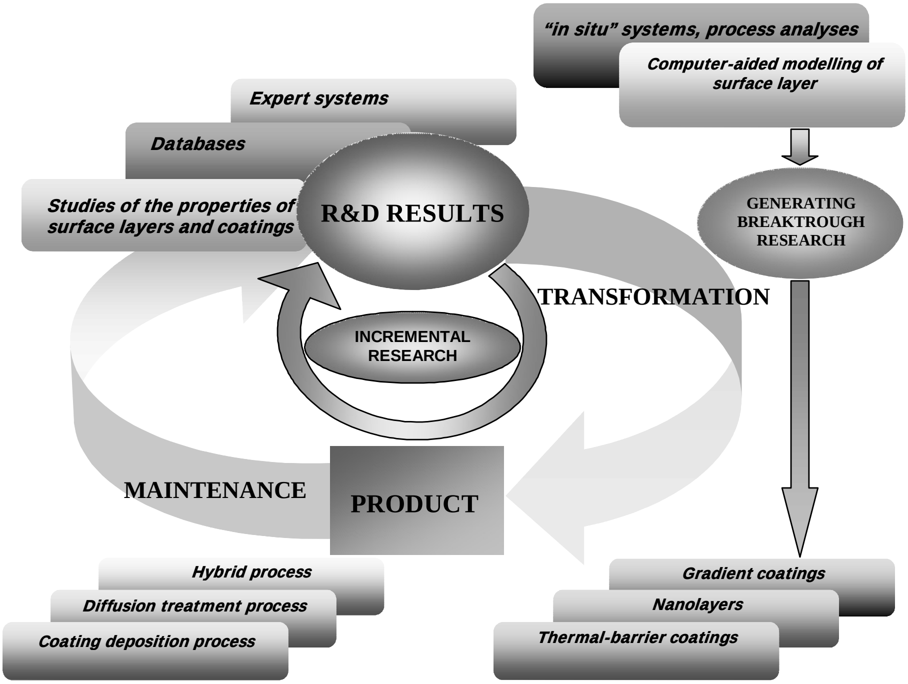

Fig. 8. Mechanism for the realisation of incremental research and generating the breakthrough research

4. Mechanism of the generation of breakthrough tasks

The experience gathered during the realisation of the project that aimed at the development of research, technical, execution and organisational system for the creation of a new generation of hybrid surface layers, was the basis (according to the processing way of mechanisms presented in Fig. 8) of the incremental research with a significant scientific and application meaning on the scale of the European Union, i.e. that could become a subject of interest within Framework Programmes. These tasks are - apart from the already presented methods for mathematical modelling of such composites - also thermal barrier coatings (TBC) and unique technical equipment, necessary for the realisation of technological processes for obtaining such layers [6]. The break through task of this kind, constituting scientific, research and application challenges, consistent with the highest world standards, required a wide cooperation. In the cooperation network, willingly accepted by all interested parties, the most significant European units in this knowledge area (Cranfield University, Fraunhofer Institute, Institute of Surface Engineering in Kharkov) were included. So, one can assume that in a natural way, another mechanism of knowledge transformation has been initiated that enables an efficient and equal international cooperation in the field of advanced plasma technologies of surface layer, that has its source in the properly functioning research and implementation system on the scale of the Multi-Year Programme and is carried out within the framework of its specialist projects.

Conclusions

1. When initiating the research works in the scope of advanced manufacturing and maintenance technologies, the key role has the setting of strategic and detailed (operational) goals in the areas identified as niche ones (such as hybrid technologies of constituting surface layers) and the adaptation of appropriate realisation mechanisms (knowledge transfer) depending on the character of works - incremental or breakthrough. The realisation structures have a secondary meaning, when taking into consideration the network and virtual possibilities of their creation and their flexible adjustment to the applied mechanisms.
2. The realisation of the incremental tasks, usually connected with the development and adaptation of the innovative solutions on the basis of the existing scientific knowledge, is a mechanism for the creation of research, technical and staff potential, gaining realisation and organisation experience, a thorough knowledge of the research and application that, as a consequence, leads to the natural generation of breakthrough tasks, consistent with the highest world standards.
3. The virtual structures created with no administrative relations are characterised by a huge dynamics and operation elasticity. Such structures eliminate the overlap of research works and unify the systems of collecting data, thus enabling the creation of professional expert systems. The centralised systems of the verification and application of the obtained results lead to great savings and also to professionalism of the market products offered. The key difficulty is to assess the share of network users in the potential effects of products commercialisation and the way of participating both in the content related and in financial results.
4. A particularly important issue is to develop the cooperation mechanisms between the tasks executors representing different scientific, technical and organisational specialisations. In the presented hybrid technologies of surface layer it refers for example to plasma physicists, material engineering specialists, process control and inspection specialists, constructors vacuum devices and computer specialists specialising in the artificial intelligence issues. Such mechanisms create specialists generally familiar with the subject matter, coordinating the interdisciplinary research task, specialists dealing with the issues related to their specialisation, who act as a content

related or technological liaison between the remaining executors and the highly specialised performers, solving only concrete research and technological problems. The selection of projects executors and establishing the importance hierarchy of tasks, as well as the rules of participants cooperation and their participation in the final product is usually decisive for the success of the multidisciplinary research and application undertaking in the field of advanced product and process technologies.

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Reviewers:
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Nowe mechanizmy transformacji wiedzy innowacyjnej
na przykładzie zastosowań w inżynierii powierzchni

Słowa kluczowe

Transformacja wiedzy, transfer technologii, inżynieria powierzchni.

Streszczenie

Przy podejmowaniu prac badawczych, w zakresie zaawansowanych technologii wytwarzania i eksploatacji, kluczowe znaczenie ma wyznaczenie celów strategicznych i szczegółowych (operacyjnych) w obszarach zidentyfikowanych jako niszowe (do takich należą technologie hybrydowe konstytuowania warstw wierzchnich) i dostosowanie odpowiednich mechanizmów realizacyjnych (transformacji wiedzy) w zależności od tego, czy prace mają charakter badań przełomowych, czy przyrostowych. Struktury realizacyjne mają wtórne znaczenie przy uwzględnieniu sieciowych i wirtualnych możliwości ich tworzenia i elastycznego dostosowywania do zastosowanych mechanizmów.

Realizacja zadań przyrostowych, związanych zwykle z opracowaniem i adaptacją rozwiązań innowacyjnych na bazie posiadanej wiedzy naukowej, jest mechanizmem prowadzącym do budowy potencjału badawczego, technicznego i kadrowego, zdobywania doświadczeń realizacyjnych i organizacyjnych, gruntownego poznania przedmiotu badań i aplikacji, co w konsekwencji prowadzi do naturalnego wygenerowania zadań przełomowych, odpowiadających najwyższym standardom światowym.

Tworzone sieciowe struktury wirtualne, bez formalnych powiązań administracyjnych, charakteryzują się ogromną dynamiką i elastycznością działania. Struktury takie eliminują dublowanie prac badawczych i ujednolicają systemy zbierania danych, umożliwiając budowę profesjonalnych systemów ekspertowych. Scentralizowane systemy weryfikacji i aplikacji uzyskanych rozwiązań prowadzą do ogromnych oszczędności i profesjonalizmu oferowanych produktów rynkoych. Zasadniczą trudność stanowi jednak oszacowanie udziału uczestników sieci

w potencjalnych efektach komercjalizacji produktów i sposobu partycypowania zarówno w efektach merytorycznych, jak finansowych.

Niezwykle istotnym zagadnieniem jest wypracowanie mechanizmów współpracy pomiędzy realizatorami zadań reprezentujących różne specjalności naukowe, techniczne i organizacyjne. W przypadku przedstawionych technologii hybrydowych warstwy wierzchniej dotyczy to m.in.: fizyków plazmy, specjalistów inżynierii materiałowej i systemów sterowania i kontroli procesów, konstruktorów urządzeń próżniowych i informatyków specjalizujących się w zagadnieniach sztucznej inteligencji. Mechanizmy te kreują specjalistów znających problematykę na dużym stopniu ogólności, koordynujących interdyscyplinarne zadanie badawcze, specjalistów działających na granicy swojej specjalizacji naukowej, stanowiących łącznik merytoryczny lub technologiczny z pozostałymi wykonawcami oraz wysoko specjalizowanych wykonawców, rozwiązujących jedynie konkretne problemy badawcze lub technologiczne. Dobór realizatorów i ustalenie hierarchii ważności zagadnień oraz zasad współpracy uczestników i ich udziału w produkcie finalnym jest zazwyczaj decydującym czynnikiem w powodzeniu interdyscyplinarnego przedsięwzięcia badawczego i aplikacyjnego w obszarze zaawansowanych technologii produktowych i procesowych.