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Procedure of Integration of the Systems of Representation and Application of the Structured Physical Knowledge

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Abstract: The generation of the base of physical knowledge in the area of nanotechnologies and nanomaterials on the basis of the formalized representation of the structured physical knowledge in the form of physical efforts will allow to systemize and efficiently use the available data relating to the specified subject area. The developed software complex consisting of the Information Retrieval System, system of the automatic synthesis of the physical operating principle and system of the automatic replenishment of the physical effects database will allow to significantly increase the scope of the physical knowledge that is actively used by performance of various research and development and design works in the area of nanotechnologies and nanomaterials as well as solving the test of forecasting the new nano-engineered systems.

Key words: Physical effect, structured physical knowledge, nanotechnologies, nanomaterials, area

INTRODUCTION

On the basis of the Volgograd State Technical University over the years the works on the formalized representation of the structured physical knowledge in the form of Physical Effects (PE) (Fomenkov *et al*., 2012, 2013) and development on the basis thereof of the various automated physical data processing system have been performed. These systems include: the systems for the information retrieval by physical effects (Fomenkov *et al*., 2004), the systems of the automated synthesis of the Physical Operating Principle (POP) (Davydov and Fomenkov, 2002), systems for automatic replenishment of the PE database (Fomenkov *et al*., 2012, 2014; Korobkin *et al*., 2013a, b, 2014; Korobkin and Fomenkov, 2009a, b, 2011). It should be noted that the mentioned systems have been developed independently from each other, feature different PE database structure and information content (by composition and number of PE).

Designing of the integrated complex for representation and application of the structured physical knowledge in the form of PE consisting of the Information Retrieval System, system of the automatic synthesis of the physical operating principle and system of the automatic replenishment of the physical effects database will allow to significantly increase the scope of the physical knowledge that is actively used by performance of various research and development and design works in the area of nanotechnologies and nanomaterials as well as solving the test of forecasting the new nano-engineered systems.

INTEGRATION PROCEDURE

For the purpose of integration of the systems for representation and application of the structured physical knowledge in the form of PE there has been developed a complex (the architecture is represented in the Fig. 1) ensuring execution of the following functions:

- Authorizing users to access to the program functions
- Logging of actions performed by the complex users
- Editing the base of the physical-technical knowledge in the form of PE
- Searching the descriptions of the new PE on the basis of the link to an Internet-resource or to a local directory
- Searching the PE descriptions on the basis of a search query for the Yandex and Google systems
- Verification of the base of the physical-technical knowledge for detection of the redundant PE and PE with the mismatched input and output cards
- Searching the physical effects through the PE database by a formal (descriptive) request

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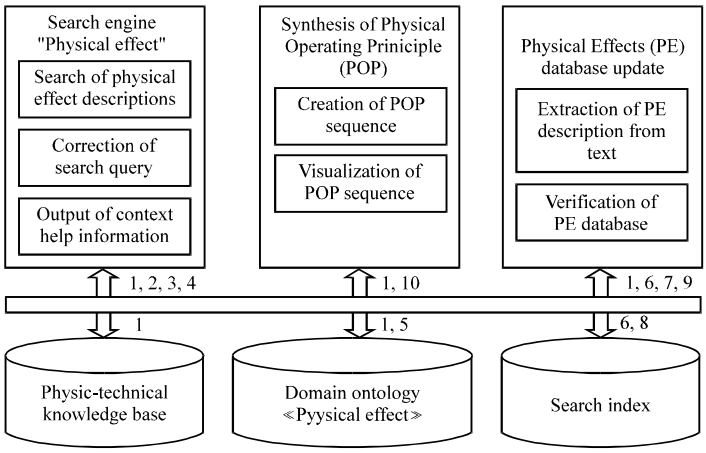

Fig. 1: Architecture of the software complex. 1: Input and output PE cards; 2: Queries to the database physic-technical knowledge; 3: Recommendations for changes the search query; 4: Help information for search queries creation; 5: References to web sources; terms of domain concepts and conceptual relations; 6: Preliminary cards of extracted PE description; 7: Lists of identical PE; 8: Urls to web sources; 9: List of references with PE description from database of physic-technical knowledge and 10: Sequence of physical effects forming a physical operating principle

- Full-text search for physical effects in the PE database
- Construction (synthesis) of the PE sequences implementing the physical operating principle

For the purpose of implementation of the above-mentioned functions the following methods have been developed and approved:

- Search for the physical effects in the physical-technical knowledge database on the basis of the developed models of search queries and physical effect
- Decision-making by the adaptivity sub-system generating prompts for a user on the basis of analysis of his actions, values of the user attributes and knowledge of the system operating features
- Adjustment of the search queries on the basis of the erroneous situations dictionary and query adjustment heuristics
- Synthesis of the linear structures of the physical operating principle
- Visualization of the linear sequence of PE constituting POP
- Retrieval of the structured physical information from the electronic sources and replenishment of the physical-technical knowledge database on the basis of the designed subject area ontology (software)
- Semantic text analysis
- Subject filtering of the text documents files
- Retrieval and recursive traversal of the links from hypertext documents
- Determining semantic similarity of text documents
- Database verification in terms of completeness and data consistency

The FE database contains as the main core the effects from the so-called global base (Fomenkov *et al*., 2013) containing over 1200 PEs. In the software package testing mode about 60 new PEs were found and described. It should be noted that the majority of the PE found are of particular interest since they are described in the physical journals and in the patent materials for the recent years. Besides, the literature sources have been found on the basis of which the information relating to the existing descriptions of about 40 PEs (essence, practical application) has been enhanced.

SOFTWARE COMPLEX TESTING

The developed software complex has been tested for generation of the physical-technical knowledge base and forecasting of the new nano-engineered systems on the basis thereof.

In order to test the solution of these tasks we generated an additional (limited) package of descriptions of PE in the nanosystems area and prepared the appropriate guidance materials.

The tasks of forecasting the appearance of the new nano-engineered systems may be performed with the

Table 1: Descriptive query A, B, C

A	B_1	B_2	C
-	-	-	Parametrical, mechanics, strength (Pa) (increase)

use either of the sub-system for the physical effects searching by the queries of different kind or of the sub-system for synthesis of the physical operating principles (Fomenkov *et al*., 2004; Davydov and Fomenkov, 2002).

Here we provide an example of solution of the relevant forecasting tasks.

Example 1: A query in a natural language (technical requirement): how to improve the strength characteristics of materials?

We formalize the query to physical effect searching subsystem using the descriptor language: input, object, output. According to the description structure the component of the input (A), output (C), initial object state (B_1), finite object state (B_2) formalized query (Fomenkov *et al*., 2004) appears as follows in Table 1.

The analysis of the effects found provides the following forecast: one of the most efficient ways of the substantial increase in the strength characteristics of the polymer and metal-based materials is addition of different nanostructures thereto. The examples implementing the specified approach are provided in the description of PE No. 1051 "Reinforcement of polymeric and composite materials" and PE No. 1061 "Reinforcement of elastomeric composite materials", ib., the literature is provided that allow studying this forecast in details:

- PE No. 1051: reinforcement of polymeric and composite materials
- Input: relative concentration of carbon nanotubes (percentage) (increase from 0-10%)
- Output: maximum strength (Pa) (increase)
- Object: polymer matrices (epoxide resins, petroleum resins, etc.) with addition of single- and multi-walled carbon nanotubes. Metal-based constructional materials volumetrically reinforced by the nanoparticles of the diamond-like carbon.
- Output card PE No. 1061: reinforcement of elastomeric composite materials
- Input: relative concentration of nanoparticles (%) (increase from 0-45%)
- Output: nominal tensile strength (MPa) (Increase)
- Object: amorphous elastomeric matrices (solid high-molecular synthetic rubbers) with addition of nanoparticles. Constructional materials on the organic and organoelement base nanostructured by the carbon and/or silicon oxide based nanoparticles.

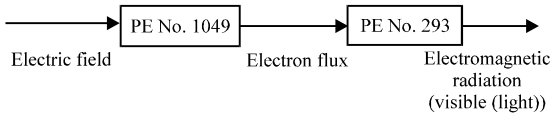

Fig. 2: Variant of the linear synthesis of the POP. PE No. 1049 "Field electron emission of carbon nanotubes"; PE No. 293 "Cathodoluminescence"

Example 2: A query in a natural language (technical requirement): how to improve the performance of the cathodoluminescence sources?

The luminescent light sources work on the principle of the electron-beam excitation of a luminophor. Thereunder the task for synthesis of the physical operating principle (Davydov and Fomenkov, 2002) will appear as follows:

- Input: electrical field
- Output: electromagnetic radiation (visible light)
- Restrictions: chain length ≤2, mandatory use of the PE No. 293 "Cathode luminescence"

From the synthesized chains there has been selected a variant represented in the Fig. 2. In the standard luminescent light sources the thermionic cathodes are usually used that feature high emission characteristics. However, the requirement to the cathode heating up to a few hundred degrees Celsius complicates the source structure and results in the increased energy consumption. The specified shortcomings are eliminated by the use of cold field emission cathodes on the basis of carbon nanotubes (PE No. 1049 "Cold field emission of carbon nanotubes").

The use of the carbon nanotube emission properties will allow designing the cold field emitters exceling the other types of the field emission cathodes in performance. This allows designing the more efficient cathode luminescent light sources (reduced energy consumption, easy switching on/off, absence of the environmentally hazardous gas vapors, etc.).

The most labor-intensive procedures (searching and retrieval of descriptions of the new physical effects (Korobkin *et al*., 2013a, b, 2014; Fomenkov *et al*., 2014; Korobkin and Fomenkov, 2009a, b, 2011)) are automated and supported by the subsystem for knowledge base replenishment from the electronic primary sources of information.

DISCUSSION

If the task of forecasting the appearance of the new nano-engineered systems cannot be solved by means of

the above-mentioned methods then it is necessary to enhance the content of the PE package in the relevant subject area. One of the main options of adjustment of the automated information systems handling with PE to the real user task is the openness of their content management. A user may create the content he needs on his own, i.e., to create the relevant object-oriented PE collections.

The next steps towards enhancement of efficiency and performance of the integrated complex of representation and application of the structured physical knowledge in the form of PE suggest the application of the multiagent approach (Zaboleeva-Zotova *et al*., 2013; Kravets *et al*., 2014).

CONCLUSION

Construction of a base of knowledge in the area of nanotechnologies and nanomaterials on the basis of the model for description of the physical effects will allow to systemize and efficiently use the data available within the relevant subject area (Fomenkov *et al*., 2013).

The proposed set of methods of the information processing in the PE knowledge base allows creating the unparalleled reference systems that significantly enhance the scope of the physical knowledge used by performance of the various research and development and design works in the area of nanotechnologies and nanomaterials as well as solving the test of forecasting the new nano-engineered systems.

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