ENGINEERING TRAINING FOR HIGH-TECHNOLOGY SECTOR

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The article deals with engineering training for high-technology sector of Russian economy. It suggests competence model of a specialist, the scheme of professional standard development process, a competence model of a graduate and approaches to the matching of graduate's competences and professional standards requirements.

Key words: *engineer, competence, professional standard, innovation, technology.*

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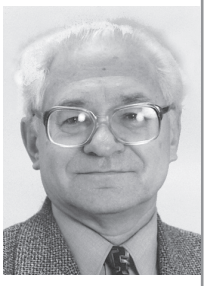

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The modernization course, which has been chosen by our government lately, is based on innovative development of economy. There are some models of innovative systems in the world. It is a challenge for Russia to choose the model and to develop the methodology of the innovative development.

A model which has been very popular lately has the name "triple helix" [1]. This model ensures the interaction of three basic components of innovative activity: universities – enterprises – state. It is proved that the core of the innovative activity must be a university. The "triple helix" started to be implemented in Russia. The first signs are the innovative system of Tomsk State University of Control Systems and Radioelectronics (TUSUR) and the innovative project "Skolkovo".

Though, there are barriers which are difficult to overcome. They are the following: there is low demand for scientific results in Russian economy, most of Russian enterprises haven't got long-term stimuli for innovative development, the innovative structure in the country is not developed, there is no business culture in higher school etc. To overcome those barriers it is appropriate to change the way of "Triple helix" implementation in Russia by paying more attention to the "Third helix", that is to address to the authority and to use the powerful administrative resources and to strengthen its role in innovative processes. Thus, there appears a concept of "new industrialization" (neo-industrialization) of Russian economy based on domestic high-tech complex development.

The training of engineers for high-tech sector of Russian economy has a lot of problems. The authors of the article consider some of them.

1. Analytical study of the prospects of innovative development of high-tech complex in Russia.

Для определения потребности в соотTo determine the need for the specialists, their competence requirements it is necessary first to study the prospects of innovative development of basic sector of Russian economy. The objects of the study should be the primary information sources:

1. Federal programs and federal program of regional development

funded by federal budget [2]. The programs are subdivided into several directions, for example:

- High-tech technology development: space program, global navigation system, civil aircrafts, broadcasting, marine equipment, nano-industry, electronic component base and radioelectronics, domestic machine-tool construction and others.
- Transport infrastructure: railway transport, roads, ferry, water transport, civil aviation etc.
- Safety: nuclear and radiation safety, state boundaries, destruction of chemical weapons, modernization of the Unified System of Air Traffic, fire safety, the world ocean, exploration of the Arctic and Antarctica etc.

2. Basic directions and ways for further development of high-tech and medium-tech industries in Russia [3]. According to "Rosstat" classification there are the following groups in manufacturing industries.

- High-tech sectors: aircraft production including spacecraft, computing equipment, broadcast and radio equipment production, medical equipment production, measuring, optical equipment production, pharmaceutical products
- Medium-tech industries of high level: machinery and tool production, shipbuilding industry and other vehicle production, chemical production, production of chemical machines and electrical equipment, production of cars, trailers and semitrailers.

The "core" of high-tech and medium-tech industries is a military-industrial complex (MIC). That is why it is necessary to include the annual reports of Russian Technologies State Corporation to the list of the studied objects.

3. The prospects of Russian's transition to the sixth mode [4].

The high-tech and medium-tech industries mentioned above reflect the tendencies of the past rather than the future. These are the industries of the third, fourth and the first stages of the fifth technological mode. It is mostly MIC high-tech enterprises that refer to the fifth one. But the world is working on the sixth technological mode. What are its basic directions? First of all, they are nanotechnology, biotechnology, information and communication technologies and new materials technology. By 2020-2025 there will be a science and technology revolution based on developments synthesizing achievements in basic technologies in the above mentioned areas.

Thus, Russia faces an extremely difficult task – to make a transition to the sixth technological mode without acquiring the fifth one. Can Russia make such innovative breakthrough being in crisis? The analysis made by the Russian Academy of Science (RAS) [4] shows that in Russia there are researches and developments which are breakthrough in all the directions of the sixth technological mode (Fig. 1).

2. Formation of competence models of specialists for neo-industrialization.

It is necessary to form a generalized model of the required specialists for the corresponding industries basing on the results of prospects study of high-tech complex innovative development.

The competence model of a required specialist can be presented as the following sequence [5]:

$$Ms = \{S, A, FA, CF, E, Q, EX\}, \quad (1)$$

where S stands for sector (sphere of professional activity); A – activity type; FA – j-th labour function of activity type; CF – competence to fulfill the j-th labour function; E – educational level; Q – required qualification level; EX – work experience.

The labour functions FA of the competence model of a specialist (1) are a hierarchically connected set (Fig. 2). Labour function decomposition goes on till the final element of the tree becomes an obvious task for a performer.

Every labour function FA of a lower decomposition level corresponds to the competence CF, which presents a set of the following components: FA –labour actions; FK- knowledge; FS – skills; FP – professionalism; FPQ – personal qualities.

Fig. 1. Researches and developments in critical technologies sphere in Russia

Information and communication systems

- software production technologies
- bio- technologies
- intelligent navigation and control system technologies
- technologies of data processing, storage, transfer and protection
- technologies of distributed calculations and systems
- electronic component base technologies

Environmental management

- technologies of atmosphere and hydrosphere monitoring and forecasting
- technologies of resources evaluation and lithosphere and biosphere condition forecasting
- natural and technological disaster mitigation and risk reducing technologies
- recycling technologies
- environmentally sound exploration and mining technologies

Nanosystem and material industry

- biocompatible materials technologies
- membrane and catalyst system technologies
- polymer and elastomer production and processing technologies
- composite and ceramic materials production and processing technologies
- nanotechnologies and nanomaterials
- mechatronic technologies and microsystem technology

Energy and energy efficiency

- nuclear power technology, nuclear fuel cycle technology and nuclear safety technology
- hydrogen power technologies
- technologies of efficient energy transportation, distribution and consumption
- renewable energy sources technologies
- technologies of fuels and energy from organic materials

Living systems

- bioengineering technologies
- biocatalytic, biosynthetic and biosensor technologies
- biomedical and veterinary technologies for human and animal life support and safety
- genomic and post-genome technologies of medicines
- environmentally and resource saving food processing and production technologies
- cell technologies

Transport and aviation and space technologies

- space, aviation and marine technologies of new generation
- new types of transport systems technologies and control
- energy efficient engines and props technologies

3. Development of professional standards for neo-industrialization specialists.

The competence model of specialists should become a base for developing professional standards in the industries involved in the neo-industrialization. The process of professional standard development is a content specification of the generalized competence model of a specialist (1) according to an engineering position. The process of professional standard development is shown in Fig. 3 [6].

The problem of professional standard formation and its correlation with education standards is very acute nowadays. There is a great imbalance between the employers' requirements to the employees on the one hand and the training quality of higher school graduates on the other hand [7].

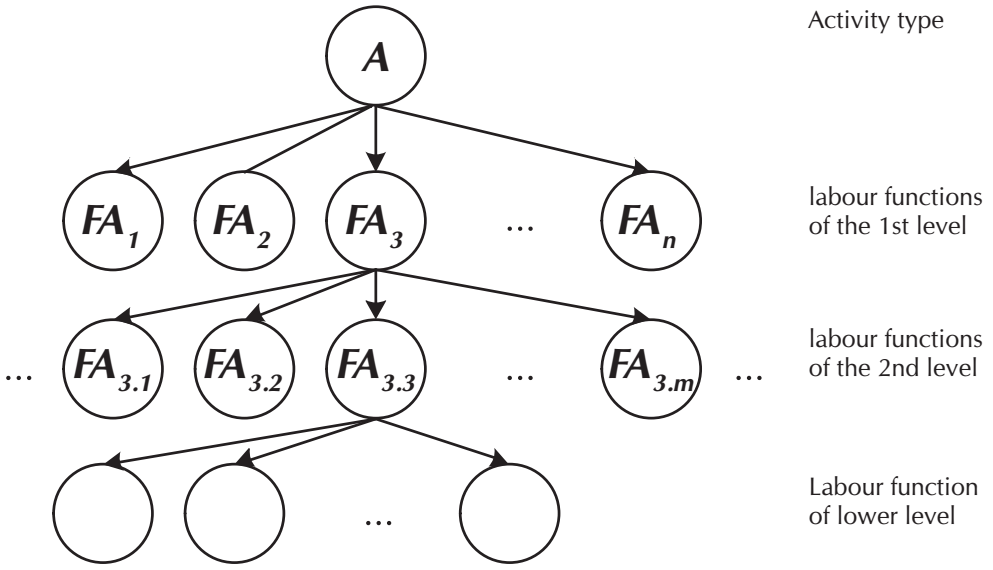
Nowadays the employers' requirements are formed in terms of graduates' skills, abilities, readiness etc. rather than in terms of their knowledge. Practical activities ask graduates not what they know but what they can do and how they act in standard and non-standard situations of professional life. We mean that knowledge as a result of higher education is necessary but insufficient for the required educational level. Professional knowledge should be a part of professional competencies.

4. Coordination of graduate's competencies with professional standards requirements.

With three-level educational system (bachelor, specialist and master degrees) there appears a problem of requirements coordination. These are the graduates' competencies determined by Federal State Education Standards of Higher Professional Education (FSES HPE) and the future job requirements.

To coordinate the graduates' competencies with a competence model of a neo-industrialization specialist (1) and with corresponding professional standard is suggested us-

Fig. 2. Hierarchical block diagram of labour functions of the competence model of a specialist



ing a competence model of a graduate [7]. Its scheme is shown in Fig. 4.

This scheme shows all the training result elements according to the Federal State Education Standards of Higher Professional Education (FSES HPE) starting from the training direction (TD) up to the complex: knowledge (K) and skills (S).

Practical comparison of the competence models of the specialist with the competence models of the graduates (Fig.4) in different engineering training directions showed great differences between them – a lot of competences required by employers are absent in FSES. To solve the problem the authors suggest [7]:

- using methods of formation of the variable part of the basic education program (BEP) which makes possible to take into account employers' requirements;
- organizing further professional training of engineering bachelor graduates.

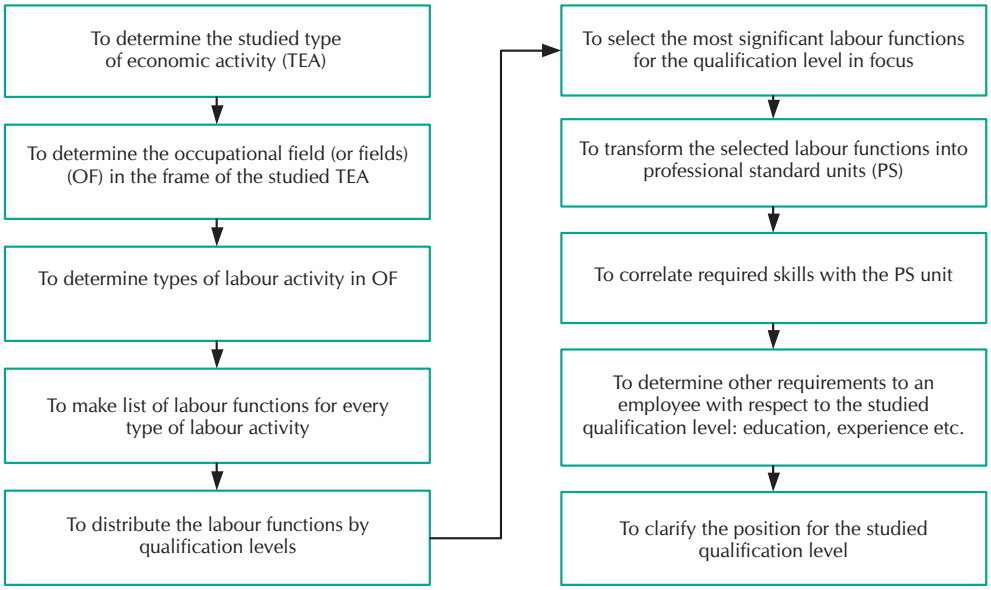
5. Quality – conceptual framework of high-tech industries.

Измерение качества продукции, плаProduction quality measurement, planning, improving and quality management are integral parts of high-tech production management. That is why the quality management engineers (quality management, standardization and metrology) can be regarded as universal specialists of Neo-industrialization economy. Thereby, the experimental test and the implementation of the suggestions mentioned above were done by the authors with quality engineers.

Using the competence model of the specialist (1) a competence model of the quality engineer was developed in BSTU [6], a part of which is shown in Fig.5. This figure shows the implementation of the scheme (Fig.2) in the form of labour function decomposition of the quality engineer for A – activity in quality management system (QMS).

Besides, the quality engineer's competences were determined which

Fig. 3. The development of professional standard content



is necessary to fulfill the corresponding labour functions of the lower level shown in Fig. 5 [6].

Basing on the model (Fig. 5), using the results of employers' survey and taking into account the requirements of Qualification schedule the professional standard for the position "quality engineer" was developed [8]. It determines the following:

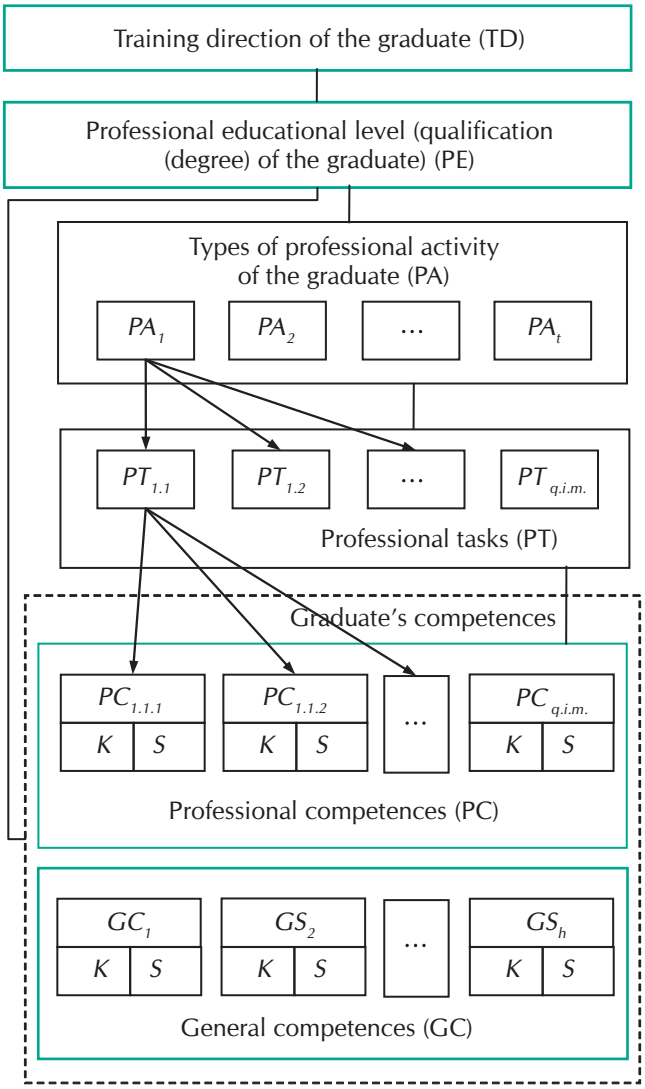
1. Type of economic activity (occupational field).

2. Type of labour activity and its connection with existing regulations.

3. A card of labour activity type that contains: a full title of labour activity type; qualification level; possible job titles, general description of labour activity, possible workplaces, work conditions, professional; education requirements, a list of professional standard units.

4. The description of all the professional standard units each of which

Fig. 4. Block diagram of a competence model of the graduate

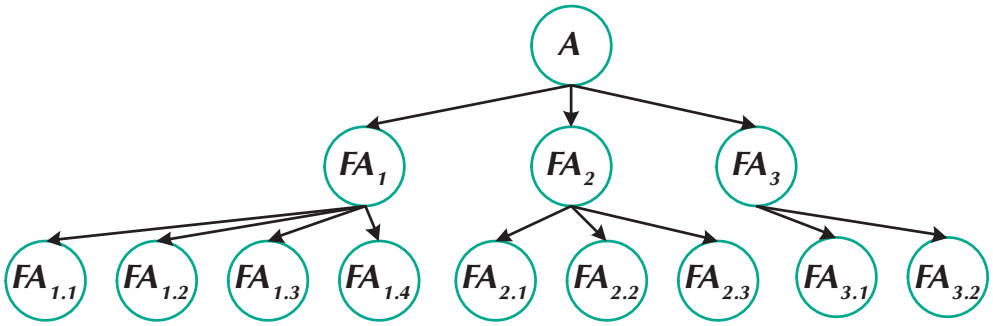


contains the following: unit name; basic labour actions; labour means; labour objects; qualification level characteristics (irregularity, responsibility, independence); knowledge needed; necessary skills.

The bachelor and master competence models were developed to make agree graduates' competences with professional standard requirements according to the scheme (Fig.4). The assessment methodology for Bachelor and Master Degrees in quality management (direction 221400) with professional standard requirements for "Quality engineer" was developed [8].

We discussed only some of the problems connected with engineering education for high-tech industries of modernized Russian economy. But the information given in the article can serve a basis to form a training program for future engineers who will be able to implement the projects of the country's neo-industrialization.

Fig.5 . Hierarchical block diagram of labour functions of the quality engineer



FA_1 – participation in organization, management and control of the enterprise's QMS: $FA_{1.1}$- to take part in QMS creation and development planning, $FA_{1.2}$ – to take part in development and improvement of QMS documentation, $FA_{1.3}$ – to take part in management of processes in the enterprise, $FA_{1.4}$ – management of quality activities; FA_2 – studying, analyzing and improving the enterprise's QMS: $FA_{2.1}$ – to organize and manage the QMS internal audit, $FA_{2.2}$ – to collect and analyze data about QMS functioning, to develop recommendation on its improvement, $FA_{2.3}$ – to manage the actions on QMS improvement; FA_3 – to communicate with external organizations: $FA_{3.1}$ – assessment activities on QMS, $FA_{3.2}$ – to interact with a customer representative.

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