INNOVATIVE ENGINEERING

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A process of innovation can be defined as a basis for socio-economic development of a modern society. Therefore, one of the priority components in the economic policies of developed countries is a world-wide support of a continuous process of innovations.

A process of creating something out of existing and available resources is called engineering. In accordance with this definition, engineering is an area of human intellectual and practical activity, a discipline and profession, whose goal is to implement achievements of science and technology and to use laws of nature and its resources for solving specific problems and achieving goals and objectives of mankind.

Historically, the term “engineering” emerged in connection with construction. Later, a combination of words “Construction” and “Engineering” was introduced into definition of other engineering areas such as, e.g., mechanical engineering, aeronautics, and others.

Since long ago, in a wide range of different kinds of existing engineerings (construction, technology, software, social, etc.) a need occurred for the creation of “engineering innovations”. Such a necessity was due to the low efficiency of the existing processes of innovation. According to estimates by various experts, the existing efficiency of the existing innovation processes does not exceed 10%. This means that, on average, only one in ten innovative developments receives acceptance in the market. If we assume that each of the failed projects consumed significant financial resources and time, it becomes clear why it is necessary to provide special educational and methodological provisions for the innovation process, which has been called “innovative engineering”. In other words, It is necessary to create conditions at which an object of innovative development becomes on demand in the planned amount, i.e., organically fit into the multidimensional space of the future.

There exist many individual reasons and their combinations, which may lead to a failure of projects. Analysis of the causes that negatively affect the final result of an innovative development is a subject of studies that are carried out within the framework of the methodological component of innovative engineering. The basis of this analysis is used for developing various recommendations and creating circuits and algorithms for the process of innovation. Practical implementation of the methods of innovative engineering allows avoiding typical mistakes in the creation of innovative products.

The life cycle of a xompleted innovative product consists of several stages. The innovative step is the first one. It serves as a starting point for development and determination of basic properties and characteristics of the product to be developed. If the product is an innovative technological system, then we are talking about an innovation stage of the life cycle of technical systems (ISLCTS). In general, the following tasks have to be solved during fulfillment of ISLCTS stages:

1. Conducting a functional analysis of the primary innovation (innovative idea). Analysis of functions to be fulfilled by the proposed device and revilement of existing methods and devices for performing similar functions. Identification of functional, economical, and other advantages of the proposed innovations as compared to existing devices used for a similar purpose. Checking other ways to

implement such functionality. Determining feasibility of the proposed innovation on the basis of existing and available resources.

2. Identifying and analyzing the needs that must be met by the proposed innovation. Identification of existing and potential markets for sales of the innovative product, as well as segmentation of these markets for approximate quantitative evaluation of a demand for the product.

3. Determining economic feasibility of the development and manufacture of the innovative product. Conducting functional and cost analysis for the market representation of the innovation.

4. Examination of the proposal for non-infringement with respect to potential markets.

5. Correcting the results of the primary marketing analysis of innovative proposals based on the results of the subsequent marketing and patent analyses by modifying the proposed and adding new consumer properties. Creating a market way of innovation as a combination of features and technical specifications that are required for fulfillment of new functions.

6. Creation of the general structural-functional model (image) of the future product. Conducting an external system analysis to identify various types of combined requirements for this type of products (safety requirements, medical requirements, military tactical and technical requirements, the requirements of the EMC and others.). Prediction of the various types of consequences (positive and negative) that may manifest as a result of the practical implementation of innovations.

Adjustment of the structural and functional image of the product based on the results of the external system analysis.

7. Developing a detailed functional block diagram of the algorithm of the system. An internal system analysis and functional synthesis. Determination of the main and auxiliary system functions. Determination of the functional components and their characteristics for realization of functions of each system. Distribution of functions between the mechanical, optical, hydraulic, pneumatic, electrical, electronic, chemical, biological and other parts of the innovation system. Defining a functional relationship between all parts of the system, their compatibility, as well as the nature of the human-computer interaction.

8. Identify different kinds of contradictions at the functional level, solving problematic and inventive tasks. Preparing materials for patenting.

9. Documentary development of innovative proposals for the prototype of the proposed innovation, taking into account the carried-out corrections and the basic requirements (technical, medical-technical, tactical-technical, technical-didactic, etc.).

10. Implementation of the component synthesis for the system being developed on the basis of its functional scheme. Development of fundamental kinematic, hydraulic, optical, electrical, and other theoretical drawings and prototype circuits. Selecting and ordering equipment and materials for the manufacture of the prototype.

11. Design and manufacture of parts and units for mechanical, hydraulic (flow-capillary), pneumatic, optical and other parts of the product’s prototype.

12. Development of schematic and technical schemes of electronic circuits of the prototype, their modeling and prototyping. Development of printed-circuit boards and electrical installation components.

13. Development of software and programmable electronic components for external computer control.

14. Assembling, testing and conducting laboratory and production (medical, field, etc.) tests of the prototype.

15. Preparation of technical specifications of the project for designing engineering prototypes of the innovative product.

The innovative engineering serves as a tool for implementation of the ISLCTS. Within the framework of its methodological component it is provided to develop and use principles and practical recommendations for transformation of a primary idea into an innovative product. As part of its methodological component used simultaneously developed principles and practical recommendations for the primary idea of transformation into an innovative product. For example, the list of IP stages of ZHTSTS given above can be used as a proven recommendation.

To perform external systematic analysis it is recommended to use the concept of "ideal final results" practiced in the Theory of Solution of Inventive Problems (TSIP) as an image of the innovation formed in the mind as described by characteristics peculiar to features of the new product. An idealized virtual imagination of the object of innovation prior to its materialization allows creating its marketable image. This is necessary for conducting market research, making market corrections, and forecasting various consequences and implications associated with the innovation (economic, industrial, social, mental, etc.).

it is recommended to carry out internal functional synthesis, by using as a guideline the concept of so-called "ideal system". The ideal system is a system that does not physically exist but properly functions. The idealized system allows increasing the functional load of the projected system in order to simplify it, while maintaining all the planned features. Such a system also establishes the principle of priority of the function to be performed with respect to the device which has to perform this function. For example, to measure the temperature of the engine it is not at all necessary to place a thermometer or a temperature sensor inside the engine. It is sufficient to use an existing resource, e.g., coil resistance that linearly increases with heating of the winding. Thus, the motor winding accomplishes two functions: it creates a magnetic field needed for rotation of the rotor and measures the temperature of the engine without installation of an additional temperature sensor.

The principle of the priority of the function performed is very important for a functional analysis and synthesis. One and the same function can be fulfilled by different components or devices of different systems. Therefore, in the process of synthesis and functional analysis it is possible to operate not with particular devices or system components but rather with their functions. For example, an internal functional analysis of such technical systems as a power system, communication system and a car shows their functional similarity (functional isomorphism). In other words, although a power system, a communication system, and a transport system are different in their target functions, their system functions are very similar.

For example, an energy system is characterized by conversion of energy of one type into the electric energy, conversion of electric energy to a form suitable for transmission over long distances, transmission of electrical energy via power transmission lines, and a reverse power conversion for use by consumers.

A communication system is characterized by conversion of information from one type into an electrical signal, conversion of an electrical signal to a form suitable for long-distance transmission, transmission of signals through communication lines, and signal inversion to the original type of information signal.

A car is characterized by conversion of heat energy into mechanical energy of reciprocating motion of the pistons, transformation of the reciprocating motion of the pistons into a rotary motion by a crankshaft mechanism, transmission of torque to the propelling means, i.e., drive wheels, and inversion of rotation of the wheels in a linear translational movement of the car.

All systems exemplified above have the functional structure of conversion and transmission of energy or information.

The functional analysis allows making an expert assessment about fundamental possibility for creating the proposed object of innovation. To do this, it is necessary to determine an existing scientific and technological potential with which it would be possible to implement the innovative product.

Estimation of the fundamental possibility of the creation of innovation is not sufficient for making a decision about the appropriateness of its development and implementation. To do this, it is necessary, by using the result of the functional analysis, to perform a value analysis. The results of the latter are used for economic calculations, which are necessary for determining the cost of development and production innovation, as well as for determining approximate market price.

An important operation to be carried out within the framework of the external system and functional analysis is the definition of a combination of factors of influence on the process of implementation of the innovations. Many innovative projects suffered a setback due to the fact that some of the requirements for this type of product was not taken into account. An example is the case of the apparatus for measuring acidity in a medium human digestive system. A radio pill was swallowed by a patient, a continuous pH-measurement was conducted in the course of passing of the pill through the digestive tract, and the pill was then naturally excreted. The pill was extracted from feces, washed, disinfected and was ready to host the next patient. Technical readiness of the expensive capsules did not mean that the next patient will be ready to swallow the pill that has been present in the feces. Thus a reasonable refusal of the patients to undergo this study was due to the fact that the developers had not taken into account the factor of natural human disgust.

Another and the most significant cause of innovation failure is to ignore or unfairly consider alternative ways and means to meet the same requirements when carrying out external system analysis. In this case, the market recognition can be given to a competitive method used for achieving the goal of innovative development. An example is the innovative project of one of the Israeli start-up firms promoting an effective method for compression of video information. The method allowed to significantly increase the transfer rate of video information via communication channels and reduce the amount of memory for storing this information. However, another innovation that allowed to dramatically increase the bandwidth communication channels and significantly reduce the cost of the memory also was successfully completed by that time. Thus, the proposed method for compressing video information appeared to be economically non-competitive.

According to the definition, the innovative engineering involves the use of all existing development tools and resources for creating innovative products in demand. With all the variety of methods and tools that are used in the process of innovation, the main innovative resources are innovative specialists. In accordance with the nature of the work, this category of professionals is the innovative engineers. Creating innovation is carried out thanks to their personal qualities and skills.

The process of formation of personal qualities in innovative engineers is determined by the creative atmosphere in the country and in the team, which must be supported and stimulated by the state innovation policy. According to various estimates, there are between 30 to 50 distinguished personal qualities. Of these, motivation, imagination, and thinking can be isolated as basic personality traits.

Desire as a concretized need may be defined as an impetus to action or a motivation. Motivation is an important and primary factor in the emergence of innovative ideas. When combined with persistence in solving problems, the motivation is an essential component of success. A man/woman puzzled with a specific problem becomes a pragmatist in the search, assimilation, and interpretation of all information received in the projection on the desired solution.

With respect to any activity a motivation has internal and external components. The internal (intrinsic) motivation is caused by the content of specific activities. A subject of the motivation my like likes the process iself and the nature of the work performed. To a large extent this is due to his/her ability to perform a specific activity and obtain a stable positive result of the performed work. The external (extrinsic) motivation is associated with influencing factors which are beyond the specific activity of the subject of motivation. These factors include financial interest, high social aspirations, etc.

The second most important factor that may cause innovative ideas is imagination. Imagination, as a form of reflection of the world, is a mental process that creates images and manipulates them at various angles, states, and combinations of states in the past, present, and future. An imagination helps to forecast future stages of activity and its results. There are several forms of imagination: active, passive, creative, recreative, and fantasy.

The highest form of active imagination is a creative imagination, which involves self-creation of images and their subsequent implementation. This kind of imagination is an integral part of any kind of work, because it is inherent in any creative person - a writer, artist, inventor, etc. Without this kind of imagination it would not be possible to solve many inventive problems, to make great discoveries, create masterpieces of art, etc.

Creative thinking is the third most important personal quality of an innovative engineer. It is based on a creative imagination. In contrast to the visual-figurative, visual-verbal and logical thinking, which provide an assessment and analysis of actually observed and perceived objects and events, the creative thinking operates with virtual objects. It requires the ability to keep in mind a variety of subjects, images and relationships between them. At the same time all these factors initially synthesized in a static system are subjected to various kinds of combinatorial or focused structural and functional changes to achieve an acceptable result. Creative thinking is a process carried out in the imagination of mental manipulation in a projected system in statics and dynamics in space and time, in the subsystems and super-systems using conventional operations and ways of thinking.

The following operations of thinking can be isolated in psychology: analysis, synthesis, generalization, comparison, classification (systematization), abstraction, and concretization. These operations allow us to carry out the process of penetration into the depths of a confronted problem, to consider the properties of constituent elements of the problem, their relationship and the nature of the contradictions. For his/her ability to think a person is obliged to Mother Nature as little as to the God. Due to the Nature, a human being has the brain - the body of thinking. The ability to think is a product of upbringing and education, a normal result of a biologically normal brain. In this context, the German philosopher Karl

Jaspers said: "Most people do not know how to think, because from birth they can only sneeze and cough but in order to think they have to be taught to this skill."

Professional training in the field of innovation engineering must take place in close connection with the formation of a system thought, based on all variety of mental operations and forms of thought. In contrast to the operations of thinking, the forms of thinking are formal structures of thoughts. Psychologists distinguish three forms of thinking – concept, judgment, and reasoning. Based on the concepts and judgments we make inferences that are inductive, deductive, and analogous. In turn, the analogies are direct, subjective, symbolic, and fantastic. For example, through analogies it is possible to mutually use those ways of formulating and solving problems that were established in different branches of human knowledge.

As can be seen from the list of ISLCTS stages, in the greater part of these stages, the innovative professionals have to operate with imaginative presentations of the proposed innovation and to carry out a systematic analysis and perform functional synthesis. The specifics of this kind of activity require, first of all, a continuous development of innovative methodological component of the innovation engineering, and second of all, the use of existing and creation of new special teaching methods for the preparation of innovative engineers. These methods should be aimed primarily at the development of creative imagination and creative, systematic and functional thinking.

The course on Development of Creative Imagination (DCI) (by P. Amnuel) can be used as a teaching aid for development of the creative thinking. Creative thinking develops in the process of solving innovative and inventive problems for resolving various kinds of contradictions. An effective training and methodical base for the development of creative thinking is, for example, the theory for solving inventive problems (TSIP). A two-dimensional didactic method was created for development of the system and functional thinking.

The method of two-dimensional didactics is considered as an integral part of the process of qualification training of innovative engineers. This method allows us to more fully and purposefully use the didactic potential of the studied general theoretical and specialized disciplines. It is also applicable in the implementation of functional training. In studying general theoretical and special subjects, the didactic bi-dimensionality is realized by associative linking of studied laws, phenomena, principles, effects, etc. to the corresponding isomorphisms of other subject areas.

As an example, we may refer to the general disciplinary representation of Ohm's law. Objectively, the Ohm's law mathematically describes not only a ratio of the electromotive force to the electric resistance. The general mathematical and semantic model also describes:

- a relation of the magnetomotive force to the resistance of the magnetic circuit;
- a ratio of the hydraulic or pneumatic pressure to the hydraulic or pneumatic resistances;
- a ratio of a directed mechanical force or torque to the mechanical resistance.

We provided only an incomplete list for implementations of the Ohm's law model. This list indicates to the existence of a general law which can be stated as follows: "The result of the impact of the driving force to any physical object (body or particle) is directly proportional to the magnitude of this force and inversely proportional to the resistance exerted by the object when it is in motion."

The model of two-dimensional didactics is used for functional training. The functional training is based on a postulate stating that a number of system functions far less than a number of systems in which these functions are implemented. Examples include functions such as conversion, storage, cooling, gain, acceleration, and others. From the standpoint of the preparation of innovative engineers, it is very important to accumulate knowledge needed for a system functional synthesis of subjects of the innovation. For use in the process of training, these skills are grouped according to the principle of functional analogies. Let us consider as an example a function of "accumulation". This function is associated with the processes of accumulation of various types of resources (money, energy, information, etc..) and individual factors.

The accumulation function is needed:

a) in a non-uniform admission and partial use of resources;

b) in a time-limited accumulation and relatively long-term use of resources;

c) in a long-term accumulation and short-term of the accumulated resources.

An example of transient accumulation and a relatively long use of the accumulated resources include purchasing food for a week, charging mobile phones, operation of flywheel accumulators, operation of analog-time capacitors, use of gas bombs, etc.

Long-term accumulation and short-term use of accumulated resources are realized at the consumer level at one-time use of a large amount of previously accumulated money; in installations for electric pulse treatment of materials, copra devices, flywheel forging presses, and the like.

Accumulation factors may be positive or negative. Negative factors, for instance, include accumulation of doses of radiation or heavy metals in the human body. To the negative factors may also relate accumulated fatigue in metal, since this phenomenon frequently causes accidents and man-made disasters.

Systems and devices that carry out accumulation of various types of resources are: banks, capacitors, receivers, flywheels, copra, disk devices, solid state memory devices, or the like.

The methodological basis of innovative engineering is the choice and use of the resources needed to create a competitive product with new properties and characteristics sought by the market. Practical implementation of methods used in sequential creation of an innovation product is defined as the process of innovation. Together with the development and application of effective methods needed for creating innovations, it is necessary to provide appropriate training of innovative engineers. Methodological and educational segments of the innovative engineering are its main intangible resources. The development and use of these resources is a fundamental factor in increasing the efficiency of the innovation process.