Electronic Information and Education Environment as a Training Tool for Resource-Efficient Management of Polymer Waste Processing

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***Abstract*—Industrial engineering of modern enterprises in order to modernize them, improve the quality of products and introduce new production management systems leads to the need to form highly qualified personnel support, which is especially important for processes of polymer waste processing in order to reduce environmental pollution and return valuable raw materials to production. For resource-saving control of polymer waste processing processes functional structure of electronic information and educational environment is proposed, which allows to form individual paths and to carry out practical-oriented training of specialists involved at each stage of life cycle of production of technical polymer products from secondary raw materials. The electronic information and educational environment proposed in the work was successfully tested on the basis of the training center "Polymer-ecology" of Saint-Petersburg State Institute of Technology with cooperation with LLC "Plastic processing plant named after "Komsomolskaya Pravda". The use of the environment as a tool to ensure the quality of training of highly qualified personnel of polymer industry enterprises allows to increase the professional level of specialists in the field of development of composite polymer mixtures based on secondary polymer materials and technologies of their processing into technical products with improved environmental and consumer characteristics.**

Keywords— engineering team; polymer recycling; polymer waste; secondary raw materials; e-learning

I. INTRODUCTION

In "Industrial Development Strategies for Processing, Recycling and Disposal of Production and Consumption Wastes up to 2030", Approved by Order of the Government of the Russian Federation No. 84-r of 25 January 2018, as one of the main areas of action for the task of establishing and expanding a national industrial industry and processing infrastructure, disposal and decontamination of wastes, their use as secondary raw materials for production of new products is indicated the necessity to create a highly qualified personnel reserve, as well as training, retraining and advanced training of industry personnel in waste treatment and disposal [1, 2].

Polymer wastes, partially recovered in the process of solid municipal waste treatment, as well as formed in the process of production and use of plastic products, are promising to be used as secondary resources for production of technical products (polymer film, carving products, polymer pipes, packaging materials, containers, fasteners, heat-sound insulating material, etc.). At the same time, the main difficulty lies in separation and isolation of pure fractions from mixed wastes, as local and common heterogeneities of composition of composite mixtures can be present, which accidentally vary, and which are difficult to describe quantifiably [3, 4].

One of the tools of resource saving, waste treatment and recycling is development of personnel support system of polymer industry enterprises [5], which provides on the basis of development and introduction of innovative technologies complex life cycle management of technical polymer products from secondary raw materials with improved ecological and consumer properties.

Thus, the development of an electronic information and educational environment for comprehensive training of specialists in the field of resource-saving management of polymer waste processing is a pressing, socially significant and economically viable task.

II. FORMATION OF TRAINING PATH FOR SPECIALISTS IN THE FIELD OF POLYMER WASTE PROCESSING

The difficulty of controlling the process of polymer technical products production is due to the presence of a changing (unpredictable) composition of raw materials, multi-factor interactions and connections arising in the course of the process, diversity of physical and chemical processes of secondary raw materials and materials processing, variety of technological equipment, a large number of controlled parameters, sensitivity to the occurrence of scrap in the selection of control effects, as well as strict requirements to environmental indicators of production [3, 6]. Therefore, in order to train specialists in the field of resource-saving control of polymer materials processing processes, it is necessary to apply a complex approach, which takes into account all stages

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of the life cycle of the technical product. Taking into account the requirements of professional standards, the personnel target groups include the following specialists involved in each stage of the technical product life cycle: specialists to ensure the production cycle of secondary polymer materials, technical and economic assessment of the life cycle, monitoring and ensuring the safety of the production environment, as well as automated production management using digital technologies [5, 7]. The training path methodology is based on a frame description and includes the steps shown in Fig. 1:

1) Define a target personnel group (*TPG*) for training $Fr^{(1)}$ ::= <*TPG*, $Q^{(1)}$, $A^{(1)}$>, where $Fr^{(1)}$ – frame prototype *"TPG"*, components of which are attributes $Q^{(1)}$ and its characteristics $A^{(1)}$. Target personnel groups are given in Fig. 2.

2) Creating a set of professional competences (*PCs*) for training *TPG* $Fr^{(2)}$ :: = <*PCs*, $Q^{(2)}$, $A^{(2)}$> based on an analysis of Generic Labour Functions (*GLF*) of the respective professional standards for each *TPG*. The list of *PCs* is given in Fig. 2.

3) Development of practical-oriented training modules for learning results (*PCs*) (*TM*) $Fr^{(3)}$ :: = <*TM*, $Q^{(3)}$, $A^{(3)}$>, given in Fig. 2.

4) Development of e-learning course (*ELC*) $Fr^{(4)}$ :: = <*ELC*, $Q^{(4)}$, $A^{(4)}$>. Training complexes are used to learn the competency results of training, allowing taking into account the characteristics of the object of study, to accumulate expert knowledge in the field of process control, as well as to form competency-oriented training results.

5) Development of control and measuring material (*CMM*) $Fr^{(5)}$ ::= <*CMM*, $Q^{(5)}$, $A^{(5)}$>. *CMM* as test jobs are used to quantify *PCs* ($q_1^{(5)}$). For qualitative assessment of educational results (*ER*) the instructor is given the opportunity to set additional situations at the object of study; monitor the actions of the trainee ($q_2^{(5)}$) and modes of operation of the subject of study ($q_3^{(5)}$); analyze and evaluate the trainee 's actions based on the results of training protocols ($q_4^{(5)}$).

6) Final evaluation of *ER* development of *PCs* $Fr^{(6)}$ :: = <*ER*, $Q^{(6)}$, $A^{(6)}$>. To evaluate the final *ER*, criteria grid is used, which compares the training criteria and the results achieved, and allow the instructor to formalize the evaluation process based on the results of the practical task. The result of the training of specialists in the field of polymer waste processing is the formation of a certificate of polymer technical product production taking into account the requirements of the product market, environmental safety requirements and economic efficiency of each stage of the life cycle and production as a whole. The certificate of manufacture of the polymer product from the secondary raw material includes description of the raw material preparation process, equipment data, tooling and tools, ranges of technological modes of the injection casting process, requirements to the product quality indicators, environmental safety requirements, as well as technical and ecological production indicators. The product certificate is formed based on the results of combining reports for each stage of the life cycle of the polymer product with unique properties. At the same time results of work of each stage (stage) are transferred to the subsequent, and data of the report of the previous stage are input data for studying and performance of the subsequent practical tasks.

III. Functional Structure of The Electronic Educational and Information Environment

In order to implement the proposed path of training of specialists in the field of polymer waste processing in the form of electronic training, an electronic information and educational environment has been developed, including electronic information and educational resources in the field of polymer processing and production, a set of information and telecommunication technologies, appropriate technological means and ensuring the full development of educational results [8-10]. The enlarged functional structure of the environment, presented in Fig. 3, includes: information support (database of technological regulations and maps, which contains information on finished products, raw materials and materials, technological modes of production, equipment, database of professional standards, trainees, educational and methodological materials); algorithm support (module for formation of individual training paths of specialists, module for formation of technical polymer product production certificate), user interface (trainees), instructor interface, administrator interface, expert interface.

The core of the electronic information and educational environment is training complexes, which allow on the basis of mathematical models of key processes (drying, extrusion, injection casting) to carry out research of cause-and-effect relations of the object of study, to determine technological modes of equipment for obtaining polymer products with specified quality requirements, as well as to simulate the occurrence of abnormal situations in order to train specialists in the skills of accident-free operation of technological processes.

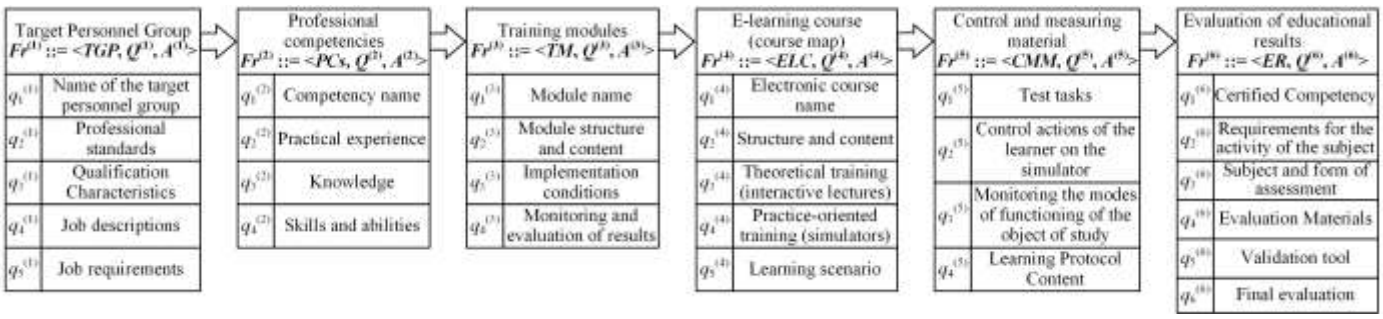

Fig. 1. Process of formation of training path of specialists in the field of polymer waste processing

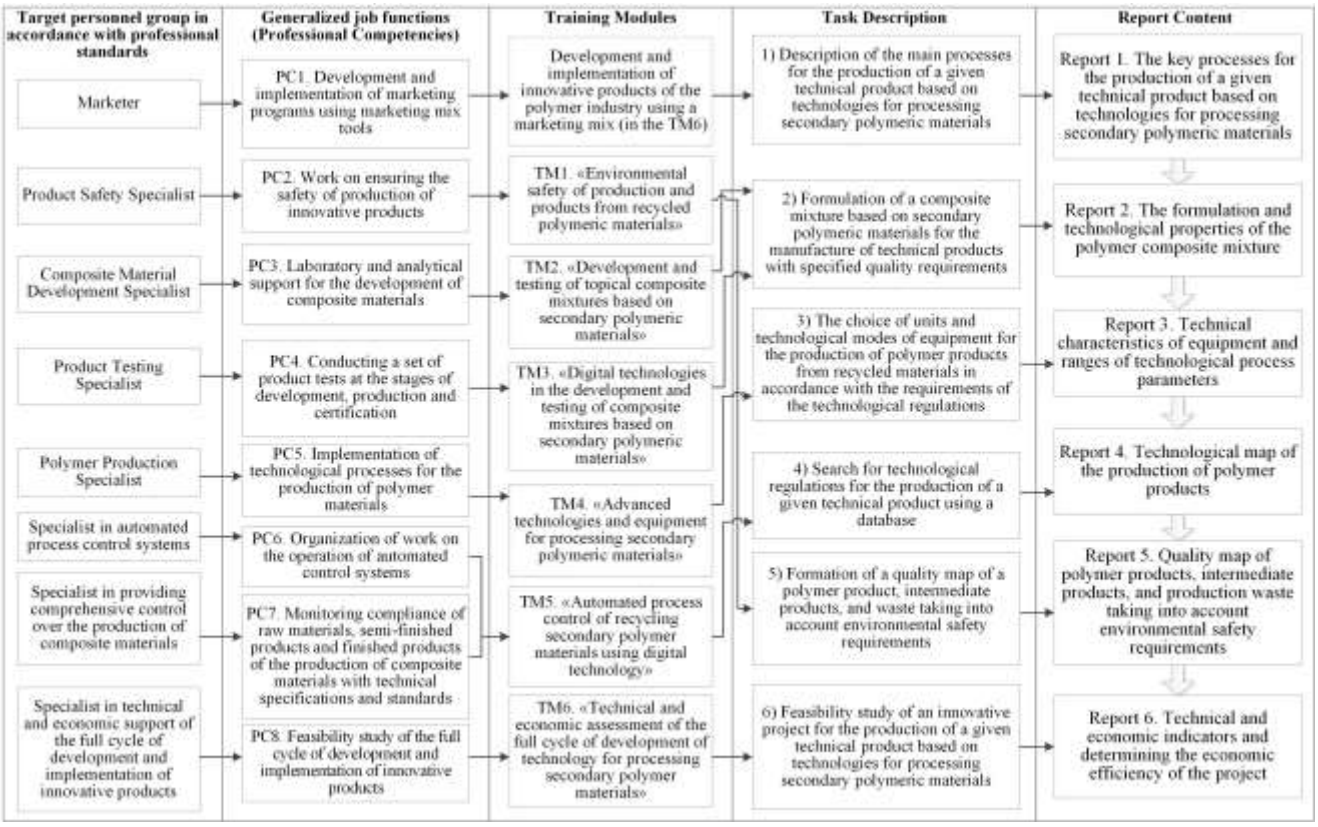

Fig. 2. Structure of personnel support model for resource-saving control of polymer waste processing processes

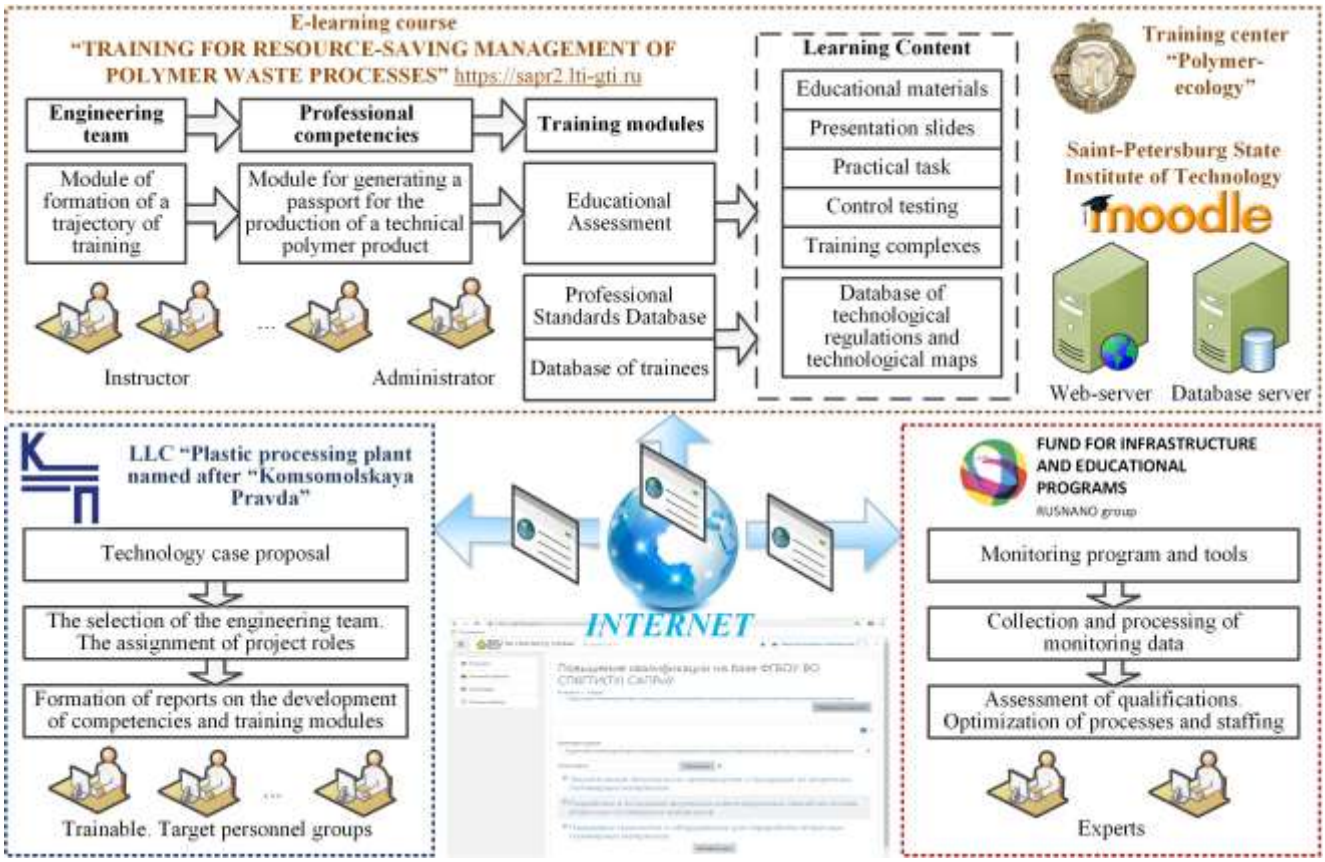

Fig. 3. Structure of the electronic information and education environment

The information support of the medium is adjusted to different modes of operation of the control object (processes of polymer waste processing) by changing the ranges of the corresponding parameters. This enables the adaptation of the electronic information and education environment to various modifications of the subject of study, which allows using the environment for training in resource-efficient management of various technological processes and production with recycling.

The electronic information and education environment is based on the Moodle learning management system using the SQLite database management system and MS Visual Studio software development environment. The developed environment software has a flexible architecture that supports enhanced functionality by developing and connecting additional software modules.

IV. Conclusion

Testing of the electronic information and educational environment, carried out on the basis of the training center "Polymer-ecology" of Saint-Petersburg State Institute of Technology with cooperation with LLC "Plastic processing plant named after "Komsomolskaya Pravda", confirmed its operability and the possibility of using it to train specialists in solving the problem of reconfiguration of production to a new type of product, problems of determining a formulation of a composite mixture based on secondary polymer materials; as well as tasks of selection of technological modes of polymer product production with specified requirements for quality and consumer properties of final product.

The use of modern technologies of practical-oriented training allows to increase efficiency of production due to introduction of innovative production technologies, to increase quality of produced products, to intensify recycling processes, to improve ecological characteristics, and, above all, to increase professional level of personnel support of industrial enterprises in conditions of digitalization of economy and modernization of system of professional standards and qualifications.

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