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Education and Research Laboratories as a Means of Enhancing the Quality of Professional Engineering Education in Design and Production of Composite Parts

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ABSTRACT

Relevance of this research is determined by quality improvement of professional engineering education. The purpose of this paper is to offer practical recommendations for those interested in establishment of education and research laboratories as a means of enhancing the quality of professional engineering education in design and production of composite parts. Structure and function analysis was the main approach within this research used to identify the functions and structure of the Center of Composite Technology as well as the purposes of education and research laboratories. Structure and function analysis approach, the main one within this research, was used to identify the purposes of education and research laboratories that all together provide synergetic effect in adaptation of a future professional to industrial conditions and make him or her able to meet competition in the labor market. Purposes of education and research laboratories were defined by 75 academics and 250 students at Kazan National Research Technical University n.a. A.N. Tupolev that took part in this study. Main results of the research are identification of the functions (professional and educational) and structure of the Center of Composite Technology as well as the purposes of education and research laboratories (design and simulation, material science, tooling manufacturing, preforms and prelaminates, molding, quality control, assembly and joining, equipment manufacturing). Significance of these results is that identified functions of the Center of Composite Technology allow considering the center an innovative component of the material and technical support of engineering education, providing practical training of students. Identified purposes of these laboratories set practical trends in engineering education as provided by industrial strategy of a region.

KEYWORDS
Center of composite technology, education and research laboratories, engineering education

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Introduction

Relevance of this research is determined by quality improvement of professional engineering education. Special attention should be paid to

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engineering education of future professionals in design and production of composite parts as they will be dealing with strength and impact, acoustic testing, physical-chemical study of composites, including non-destructive testing (Gerdeen, Lord & Rorrer, 2005). Composite materials are materials made from two or more constituent components that ensure their performance and processing characteristics (Miller, 1995). Composites may use metal, polymer or ceramic matrices. Reinforcement is provided by specific fillers in the form of fibers, whiskers and various particles. Plastic properties, strength and a wide range of application make state-of-the-art composites stand out (Baker, Dutton & Kelly, 2004; Niu, 2005). As for production, these materials contain metal or non-metal basis that is reinforced with strong fibers, filaments, etc. There are polymer composites reinforced with boric, carbon, glass fibers or aluminum composites reinforced with steel or beryllium fibers. While combining different components, one can get composite materials with different strength, elasticity, resistance to abrasion (Kerber et al., 2008). Aircraft Manufacturing Department of Kazan National Research Technical University named after A.N. Tupolev offers a program in Design and Production of Composite Parts. In the course of training, it is critical to develop practical skills in composite technology. It is well-known that application of theoretical knowledge into practical production of a specific part is the best way to master any discipline. Besides, practical work, aimed at manufacturing of specific part, is the strongest stimulus for creative thinking. If a student achieves practical result that outstrips existing design and technology, he or she gets enthusiastic about his/her profession. And one may be confident that this student becomes a good professional. Obviously, the most efficient education scheme would be the one that includes a final project featuring a practical section — production of a composite part. This work is supported by the Ministry of Education and Science of Russian Federation within the scope of the project under unique identification number RFMEFI57414X0078. The purpose of this paper is to offer practical recommendations for those interested in establishment of education and research laboratories as a means of enhancing the quality of professional engineering education in design and production of composite parts.

Materials and Methods

Structure and function analysis was the main approach used to identify the functions and structure of the Center of Composite Technology as well as the purposes of education and research laboratories. The point of structure and function analysis approach is to review the subject of research as a structured system of interconnected components that have their own functions and purposes (Magdanov, 2010). If education and research laboratories are the means of enhancing the quality of professional engineering education in design and production of composite parts, then the purposes of these laboratories may correlate with setting practical trends in engineering education as provided by industrial strategy of a region. Structure and function analysis approach makes us identify the purposes of education and research laboratories that all together provide synergetic effect in adaptation of a future professional to industrial conditions and make him or her able to meet competition in the labor market. The following methods were used in the course of research: theoretical (analysis, synthesis, generalization, systematization), sociological (observation, interview, survey).

Results

Main results of the research are: 1) functions and structure of the Center of Composite Technology; 2) purposes of education and research laboratories.

Functions and structure of the Center of Composite Technology

It is found that the quality of professional engineering education in design and production of composite parts improves, given that material and technical support of engineering education meets the requirements of a cutting edge composite enterprise. It is determined that the Center of Composite Technology is an innovative component of the material and technical support of engineering education. The functions of the Center of Composite Technology are as follows:

1) Professional, as it makes students familiar with the main steps of design and production of composite parts. This function makes it possible to establish the Center of Composite Technology as a small-scale research and development enterprise that includes the following education and research laboratories: design and simulation, material science, tooling manufacturing, preforms and prelaminates, molding, quality control, assembly and joining, equipment manufacturing.

2) Educational, as it provides a possibility, first of all, to train students using simple and clear processing examples, secondly, provide advanced training to industrial employees, and in the third place, experiment with innovative design and processing solutions. This function aims at organization and equipment of education and research laboratories in compliance with requirements of the state-of-the art composite industry, and the cutting-edge technologies should be at disposition (Figure 1).

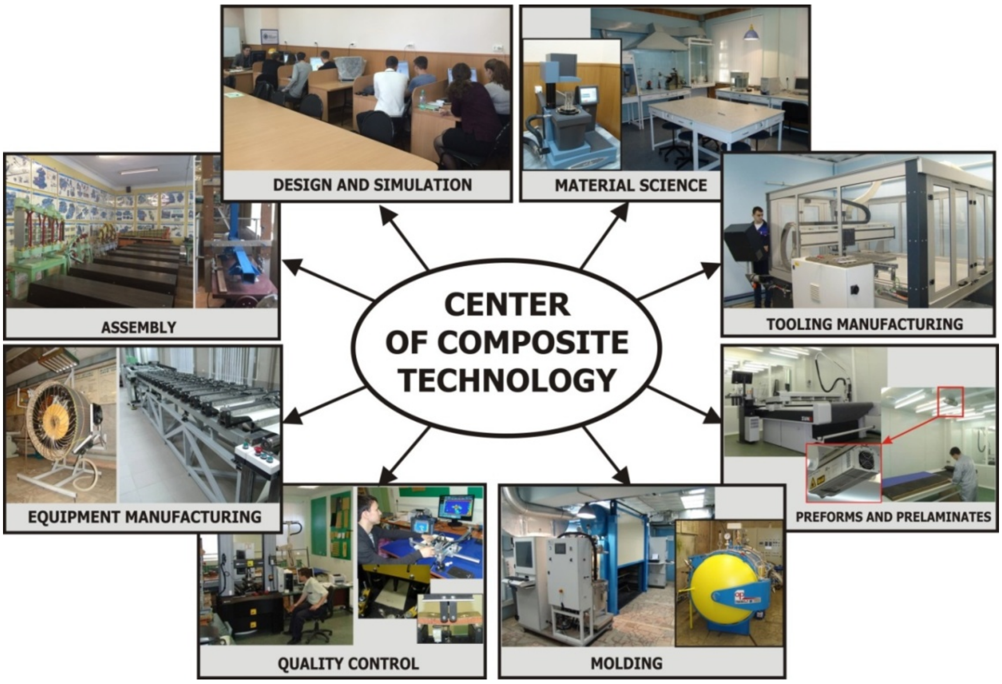

Figure 1. Structure of the Center of Composite Technology

Figure 1 demonstrates that equipment of the Center of Composite Technology and its maintenance require substantial funding. It is observed that significant part of maintenance and material (composite and auxiliary) costs are covered by the revenues from research and development performed under contracts with industrial enterprises.

Purposes of education and research laboratories

Purposes of education and research laboratories were defined by 75 academics and 250 students at Kazan National Research Technical University n.a. A.N. Tupolev.

Design and simulation laboratory provides education in the following areas of expertise: a) methods of tooling and equipment 3D modeling; b) writing of mechanical treatment control programs for NC units; c) writing of control programs for specific processing equipment, such as cutter, TFP machine, radial braiding machine, etc. d) design of ply book for bagging layers; e) design of injection points location scheme for transfer molding, and simulation of resin injection and part impregnation; f) structural analysis – calculation of deflection mode of composite parts; g) simulation to study production processes (Figure 2).

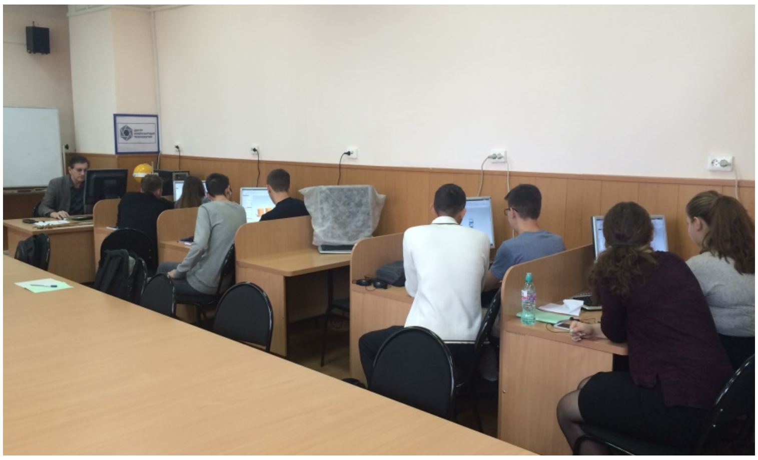

Figure 2. Design and Simulation Laboratory

Siemens NX software is used for geometry design. Items b and c are performed in specific software. Items d and e are performed in FiberSIM by Siemens and PAM RTM by ESI Group. Structural analysis (e) is done in ANSYS and NASTRAN.

Material science laboratory targets training in physics and chemistry of composites. This lab is comprised of two parts: Chemistry Department and Physical-Chemical Department (Figure 3).

a *b*

Figure 3. Material Science Lab: *a* –Chemistry Department; *b* – Physical-Chemical Department

This laboratory provides training options in methods used to study properties of composite materials, to generate new composites with given properties, to develop and optimize modes of molding, including compression, transfer and other types of molding. Chemistry Department is equipped with standard facilities necessary to study polymers. Physical-Chemical Department is equipped with the following devices: rheometer to study polymers' rheology; dynamic mechanical analyzer to study viscoelastic behavior of materials (elastic modulus), based on various factors, such as temperature and load application frequencies in the first place; thermal mechanical analyzer to study changes in linear dimensions of material with temperature, time, load and sample atmosphere under control; differential scanning calorimeter to study physical-chemical processes in substances in wide range of operation temperatures; optical microscope, and infrared spectrometer to study chemical composition of polymers.

Laboratory of tooling manufacturing aims at development of knowledge and skills in methods and means of molding tooling production. This laboratory is equipped with NC units for mechanical treatment of various materials, including metals, mold plastics, silicone, etc. (Figure 4).

Figure 4. Laboratory of Tooling Manufacturing

Laboratory of preforms and prelaminates reflects the wide range of state-of-the-art methods for semi-finished net-shape parts production from dry materials and prepregs. To demonstrate a well-known method of preform production called ‘lay-up’, a cutter Zünd and 3D laser projector are used. Lay-up is performed in a cleanroom rated ISO 7/ ISO 8. Innovative methods of preform production are presented with the following equipment: a) Tailored fiber placement (TFP) machine (Figure 5), b) Radial braiding complex based on HERZOG braiding machine (Figure 6), c) Tufting and blindstitching complex for preforms manufacturing (Figure 7) (Khaliulin, Khilov & Toroptsova, 2015; Mattheij, Gliesche & Feltin, 1998).

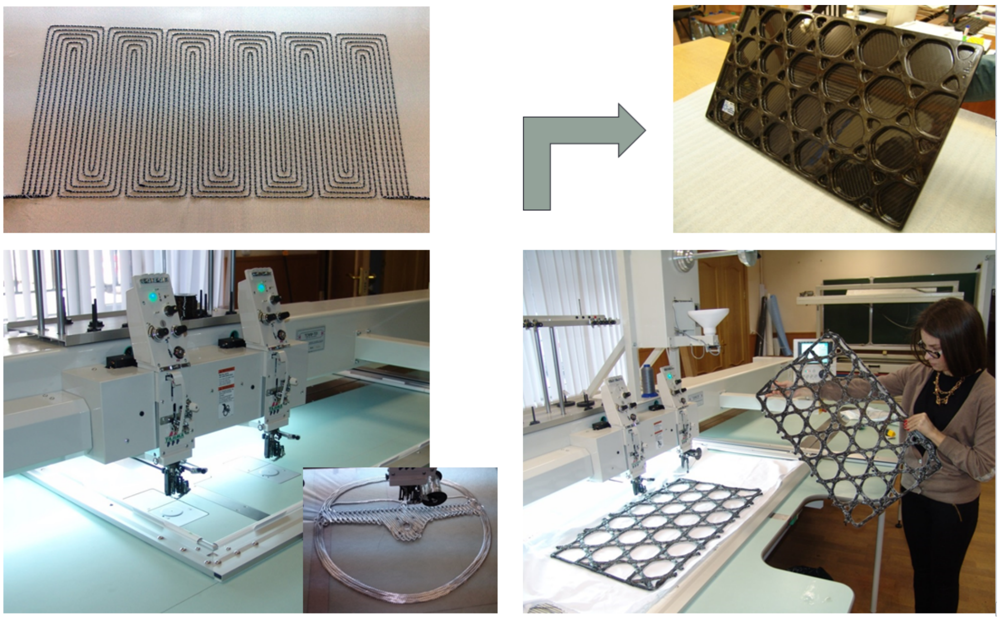

Figure 5. Tailored Fiber Placement Machine (TFP)

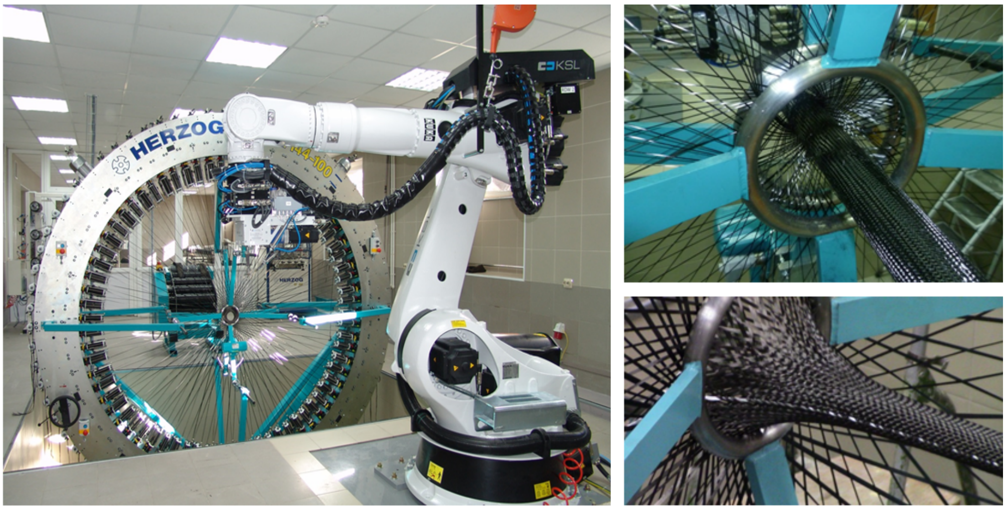

Figure 6. Radial Braiding Complex

Aforementioned pieces of equipment provide students with an idea on cutting edge composite technologies. Currently, those are being widely used in design and production of truss structures for spacecrafts as well as different transport facilities.

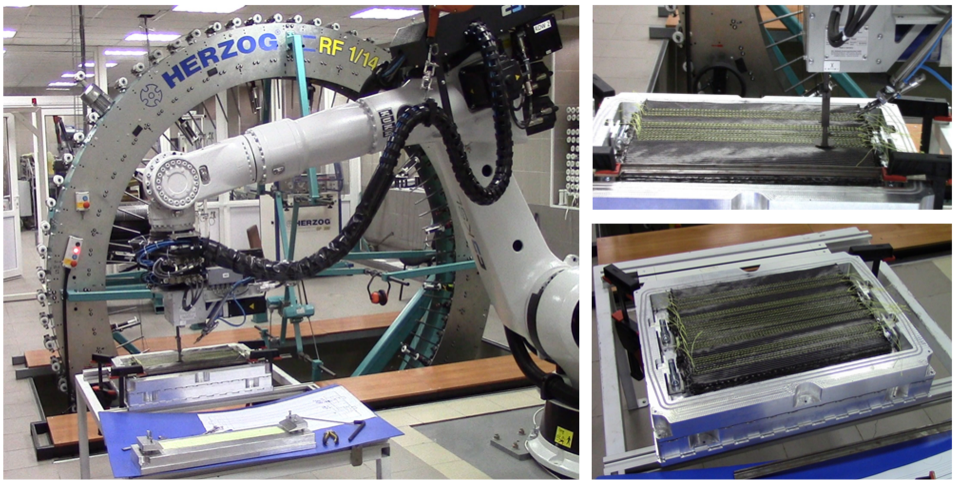

Figure 7. Tufting and Blindstitching Complex

Laboratory of molding consists of three departments. In the first department, thermal compression methods are studied (Figure 8). The following equipment is used: small autoclave (Figure 8, a), hydraulic press (Figure 8, b), pneumatic press (Figure 8, c), vacuum press (Figure 8, d). In the second department, transfer molding is studied, including RTM (Resin Transfer Molding), Light RTM, RFI (Resin Film Infusion) and infusion.

a

b

c

d

Figure 8. Equipment for Thermal Compression Molding: *a* – Autoclave; *b* – Hydraulic Press; *c* – Pneumatic Press; *d* – Vacuum Press.

Figure 9 shows two sets of equipment for RTM.

Figure 9. Complex for RTM

In the third department, alternative molding processes are studied. Particularly, these studies involve a machine for ultra-violet curing (Figure 10).

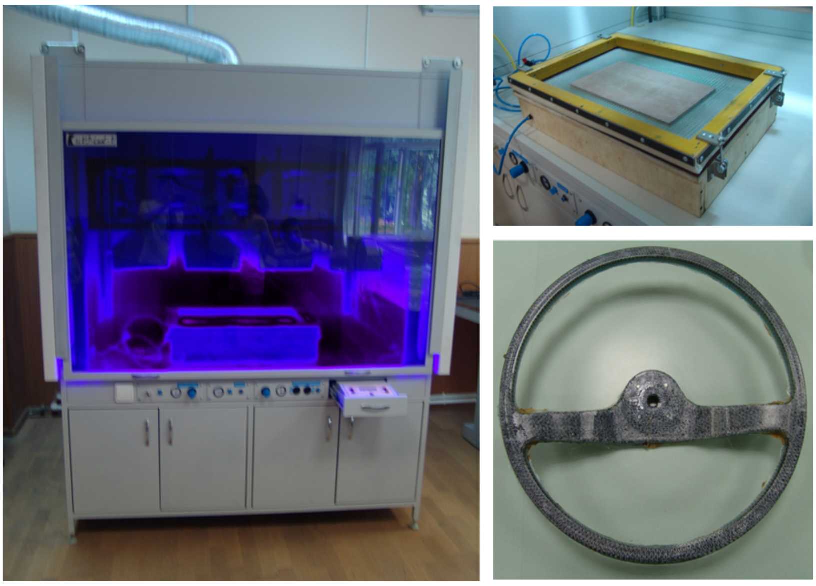

Figure 10. Machine for Ultra-Violet Curing

Analytic equipment developed and produced by Inasco Company is used to study transfer molding and real-time monitoring of composite parts production based on material state (Figure 11).

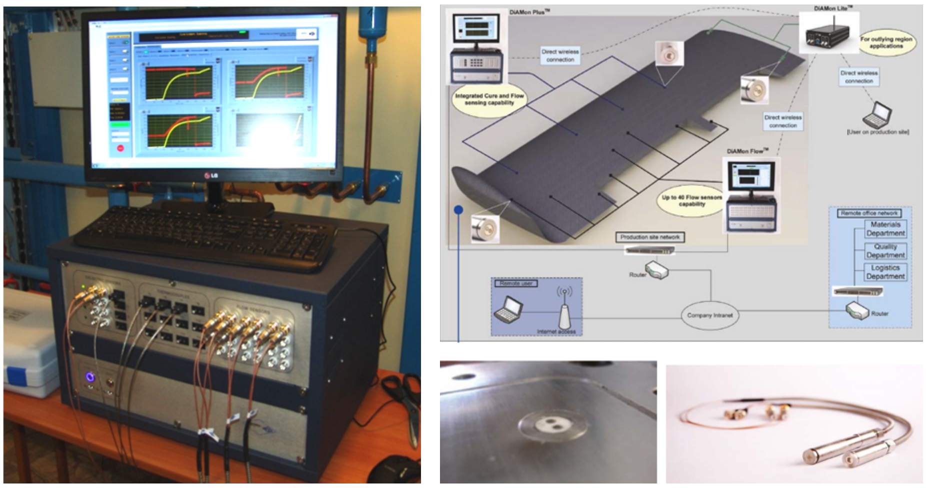

Figure 11. Equipment for Studying Resin Flow in a Preform

Quality control laboratory includes four departments: part and tooling geometry control, material quality control, static testing and impact testing. To control part and tooling geometry, measuring arm is necessary. It may operate either in contact or in scanner mode (Figure 12).

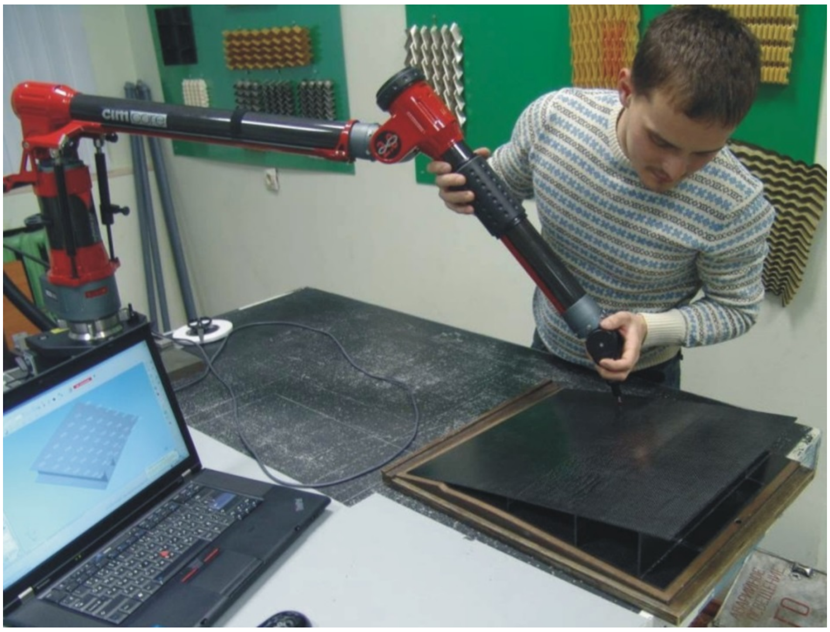

Figure 12. A Measuring Arm

Material quality control is performed with Omniscan MX2 ultrasonic phased array flaw detector (Figure 13).

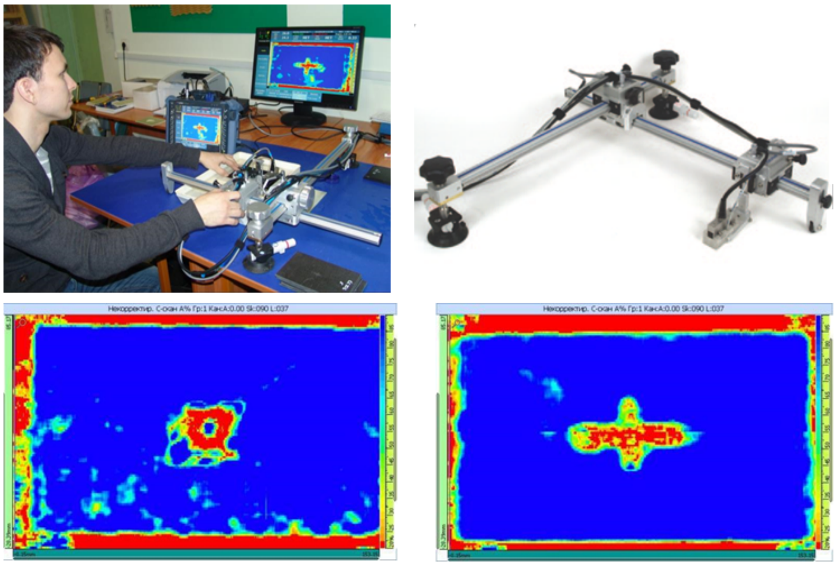

Figure 13. Non-Destructive Testing of Composites

To study static testing methods, a universal electromechanical testing system, an environmental chamber and a set of testing accessories are used (Figure 14).

Figure 14. Static Strength Testing System and Accessories

Figure 15 demonstrates equipment that is used to study impact resistance and durability of materials and structures. The set includes drop weight and pendulum testers as well as testing accessories.

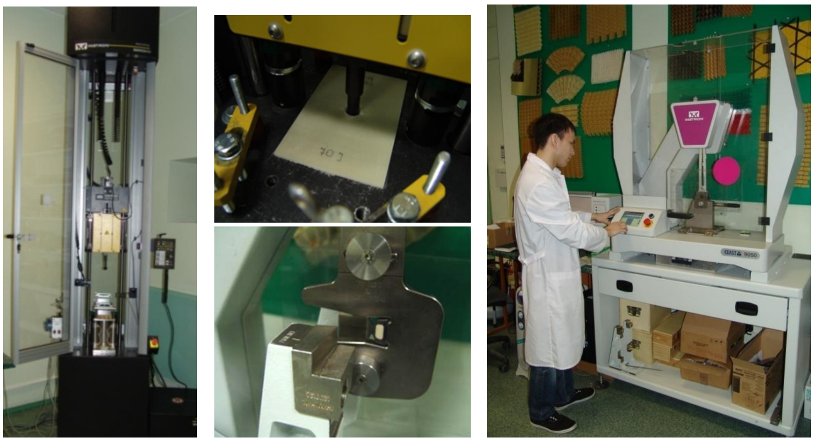

Figure 15. Drop Weight and Pendulum Testers

Laboratory of assembly and joining aims at providing knowledge and skills in methods of thin-walled composite parts positioning, accuracy assurance as well as adhesive and mechanical joints (Figure 16). This laboratory accommodates assembly jigs for 2D and 3D units. These units contain truss and shell composite elements. Specific tooling and instruments are used to study assembly methods.

Figure 16. Laboratory of Assembly and Joining

Laboratory of equipment manufacturing provides basis for implementation of creative initiative of students and researchers (Figure 17). Under supervision of faculty staff, scientific and technical ideas that emerge while working on graduate projects and theses find their way and become reality in this laboratory (Khaliulin & Khisamova, 2011a; Khaliulin & Khisamova, 2011b; Khaliulin & Khisamova, 2011c; Khaliulin & Khisamova, 2012a; Khaliulin & Khisamova, 2012b; Khaliulin, Batrakov & Dvoeglazov, 2010; Khaliulin, Batrakov, & Danilov, 2013).

Additionally, when it comes to solving practical engineering tasks in the course of state- or industry funded projects, this laboratory becomes the main place of action. In particular, this laboratory is used for development of technology and equipment for manufacturing of folded cores for sandwich panels from glass and carbon reinforced plastic (Figure 17, *a*) and aramid paper (Figure 17, *b*) (Khaliulin & Gershtein, 2016a; Khaliulin & Gershtein, 2016b; Khaliulin & Gershtein, 2016c; Khaliulin, 2016). This kind of composite structures are in demand in automotive industry as well as in the body of untight spacecrafts (Khaliulin & Gershtein, 2016d).

a *b*

Figure 17. Laboratory of equipment manufacturing: *a* – equipment for carbon fiber reinforced folded core manufacturing; *b* – facility for aramid m-type core manufacturing

Discussions

There is a lack of information in scientific literature on the problem of material and technical support improvement in the area of design and production of composite parts. It is found that published works of the experts in this domain describe the contents of technologies aimed at composite parts production. The reason behind this phenomena is that conventional education and technical literature provides descriptive information on technology and processing equipment (Niu, 2002; Khaliulin & Shapaev, 2004). Besides, methods of processing parameters calculation are usually explained using abstract examples (Khaliulin & Razdaibedin, 2015; Khaliulin & Dvoeglazov, 2013; Khaliulin & Inkin, 2012; Khaliulin et al., 2012). And all the details, know-how and practical methods remain outside of the scope of education process. So, a graduate is forced to acquire missing skills and knowledge in the industry, thus spending additional time. The reason is obvious: theoretical learning has the lead in academic curriculum. It is suggested that practical training takes place in the industrial enterprise. However, the fact that such training will be one-sided and limited to specific industrial equipment is not discussed.

Studies aimed at the problems of engineering education take into consideration forms, methods of education, selection and patterning of instructional materials (Lunev et al., 2016). This is due to the requirements set in educational standards that educational programs should meet, specific features of teaching engineering subjects (interdisciplinary approach, flexibility, a connection between technical knowledge, professional awareness and experience at the point of training). A matter of material and technical support of engineering education remains outside of the scope of scientific research. We are certain that material and technical support of engineering education is a matter of particular importance for technical universities. It is material and technical support that provides a possibility to engage students in production process.

All the aforementioned made the research matter relevant: establishment of education and research laboratories as the means of enhancing the quality of professional engineering education in design and production of composite parts. This paper discusses a structure of education and research center as well as a range of production equipment for the laboratories. An approach to laboratory structure stated in the paper will ensure quality improvement of professional engineering education due to the possibility to gain practical skills in composite parts production.

Conclusion

It is found that establishment of education and research laboratories ensures that the students gain practical skills in composite parts production; get general information on processing equipment, learn to operate and program this equipment; get a comprehensive environment for engineering and scientific work. It is revealed that establishment of education and research laboratories ensures transparency of engineering education and provides conditions for an engineer to be socially protected by the quality of his/her education and future professional opportunities it opens up.

Information in this paper may be helpful for academic staff at technical universities as well as staff at advanced training and retraining centers at the point of selection and patterning of advanced training contents. Results of the research point out trends for the future studies in this domain, that would be development of ways for technical universities to cooperate in order to improve material and technical support of engineering education.

Disclosure statement

No potential conflict of interest was reported by the authors.

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