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# INNOVATION TECHNOLOGIES IN TRAINING SPECIALISTS IN ENGINEERING MATERIALS SCIENCE

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**Abstract.** The aim of educational program TEMPUS is the integration of Eastern countries in the Bologna process. Participating of Lviv Polytechnic National University in project “Modernization of two cycles (MA, BA) of competence-based curricula in Material Engineering according to the best experience of Bologna Process – 543994-TEMPUS-1-2013-1-BE-TEMPUS-JPCR” allows to improve the quality of training of specialists in the field of materials science. Directions of “MMATTENG” project realization by Applied Material Science and Materials Engineering chair, implementation of computer-integrated technologies within the project, formation of modernized educational programs, trainings and retrainings of lecturers, seminars on the base of EU Universities, enterprises and companies-developers of software products and formation of the common research centers of materials science with participation of leading foreign and home companies are described in this article.

## Introduction

Higher education is one of the most important fields of the development of Eurointegration . The entry of the Ukrainian education into European educational space is realized within the Bologna process. At present 46 European countries, including Ukraine, are participants of this process. Launched in 1999 by the Ministers of Education and university leaders of 29 countries, the Bologna Process aims to create a European Higher Educational Area ( EHEA). It should be noted that this process doesn’t foresee the formation of identical educational systems in member-countries. Its main task is to improve the mutual understanding and strengthening of relations between different educational systems. Several projects have been proposed by the European community with the aim to enhance the integration of Eastern countries in the Bologna process [1-4]. One of them is the educational program TEMPUS, launched in 1990 for improvement of educational systems in 27 EU member-states and partner-countries. It provides a financial support for realization of structural reforms of higher education, interuniversity cooperation on improvement and application of educational programs, development of scientific and methodical investigations [5]. Ukraine has been an active participant of TEMPUS program since 1993, the time of joining it [6].

In accordance with the results of competition in 2013, 33 TEMPUS projects have been executed with participation of Ukrainian universities, enterprises, and research institutes. One of such projects is the project “Modernization of two cycles (MA, BA) of competence-based curricula in Material Engineering according to the best experience of Bologna Process — 543994-TEMPUS-1-2013-1-BE-TEMPUS-JPCR” (MMATTENG), which operates for 3 years (2013-2016) [7].

Participants of this project are representatives of higher educational institutions of 4 EU countries (Belgium, Germany, Poland, France) and 3 partner-countries (Ukraine, Israel, Russia). Ukraine is represented by the chairs of the National University “Kyiv polytechnic institute”, Lutsk National Technical University, Pryazovskyi State Technical University and National University “Lviv polytechnic” (Department of Applied Material Science and Materials Engineering (AMSME). Members of the “MMATTENG” project consortium include also the Ministry of Science and Education of Ukraine, Company “Metallurgical plant “Azovstal” (Mariupol, Ukraine), Office of engineering, consulting and management (Berlin, Germany) [8]. The main goal of the MMATTENG project - to improve the quality of training of specialists in the field of materials science - is realized via:

− analysis and modernization of educational programs of qualification levels of Bachelor and Master in materials science;

− formation of modernized educational programs with the integrated infrastructure support;

− introduction of computer-integrated technologies in educational process;

− training and retraining of lecturers of member-countries by participation in trainings, seminars on the base of EU Universities, enterprises and companies-developers of software products;

− creation of training-scientific laboratories “Material Engineering Service-Office” (MESO).

Thus, realization of the “MMATTENG” program will allow the higher schools of Eurointegrated countries to develop a common platform for specialists training in the field of materials science and will form prospects for the development of didactic and scientific cooperation.

**Directions of “MMATTENG” project realization by AMSME chair**

High schools – coordinators of “MMATTENG” project – proposed to introduce the following disciplines into the training process:

− “Metallurgy”, “Microstructure investigation technique” and “Damage and reliability of materials” — Ecole Nationale Supérieure de Chimie de Lille (ENSCL);

− “Technologies and applications of Superconductive materials”, “Effective communication with groups, presentation techniques” and “Survival in Labor Market (carrier managing)” — Technische Universität Berlin (TU Berlin);

− “Materials Selection”, “Basics of material science incl. fatigue behavior”, “Light weight materials for transportation applications”, “:CAD-CAM - CAE Siemens NX” — Katholieke Universiteit Leuven (KU Leuven);

− “Strengthening technologies of materials treatment” — Pryazovskyi State Technical University;

− “Nano materials technologies” — Nosov Magnitogorsk State University;

− “Materials from renewable source” and “Project management (business planning, funding, marketing, performance)” — Cracow University of Technology;

Realization of the “MMATTENG” project by the chair of applied materials science and materials treatment of the National University “ Lviv Polytechnic” started from the analysis of current training plans for students in the direction 6.050403 “ Engineering materials science” and in speciality 8.05040301 “Applied materials science” and also their comparison with the disciplines proposed by the “MMATTENG” project. Programs of some disciplines were very similar by content to those recommended by the project and didn’t require special matching. These subjects were as follows:

− “Metal Science” (“Metallurgy”);

− “Structure investigation technique” (“Microstructure investigation technique”);

− “Principles of materials selection” (“Materials Selection”).

Other disciplines of the project will be used as separate modules in disciplines of training Bachelors and Masters in the field of materials science:

Module “Materials from renewable sources” in discipline ”Non-metallic materials”;

− Module “Technologies and applications of superconductive materials” in discipline “Physics and chemistry of surface”;

− Module “Basics of material science incl. fatigue behavior” in discipline “Mechanical properties and structural strength of materials”;

− Module “Light weight materials for transportation applications” in discipline “Non-ferrous metals and alloys”;

Remaining disciplines of the project were introduced by the AMSME chair into educational programs for training specialists in materials science, namely:

- “Damage and reliability of materials”;

− “Nano materials technologies”;

− “CAD-CAM - CAE Siemens NX”;

− “Strengthening technologies of materials treatment”;

− “Effective communication with groups, presentation techniques”;

− “Survival in Labor Market (carrier managing)”;

− “Project management (business planning, funding, marketing, performance)”.

Within the MMATENG project the pilot training of lecturers was organized on the base of KU Leuven from January17 to February 2, 2015. Its aim was to acquaint lecturers with the materials science educational and research resource base of KU Leuven and also to study the teaching programs and methods of such disciplines as “Metallurgy”, “Microstructure investigation technique”, “Materials Selection”, “Damage and reliability of materials”, “Light weight materials for transportation applications”, “CAD-CAM - CAE Siemens NX”, ”Basics of material science incl. fatigue behavior”. The AMSME chair was represented by the project co-coordinator Prof. Z. Duriagina, assistant professors L.Bohun, E. Pleshakov, T.Tepla (Fig.1). Later the trainings will be organized on the base of other high schools-discipline developers.

At present the staff of AMSME chair works intensively on introduction of the developed recommendations under the project in the educational process: lecturers develop educational working programs of new disciplines and modules , lecture summaries, work out the methods of laboratory and practical lessons, in cooperation with assistance staff prepare the methodical materials for lessons, they are preparing to deliver these disciplines and modules in English.

**Fig. 1.** Participants of the training at KU Leuven

**Directions of “MMATTENG” project realization by AMSME chair**

A wide use of computer-integrated technologies is the basis of not only production and science quality and efficiency but also of education. Mastering of computer technologies by students- materials science researchers will allow them in their professional activity to make the most optimal decisions: from design modeling and selection of the components materials via creation of the technological processes of their manufacture to prediction and assessment of their service properties.

Students training and their work in open information and computer-integrated systems starts with mastering the elementary computer software for computer aided design ( CAD), computer-aided manufacture ( CAM), computer- aided engineering (CAE) and ends with mastering the industrial- licensed programs.

Within the project activities the MMATENG chair of the National University “Lviv polytechnic” was presented the computer class AB, integrated package CAD/CAM/CAE of modern version NX9 by the company Siemens PLM Software and educational program CES EduPack 2014 by the company Granta Design. Training in KU Leuven gave the opportunity to the lectures to make acquaintance with those up-to-date program resources during master classes organized by the representatives of companies Siemens PLM Software (Germany) and Granta Design (University of Cambridge, Great Britain) (Fig. 2.) [9].

The NX resources of CAD/CAM/CAE system are highly-productive, integrated solutions for engineering and technological design including all basic functionality, necessary for solving the tasks of engineering training. In Ukraine NX occupies the sound positions due to the wide possibilities of this system use in different branches of industry of Ukraine (aviation, machine-building, ship-building and other industries). Its use simplifies and enhances the processes of the components development by engineers when creating innovative products, thus ensuring their competitiveness on the market.

The modern version of NX Student Edition available for students training possesses all possibilities of commercial NX version for modeling, however it does not include the functions of CAE- and CAM. Through participation in the MMATENG project the students, post-graduate students and scientific and teaching staff of AMSME chair had access to the complete NX9 resource (Fig. 2) [10-13].

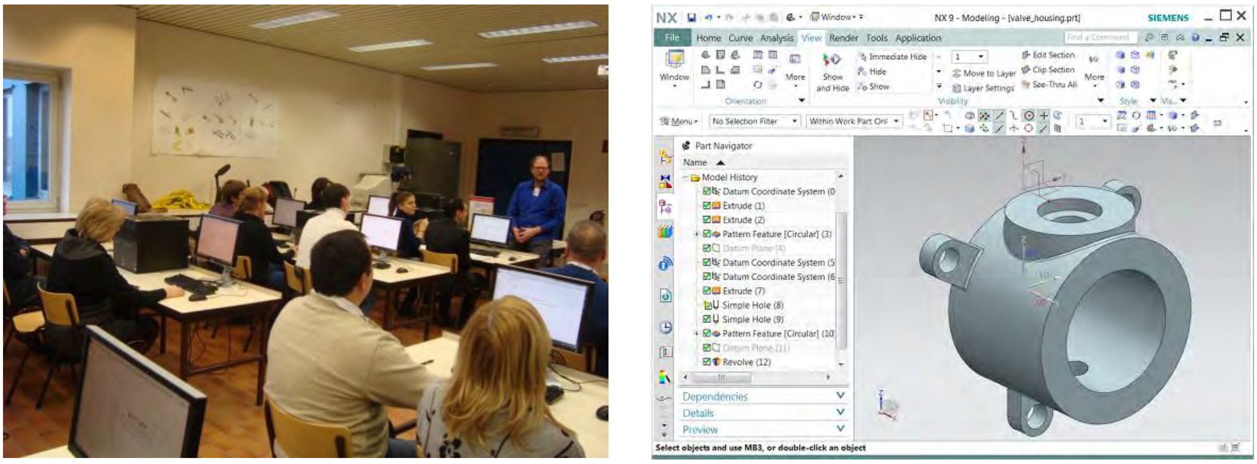


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**Fig. 2.** Master-class on mastering the computer program CAD NX9 (a) and example of object made by solid modeling (b) [11]

Attachment CAD to NX resource [10,12] contains a system of three-dimensional hybrid solid modeling, providing everything necessary for an engineer working with a solid, surface and wire-frame model. The navigator visually represents the model elements, order of its construction, allows us to select the structural elements, change them and connections between them efficiently. The history of model construction can be observed step-by step, copied and it is possible to insert into a model structural elements of unlimited number. Moreover, a designer can work directly with geometrical elements of a 3D model, thus enabling the introduction of the necessary changes both into parametrized and non-parametrized model, transform surfaces and solids into typical elements and also introduce them in the design data base for the repeated use. It is possible to create families of components and control them, to form libraries of standard products used at enterprises.

The presence of associative connection between components significantly simplifies the work: when one part is changed all other parts related with it automatically move or even change their geometry. A three-dimensional model of packaging arrangement allows estimating of the possibility of mounting and demounting of different aggregates of the design product, convenience of access to them. The above mentioned makes it possible not only to improve the project quality but also to reduce its creation time and costs.

A key component of the technological design system is the CAM NX 9 attachment, which contains complete software package for components manufacturing on machines with a digital control system. A wide set of CAM functions allow treatment of the components of complex configuration, like turbine blades, moulds, punches. The better control over cutting zones in manufacturing cast and weld tools, more rapid programming due to simultaneous treatment of several elements increase the effectiveness of creation of the treatment programs. New programming tools of the checking-measuring systems in NX9 enable measuring of components of different configuration. A module of measuring results analysis proposes new tools, powerful graphical medium for visualization of measuring. The NX9 enhances the development of instrument models thanks to the easier access to the library of standard components of cast and die tools.

Computer-aided engineering (CAE) (Fig.3) is the integral part of NX9 software product. The attachment proposes modern tools and solutions for modeling of structural, thermal, in-line, kinematic tasks and further optimization and control over modeling and design data. It consists of the main integrated modules:

− NX Nastran ─ instrument for solving problems of solid deformation mechnics by the finite element analysis method(FEA);

− NX Thermal – for solving a wide spectrum of thermal problems;
− NX Flow– for modeling problems of hydro-gas-dynamics and heat mass exchange.

The NX Nastran module [12, 13] allows the construction of a finite elements mesh based on the existing geometry. All performed constructions are related associatively with the model of the component and therefore when changing the component parameters they are automatically changed too. When the finite element model is built, the module proposes a wide choice of calculation methods, including the stress-strain state, eigenfrequencies and oscillations, stability, durability and so on.

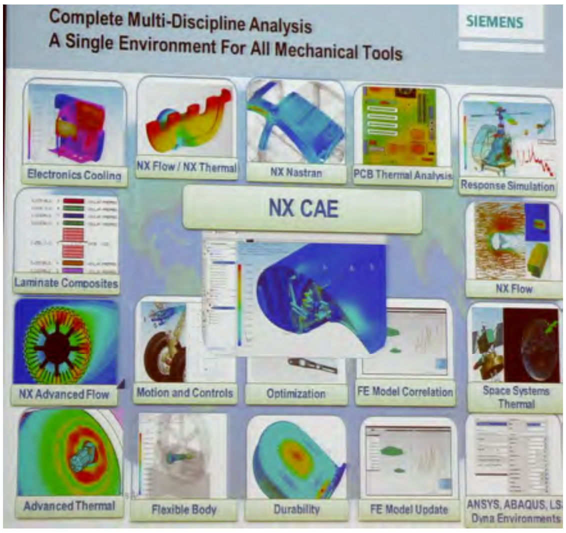


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**Fig. 3.** Illustrations from presentation at the training on CAE NX 9 capabilities [13]

Isotropic, orthotropic and anisotropic models of materials are supported; the temperature variations of the material can be also considered. The results of the stress-state analysis are presented in the intuitively understandable color graphical form that simplifies their interpretation. They can be presented as animated images, and results of different loading modes can be compared in one window of results. This allows us at the early stages of design to compare different options of components and to find the optimal design solution.

To model casting a special module is created. By setting a calculation model, which is related associatively with the component geometry, it is possible to analyze the casting process by the time of pouring, probability of air bubbles formation, lines of flows fusion and obtaining a final ingot. The library of typical materials is used in calculations. There are also tools of visual emulation of the process. The results of analysis include the animation of the cast front movement, time of form filling, location of junction lines and temperature variation during casting. All mentioned above makes it possible to evaluate the applicability of the created model and if necessary to introduce the required changes. All attachments and modules of NX 9 resource are deeply integrated and associatively related with the data base of the resource. In this way the main principle of NX is realized: once introduced information is used in the work of other modules when solving various tasks.

To introduce NX9 in the educational process a corresponding infrastructure (in particular the computer class with software) was prepared at the AMSME chair, special educational program of the discipline “CAD-CAM - CAE Siemens NX” was developed, and a possibility to use NX 9 for solving separate engineering problems, e.g in the discipline “Mechanical properties and structural strength of materials” was considered. This resource will be applicable during study and use of modern 3-D printing technologies of the components both during laboratory lessons and also for industrial application in different branches of materials and components manufacture. The spectrum of materials for 3D- printing is extremely wide: from metals and metal alloys to non-metal, composite and powder-sintered materials. In the training program this technology was paid main attention to: methods of manufacturing products and workpieces on modern 3 –D printers were considered, schemes of formation and structure-formation, advantages and their restrictions were characterized ( Fig.4) [14]. For example, for some types of components the use of 3-D printing can be limited by the formation of anisotropic structure ( Fig. 4b). On the other hand this technology can be actively integrated in the traditional manufacturing processes. For example in 3-D printing it can be used instead of preliminary compression operation before sintering as a highly-efficient operation to compare with compression. In foundry engineering it allows to obtain accurate models that can be manufactured from different materials.

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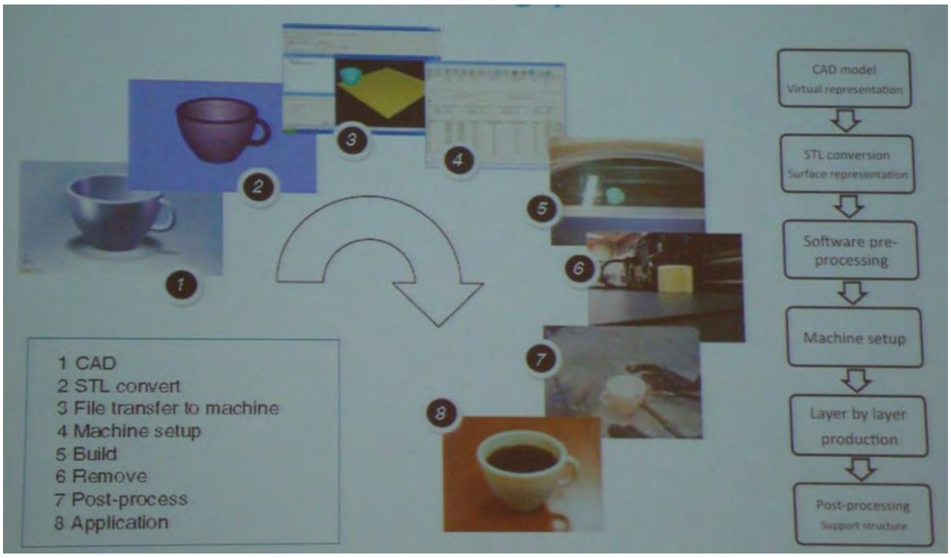


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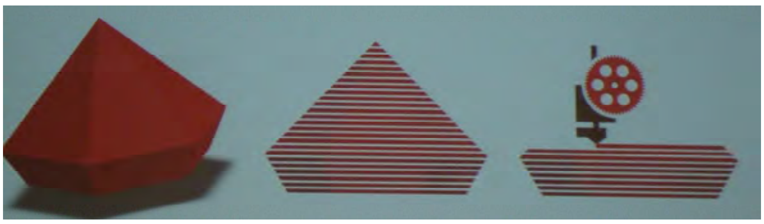

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**Fig. 4.** Industrial 3D printer of KU Leuven laboratory - Department of Mechanical Engineering (a), principle of workpieces and components manufacture (b) and a chart of anisotropic structure formation (c) [14]

From the point of view of preparation of specialists in engineering materials science the software CES EduPack of company Granta Design is of a special interest (Fig. 5). The CES software was created together with the leading materials science experts and programming specialists of Cambridge University, therefore the materials science aspects and modern computer possibilities are successfully combined in this software [15-17].

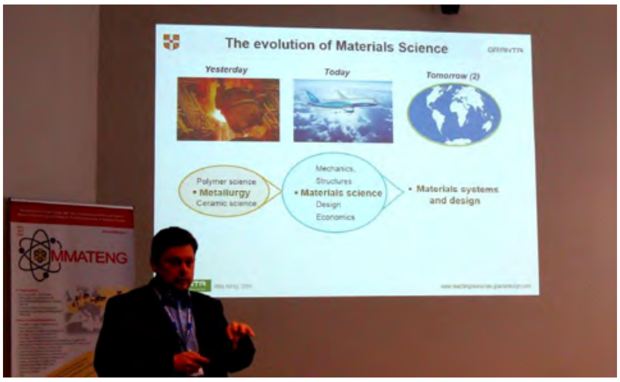


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**Fig. 5.** Branches of application of CES Edu Pack software (from presentation [17])

The software is based on the wide data base, allowing to select from all groups of metal , non-metal, composite materials and modern biomaterials the one most suitable for the given component production. By entering the initial properties into the program (mechanical, physical, economic and other) a required group of materials can be separated from which, by introducing additional parameters, one can choose this only material most optimal for a component manufacturing [17]. Applying this software the selected material can be completely described: its chemical composition, physical and mechanical properties, possible way of manufacturing, economic and environmental suitability of its use. When necessary different types of surface treatment can be suggested and assessment of the properties change of selected materials after treatment can be done. One more interesting thing is that the program allows to choose cheap materials. Recently in the world practice the cheap materials – plastic materials, composite materials, ceramics and many others - have often been substituted for expensive steel materials. All these materials are described, illustrated in detail, their properties and ways of manufacturing are presented on the screen and economic suitability is compared by plots with those for steels, iron and nonferrous metals.

Since recently people care about the planet cleanness, a special accent is done in the CES EduPack software on ecology-friendly and sustainable development of materials ( Fig.6). Using this program students study how to select materials not only by their functional properties but also by their biological features, ability for recycling and decomposition time. That is, when using the software such materials can be selected which meet not only the requirements for mechanical physical, chemical and technological properties but will be also environment-friendly.

One thousand (1000) universities and colleges worldwide are now using the CES EduPack software and teaching resources to support their training on materials in engineering, science, processing, and design. Therefore the introduction of this software in Ukraine will not only improve the efficiency of professional training in materials science but will also allow our students to integrate into the education process of European high schools within the program of students academic mobility. In the process of students training at AMSME chair the CES EduPack software will be used in many professional-oriented disciplines: “Material Science”, “Heat Treatment” “Non-ferrous metals and alloys”, “Non-metallic materials”, “Alloys with special properties”, “ Powder and composite materials” and other.

Except of the environmental aspect, the problem of application of resource-saving technologies and new materials, which are more and more actively introduced into production, is very important. In this relation this problems must be paid much attention to when preparing materials science specialists. For example, ceramic and composite materials can be full-value substitutes of the existing metallic materials.

At present instead of high-strength, heat-resistant and refractory steels the leading automobile, aviation and aerospace EU companies investigate and introduce composite materials (Fig.7) [18], in particular with frequent use of 3D printing technologies. Main advantages, that stipulate the use of composite materials, is the possibility of the last to provide the required service characteristics, to decrease the construction weight and to prepare a solid assembly which is usually manufactured of several units. This allows one to obtain the higher service parameters of aircraft with less consumption of fuel.

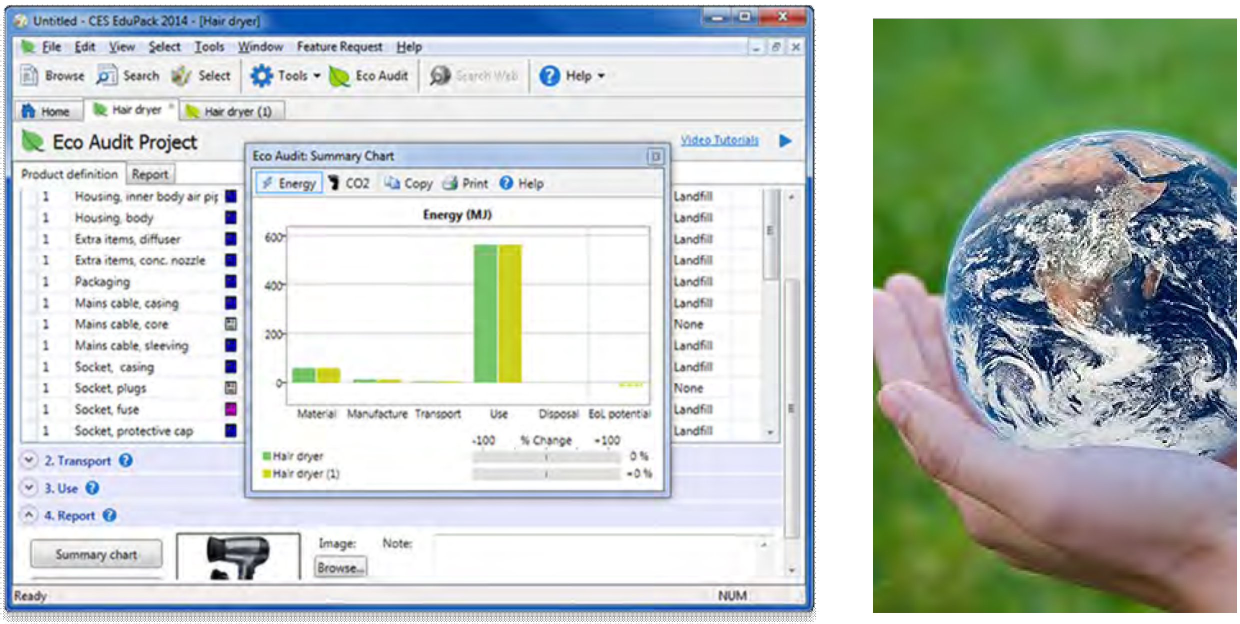



**Fig. 6.** Interface of environmental audit of CES Edu Pack software (from presentation [17])

With the MMATENG project support (computer class, integrated package CAD/CAM/CAE of modern NX9 version, CES EduPack software, equipment) the Material Engineering Service-Office (MESO) was created at AMSME chair. A strategic task of MESO is the application of the results of the TEMPUS MMATENG project for scientific investigations and training of competitive specialists in materials science. The main directions of its activity are:

− Development and realization of innovation educational-scientific programs in engineering materials science, based on modern achievements of science, technology, mechanisms of students involvement in research activity on all levels of educational process;

− Formation of educational working programs on engineering materials science with account of the requirements and proposals of industry partners and prospective employers;

− Development of end-to-end educational programs on engineering and applied materials science according to EU standard that foresee the issue of double diplomas of higher education ( including post-graduate courses) on the base of high schools of Poland, Germany, France, and Belgium;

− More intensive international mobility of students , lecturers and scientists in the field of engineering materials science;

− Monitoring and assessing the demands of the region in applied developments on engineering materials science;

− Engineering- technical and research activity in the field of materials science to the order of management subjects;

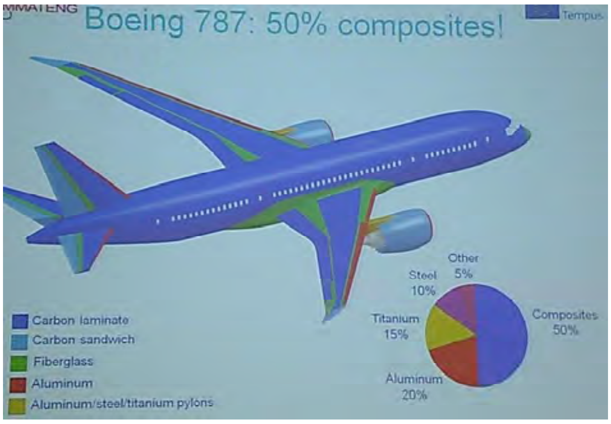
− Organizing and holding trainings and retraining of specialists – materials scientists, specialists in heat-related problems, specialists in casting for companies of different ownership of the Western region of Ukraine;

− Systematic advanced training of lecturers in materials science of the university and related chairs in high schools of the Western region, using information technologies in educational activity;

− Conducting scientific researches on the formation of creative teams, which will include scientific-pedagogical experts, doctoral candidates, post-graduate students, masters;

− Widening of scientific cooperation with NAS establishments, national branch academies and high schools of Ukraine;

Development of the system of common scientific-educational centers with participation of foreign companies and high-technology firms.

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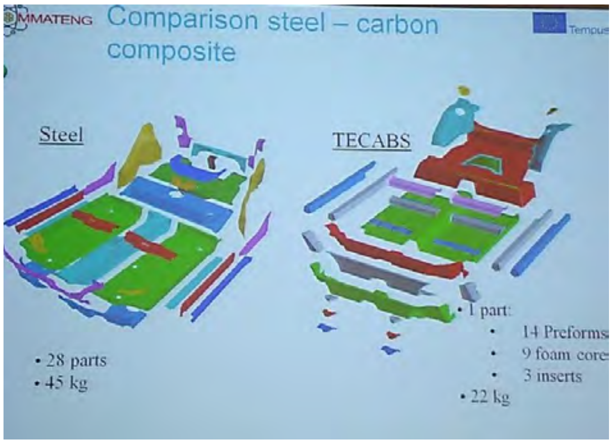


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**Fig. 7.** Prospects of substitution of composite materials for metallic alloys using modern technologies [18]

## Conclusions

Participation in the "MMATTENG" project within the TEMPUS program will enable the integration of training the materials science researchers into a common European educational system, will create prospects of their further didactic and scientific cooperation. This will improve the quality of education and soundness of scientific approaches to creation of new materials and technologies.

Implementation of the computer integrated technologies into training of specialists in materials science will allow them to use the obtained knowledge in their industrial and scientific activity for a quick and efficient solution of materials science problems.

The activity of MESO, integrated into the European educational space, will provide the more active training of competitive and skilled specialists in materials science, will intensify international mobility of students, lecturers, and scientists, will ensure the training and retraining of specialists – materials science researchers, experts in heat-related problems for the enterprises of the Western region of Ukraine, can be the basis for formation of the common research centers on materials science with participation of leading foreign and home industrial companies.

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