MAIN ASPECTS OF TRAINING IN FIELD OF COMPUTER-AIDED TECHNIQUES (CAX) IN MECHANICAL ENGINEERING

Andrzej Lukaszewicz[1], Grzegorz Skorulski[1], Ryszard Szczebiot[2]
[1]Bialystok University of Technology, Poland; [2]Lomza State University of Applied Sciences, Poland
a.lukaszewicz@pb.edu.pl, g.skorulski@pb.edu.pl, rysbiot@pwsip.edu.pl

Abstract. The purpose of the paper is to present the basic factors related to the application of CAx systems in mechanical engineering education. The main aspects of parts and assemblies modelling in 3D MCAD (Mechanical CAD) systems are discussed. The general rules and selected methods used in creation of 3D models are outlined. As a result of the authors' experiences based on the long-time education process carried out with the use of CAx tools, the main recommendations for academic teachers and users of CAx systems have been presented.

Keywords: CAx, engineering education, mechanical engineering.

Introduction

CAx tools, like: CAD, CAM, CAE, PLM, are more significantly relevant in the development process of new goods. They considerably reduce the time of introducing a new product version into market. Testing virtual prototypes helps introduce the final version into the market quicker. This leads directly to lower costs.

One of the primary purposes of the Computer-Aided technologies education is learning the methods of the 3D modelling concept [1-6]. Today, feature based modelling is a classic in mechanical field [7-9]. Nowadays, the teaching of CAx systems and CAx engineering applications is an inseparable part of the product development process in all kinds of industry [10-12]. Computer-Aided Design (CAD) represents one of the key lectures in the mechanical engineering education as well as several other engineering disciplines [12-13]. The results of the CAD method investigations show that an evolution of the parametric 3D techniques, based on knowledge, special approaches and optimization, is developing more and more widely [14-17].

The education development of geometrical design methods should be directed at increasing the knowledge of advanced part and assembly modelling [18]. At present, widely used CAx systems, like SolidWorks or SolidEdge, are based on the geometry modeller and mostly work in three environments: part, assembly and drawing. One of the advanced techniques in the case of part modelling is a group of tools called as multibody methods [19].

Dynamic development of the existent CAD systems and appearance of new ones result in the fact that the choice of the appropriate product is becoming more and more difficult. The costs of purchase, service and training should all be taken into consideration, the first one being probably the most important in the case of commercial use. Another important issue is the possibility of adjusting the system to the requirements of a particular industry (branch, production profile, cooperation with partners, etc.), i.e. what tools are offered in the so called basic version, whether there are additional tools (and at what price) working in a given CAD environment (specialised tools, CAM and CAE programs, libraries and standards).

Development of modern manufacturing techniques (e.g., CNC, Rapid Prototyping (RP), Reverse Engineering (RE)) requires use of CAx. The applications of CAx systems used in manufacturing and CNC field are outlined in many papers [20-24]. The RE methods can be used to accurately reproduce free-form shapes using contact [25] and non-contact [26] measurement techniques. Virtual analysis using CAE tools in CAx systems is used in every branch of mechanical engineering. For example, multibody dynamic investigations of mechanisms were presented in [27-30]. Stress-strain analysis, mostly using the Finite Element Method (FEM), was described in works [31-35].

This work presents the possibilities resulting from the application of advanced modelling techniques in parametric CAD systems. Selected methods and tools, which use the advantages of parametric modelling, were described on the basis of a popular system of surface – solid modelling SolidWorks. SolidWorks environment is widely used all over the world by designers in mechanical engineering, also in the field of food industry equipment as well as agricultural machinery.

The comments provided in the paper result mainly from the experiences acquired by A. Łukaszewicz in the process of work with SolidWorks and teaching CAx systems (from 2001) and skills gained by G. Skorulski, while working with CAM systems (from 2003) at the Faculty of Mechanical Engineering of the Bialystok University of Technology.

Materials and methods

Implementation of CAD systems

The following factors have a determining influence on effective implementation of CAD systems in mechanical branches (sorted by importance in industry):

- PRICE!!! (software, hardware, engineering staff training, service);
- large number of users of concrete CAD system in particular country and worldwide;
- availability of graduates using CAD, CAM, CAE systems;
- engineering education in local technical universities with usage of concrete CAD system;
- possibility of CAD system accommodation to establishment requirements (branch of industry, profile of production, collaboration with other companies);
- modular structure of CAx system based on the environment of the main CAD modeller;
- possibility of import-export of 3D models in standard, neutral file formats and other native formats of popular CAD systems;
- easy access to software updating (Service Pack);
- CAD system version in the native language;
- access to libraries of standardized elements and 3D models of leading producers;
- professional support of local representatives and using online tools;
- rapid reaction to the user's problems (technical service);
- availability of PDM/PLM software working in specific CAD system environment.

Progression of requirements in CAx branch

The CAx learning should be directed for rapid varying needs and requirements of manufacturing firms, like:

- collaboration with companies in aspects of their expectations and skills for a designers;
- investigation of requirements in a specific field of industry from graduates;
- development in technical universities of new methods in all cases of product's lifecycle;
- testing at the start and the end of the CAx education process of knowledge of many aspects;
- development by CAx education staff the general rules of parts and assemblies modelling as well as manufacturing issues.

Training of designers

Trainings of CAx users should be a continuous process. In industrial practice, the following factors should be taken into consideration:

- nowadays, new CAx release brings new modelling methods;
- employers realise now that professional training courses, organised by authorised centers, help for designers use their potential more fully;
- costs of employers spending for participation of engineers in trainings will return quickly through better work efficiency;
- CAx software companies offer trainings in many issues of basic and advanced design methods and tools;
- possibility of independent learning based on online resources.

Part modelling

An education development of CAD techniques must be directed to increase the knowledge of geometrical modelling. A 3D model is the basic information of virtual product in all CAx software.

The main rules of parts modelling in MCAD systems

The following aspects should be used for an efficient part model based on the appropriate design intents:

- adequate location of a part in virtual space;
- correctly selected origin of the coordinate system;
- properly defined plane for the first sketch;
- right choice of base feature ("base feature" means the first operation in design tree that creates the solid or surface body);
- use of symmetry planes;
- easy sketch entities;
- proper use of sketch relations;
- fully-defined sketch;
- correct parent-child relations of operations (feature);
- correct defining of feature.

Multibody techniques

All performances made on separated objects in part environment are multibody techniques. There can be used in solid as well as surface modelling.

Multibody methods are as following [19]:

- bridging;
- local operations;
- copy of objects using patterns;
- union, intersection and difference of bodies;
- usage of features with the "merge results" option;
- use of imported parts of body fragments of the part;
- moving and scaling of bodies.

Assembly modelling

Modelling of assemblies in MCAD software is an important stage in the design process. Generally, an assembly model is a set of components saved in one file. Surface – solid modellers offer an environment for work with assemblies. Assembly modelling techniques in MCAD provide to elastic structure of any machine, device or vehicle.

The main rules of assemblies modelling in MCAD systems

The main principles of assembly modelling having influence on the effective and robust virtual 3D model:

- proper division of assembly structure;
- adequate choice of the first component in assembly space (e.g., the body of the machine, housing, mounting plate);
- using of component patterns;
- using of standardized elements from software or online libraries,
- non-defining unnecessary mates,
- work with assembly configuration,
- proper use of state of sub-assemblies mobility,
- appropriate work with large assemblies mode.

Results and discussion

The valuable experience of instructors (academic teachers) in the dynamically developing CAx branch as well as efficient teaching methods are an essential factor in the process of integrated product development. The application of CAx systems and manufacturing techniques (e.g., CNC machining, RE and RP) leads to rapid introduction of new products to the market.

Modern educational procedures in engineering fields are an essential factor in the process of integrated product development. Research of the professional group of CAx experts [4] should be a source of important information about industry expectations and then should be quickly introduced in the real educational process.

Libraries integrated with CAD software enable the use of standardized parts. In addition to the existing collections offered by different manufacturers, it is also possible to create your own library containing prepared elements. A valid and functional project library helps reduce the amount of time and work performed, and allows quick and easy access to the created part and assembly files.

Conclusions

Requirements for designers force them to analyse methods of project implementation in detail and to choose the best design method. The design process requires creation of a correct and editable 3D model. For this reason, it is extremely important to properly plan the assembly structure. The main advantage of designing with the use CAx systems is the significant reduction in the development time of the project. Correct execution of the 3D models also makes it easy to introduce the necessary changes in the design. The ability to perform a lot of analysis, CNC-code, visualization, and 2D drawings on the design phase allows better adapting of the product to the assumptions of the design.

Acknowledgements

The paper was performed within a framework of S/WM/1/2018 realised in the Bialystok University of Technology and financed with funds from the Ministry of Science and Higher Education.

References

[1] Dankwort C., Weidlich R., Guenther B., Blaurock J.E. Engineers' CAx education - it's not only CAD. Computer-Aided Design, vol. 36, 2004, pp. 1439-1450.
[2] Yea X., Penga W., Chena Z., Cai Y. Today's students, tomorrow's engineers: an industrial perspective on CAD education. Computer-Aided Design, vol. 36, 2004, pp. 1451-1460.
[3] Chester I. Teaching for CAD expertise. International Journal of Technology and Design Education, vol. 17, 2007, pp. 23-35.
[4] Samek A., Rochatyński R. Selection of team experts for successful design. In: Design methods for industrial practice (ed. R. Rochatyński), University of Zielona Góra Publ., Poland, 2008, pp. 53-62.
[5] Dai S., Li W.W., Fang C., et al. Exploration of CAx engineering education compliant with regional economy development. Proceedings of International Conference on Advanced Education And Management, Jan. 04-05, 2014, Beijing, China, pp.233-236.
[6] Faath A., Anderl R. Interdisciplinary and consistent use of a 3D CAD model for CAx education in engineering studies. Proceedings of The ASME International Mechanical Engineering Congress and Exposition, Phoenix, USA, NOV 11-17, 2016, vol. 5, Published: 2017, Article Number: UNSP V005T06A031.
[7] Anderl R., Mendgen R. Modelling with constraints: theoretical foundation and application. Computer-Aided Design, vol. 28, issue 3, 1996, pp. 155-168.
[8] Rynne A., Gaughran W.F., McNamara B. Parametric modelling training strategies to capture design intent. Proceedings of 17th International Conference on Production Research, Blacksburg, USA, 2003, pp. 1-8.
[9] Oxman R. Thinking difference: Theories and models of parametric design thinking. Design Studies, vol. 52, 2017, pp. 4-39.
[10] Shepherd B. Progress towards solving common CAx challenges in the automotive industry. In: Digital Products (eds Dankwort W., Hoschek J.), Vieweg + Teubner Verlag, 2000, pp. 131-133.
[11] Bodein Y., Rose B., Caillaud E. A roadmap for parametric CAD efficiency in the automotive industry. Computer-Aided Design, vol. 45, issue 10, 2013, pp. 1198-1214.
[12] Łukaszewicz A., Panas K., Szczebiot R. Design process of technological line to vegetables packaging using CAx tools. Proceedings of 17th International Scientific Conference on Engineering for Rural Development, May 23-25, 2018, Jelgava, Latvia, pp. 871-876.

[13] Puodziuniene N. Review of contemporary CAD systems in industry and education. Proceedings of 17th Inter. Conference on Mechanika. April 12-13, 2012, Kaunas, Lithuania, pp. 246-250.
[14] González-Lluch C., Company P., Contero M., et al. A survey on 3D CAD model quality assurance and testing tools. Computer-Aided Design, vol. 83, 2017, pp. 64-79.
[15] Francese M.A., Francese D.L. Food packaging optimization by means of integrated CAD/CAE and statistical techniques. Proceedings of 4th International Conference on Simulation and Modelling in the Food and Bio Industry, June 15-17, 2006, Naples, Italy, pp. 85-90.
[16] Miatliuk K., Łukaszewicz A., Siemieniako F. Coordination method in design of forming operations of hierarchical solid objects. Proceedings of International Conference on Control, Automation and Systems: ICCAS'2008, Oct. 14-17, 2008, Seoul, South Korea, pp. 2724-2357.
[17] Camba J.D., Contero M., Company P. Parametric CAD modeling: An analysis of strategies for design reusability. Computer-Aided Design, vol. 74, 2016, pp. 18-31.
[18] Wełyczko A. CATIA V5. Przykłady efektywnego zastosowania systemu w projektowaniu mechanicznym (CATIA V5. Examples of effective system application in mechanical design). Gliwice, Helion, 2005. 352 p. (In Polish).
[19] Łukaszewicz A. Modelling of solid part using multibody techniques in parametric CAD systems. Solid State Phenomena, vols. 147-149, 2009, pp. 924-929.
[20] Brecher C., Lohse W., Vitr M. CAx framework for planning five-axis milling processes. In: Huang G.Q., Mak K.L., Maropoulos P.G. (eds) Proceedings of the 6th CIRP-Sponsored International Conference on Digital Enterprise Technology. Advances in Intelligent and Soft Computing, vol. 66. Springer, Berlin, Heidelberg, 2010, pp 419-432.
[21] Jozwik J., Piesko P., Krajewski G. Evaluation of QC10 Ballbar diagnostics method for CNC machine. Maintenance and Reliability, issue 3, 2010, pp. 10-20.
[22] Klocke F., Spöcker G., Huwer T. et al. Reducing data loss within adaptive process chains in the context of commonly-used CAx systems. Production Engineering, vol. 9, issue 3, 2015, pp. 307-316.
[23] Jozwik J., Czwarnowski M. Angular positioning accuracy of rotary table and repeatability of five-axis machining centre DMU 65 MonoBlock. Advances in Science and Technology-Research Journal, vol. 9, issue 28, 2015, pp. 89-95.
[24] Kul'ga K.S., Kitaev A.A., Sidorov I.O. et al. Design of flexible manufacturing systems on the basis of CAx software and virtual modeling. Russian Engineering Research, vol. 36, issue 7, 2016, pp. 577-586.
[25] Łukaszewicz A., Miatluk K. Reverse engineering approach for object with free-form surfaces using standard surface-solid parametric CAD system. Solid State Phenomena, vols. 147-149, 2009, pp. 706-711.
[26] Cai J. Technology of data conversion and reconstruction for complex surface based on non-contact measurement. Applied Mechanics and Materials, vol. 685, 2014, pp. 614-617.
[27] Ondrášek J. Designing cam mechanisms using CAx. In: Flores P., Viadero F. (eds) New Trends in Mechanism and Machine Science, Mechanisms and Machine Science, Springer, Cham, vol. 24, 2015, pp 185-193.
[28] Nabagło T., Jurkiewicz A., Apostoł M., et al. Modification of 2S1 tracked vehicle suspension system for improving its performance and safety. In: Nawrat. M.A. (eds) Innovative Control Systems for Tracked Vehicle Platforms, Studies in Systems, Decision and Control, Springer, Cham, vol. 2, 2014, pp. 217-226.
[29] Nabagło T., Kowal J., Jurkiewicz A. High fidelity model construction and its verification based on 2S1 tracked vehicle. In: Nawrat. M A. (eds) Innovative Control Systems for Tracked Vehicle Platforms. Studies in Systems, Decision and Control, Springer, Cham, vol. 2, 2014, pp 205-215.
[30] Kulesza Z., Trochimczuk, R. Dynamics of multibody surgical robotic single incision laparoscopic surgery tool, Proceedings of 23rd International Conference on Engineering Mechanics, May 15-18, 2017, Svratka, Czech Republic, pp. 558-561.
[31] Grodzki W., Łukaszewicz A. Design and manufacture of unmanned aerial vehicles (UAV) wing structure using composite materials. Materialwissenschaft und Werkstofftechnik, vol. 46, issue 3, 2015, pp. 269-278.
[32] Mieczkowski G. Electromechanical characteristics of piezoelectric converters with freely defined boundary conditions and geometry. Mechanics, vol. 22, issue 4, 2016, pp.265-272.

[33] Trochimczuk R., Prochor P. Finite element analysis of temperature distribution in sport horses' skin during rehabilitation massage, Proceedings of 16th International Scientific Conference Engineering For Rural Development, May 24-26, 2017, Jelgava, Latvia, pp. 935-940.
[34] Sidun P., Łukaszewicz A. Verification of ram-press pipe bending process using elasto-plastic FEM model. Acta Mechanica et Automatica, vol. 11, issue 1, 2017, pp. 47-52.
[35] Mieczkowski G. Stress fields and fracture prediction for adhesively bonded bi-material structure with sharp notch located on the interface. Mechanics of Composite Materials, vol. 53, issue 3, 2017, pp. 305-320.