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ANALYSIS OF ADVANCES IN CAD/CAM/CAE SYSTEMS IN ENGINEERING SPECIALTIES

Abstract. Modern technologies offer many advances in CAD/CAM/CAE (Computer-Aided Design/Computer-Aided Manufacturing/Computer-Aided Engineering) technologies, changing the landscape of product development and engineering design. This article describes significant advances in CAD/CAM/CAE systems and analyzes their impact on various industries and the broader engineering field. In the machinery industry or automation industry, CAD, CAE, and CAM complement each other. Design with CAD and then manufacture with CAM. CAD is the design process using computer technology, CAE is the use of computer simulation to analyze physical problems, and CAM is the use of computers and computer software to control machines for manufacturing, usually suitable for mass-produced parts.

Key words: computer-aided design, computer-aided manufacturing, computer-aided engineering, computer technology, product development, engineering design, 3D models, machining optimizations, simulation techniques, collaborative tools.

Introduction. CAD/CAE/CAM are three functional types of industrial design software, representing computer-aided design, computer-aided engineering, and computer-aided manufacturing. CAD/CAE/CAM will be included in the basic functions of large-scale industrial design software suites. CAD emphasizes the design of the product itself from scratch, such as appearance, component position matching, material, etc. CAE for simulation, analysis requirements design, and CAM for 3D prototyping and fabrication purposes.

Computer-aided design (CAD) refers to the process of using computer software to create and analogize physical designs to show the appearance, structure, color, texture, and other characteristics of newly developed products. To put it simply, CAD is used to assist in designing and drawing. With the continuous development of technology, computer-aided design is not only suitable for the industry but also widely used in many fields such as graphic printing and publishing. It involves both software and dedicated hardware.

Computer-Aided Engineering (CAE) is mainly used for simulation analysis, verification, and improvement of designs. With the rapid development of computers and 3D CAD in recent years, the proportion of CAE applications has become higher and higher, the difficulty of use has become lower and lower, and the number of users has grown significantly. Compared to CAD, CAE users require more physics-related knowledge to set conditions and interpret results. As for the mathematical methods used in the calculation process, such as differential equations, finite element method, finite volume method, etc., all can be handed over to the computer for processing.

Computer-Aided Manufacturing (CAM) is the process of manufacturing product components in which engineers make extensive use of product lifecycle management computer software. In other words, CAM is used to assist manufacturing, and the final output of CAM automatic programming is the CNC machining program. The 3D models of components generated in CAD are used to generate the CNC code that drives the numerically controlled machine tools. This includes the engineer selecting the type of tool, the machining process, and the machining path.

Computer-aided design, computer-aided manufacturing and computer-aided engineering (CAD/CAM/CAE) technologies find more and more applications in today’s industry, e.g., in the automotive, aerospace, and naval sectors. These technologies increase, to a great extent, the productivity of engineers and researchers, while at the same time allowing their research activities to achieve higher levels of performance. A number of difficult-toperform design and manufacturing processes can be simulated using more methodologies available, i.e., experimental work combined with statistical tools (regression analysis, analysis of variance, Taguchi methodology, deep learning), finite element analysis applied early enough at the design cycle, CAD-based tools for design optimizations, and CAM-based tools for machining optimizations. As the tools available have become more sophisticated, engineers/researchers consider this challenge as an opportunity for more accurate design, manufacturing, and simulations. This Special Issue includes papers that cover a variety of relevant issues and provides an opportunity for researchers to present recent advances in CAD/CAM/CAE technologies.

A set of computer aided engineering (CAE) simulations, including induction hardening, superimposed stroke peening (mechanical post-treatment), and a fatigue assessment considering local material properties, is presented in. The electromagnetic–thermal simulation of inductive heating was performed with Comsol®, the thermo metallurgical–mechanical analysis of the hardening process utilized Sysweld®, and the mechanical post-treatment was numerically simulated by Abaqus®. A finite element analysis (FEA) based topology management optimization study on a two-stage spur gear reducer housing body and cover is presented in. The study aims at optimizing the overall weight of the reducer by thinning specific areas of the casted gearbox housing elements. The topology optimization algorithm gives an optimal structural shape of the housing elements of the reducer with the largest stiffness, considering the given amount of mass that will be removed from the initial design space. Solidworks® was used as a tool for this research.

CAD/CAM/CAE technologies have become crucial in the development of product design, manufacturing and design methods. These technologies are making great strides thanks to innovations in artificial intelligence, product and device detailing, simulation methods, and project assembly tools. Below is an analysis of CAD/CAM/CAE systems achievements.

Generative Design: Advancements in generative design algorithms that allow software to generate numerous design alternatives based on specified constraints and objectives, enabling engineers to explore innovative solutions efficiently.

Integration of AI and Machine Learning: Increased integration of artificial intelligence and machine learning techniques into CAD/CAM/CAE software for tasks such as design optimization, pattern recognition, and predictive analysis, leading to more intelligent and automated design processes.

Cloud-Based CAD/CAE: Continued migration towards cloud-based CAD/CAE platforms, offering enhanced collaboration, scalability, and accessibility for distributed design teams.

Additive Manufacturing Optimization: Further development of tools and algorithms for optimizing designs specifically for additive manufacturing processes, enabling the creation of complex geometries with improved efficiency and performance.

Real-Time Simulation: Advancements in real-time simulation capabilities, allowing engineers to obtain immediate feedback on design changes and performance predictions during the design process.

Digital Twins: Enhanced integration of CAD/CAM/CAE with IoT (Internet of Things) technologies for the creation and management of digital twins, enabling real-time monitoring, analysis, and optimization of physical assets.

Human-Centric Design Tools: Development of design tools that incorporate human factors and ergonomic considerations more effectively, facilitating the creation of products and environments that had better suit user needs and preferences.

Simulation-Driven Design: Continued emphasis on simulation-driven design methodologies, where simulation results are used as primary inputs for the design process, leading to more efficient and optimized designs.

Cross-Disciplinary Collaboration: Improved tools and workflows for facilitating collaboration between different disciplines (e.g., mechanical engineering, electrical engineering, and software development) within integrated CAD/CAM/CAE environments. Sustainability and Environmental Analysis: Integration of sustainability metrics and environmental analysis tools into CAD/CAM/CAE software, enabling designers to assess the environmental impact of their designs and make informed decisions to minimize resource consumption and emissions.

Conclusion. The advancements in CAD/CAM/CAE technologies signify a paradigm shift in engineering design and product development. These advancements empower engineers to tackle complex challenges, drive innovation, and deliver superior products to market. As we progress further, the integration of AI, additive manufacturing, simulation techniques, and collaborative tools will continue to redefine the future of CAD/CAM/CAE. CAD/CAM refers to the use of computers to analyze, simulate, design, draw and draw up production plans, and manufacturing procedures, and control the production process, that is, from design to processing, all relying on the help of computers, so CAD/CAM is an important part of automation, affecting industrial productivity and quality.

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