المجلة الإلكترونية الشاملة متعددة التخصصات
العدد السادس والعشرون شهر(7) 2020

Investigating strengths, weaknesses and opportunities of Computer aided manufacturing process in 21 century

Fahad salem althalab

Specialised Trainer (B)

E-mail: fs.althalab@gmail.com

Abstract:

It cannot be said that the computer is an invention in itself, because it was the product of many scientific innovations and mathematical applications. Computers are actually diverse, and according to the need to use them, computers have a low-end ability to accomplish tasks. There are many areas in which the computer can enter in the industrial field.

This research aims to investigate the strengths, weaknesses, and opportunities of the computer-aided manufacturing process in the twenty-first century and by drawing on the deductive approach, through previous studies, research, master's and doctoral dissertations.

Where the study concluded that computer manufacturing is done through the use of computer systems to plan, manage and control manufacturing processes through direct or indirect computer interaction with production sites at the factory, as it works to improve design quality and increase productivity. However, he faces many weaknesses that affect manufacturing.

Keywords: strengths, weaknesses, opportunities, manufacturing process, 21 century.

Introduction

Primitive computers were in no way similar to the computers used today, most of which consisted of huge metal structures the size of an entire room and were consuming huge amounts of energy. Developers who want to improve processing speeds must either find larger rooms or find alternative solutions. Fortunately, the alternative solution was the invention that emerged in 1947, where a group of scientists developed a new technology called contact point transistors, where these transistors amplify the current The electrician can be used as switches as it was much smaller and more reliable than vacuum tubes in addition to consuming less energy, and the invention of integrated circuits had an important role in paving the way for a new era of personal computers, and over time this allowed the ability to operate equipment supported by millions of circuits on a chip The size of a postage stamp (Mileham, R., 2008).

The computer has been able to invade the lives of individuals greatly, so it is used in all areas of their lives, and starting from this great position that has been enjoyed by it, the manufacturers have been interested in producing many shapes and types for it in line with the user's need, including the mobile device, office equipment, etc., wherever the device It was more developed that the benefits were more benefits than it is, and it is worth noting that its use is common in homes, institutions, businesses and education, as it is an integral part of the services, entertainment and other sectors, but in this article we will talk about the importance of computers soon and in depth (Shapiro, L. G., 2020).

The fields of computer use are many and varied, as most applications in most fields of industry, agriculture, commerce, education, medicine, and others depend heavily on computers, which makes it difficult with him at the present time to imagine those areas without a computer, and because the computer is called every electronic device that can be program.

Computer use is widespread in various fields of industry, which has enhanced accuracy, speed and automation of production, and examples are factories that rely heavily on computers, automobile factories, aircraft, electronics, refrigeration and air conditioning equipment, metal plants, oil and heavy industries, and many others. The computer is also used in maintenance programs, business scheduling and preparing lists Requirements and timing required for their availability ... etc. One of the most notable features of the last two decades in the field of manufacturing is the emergence and development of software that primarily serves design operations, and this category of programs has been dubbed "Computer Aided Design" or CAD. These programs varied, starting from the simplest, which does not have the capabilities other than drawing in only two dimensions in space, and finally with giant programs that enable the designer to draw three-dimensional and represent complex surfaces and change the viewing angle quite easily. And because the role of this software ends with completing the design to the fullest extent and outputting it in the form of a standard graphic file, then there must be other programs that complete the manufacturing process to take this graphic file and ask to specify a set of settings that will enable it to convert this drawing into a sequence of commands and settings that will Send to one of the digital control machines. This type of software is called Computer Aided Manufacturing (CAM) (Lin, W. S., 2020).

Computerized manufacturing programs are distinguished by the availability of the ability to simulate the industrial process before it is actually implemented on the digital control machine, which means easy to verify and follow the generated manufacturing code and ensure its suitability and achievement of the required product with the required specifications before the actual testing process of the manufacturing code begins.

Consequently, the main goal of using computer manufacturing programs is to produce the Manufacturing Code, which will be directed to digital control machines. These programs always contain a Post Processor export processor that can be configured and fed with the specifications, characteristics, and capabilities of a digital machine that will implement this product in order to be completed. Taking all these factors into consideration when the process of generating the manufacturing code begins, and here the program helps in determining the operations that meet the product specifications, which provides the factors that control the operations.

So, given the great role computer plays in the field of manufacturing, this study aims to investigate the strengths, weaknesses, and opportunities of the computer-aided manufacturing process in the twenty-first century.

Research objectives:

This study came with the aim of achieving the following goals:

1. Identify the computer aided manufacturing process.
2. Identify the strengths of the computer-assisted manufacturing process in the twenty-first century

3. Identify the weaknesses of the computer aided manufacturing process in the twenty-first century
4. Identify the opportunities in the computer aided manufacturing process in the 21st century

Computer aided manufacturing

Computer-aided manufacturing (CAM) is the use of computer software to control related machines and machines in the field of manufacturing parts, and in all manufacturing, production, management, and warehousing operations. The goal of production speed.

The last decades of the twentieth century witnessed a tremendous development in the fields of information technology, and various traditional sciences such as mechanics, electronics, communications, automation and control benefited from this progress, and this development was accompanied to achieve qualitative leaps on various levels and stages, starting with design and through the accurate calculation of the components of the product and simulation through to production and manufacturing. The areas of traditional engineering, such as mechanics, electronics and automation, are no longer fulfilled sporadically for the purpose of designing and implementing an integrated product. Integration between these specializations has become the key to success in finding economic products of high quality and reliability that secure the needs of the investor (Yao, S., et al, 2007).

CAM technology saves time and cost in production and marketing by converting computer CAD designs into a very accurate physical model, and also allows the use of end-use products,

especially those with complex, subtle details quickly. There are many forms of cam systems, some of which are used to produce large sizes of products such as parts for cars, trains and airplanes, and some are used to produce small sizes, such as jewelry. This area of growing and spreading in all areas of production includes making use of computer technologies to direct types of machines digitally or automatically to produce products characterized by high speed (Beuer, F., et al, 2008.).

The computer is used as an assistant for CAM manufacturing, not only in controlling operating machines of all kinds, such as lathes, drills, etc. but also in planning and production control processes. Integration has already been achieved between design and production thanks to the growing use of computer technology has become what is called integration systems Computer-aided design and manufacturing with CAM Integrated Systems / CAD work in these systems using information and data resulting from the process of computer design CAD process directly in the computer manufacturing procedures CAM (Mazzoni, S., et al, 2015).

The abbreviation of Computer Aided Manufacturing and the computer aided process begins with a file designed by a computer or a moderator through which the cam program can be started from the first steps of its manufacture or operation, so that a programming engineer or technician can choose the appropriate CNC digital control machine for the process It can also arrange manufacturing processes and stages of operation and choose the appropriate cutting tools and how to install on the machine, through this we can produce a G-Code driver that is compatible with the digital control machine (Yao, S., et al, 2007).

Computer Aided Manufacturing (CAM) is the use of computer software tools that assist engineers and mechanics in product components or prototyping. Its primary goal is to create a faster production process and components with more accurate dimensions and consistency of materials, which in some cases, use only the required amount of raw materials (and thus reduce waste), while simultaneously reducing energy consumption. CAM is a programming tool that makes it possible to manufacture physical models using computer aided design (CAD) programs. CAM creates real-life versions for components designed within the software package. It was first used in the 1971 CAM to design the car body and tools (Sundar, S., Selwyn, S. T., & Elanchezhian, C., 2005).

Historically, CAM software has been seen to the many shortcomings that have necessitated an overly high level involvement of skilled CNC mechanics. Fallows created the first CAM program but this had severe shortcomings and was immediately taken back to the developing stage. The CAM code production program for the machine is at least capable, as each machine translator has added a standard G code set to increase flexibility. In some cases, such as improperly setting up CAM programs or certain tools, the CNC machine required manual editing before the program will work properly. None of these issues were insurmountable so an engineer could not think of overcoming models or managing small production; G - law is a simple language. High production or high-precision stores, faced a different set of problems in which the CNC machinist experience both must hand code software and run CAM software (Chang, T. C., & Wysk, R. A., 1997).

Computer Aided Manufacturing (CAM) as the use of computer systems to plan, manage and control manufacturing processes through direct or indirect computer interaction with factory production sites. As the definition shows, computer manufacturing applications can be confined to two groups (KARATASLI, Ö., 2011):

1- Computer control and control:

This includes direct applications in which the computer is directly linked to manufacturing processes for monitoring and controlling operations.

2- Manufacturing support applications:

These include indirect applications in which the computer is used to support the production processes at the factory, but there is no direct link between the computer and the manufacturing processes. The distinction between the two groups is essential and essential to understanding the principle of computer manufacturing. Computer control and control can be divided into monitoring and control applications. The monitoring process includes direct computer communication with the manufacturing process in order to observe the process and related equipment and extract data from it.

There are many examples of Computer Aided Manufacturing (CAM) support operations, including the following (Krouse, J. K., 1982):

1- Computer numerical control (NC) programming, whereby control programs are set up to automate the movement of the kit.

2- Plan automated computer operations, as the computer prepares lists of the sequence of operations required to manufacture a specific product.

3- Guess the record time needed for production operations.

4- Production scheduling where the computer selects the appropriate schedule to meet production requirements.

5- Planning raw materials where the computer plays an important role in setting the necessary plans for preparing raw materials orders and purchasing the components and quantities necessary to obtain the production schedule.

6- Control of workshops in this field, data is collected from the factory to determine the progress of the various production workshops. In all of these examples, human presence is absolutely necessary, either to enter data into computer programs or to interpret computer outputs and use them in the appropriate event.

The CAM technology enables manufacturing instructions for the NC digital controller as direct translation of the product design which is accomplished using CAD technology, i.e. linking product design instructions to the instructions needed for its computer-aided manufacture and computer-assisted manufacturing indicates the use of computers in designing manufacturing and controlling machinery and equipment to achieve efficient flow of raw materials and parts and that the integration between (CAD / CAM) in today's factories accomplishes what Follows (Hayyan Syed., 2016):

1. The high quality of the product: the ability to produce the product with specified specifications when orders are launched its production.

2. High quality design, through the possibility of design, analysis and testing before the creation of the physical model, as designers can store and retrieve designs, either for updating or issuing a list of industrial materials involved in installing the product, which in turn leads to a significant reduction in design time.
3. Reducing production costs: as reducing inventory is the efficient use of individuals by improving scheduling and speed in implementing changes in design all lead to lower production costs.
4. The consistency of data in the system, as the integrated relationship between the two systems results in efficient and accurate control of the flow of information between the two systems and into other activities, through the ability of the CAD system to create correct programs for CNC machines, so that there is no opportunity for the transmission of incorrect programs, which ensures improvement in the quality of The product is completely towards the required specifications and bridges the Gap Quality gap.

5. The CAM / CAD system is distinguished as a manufacturing design, that is, the design is tested in the CAD center before it passes to the CAM center, as the CAD systems have simulation, 3D animation, classification verification, and linking of parts and accessories.

CAM technology was based on a high level of knowledge base associated with production planning and control after the use of CAE / CAD. CAM technology is used to control manufacturing processes computerized, including material flow,

through a direct conversion of the final design specifications prepared by the CAD system into detailed manufacturing steps that translate the design model idea To a physical product using a set of machines, and after receiving the appropriate manufacturing instructions to treat a specific part of the self-database or from a separate computer that links and coordinates the procedures between those machines.

Strengths and advantages for Computer-aided manufacturing (CAM).

It is possible to obtain strong advantages from the CAM / CAD system in the transition from the stages of imagination and visualization of the form of the product to its implementation, whether as a prototype or as a useful approach. Perhaps the most important of these advantages, reducing hard manual work and improving the continuity of "development" and accuracy in both design and manufacture. In addition to this, long-term results include improved scheduling and continuity of operations, control, and communication between parts of the production unit. But the real advantages and opportunities are:

Design Optimum:

It clearly showed that one of the most important tangible benefits by applying the CAM / CAD system is the ability to reach the best or actual design in a real way as well as to make the necessary exchanges in a shorter time and lower costs, and the ultimate goal is to achieve complete computer control over production and manufacturing systems. The specific specifications and the fixed industrial standards control the construction of the product so that an integrated product is brought out to

the world and all its particles and elements are controlled (Beuer, F., 2008).

Design Complex for Products and Systems:

The solution to most complex and multi-data design problems cannot be dealt with easily except by using a computer. Technical calculations for designing complex products or even some simple products require dealing with an enormous amount of information and considerations that may include a large amount of complex calculations to resist the raw materials to mechanical stresses, loads, stresses, and response levels. The material for successive operations and then responds to the types of use after the appearance of the final product. It also includes equal ability from the quantitative and qualitative calculations of the ores, making and specifying and building their schedules, and determining their engineering and environmental compatibility (Li, W. D., et al, 2005).

This implies the necessity to use innovative and sophisticated methods that can absorb this huge amount of technical information to conduct inspection and control the quality of products. Among these, and even the most important one, is to take advantage of modern communication technology that imposed the assimilation of the speed of using the computer in dealing with fees and technical accounts required and exchanging them either with clients or with the company's various departments.

Design Developed-Well:

Productive processes and quality specifications for a product begin very early in the early design stages.

At the design process, the designer defines the elements to be handled, symbols and standard parts to be handled. Then he will have to store it to be always at his fingertips in order to retrieve it at any time very quickly to use it in any new drawing or new design or even to modify the existing design. Therefore, making a technical archive for pre-used designs, symbols, parts and configurations or a database with technical specifications, installations and types of relationships between the different units that make up the product is necessary for a good designer and an effective system. Such an archive is a form of limited database that provides the designer with a thoughtful reference that facilitates building, modification and development of the product (Ong, S. K.,2008).

Optimization use of resources:

The computer provides the possibility to rationalize the use of resources from the available materials, components and energies required for engineering and industrial designs. It can, through its database on all parts of a product (Guo, Q. L., 2010):

• To produce material lists, lists, standards, quality control parameters, test methods and equipment,

• Developing programs that monitor the areas of communication and interferences between parts and analyze the structural structure and conduct a continuous evaluation of the areas, volumes and weights of any part of the product under manufacturing and the impact of that on the construction of the overall product.

Distinguished design:

CAM systems are characterized by unparalleled accuracy in what we know of other production systems in the production of models and products, whether in the broad ability of these systems to implement complex technologies or in finishing surfaces with touches and degrees of smoothness that were not previously available in any of the traditional production systems known. This certainly gives the designer a great deal of freedom in design without considering the possibility of implementation even if the design contains elements that are difficult to operate with conventional machines such as the presence of narrow grooves or complex paths or the presence of partially blocked holes and undercut (Sundar, S., 2005).

Materials Safer:

The use of safe and advanced materials and materials. Most computer manufacturing technologies are compatible with the use of Non-Toxic and does not affect the manufacturer during its circulation in the different production stages, just as it has no effect on the user of the product when it is completely manufactured. Also compatible with the use of rapid soluble feedstock, do not produce ash residue, as are these intermediate raw materials clearly energy-saving compatibility, it has a very low melting temperature (Sundar, S., 2005).

Limited requirements space:

CAM system operation machines can be quite small in size, which saves you from needing a lot of space as limited space as part of a room may suffice, for example, to accommodate them.

Which enables the designer to acquisition of samples from them to facilitate the production of prototypes. and devices produced by a company like SolidScape or DelCAM that are compatible with most CAD systems known to use on PC are good models for machines of this type (Stobart, S. C., 1991).

Quality High Product:

It can be given very high production quality that meets the highest international specifications and with finishes and Excellent casting quality which sometimes makes it not necessary to track down operations their production (Flury, S., 2016).

A distinctive alternative:

It is used in making models for small products such as jewelry parts, precision parts, such as watches, computer components, or any similar models in size that may not exceed a few millimeters in size (Flury, S., 2016).

Increasing productivity:

This is achieved by reducing the time needed to install, analyze, and complete design drawings. It has become a priori knowledge that using a computer design system leads significantly to raising performance rates for design departments in industrial enterprises due to the time it reduces in preparing drawings and designs. This increased productivity translates into lower costs as well as less time to complete the project (Poggio, C., et al, 2016).

Quality improvement:

The computerized design system allows the designer to perform deep and accurate design analyzes, and also provides a large number of alternative designs that can be chosen. The design errors are less due to the high accuracy provided by the system, and these factors lead us to better designs (Poggio, C., et al, 2016).

Standardization of the language of dealing and exchange:

The engineering drawing is an international language that overcomes the barriers of translation, and the use of a computer design system leads to better engineering drawings, to standard specifications in drawing and to reduce errors, and thus we obtain designs that can be understood by all workers in the fields of engineering regardless of their languages (Poggio, C., et al, 2016).

Providing an extensive database of the manufacturing process:

when creating drawings for a product (setting dimensions on the product and its parts and specifying lists of materials and their specifications ... etc), there is a lot of data that can be used in manufacturing processes (Poggio, C., et al, 2016).

Flexibility:

Its means design flexibility and size flexibility, i.e. the company's ability to provide new products or response to the amount of production.

Ease of use

For a user who is just getting started as a CAM user, providing capabilities of process handlers, templates, libraries,

Automated machine tool kits, machine building and task feature specific feature and tailorable user interfaces build user confidence and speed of learning curve.

Wide range of Applications:

CAM systems are used in medical applications in the work of prosthetic devices and very subtle body organs alternatives. It has proven successful in implanting vertebrae in the human body, with the same degree of success with which it can be used in the production of mechanical parts and small, high-precision products, so that it has been used in making structures. Medical and artificial joints and some very fine organs in the human body, such as an alternative to vertebral bones or limb bones in the human body. This advantage is used industrially to produce models for small products, such as jewelry, watch parts, or any similar models, the size of which may not exceed a few millimeters (Poggio, C., et al, 2016).

In (Gehrke, P., 2014) mentioned about other strength of CAM which are:

1. Manufacturing requires minimal supervision and can be achieved during non-social working hours.
2. Manufacturing is less labor intensive and saves labor cost.
3. Precise machines, manufacturing can be repeated continuously with large batches.
4. Little error has occurred, and machines can operate continuously.

5. Prototypes can be prepared very quickly for detailed inspection before final designs are made for manufacturing.
6. Virtual machines can be used to evaluate operations and results on screen

Weaknesses of Computer aided manufacturing process in 21 century

The computer-aided manufacturing process demonstrated in the twenty-first century some weaknesses that may affect work efficiency and achieve its goals and objectives, namely (Baroudi, K., & Ibraheem, S. N., 2015) and (Makris.S., et al, 2012):

1. The general state of the economy in a country that may entail high financial costs.
2. Maintenance operations, as it is necessary to pay attention to the routine and preventive maintenance of machines and equipment, ensuring that there is no sudden stop in these machines, and that the work in the factory is interrupted.
3. Defects in raw or raw materials and their different specifications.
4. Poor handling of storage and transfer of the final product to consumers.
5. Poor standardization and calibration methods.
6. Poor level of standardization in different stages of production.
7. Weak inspection procedures in the different stages of production.
8. It depends on the accuracy of the mathematical representation of the systems and on the input variables. In many systems, mathematical representation is highly complex because there are many factors involved in the situation.

System units or components may also be subsystems, each of which interacts with one another. The input variables often include the conditions and conditions that surround the sequence of operations or that control the behavior of the object being represented. Often it is up to the designer to guess or infer a number of these variables.

9. The relatively high cost of supplies and consumables.
10. Maintenance of the machine is very expensive.
11. May result in a loss of workforce with a high level of manual skill.
12. The need for highly trained personnel and technicians to ensure appropriate tools and preparation of procedures

In another study (Geddes.D .(2019) and (James. TH ., 2019), they indicated weaknesses that are represented below:

Cost

The computer technology applied in CAM is expensive to achieve and support. This is confused by the point that technology is not fixed. New hardware, tools, and software programs continually come on the store, and engineers and business people should attempt to keep up with those modifications for compatibility purposes. Moreover, it costs money to encourage team members to use the technology. it means the cost of CAM does not stay after the fundamental implementation.

Waste

CAM depends on the perfect designs designed by computer software. If there is a defect in the design, some of the materials may be wasted and lost,

Because you may un discover the flaw until you notice the original product. That isn't a tremendous subject if the products are recyclable or are cheap. However, it suits an obstacle in products built of materials that can't be practiced repeat, such as Styrofoam, or which it has a huge cost, such as a car. You also have to take the time and effort to distribute or reuse the waste and take replacement materials.

Finished Design

The CAM depends on the designs from a CAD system. Therefore, it doesn't support designers significant, as it concentrates on the final stage of an assigned project. It is difficult to improve a CAM system without the first becoming the CAD system.

Technology Failure

Computers worked in CAM may break down, as can the associated equipment and tools, such as robots. Each time this occurs, there is a risk for the slowing or discontinuance of the product. That is not acceptable during an organization is on a stringent production calendar. The risk is most distinguished in the organizations that depend on an assembly-line construction, as a failure in these kinds of companies concerns all cases of production through the failure rather of only a separate production area.

The opportunities of Computer aided manufacturing process in 21 centuries:

In light of the current changes locally, regionally and globally, the process of computer aided manufacturing in the twenty-first century, the results of studies have shown that the available opportunities that can confront this process and work to achieve its goals and objectives are numerous, including (Edwards, Jeffrey R, 1989) and (Culler, D. E., & Burd, W., 2007):

1. The growing need for greater flexibility and higher speed in interacting with market demands.
2. The need to increase productivity as quickly as possible.
3. Increasing the rate of return on investment and thus raising productivity rates by a third or a quarter.
4. The growing growth in technology and computer dependency in most businesses.
5. The high ability to use colors in the design and assembly stages.
6. The constant need to review the opportunity tens of thousands of parts.
7. Reducing the exploitation of resources, especially at the time of workers' work.
8. The need to reduce setup and configuration time and overall wait.
9. The increasing demand for improving product quality.
10. Expand control over production flow.
11. Expand control over costs.
12. Expand control of time and respect for clients

13. Establish a program for foreign direct investment and joint ventures in the supply of components related to resources.
14. Expanding the establishment of research and consulting centers within the institution.
15. Increasing local, regional and global interest in the importance of quality assurance and continuous improvement in products.
16. Concluding cooperation agreements with local, regional and international institutions.

Conclusion:

The use of computers has evolved greatly in recent times in many commercial, governmental, military, research and industrial operations, as there are many areas in which the computer can enter as a type of important equipment, which can manage projects or arrange things or to Other things.

And recently, the importance of computers appeared in the field of design and manufacture, and this cam (computer aided manufacture) ... what is called and this field includes design processes that contributed to it. The extraordinary development of the use of computers in drawing has made a major development in engineering design processes and from them to textile design processes. Where a design engineer can Carry out the design process through the computer and then transfer it by printing to the final image necessary to transfer this design to the executive side with the required sizes.

As the computer-aided manufacturing process includes many strengths, the most prominent of which is that it increases the productivity of products, working to improve the quality of design, in addition to improving the means of implementation of the design and others.

But it also includes a weak ratio that prevents the use of computer aided manufacturing such as poor handling of storage and transfer of the final product to consumers, poor standardization and calibration methods and weak inspection procedures in the different stages of production...etc.

References:

Hayyan Syed. (2016). Computer use fully in manufacturing and automation. College of Mechanical and Electrical Engineering Department of Mechatronic Engineering Department. ALBaath University

Beuer, F., Steff, B., Naumann, M., & Sorensen, J. A. (2008). Load- bearing capacity of all- ceramic three- unit fixed partial dentures with different computer- aided design (CAD)/computer- aided manufacturing (CAM) fabricated framework materials. European journal of oral sciences, 116(4), 381-386.

Yao, S., Han, X., Yang, Y., Rong, Y. K., Huang, S. H., Yen, D. W., & Zhang, G. (2007). Computer-aided manufacturing planning for mass

customization: part 1, framework. The International Journal of Advanced Manufacturing Technology, 32(1-2), 194-204.

Chang, T. C., & Wysk, R. A. (1997). Computer-aided manufacturing. Prentice Hall PTR.

Mazzoni, S., Bianchi, A., Schiariti, G., Badiali, G., & Marchetti, C. (2015). Computer-aided design and computer-aided manufacturing cutting guides and customized titanium plates are useful in upper maxilla waferless repositioning. Journal of Oral and Maxillofacial Surgery, 73(4), 701-707.

Sundar, S., Selwyn, S. T., & Elanchezhian, C. (2005). Computer Aided Manufacturing. Firewall Media.

KARATASLI, Ö., Kursoglu, P., Capa, N., & Kazazoglu, E. (2011). Comparison of the marginal fit of different coping materials and designs produced by computer aided manufacturing systems. Dental materials journal, 30(1), 97-102.

Krouse, J. K. (1982). What every engineer should know about computer-aided design and computer-aided manufacturing: the CAD/CAM revolution (Vol. 10). CRC Press.

Beuer, F., Steff, B., Naumann, M., & Sorensen, J. A. (2008). Load- bearing capacity of all- ceramic three- unit fixed partial dentures with different computer- aided design (CAD)/computer- aided manufacturing (CAM) fabricated framework materials. European journal of oral sciences, 116(4), 381-386.

Li, W. D., et al. "Collaborative computer-aided design—research and development status." Computer-aided design 37.9 (2005): 931-940.

Ong, S. K., Yuan, M. L., & Nee, A. Y. C. (2008). Augmented reality applications in manufacturing: a survey. International journal of production research, 46(10), 2707-2742.

Guo, Q. L., & Zhang, M. (2010). An agent-oriented approach to resolve scheduling optimization in intelligent manufacturing. Robotics and Computer-Integrated Manufacturing, 26(1), 39-45.

Sundar, S., Selwyn, S. T., & Elanchezhian, C. (2005). Computer Aided Manufacturing. Firewall Media.

Stobart, S. C., Thompson, J. B., & Smith, P. (1991). Use, problems, benefits and future direction of computer-aided software engineering in United Kingdom. Information and Software Technology, 33(9), 629-636.

Gehrke, P., Alius, J., Fischer, C., Erdelt, K. J., & Beuer, F. (2014). Retentive strength of two- piece CAD/CAM zirconia implant abutments. Clinical implant dentistry and related research, 16(6), 920-925.

Flury, S., Schmidt, S. Z., Peutzfeldt, A., & Lussi, A. (2016). Dentin bond strength of two resin-ceramic computer-aided design/computer-aided manufacturing (CAD/CAM) materials and five cements after six months storage. Dental materials journal.

Poggio, C., Pigozzo, M., Ceci, M., Scribante, A., Beltrami, R., & Chiesa, M. (2016). Influence of different luting protocols on shear bond strength of computer aided design/computer aided manufacturing resin nanoceramic material to dentin. Dental research journal, 13(2), 91.

Baroudi, K., & Ibraheem, S. N. (2015). Assessment of chair-side computer-aided design and computer-aided manufacturing restorations: a review of the literature. Journal of international oral health: JIOH, 7(4), 96.

Makris.S., MakrisDimitris.S, ChryssolourisGeorge. CH .(2012). Computer Aided Manufacturing (CAM). In book: Encyclopedia of Production EngineeringChapter: Computer Aided Manufacturing (CAM)Publisher: SpringerEditors: Luc Laperrière, Gunther Reinhart

DOI: 10.1007/978-3-642-20617-7_6550

Geddes.D .(2019). Manufacturing: it’s not a battle of men or machine.technical foam services.engineering excellence in foam conversion.

James. TH .(2019). The Advantages and Disadvantages of CAD/CAM.bizfluent.

Edwards, Jeffrey R. "Computer aided manufacturing and worker well-being: a review of research." Behaviour & Information Technology 8.3 (1989): 157-174.

Culler, D. E., & Burd, W. (2007). A framework for extending computer aided process planning to include business activities and computer aided design and manufacturing (CAD/CAM) data retrieval. Robotics and Computer-Integrated Manufacturing, 23(3), 339-350.

Mileham, R. (2008). Powering Up: Are Computer Games Changing Our Lives? (Vol. 1). John Wiley & Sons.

Shapiro, L. G. (2020). Computer vision: the last 50 years. International Journal of Parallel, Emergent and Distributed Systems, 35(2), 112-117.

Lin, W. S., Yang, C. C., Polido, W. D., & Morton, D. (2020). CAD-CAM cobalt-chromium surgical template for static computer-aided implant

surgery: A dental technique. The Journal of prosthetic dentistry, 123(1), 42-44.