Jozef Novák-Marcincin, Anton Petík

COMPUTER AIDED MANUFACTURING - INSEPARABLE PART OF CAD/CAM/CAE SYSTEMS

In the conception of computer aided systems, systems of computer support, respectively CA systems most of us consider only computer systems supporting the drawing, design and constructing of parts and products, so these systems which are called CAD systems (Computer Aided Design). This oneside view is determined by several factors: simple CAD systems without further relation to manufacturing (especially AutoCAD) were extensively used as first in construction offices of our factories and enterprises from 1990; the number of installation of these systems and thus also the number of CAD systems users is several times prevailing the number of the other computer aided systems users; the other CA systems (for example systems of computer aided manufacturing) are dependent on data which have to be processed and prepared by CAD systems; education of the CA systems is mostly realized only in the area of CAD systems; etc.
In spite of the above facts, it is obvious, that maximal benefit for production enterprises is reached only by complete application of the computer aided systems to realization of the product, this means that besides of the design and dimensioning of parts and products also to design of the production technology, design of the working-place, design of the working tools and fixtures, realization of own manufacturing and following testing the product quality.
The aim of this paper is briefly but completely describe the main features of the systems for computer aided manufacturing - CAM and thus fill the space in knowledges which exists in considered area.

Short history of the CAM systems

The history of computer aided systems is mainly the history of computer design and constructing thus it is at the beginning joined with history of computer graphics. It was not possible to create, to research and to manipulate with solids by computer before the computer graphics was introduced. Computer aided design and constructing was reduced only to computing.
First design of calculating machine - calculator with graphics options was introduced by Vannevar Bush in 1945, but his proposal has not ever been realized in practice. First computers which allowed interactive graphics were made at the beginning of the 60th years thanks to General Motors, Lockheed, NASA and Bell Labs. First systems of computer graphics and computer aided design and constructing were developed for various hardware platforms, but the biggest producers of computer equipment (IBM, DEC, Control Data, Texas Instruments) have ignored this area. First proposals of these systems were often realized by customers; a lot of work was performed by famous research centres, for example Masachusets Institute of Technology, University of Utah and Xerox Parc in California. There were developed several tenth of systems which solved the tasks of computer aided design in various areas and which were different by quality and completeness. Gradually, about fifteen of the solutions have also been seriously used outside of the developing workplaces. The beginning of the 80th years was carried by the Unix suceeding the older proprietary systems and CA systems which did not adapt to this trend either disappeared, or rapidly yielted from their positions. 80th years are characterized by dominating of big companies which produce sophisticated software systems for computer aided design and later also for following technical processes. Cooperation between customer and company providing CA systems was very close, some of the companies have supported only one customer, respectively were created as department of big industrial giants. Europe did not want to lag behind the development in the U.S. and mainly in

France appeared companies interested in developing the computer aided systems and some of them have important position in the area of CA systems at present.
History of computer aided manufacturing becomes from 50th years, when the conception of numerically controlled machines was designed. This was first impulse for entrance of electronics and later computer technology into the production support. However, more extensive development of computer aided manufacturing systems was enabled by creating the conception of the computer numerically controlled production machines, which is dated to 1970. Since the CAM systems allow the data about product geometry, which has been created by CAD system, to be used directly for creating NC programmes for NC and CNC production machines; the big systems covering the areas of computer aided design and also following computer aided manufacturing appeared at 80th years; these systems are so-called CAD/CAM.
The most important company, which produced extensive and expensive CAD/CAM system was Computervision, that practicaly dominated in the areas of aircraft and automobile industry. IBM has developed own CADAM system, which was later united with CATIA system. At the beginning of 90th years six companies are strongly entering to foreground by producing the systems working under Unix close by prices and quality: four from U.S. (Computervision, EDS/Unigraphics, SDRC, PTC) and two from France (Matra Datavision and Dassault Systemes, where the majority is owned by IBM). These companies have created modular systems determined mostly for area of the machinery with price several hundred thousands U.S.$ for full (hardware and software) working place. These companies are also dominating in the area of big CAD/CAM systems at present.
Area of personal computers (Personal computer - PC) was not attractive for CAM systems for long time. It was mainly due to the fact, that CAD systems for PC were designed only for 2D drawing in regard to their small calculating performance and these did not dispose with functions for creating of solid models, from shape of which is possible to derive programmes for NC production machines and also it did not allow to create the NC programmes effectively, because of their small calculating perfomance. At the beginning of 90th years the big CAD/CAM systems working on workstations were only available for the area of computer aided manufacturing. Calculating and graphical performance of the machines working under Unix has been increased much rapidly against the PC, mainly thanks to products of Silicon Graphics during 1990 - 1994. Until uncommon development in the area of developing the PC components during the second half of 90th years, with entering the PC with processors Pentium, Pentium Pro, Pentium II, which are competitive by performance to workstations, but their price is only partial, has enabled to the developers of CAM systems to be oriented also to the area of PC and thus enable benefits of CAM to more users.

CAM - systems of computer aided manufacturing

CAM (Computer Aided Manufacturing) systems are systems for preparing the data and the programmes for controlling of numerically controlled machines for automatized production of the mechanical parts, whole assemblies, electronic circuits, e.t.c.. These systems use mainly the geometrical and other data, which has been gained during computer design of the part, respectively product by the CAD system.
The area of the numerical control (Numerical Control - NC) is the most worked part of CAM systems. It is technology, where the programmes for controlling of the production machines are used; for example for lathes, milling, drilling, sheet bending, grinding, conventional and unconventional cutting machines (laser, plasma, waterjet), but also for mechanical working and pressing machines by their control systems. There exists two primary types of numerical control, which are different by programme storage method. In case of CNC (Computer Numerical Control), the control system of production machine is directly connected to local control computer, where the actual programme is

saved. The second, more modern method is characterized by flexible distributed controlling of several production machines from common center - DNC (Distributed Numerical Control).
The tools for creating postprocessors, which enable the transfer of the geometrical data defining tool paths to code acceptable for control system of belonging production machine; respectively libraries of postprocessors for mostly used control systems and also modules for simulation enabling animation of production process are often integrated as a part of the CAM systems. User can verify the process of individual operations which are performed on product and thus he can prevent the incidental collisions of the tool with workpiece or fixtures.

Division and types of the CAM systems

In regard to various history of individual CAM systems and their development influenced by many various factors, it is difficult to unite these systems to common groups and to compare them mutually by their similar functions. In spite of that, by more detailed study, it is possible to find common features which enlist these systems to one of the group.
As elementary property, based on which is possible to enlist the CAM systems to some groups, is considered their completeness and compactibility with other CA (mainly CAD) systems.
Based on this, it is possible to enlist the CAM systems to two groups:

1. *CAM systems integrated in frame of the complex CAD/CAM/CAE systems.*
   There are enlisted mainly products known as „big" CAD/CAM/CAE systems, for example CADDS 5 (Computervision), CATIA (Dassault Systemes), Unigraphics (Unigraphics Solutions), Euclid (Matra Datavision), Pro/Engineer (PTC), I-DEAS (SDRC) and also „medium" CAD/CAM systems, for example Cimatron it (Cimatron) or VisiCAM into this group.
   The convenience of these systems, in regard to their completeness and integration of individual CAD, CAM and CAE modules, is that there are not existing the problems with transfer of geometrical data among individual parts and modules. The inconvenience, mainly in Unix applications, is more expensive price of hardware; this disadvantage can be strongly reduced if these systems are performed under Windows NT on efficient PC. The overview of the possibilities of the CAD/CAM/CAE systems modules for computer aided manufacturing in individual technological areas is obvious from table 1.

CAD/CAM/CAE System	Producer	CAM modules for supporting the technology:					Module for creating po-stprocesors	Module for simulation
		Machining		Mechanical working	Molding	Nesting		
		Turning	Milling					
CATIA Solutions	Dassault Systemes (France)	Lathe, Drilling	Fixed Axis Milling, Multiple Axis Milling, Rough Cutting, Milling Analysis	NC-OPT-S, NC-OPT-L	Mold and Die Machining Assistant	Nesting, Rough Cutting	(part of the manufactu-ring module)	(part of the manufac-turing module)
Cimatron it	Cimatron (Israel)	LATHE	2X-MILL, 2X-MILL 4X-POS, 5X-CONT	-	-	PUNCH, 2X-WIRE, 4X-WIRE	GPP	Cimulator
EUCLID Quantum	Matra Datavision (France)	Turning	Milling & Surfapt	OPTRIS	-	Sheet Metal Cutting & Adv. Nesting	-	NTC Mill
I-DEAS Master Series	Structural Research Dynamic Corp. (U.S.A.)	Generative Machining, CAMAND Lathe	Generative Machining, CAMAND Machinist, CAMAND Multax	-	-	Generative Machining, CAMAND Wire EDM	POST WRITE, G-POST, C-POST	CAMAND Multax
Pro/ENGINEER	Parametric Technology	Pro/MFG-TURN	Pro/MFG-MILL, Pro/MFG-ADVANCED	-	Pro/MOL-DESIGN	Pro/MFG-WEDM,	Pro/NC POST	Pro/NC-CHECK

	Corp. (U.S.A.)					Pro/SHEET-METAL		
Unigraphics	Unigraphics Solutions (U.S.A.)	UG/Lathe	UG/CAM Base, UG/Fixed Axis Milling, UG/Variable Axis Milling, UG/Core and Cavity Milling	-	UG/Flow-check UG/Moldflow	UG/Wire EDM, UG/Sheet Metal Fabrication, UG/Sheet Metal Nesting	UG/Postpro-cesing	UG/Uni-sim, VERICUT UG/Simu-lation

Table 1: Overview of specialized modules of the CAD/CAM/CAE systems for application in the CAM area.

2. *Specialized CAM, respectively CAD/CAM systems.*

   This second larger group of the CAM systems is possible to divide into several groups:

   a) Complex CAM systems determined for computer supporting of more technologies - for example SURFCAM (Surfware), SmartCAM (Camax), Mastercam (CNC Software), AlphaCAM (Licom Systems), etc..

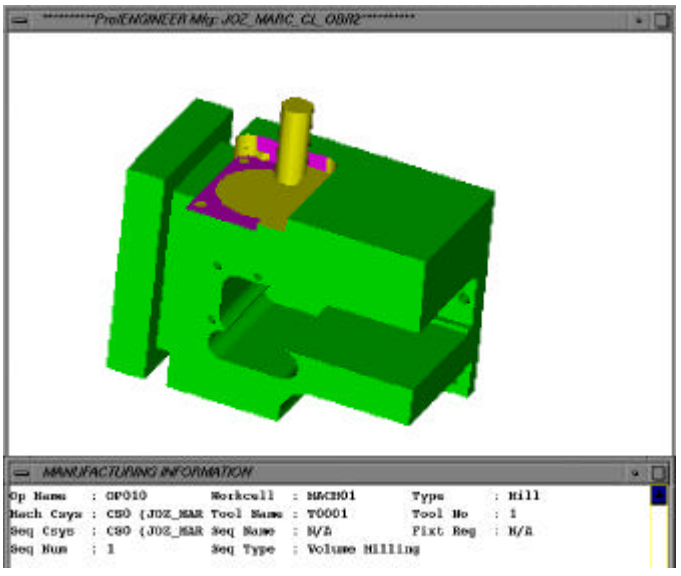
   b) Specialized CAM systems used for computer supporting of concrete technology - for example PowerMILL (Delcam) and WorkNC (SESCOI) for milling, ECAM 350 (Advanced CAM Technologies) for production of the circuit boards, etc..

   c) CAM superstructures of the specialized CAD systems - most known is HyperMILL (OPEN MIND), which is superstructure of CAD systems AutoCAD and Mechanical Desktop (Autodesk) and it is used for computer aided manufacturing which is represented by options of generating NC codes for working machines (drill, CNC mills, CNC wire EDM cutters, CNC branding machines)

   The above CAM systems are characterized especially by their maximal orientation to the computer aided manufacturing and thus their modules used for creating the solid models of products are at low level (enable to create wireframe and 2D models, but not solid models). In many cases, they do not support CAD area and models are transferred from specialized CAD systems (for example Solid Edge, Solid Works, Cadkey, etc.).

Mostly used and the best quality specialized CAM systems have modular structure enabling to create NC programmes for 2-5 axis milling machines, lathes, wire cutters, water jet cutting equipments, laser cutting, plasma cutting, etc.. They dispose by libraries of postprocessors serving for transfer of the generated tool paths to code which is suitable for control system of the production machine. Also, they dispose by modules for simulating the production process directly by computer, which allow to find incidental errors in NC programme (collision of the model and tool, intersecting to material by fast feed speed when the workpiece is not suitable designed, option to see production process from various views, transparently, or in section).

The example of milling manufacturing simulation in Pro/Engineer CAD/CAM system is shown on Figure 1, the facilities of computer aided manufacturing in the area of blanking and cutting (creating



NC programmes for control system of water jet cutting equipment) are shown on Figure 2.

Figure 1: Pro/Engineer milling manufacturing simulation

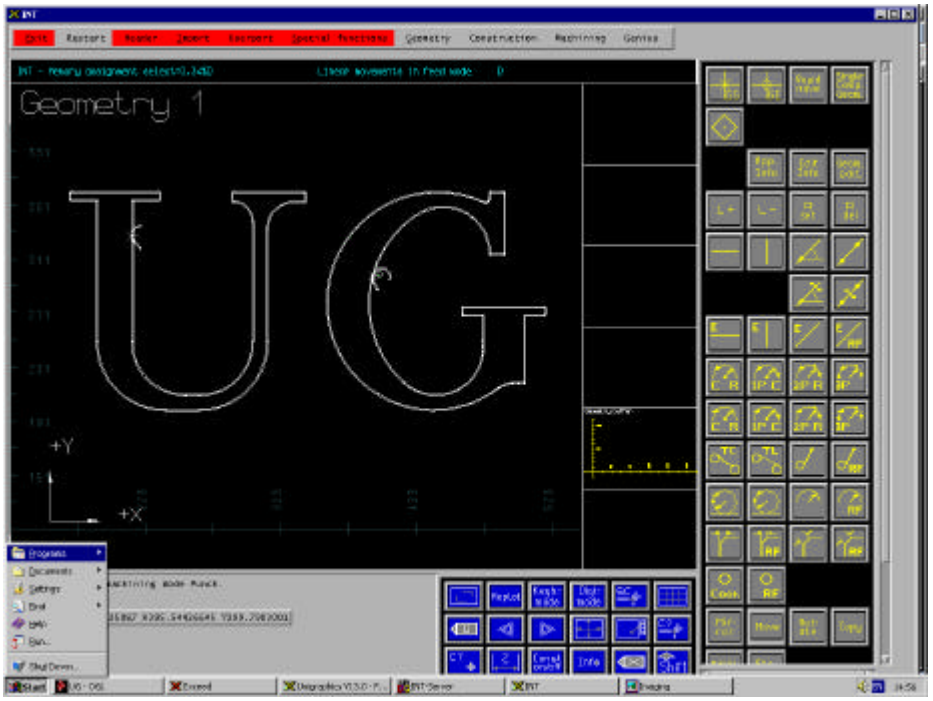


Figure 2: Computer aided manufacturing in the area of water jet cutting (Unigraphics)

Expected development in the area of CAM

The requirements to save or improve the competitive level of products urge the producers to use CAD/CAM/CAE technologies as frequently as possible in relation to their facilities and this trend is expected also in the future. Using only one component of CAD/CAM/CAE systems, for example CAD and disregarding or full omission of superstructured parts aimed to computer aided manufacturing may decrease the application effect of these modern tools in enterprise. Also the producers of computer aided manufacturing systems have to adapt to this trend and thus permanently upgrade their products in relation to saving and expanding their market positions. Thus they have to fulfil the requirements of customers as good as possible.

In the area of CAM systems it is possible to expect the following developing trends:

- implementing the new research results in the area of theory of manufacturing technologies as lathe cutting, milling, grinding to the individual modules. (computer support of new technologies as high speed machining, dry machining,hard machining, curve machining - Bezier, B-spline, NURBS, e.t.c.)
- upgrading CA modules for support of progressive technologies (water jet, laser, plasma)
- creating the modules for computer aided manufacturing in other technological areas, for example mechanical working and bending, welding, assembly, e.t.c..
- implementation of the expert systems to the area of computer aided manufacturing with aim to use formerly worked tasks and problems more effectively.
- creating the databases of postprocessors with facility to use them as completed or partial for creating other new postprocessors.

- transfer from CAD/CAM to CAPE environment (Concurrent Art to Product Environment) which allows to solve all steps of new product realisation completely from virtual design to practical realisation in the production process.
- using STEP standart (Standart for the Exchange of Product model data) for importing the CAD models by specialized CAM systems.

Present and future CAM technologies have to be able to integrate themselves to the integrated technologies of computer support from model design and its testing in virtual environment to realisation of the product manufacturing and its delivering to customer. Top CAM systems will be part of big CAD/CAM/CAE systems or will be developed individually, but with maximum facilities for connecting the other CA and information systems of enterprise.

Authors: Jozef Novák-Marcincin, Anton Petík
Faculty of Production Technologies, Technical University of Košice
Štúrova 31, 080 01 Prešov
E-mail: marcincin@kpr.po.sanet.sk