Marko Janković[1)]
Bogdan Nedić[2)]
Milan Erić[2)]
Bratislav Trifunović[2)]

1) Yugoimport SDPR, Belgrade
marko_grosnica@yahoo.com

2) Faculty of Engineering, University of Kragujevac, Serbia,
nedic@kg.ac.rs,
ericm@kg.ac.rs
trifunovicbratislav@gmail.com

COMPUTER TOOLS OF CNC PLASMA CUTTING

Abstract: *This paper presents the software, which are using in plasma CNC cutting for development new product, planning and realization of production. These softwares are described trough CAD, CAE, CAPP and CAM systems. Considered possibilities of the software, their communications, the selection of appropriate software, with an emphasis of modules and the problems characteristic for the sheet metal industry. Their use enables CNC plasma cutting, which in the industry entered a number of described advantages and novelty, compared to traditional plasma cutting.*
Key words: *plasma cutting, CAD, CAM, CAE, CAPP*

1. INTRODUCTION

The basis of plasma cutting process makes locally melting metal in the cut zone and blow molten metal away from the cut. This procedure can cut a materials of large thickness, with the formation of any cut configuration, with high productivity that does not depend on the mechanical properties of materials. With plasma process it is possible to cut materials with a thickness from 0.8 mm to 300 mm.

By integrating CNC technology and plasma cutting technology obtained a sophisticated technical system, which application is realized technologically the most economical metal cutting process in terms of speed, accuracy and cutting price. With modern processing systems for plasma cutting was performed complete integration of CAD and CAM software, which enabling process control in all stages of development and manufacturing.

At the present time when the time interval required to comes from ideas to the realization of the finished product drastically reduces, growing importance of training engineers for software application in industrial production. Their use is achieved not only the automation of design, analysis, testing, reducing time required that product appears on the market, but also decrease: the development costs, the cost of any errors that may appear on the product, loss of material resulting from the application of inadequate treatment parameters and inadequate tool construction and others. These software tools and technologies today shortly called PLM - Product Lifecycle Management system.

These software make it possible to identify the real production possibilities and possible obstacles that may arise during production a new products, as well as timely changes to the design of products in order to prevent possible irregularities. The software which used for new product development, planning and realization of production can be classified into the following groups:

- software for the design and construction using computer (CAD),
- software for the analysis and simulation of product behavior in different conditions (CAE)
- software for the design and planning of technological processes (CAPP)
- software for preparation processing, program development and management of CNC machines (CAM).

In this paper are presented possibilities of some software which used for plasma cutting, their connections, the selection, which are presented the knowledge which has to dispose engineer engaged on the development and design of new products in whose production used technology CNC plasma cutting.

2. CAD

The design and construction phase is performed using CAD software. CAD - Computer Aided Design, presents application of computers and graphic software in the

development or improvement of product design at all stages from conception to final documentation [1].

Using these software enabled the transition from traditional modes of design, which included the design with the paper and pencil on automated way using computers.

Besides new ways of designing with computer, it enabled and the transition from of the traditional way of production to computer controlled processes. Specifically, at the plasma cutting torch instead of manually managing of torch and cutting, it is possible to use conventional plasma device.

At the CAD software is defined configuration of parts which should cut with plasma. They can designed very complex forms of parts. In addition, in order to create complex sets that occur assembly and welding of individual complex parts, constructive introduced "slots" that facilitate positioning of the individual parts, where without the use of additional tools for positioning during assembly can achieve high accuracy. Slots tolerance in CAD software are defined and up to two tenth of a millimeter (Figure 1), which is limited by the precision machinery, and keeping the cutting process, not CAD software.

***Figure 1** - Using slots for positioning parts in assembly*

Traditional way of cutting sheet metal and plate in a small serial production mainly requires a lot of dressing and operations after cutting (finishing contours, drilling holes in seat, etc.), while the larger series requires the presence of a large number of templates, press tools or specialized machines for making appropriate contour. Using CAD software and CNC plasma cutting machine can get very precise contours that is not necessary require rework or perform any additional operations cutting or drilling holes.

The CAD software does not have special modules for plasma cutting as well as CAD software developed for the needs joust of plasma cutting. Application of the software for the design of parts is the same at the all parts that are made by 2D cutting processes: plasma, laser, water jet.

To generate a configuration for cutting, can be used any CAD software: AutoCad, EasyCAD, GenericCad, SolidWorks, Solid-Edge, ProEngineer, CatiaV5, SIMENS NX, PTC Creo, etc ..

The advantage of using 3D CAD software (intended for modeling) compared to 2D CAD software modules or modules for 2D drawing when making parts from sheets metal and plates is significant and in industry is increasingly used. This is because using these softwares after 3D modeling work possible further work with the part in order to obtain the final product (bending, assembly, etc.). In the following section are shown the advantages of using the module for sheets - sheet metal in the most commonly used 3D CAD software (Solid-Works, Autodesk Inventor and CATIA V5), with a focus on the specifics of solving a series of problems encountered when making parts from sheets which can be obtained by cutting plasma.

2.1 Getting unfolded states

If, after plasma cutting, is necessary to perform bending parts is desirable to use 3D CAD software which having modules for sheet metal. They have the option of automatically obtain developed states and the bending line on technical drawing from a 3D model.

SolidWorks besides to obtaining the bending line has the possibility light obtaining direction of bending which reduces the possibility of errors due to not understanding the technical drawings by the operator [2].

For parts where the bending is necessary, it is possible to use modules that are not intended for sheet metal, but the unfolded state, or more precisely DXF files can only be obtained introduction of the model in the mentioned module. Specifically, in CATIA V5 in these cases use the tool *recognize*. But such solutions are not always desirable, because when using tool *recognize* the technical drawing will not automatically create bending lines by importing models from individual modules. If importing is done from some other

software, this option enables obtain of the unfold state. So, it is very important, at the beginning of modeling, to choose the right module and advance thinking on communication with other software.

The command *recognizes* may be encountered under different names depending on the CAD software, so for example in Autodesk Inventor called *Convert to Sheet Metal Parts*, but the function is the same as in CATIA V5.

Of course, this command is used differently in each software but their function is the same. Thus, for example, radius (as well as any other element characteristic of the metal parts) in CATIA V5 must first add the model and then use *recognize*. SolidWorks 3D CAD in module sheet metal, on imported models have the option of adding the radius, and then to make a unfolded state.

2.2 Obtaining edge which technologically can not cut by CNC plasma devices

Using module for sheet metal exclude the possibility of obtaining the edge that can not be obtained by 2D cutting. Figure 2a) shows the 3D model, which is from one side cut at an angle of 45 °, and obtained by using the module for sheet metal.

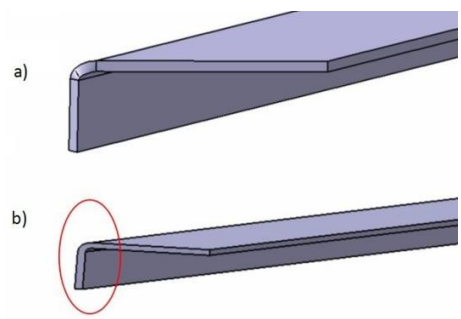

Figure 2 *- Edges (surface) obtained using the same tool: a) in the module for sheet metal; b) in a module which is not intended for sheet metal*

Figure 2b) shows the same model as on figure 2(a), but the difference is that in this case has not been used module for sheet metal. In both cases we used the same tool (subtraction of material). It is certainly, that in the second case optained the edge that can not be cut by plasma device.

2.3 Collision edges or surfaces on the unfolded state

One of the specifics when working with sheet metal is that the edges on the developed state may not overlap or touch. CATIA V5 module for sheet metal have tool *Overlapping*, which can be checked collisions on the unfolded state. Figure 3a) shows the model, which is easy to produce, but in fact this part can not be cut because on unfolded state (Figure 3b) surfaces are overlapping.

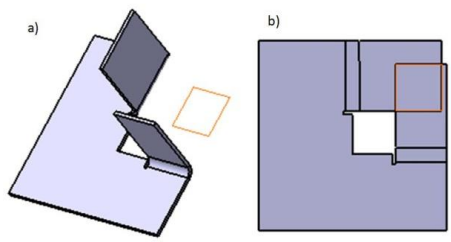

Figure 3 *- Overlapping edge on unfolding state* [3]

2.4 Corner relief

When bending sheet metal special attention should be paid to the corners where the two sides meet. At such places should be performed *corner relief* (removing excess material that occurs due to bending). For this there is automatic possibility (figure 4 obtained by CATIA V5).

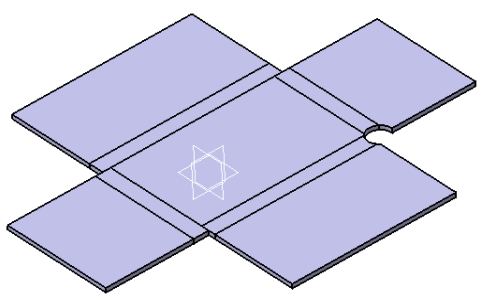

Figure 4 *– Corner relief*

Autodesk Inventor pro has tool *Corner Seam* for working with edges. It defines the distance and geometry edges on the corner (Figure 5).

***Figure 5** - Defining corners at Autodesk Inventor pro* [4]

When modeling sheet metal parts should observe the next items:

- thickness of the material is the same everywhere,
- edges can be very close to each other but can not touch,
- bending radius can not be cut
- on unfolding state can not come to overlapping or touching surfaces and edges.

These rules are "integrated" in the tools of module for sheet metal CAD software. It is clear that the use of these modules can see the advantage of using 3D CAD software in the sheet metal industry. These modules are a big help, a constructors which first confronted with this issue.

When creating 3D models, in addition to great possibilities sheet metal module CAD software, it is necessary to consider the possibilities of CNC machines on which will perform cutting, because plasma cutting devices, have a specified constraints [5].

First of all, should consider the form of corners in a developed form, depending on the equipment used. If the cutting is done on CNC plasma machines, which control unit has no limits, it is possible to process angles in the original and not a simplified form to fully correspond to the geometry of the 3D model

If the cutting perform on CNC plasma, which has limitations on the control unit, ie. it is not possible to carry out the management of movement given machine by curved lines of a higher order, it is possible to simplify the unfolded state of the 3D model. In this case, the angle of beams which is cut is a linear shape.

Another example of adapting 3D models to machine, is setting geometrical shapes when creating DXF, DWG,.. files for some CNC plasma machines. If part on unfolded state compris geometrical shapes such as ellipses, parabolas, sometimes, when creating DXF files, this kind of geometry is necessary to approximated by linear segments.

Traditional CAD softwares are designed from idea conception to the structural documentation of a product or part. In order to facilitate "communication" between the CAD and CAM software, ie. to reduce the scope of work in the CAM software (getting unfolded states, adding bending radius ...) should be used from the start of modeling modules for sheet metal 3D CAD software.

On which software to decide always is a complex issue. Based on the presented when it is complex shapes which after cutting needed to bend, then should choose a 3D CAD software with modules for sheet metal, because they are the shortest path from the model to a DXF file.

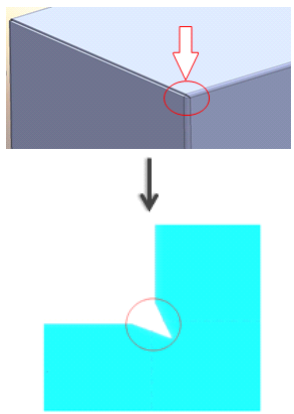

***Fig 6** - Cutting on the plasma device which has a control limit*

3. CAE

One of the characteristics of CNC plasma cutting is that the obtained contour is not necessary rework, do not any additional operations cutting or drilling holes. Therefore, in addition to all the benefits of 3D CAD software have over the traditional construction method, it is desirable modeling solutions to check analyze and optimize. It is important at an early design stage to point out the elements that are difficult, expensive or impossible to make. CAE software should definitely be applied before making documencation for production and DXF files, actually at the end or during the development of 3D models.

One of these software solutions is DFMPro, which analyzes construction in the CAD environment. It has a module for sheet metal. It is integrated with platforms: NX, SolidWorks, Solid Edge, PTC Creo, CATIA

and Inventor. In his system are integrated rules and guidelines that have been validated in industry. These rules, using the Rule Manager, can be easily upgraded and adapted to the specific company, process or machine.

For parts from sheet metal and plates that are cut and bent exist optimal value radius, distance between the edges and holes, minimum distance between holes... With DMFPro [6] in such positions can be optimized:

- Distance holes or slots from bend radius. Some recommendation is that this distance is not less than 2 mm.

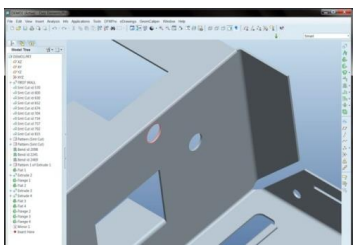

Figure 7 - *Minimum distances from the hole and bend radius*

- The minimum diameter of the holes, slots, openings... Recommendation for plasma cutting is that the minimum radius of the holes may be equal to the thickness of the material. Of course, these recommendations can be adjusted depending on the price and quality of plasma devices.
- The minimum value of bend radius. If the bending radius is too small, it can lead to deformations (cracking) material in the bending zone (Figure 8).

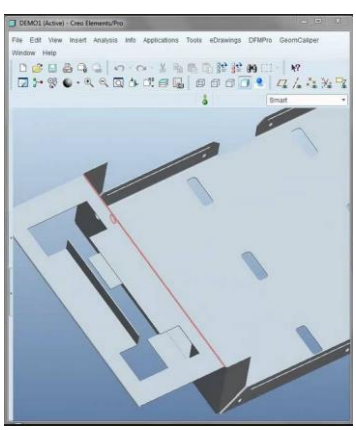

Figure 8 - *The minimum value of bend radius that will not induce the deformation of the material*

- Because facilitate production, it is recommended that all bending, which are derived from the same plane are in the same direction.
- Minimum distance between hole and contour lines.
- Minimum distance between the holes and slots.
- Is there a tool and the possibility of making part. It does not mean that each 3D model can make...

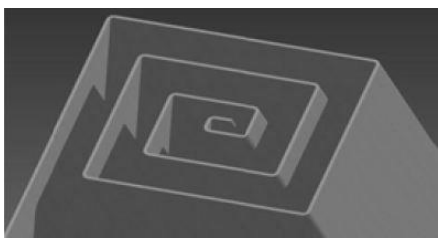

Figure 9 - *The possibility of making part*

Besides this technological analysis it is necessary to individual part or the whole assembly check on the vibration, heat flow.... These types of analyzes are known as FEM Finite Element Method, which is a numerical method for solving partial differential equations which describe the deformation solids. This is important for the individual parts of plates and sheets metal as well as for the assembly (various frames, platforms, carriers ...).

There are 3D CAD software which have modules or addition for FEM analysis: CATIA V5, AutiFEM, Inventor, SolidWorks... FEM analyses have a couple of characteristic steps:

- Display 3D geometry models
- Preparation part for the analysis - creating a gird of points
- Assigning boundary conditions (loads and constraints)
- Troubleshooting
- The visualization of results
- Analysis of the results
- Change in design, namely changes in the CAD model
- Re-perform FEM analysis

For FEM analysis, exist a specially developed software. One of the most famous is FEMAP, which has a wide application range. It is used in complex product systems and processes. As CAD software is independent and has good access to the leading 3D CAD software such as Pro/Engineer, Catia, NX, NX I-deas®, Solid Edge, AutoCAD and SolidWorks.

4. CAPP

Technological preparation of production is largely represents on definition quality solutions of technological process made of product. Systems design of technological processes can be understood as a "bridge" between the product design and the process of its production. The application of modern CAM systems and introduction of CNC plasma devices and modern technological systems of various purposes in the production, significantly increasing its productivity and flexibility.

The problem arises in the design phase of technological processes, which, on the one side it is necessary to satisfy the requirements of product designers, on the other side, to take into account the technological possibilities of production. The active use of computers in this area lead to the development of CAPP - Computer Aided Process Planning. The tendency of these systems is to appropriately uses logic operation of technologists and to made simulate of them operation by using computer programs. Development of CAPP system is a very complex task, due to the diversity of products, also because of the complexity of the design and planning of a large number of complex activities which make up the technological processes in different production conditions. This has resulted in impossibility to develop adequate universal commercial solutions CAPP system. As a consequence, a implementation level of CAPP system in the industry is still low, so the activity of designing technological processes often represent a bottleneck in the integrated production environment.

When designing a new production process, it is necessary to performe:

- major planning of production,
- planning a necesery material,
- planning of capacity,
- planning of equipmet,
- designing of technological processes.

Some of the software which is intended for solving the above mentioned tasks are: DELMIA, JobDISPO, 3DVIA Composer, SolidWorks Enterprise PDM, itd.

DELMIA

With the assistance of this program it is possible to perform effective planning, simulation and modeling of global production processes, as the implementation of best practices. DELMIA allows a visual representation of the whole factory, based on which can be make appropriate changes still in the planning phase. Its application can be: spot ways to increase the flow of materials, improved ergonomic conditions, simulated NC program on the machine, perform the optimization allocation of machines on the production plant, make a simulation of the robot, simulate flexible cables, etc.

Figure 10 shows the deployment of machines within a single production facility, defined by using this program, which has achieved the easiest and the fastest transport of workpiece, and thereby reducing the time required for the manufacture of products.

DELMIA enables automatic production of instructions for assembly and that from very simple to very complex assemblies. These guidelines contain a text description of the operations to be done in order to form a assembly as well as 3D assembly model. If this assembly containing the electrical components, this manual can be added and the corresponding electric schemes needed to connect electronic components.

CAPP software is often used by manufacturers of equipment (Figure 11), which are highly specialized in the relevant area.

Figure 10 *- Deployment of machines in the software DELMIA*

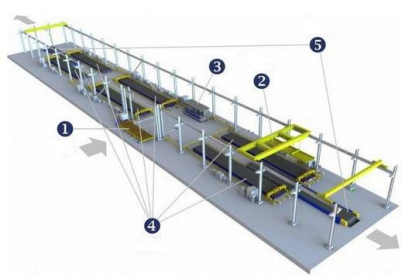

Figure 11 *– Automatic line for plasma cutting by manufactures MicroStep*

5. CAM

Further course of use constructive documentatation, takes place through the preparation for production and this activity takes place in the departments of technology companies where preparation occurs technological documentation.

CAM - Computer Aided Manufacturing, represent the software which used to create NC programs for machines and simulation of manufacturing processes. Without them it is impossible to use modern plasma cutting machines.

After designing a product or part using CAD software, it is necessary to define the production technology. Because today, for cutting metal parts using modern CNC plasma machines, defining production technology involves defining and creating "G" code on which basis the machine will perform the necessary operatios. Today, the generation of code (programs) can be performed automatically on the basis of CAD models using CAM software.

There is a large number of this software. They are adapted to final users and easy to learn. Besides starting the machine, this software performs deployment shapes of workpieces on the sheet metal panel (or board) which needs to be cut. This module is found under the name "Nesting". On this way achieves the best utilization table sheet. Defines the cutting trajectory of given contour, which defines the layout of heat that is liberated during plasma cutting. For example, if there are a lot of small workpieces it is necessary to plasma does not cut in the order the parts distributed, because in a small area will creating large amounts of heat, which will give rise to the bad quality of the cut edge and strain table sheet (or plates).

CAM softwares can load different drawing formats: DXF, IGS, CADDY, PLT, etc. Software PlasmaCAM can even upload and formats that are not traditional for CAD software HPGL / 2, which enables the transfer design from any Windows environment, for example, drawing from CorelDraw or PDF. This option involves installing special Windows drivers for printing high resolution, thereby creating a virtually ploted file which will loaded into PlasmaCAM [8]. In addition to these there is CAM software which using 3D CAD software interface (ProNes –CAM software with SolidWorks, Inventor, Pro/ENGINEER).

CAM software today go beyond the classical tasks of CAM and called CAD/CAM software. They have CAD modules. These modules have less features than conventional CAD software. They are used for the obtained unfolded state, correction of the preformed 3D models (add radius, etc.).

Today all serious manufacturers of equipment for plasma cutting with the machine offered and CAM software in different variants depending on the complexity of the cutting process, the number of machines that need to be managed... During the development such solutions are overcome of common frameworks CAM - software, so with them now is possible to performe planning, storage, documentation and analysis of the technological processes and integration with other business systems. So producer Varstroj with supplied equipment offers CAM software ZEVS RX in primary and professional versions [10].

Zevs RX - professional was designed for companies that would like better integration of the cutting process into their business process, better tracing, automation, interconnection; statistics and greater flexibility, as well as control over the cutting costs (figure 12). The professional version offers along with the high - efficient system for cutting preparation also a completion of the company's business system. Compared to the basic package.

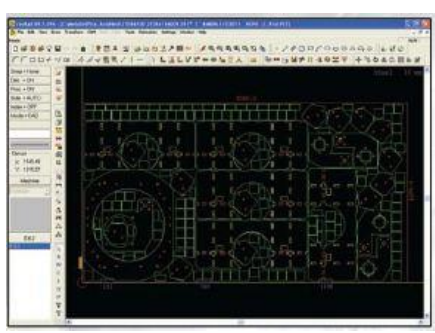

Figure 12 - *Deployment shapes for cutting in software METALIX* [8]

In addition to being in selecting cutting mood have already set the value from equi-pment manufacturers in some CAM software, there is special applications for improving quality. For example, ProNest-software for plasma cutting has two applications: plasma-conventional and plasma-high definision (increasing the cutting speed, current, giving a

better quality of cut). ProNest can be used for automatically stacking heavy cut pieces.

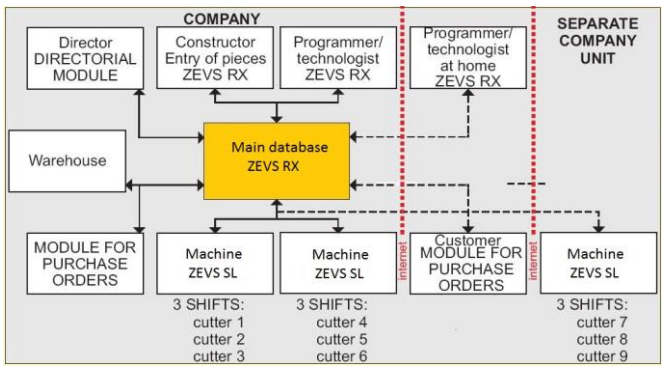

Figure 13 *- Integration CAM software ZEVS RX Profesional with process and structure of company*

6. CONCLUSION

From the second chapter clearly concludes that during design, conventional 3D CAD software have the advantage, while should be use of the module sheet metal. Always should be think about that after the CAD should used other software, so a method of modeling in CAD should be adapted to other software. During the modeling, in CAD should be take attention to the possibilities of machine.

So, to get to the final target (the final product) always is necessary to use more software and to think about their "communication". The connection between CAD and CAM are usually made by DXF files, a special link, or use the same interface.

CAD and CAE software tools have "installed knowledge" about the specifics characteristic for sheets metal, so the constructors job makes it easier. CAE software should be used as possible early in modeling phase, so the bad solutions will discovered on time.

When choosing CAM software should be used the manufacturer's recommendations, because, manufactures are these software very well adapted to machines and the customer's need. With CAM software now is possible to performe the planning, storage, documentation and analysis of the technological process as well as integration with other company business systems.

New software go far beyond the tasks of they cover, so in soon future under the the same interfaces can expect software which covering CAD/CAE/CAPP and CAM systems.

REFERENCES:

[1] Stefanović, M. (2006). *CIM sistemi*. Mašinski fakultet, Kragujevac.
[2] Devedžić, G. (2009). *CAD/CAM tehnologije*. Mašinski fakultet, Kragujevac.
[3] Devedžić, G. (2004). *Softverska rešenja CAD/CAM sistema*. Mašinski fakultet, Kragujevac.
[4] Retrieved from: http://www.solfins.com/strana/pregled-finkcionalnosti.
[5] Landeros, J. *Autodesk manufacturing academy*
[6] Retrieved from: https://dmgm.wordpress.com/2013/10/16/razvijenioblicilima/, maj, 2015.
[7] Retrieved from: http://dfmpro.geometricglobal.com/processes/dfmpro-for-sheet-metal/, maj. 2015.
[8] Retrieved from: http://www.metalix.net/products.php?cat=57, maj, 2015.
[9] Retrieved from: http://www.plasmacam.com/archive/sfsp.htm
[10] Varstroj – *Tehnika rezanja* - Katalog

Acknowledgment: This paper is part of project TR35034 The research of modern non-conventional technologies application in manufacturing companies with the aim of increase efficiency of use, product quality, reduce of costs and save energy and materials, funded by the Ministry of Education and Science of Republic of Serbia.