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AUTOMATION OF PIPELINE ENERGETICS SYSTEMS COMPONENTS MANUFACTURING

In contribution are described applications of computer aided systems in area of automation of pipeline energetic systems components manufacturing. There are used commercially offered CA systems. Disadvantage of these systems is high price and hardware exacting. Besides commercial there is possible use specialized systems, which are designed for concrete user conditions in area of pipeline energetic system component design and manufacturing. To these specialized systems we can line up the system EDBTS 11 created by workers of Faculty of Manufacturing Technologies TU in Presov. This system is designed for control program creating of BTS11 control system, which serves for controlling of slotting and baking positioning devices.

1. INTRODUCTION

Trends in area of automation of pipeline distribution system components with complicated shape manufacturing are aimed at using of computers with proper software equipment. Manufacturers of pipe components, because of the accelerating and make projecting of components more first-rated, use in the design stage CAD systems (Computer Aided Design). But manufacturers must often take care of problems with manufacturing quality of component, mainly in the cases when it is needed to make pipeline with the shape defined by several curves. There are recommended to use proper CAM systems (Computer Aided Manufacturing) in the cases of manufacturing stage. These systems use geometrical data obtained from a part in design stage and saved in CAD data bank of computer.
History of CAD systems is connected with history of computer graphics; the first system was developed on several computers and was realized by customers. In 70^{th} years were developed a lot of CA systems. From them arose around ten the most significant. In 80^{th} years came complex CAD/CAM systems for area of computer-aided design as well as area of manufacturing. In 90^{th} years arose from complex CAD/CAM systems five and these are dominant in the present time on market: Catia, Euclid, I-DEAS, Pro/ENGINEER and Unigraphics. Besides abovementioned systems get well in area of energetic, chemical industry and consumption industry enforced the biggest of the computer design systems - Plant Design Systems [1, 3].

2. COMPUTER AIDED DESIGN OF PIPELINE SYSTEMS COMPONENTS

CAD system is in sphere of design of pipeline energetic systems able to use mainly for designing of pipes with more complicated shape, which are unavoidable for creating of complete pipeline. This is the question of parts like for example knee-joint, which can be of several diameter, radius of curve and swerve angle, can be manufactured as solid or many

parts connected by welding joint. Then there are breeches pipe components in T-shape, which are made by many segments (minimally 2). In the case of first-rated realization of welding joint, it is unavoidable all the segments of a weldment and mainly parts where a weld will be realized manufacture with best precision. By this we can prevent the necessity of finishing and fitting of weldment segments in welding stage. This can reduce the time of welding and reduce the probability of bad weld realization [2].

Considering the fact that the segments of pipeline is connected to one solid there are several types of penetration with various sections (mainly circular section, tetragonal and rectangular section). In the case that these segments are manufactured by bending from thin-walled sheets and then jointed by welding is important to define and make spread out shape for semi-finished article, which in the place where the weld will be, often has the shape of a curve with compound geometry. Because of the design automation and reducing of time, which is needed, for realization of design and also for exact transmission curve defining is in the cases better to use proper CAD systems, which are differed by function, performance and by price.

From the point of application in the area of projecting of pipeline systems is possible to classify CAD systems to [5]:

1. *Small CAD systems*

   Enables only drawing on the plane and serve as drawing board. There are no special tools for automation of design of pipeline elements. We can place to these group systems as AutoCAD LT, AutoSketch, VectorWorks, DesignCAD, SmartSketch, TurboCAD, etc.

2. *Middle CAD systems*

   These systems are noted by the part, which is designed as 3D model, and then from this model are created 2D drawings. The most famous systems are AutoCAD, MicroStation, CADKEY, and Cimatron. The newest systems created especially for operation system WINDOWS is SolidEdge and SolidWorks. These systems have more or less opened architecture and some of them are specialized for design of bending parts bended from thin-walled sheets and for design of pipeline distribution systems.

3. *Big CAD/CAM systems*

   We can place here complex CAD/CAM systems, which were created mainly for workstations. In present time it is possible to use them on PC's. These systems provide not only design stage including the possibility of various types of analysis, but production stage too (CAM). There are following systems in this group: CATIA by Dassault Systems, EUCLID by Matra Datavision, Pro/ENGINEER by PTC, I-DEAS by SDRC and Unigraphics by Unigraphics Solutions.

4. *Plant Design Systems*

   These are the biggest of design systems. PDS are used mainly in area of projecting and building of technological units, in area of maintenance of production lines, for data and technical information maintenance, for serving of engineering nets in chemical and consumption industry and in energetic.

   PDS systems have the specialized application, which helps create pipeline systems. Pipeline systems are created by components, which are stored in catalogue base. PDS systems takes control in designing of pipelines, if the connection is proper (non-return flap valve, check valve etc.). System automatically complete pertinent pipeline with insulation and with heating between components takes care of possible collisions in space etc.

   Well known PDS systems are Plant Design System by Intergraph, Plant Design Management System by CADCENTRE, PASCE by EA Systems, Plant/CMS by CSA, AutoPLANT (Rebis) and Plant Space (Jacobus Technology).

Architecture of modern CAD systems consist of a system of modules, from which is possible to create a whole configuration of system (base module which enables to operate the system,

module for solid design by protrusion, or rotation of 2D geometry, module for 3D solid design, module for design of free-form surfaces, module for bended parts from sheet metal, module for assembly, module for drawings etc.). Statement of CAD systems, which include specialized module for bended parts from sheet metal are shown in Tab. 1.

Product name	Author	Class of system	Module for sheet metal parts
AutoCAD 2000	Autodesk (USA)	middle	3D Blech (product of firm SPI)
CATIA Solutions ver. 4	Dassault Systemes (Fr.)	big	Feature-Based Sheet Metal
Cimatron ver. 7.0	Cimatron (Israel)	middle	Bend
EUCLID 3	Matra Datavision (Fr.)	big	SHEETMETAL
I-DEAS Master Ser. 6	SDRC (USA)	big	I-DEAS / Sheet Metal
Pro/ENGINEER ver. 19	PTC (USA)	big	Pro/SHEETMETAL
Solid Edge 7	Unigraphics Solutions	middle	Sheet Metal, XpressRoute
SolidWorks 98 Plus	SolidWorks (USA)	middle	Sheet metal
Unigraphics ver. 16	Unigraphics Solutions	big	UG Sheet Metal Design

Tab. 1 Specialized modules of CAD systems for sheet metal parts

Modules for sheet metal parts design make projecting easier in area of bended parts and arisen by penetration of several profiles. After the bended part is created the margin bends folds and flanges are added and then we can set thickness of material. Created part is possible to modify even the requested values of material thickness; bending radius, shape and discharging value is reached. Important function of these modules is automatically displaying of bended part in unrolled shape, what can be directly moved to system for NC production technologies (punching, flame cutting, laser cutting, jet cutting, plasma cutting). Self-evident is collision control in unrolling (overlap material), control for material cranking as the result of little bending radius, or control to possibility of tool damage and part deformations [8, 11].

3. CAM SYSTEMS FOR PIPELINE ENERGETICS SYSTEM COMPONENTS

History of CAM systems is dated from 50th years, when the draft of numerical controlled machines was designed. But establishing the draft of Computer Numerical Control (CNC) machines, which is dated to 1970 enables wide progress in area of CAM systems. Because of the fact of using part geometrical data, which is possible to create in CAD system aimed for NC programs creating, the systems which arose in 80th years takes the area of computer aided design as well as computer aided manufacturing. These systems are marked as CAD/CAM systems [10].

CAM systems enables customers use them in area for preparing of data and programs for numerically controlled machines and also for automatically manufacturing off parts, assembly systems, circuits etc. Above all these systems use geometrical and other data, which were reached out in stage of computer aided design from CAD systems. The most worked out sphere of CAM systems is Numerical Control (NC) manufacturing sphere. This is the question of techniques where the NC programs are used, e.g.: lathes, milling machines, drilling machines, bending machines, gear grinding machines, conventional and nonconventional machines (water jet, laser, plasma), but also forming machines and pressing machines. There are two basic types of direction in numerical control. The difference is in the way of program storing. In the case of CNC (Computer Numerical Control) is control system of production device directly connected with local microcomputer, where the proper program

is stored. The second, more modern case is characterized by flexible distributed control of such production machines from one center - DNC (Distributed Numerical Control). Postprocessors are in many ways the part of CAM system. Postprocessor provides the translation of geometrical data, which defines tool path. This path is accepted by control system of proper production machine. CAM system very often has postprocessor library for the most using control systems and also modules for simulation - animation of manufacturing. User can take control of running operations (its chronology), which are serviced on a part and check possible collisions (tool-part, tool-fixture).

Complexity and possibility to connect CAM systems with other CA systems are characteristics by which CAM systems can be distributed to [6, 7]:

1. *Integrated CAM systems in CAD/CAM/CAE systems*
   We can place to this group systems marked "big" CAD/CAM/CAE systems e.g.: CATIA, Unigraphics, Euclid, Pro/ENGINEER, I-DEAS, but also more complicated systems of middle class e.g. Cimatron by Israeli company Cimatron or VISI-CAM system etc.
   Advantage of these systems - due to their connectivity and complexity - is that there are no problems with transfer of information and geometrical data between mentioned modules.
2. *Special CAM, respectively CAD/CAM systems*
   This second group of CAM systems is possible to distribute into subgroups:
   a) Complex CAM systems established for computer aided technology group - e.g.: system SURFCAM (by Surfware), SmartCAM (CAMAX), Mastercam (CNC Software), Alpha CAM (Licom Systems) etc.
   b) Specialized CAM systems working for computer aided certain technology - e.g.: PowerMILL by Delcam and WorkNC by SESCOI for milling, ECAM 350 (produced by Advanced CAM Technologies) for production of printed circuit plates etc.
      CAM as superstructure of specialized CAD systems. Well known program HyperMILL by German company OPENMIND. This program is superstructure for CAD systems AutoCAD and Mechanical Desktop by Autodesk and is created for computer aided manufacturing. HyperMILL enables user to create NC codes for production machines (drill, CNC milling machine, CNC electroerosion wire power saw, CNC flame cutting machines).

Abovementioned CAM systems are maximally orientated on computer aided manufacturing and their part serving for design is on low level (enables user create only wire or surface models, but not volume models). In many cases they absolutely doesn't support the stage of CAD and models are taken over specialized CAD systems (e.g. SolidEdge, SolidWorks, Cadkey etc.). The most extended and the most quality special CAM system are of modular conception and enables creating of NC programs for 2 - 5 axis milling, lathe, wire cutting, devices for water jet cutting, plasma cutting etc. They have library of completed postprocessors and serves for translating of generated tool path to shape, which is understandable to control system of production machine. These systems also have modules simulation of production process on computer display, which helps to check faults in NC program (interference with model and tool, high-speed feed of tool when model is machined, possibility to check model from various sides or in section) [4].

4. EDBTS 11 – SYSTEM FOR AUTOMATION OF PIPELINE COMPONENTS MANUFACTURING

As was mentioned in the last chapter, there are quiet a lot commercially offered CAD/CAM systems, which are characterized by high functional properties, but for many companies are out of reach because of the high price and high service costs.

In many cases are these CAM systems not used because they have functions, which in area of pipeline components manufacturing (mainly parts cut from sheet metal with following shaping) are impossible to use. Many of pipeline component manufacturers use simple programs, which are not exacting on computer capacity and very often are realized on demand of user.

To these systems is also placed program EDBTS 11 created by workers on Faculty of Manufacturing Technologies of University of Technology in Kosice with a seat in Presov. This program is aimed for creating of control programs for BTS11 control system. Positioning devices are used as supporting device for cutting torch, laser heads plasma torches or torches for water jet cutting. Mentioned technologies of cutting are the most often used technologies in production of unrolled shapes of pipeline components from thin-walled sheets. Manufacturer on requirements of user with fix pick can deliver positioning device up or portables pick up. Accuracy of position of end part devices in range -0,2 to +0,2 mm and when the program is read second time, it is read without deviation. Device consists of main axis (coordinate x), on which are with several rolling guides positioned trucks. The direction of the motions is perpendicular on themselves. On transversal path is placed tool plate, which has clamp for torch or pneumatic vertical support with clamp of torch. Propulsion of both axes provides one-way servomotor with integrated digital sensor for scanning of position and for speed control. Device is operated by control system BTS 11, which enables manual operation and program mode [9, 10].

For effective program creating for unrolled shapes component cutting from sheet metal was created special program EDBTS 11. Used coding language was Turbo Pascal 7.0 and it is able to provide it on personal computers PC 486 or Pentium with installed operation system WINDOWS 95 and higher. It serves mainly for automated generating of programs for production of pipeline systems components (mainly normal, respectively under certain angle of lead direction pipeline securing).

When the program runs, at first we can see opening dialogue window (Fig. 1) where the user must choose the type of productioned component (T-main segment, T - connectivity segment, knee-joint-segment in knee, knee-joint-pipe segment). After choosing of certain option then is displayed other dialogue window, which is presented by form for entering of input technological and dimension data. Dialogue window of program EDBTS 11 for entering of input data is shown on Fig. 2.

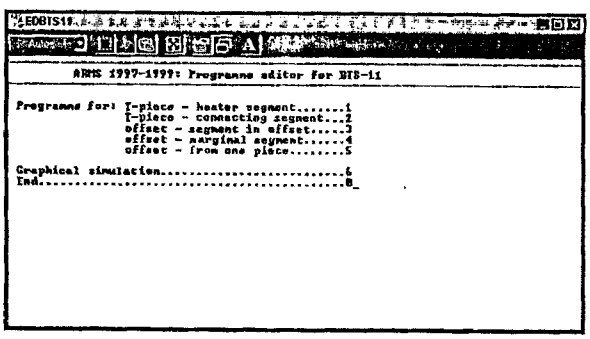

Fig. 1 Opening dialogue window of system EDBTS 11

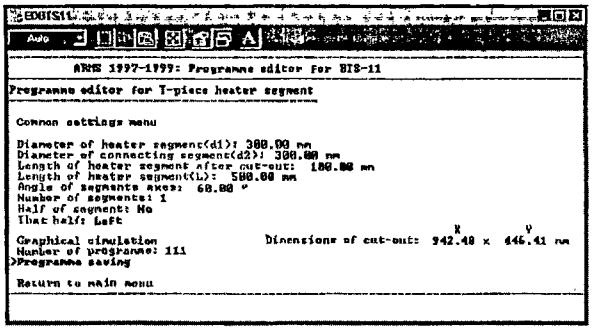

Fig. 2 Dialogue window of program EDBTS11 for entering of input data

On Fig. 3 is displayed analytical model of two cylindrical surfaces, which is used for computation of two-dimensional curve which determines path of torch (displayed view is in x-z plane). Main segment has the axis the same with z-axis. Axis of connectivity segment is intersected under β angle by axis of main segment. The point of intersection is the centre of coordinate system.
Parametrical functions of cylindrical surfaces are:

$$\text{V1:}\quad \begin{aligned} x &= r_1 \cdot \cos \alpha_1 \\ y &= r_1 \cdot \sin \alpha_1 \\ z &= v_1 \end{aligned}$$

$$\text{V2:}\quad \begin{aligned} x &= r_2 \cdot \cos \alpha_2 \cdot \cos \beta - v_2 \cdot \sin \beta \\ y &= r_2 \cdot \sin \alpha_2 \\ z &= r_2 \cdot \cos \alpha_2 \cdot \sin \beta + v_2 \cdot \cos \beta \end{aligned}$$

r_1, r_2 - diameters of cylindrical surfaces,
α_1, α_2 - circumference angle of cylindrical surfaces,
β - angle of "T",
v_1, v_2 - height of cylindrical surfaces in axis direction.

For concrete values α_1 from χ to $(\chi + 2\pi)$ and by solving of functions system we can acquire other coordinates of certain points of curve which are as penetration of surfaces: α_2, v_1, v_2. From this points it is possible to assign co-ordinates of curve for unrolled segments in plane.

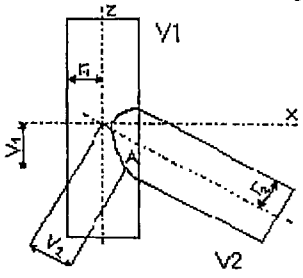

Fig. 3 Model of connection of two cylindrical pipes

The program is automatically generated when the input data are entered and when the option "Program creating" is chosen. After this it is possible to check if the program is correctly generated. It is possible after graphical simulation of motioned cutting head on plotting device in reduced scale. Simulation of cutting head in motion when the segment of pipeline component is cut is displayed on Fig. 4.

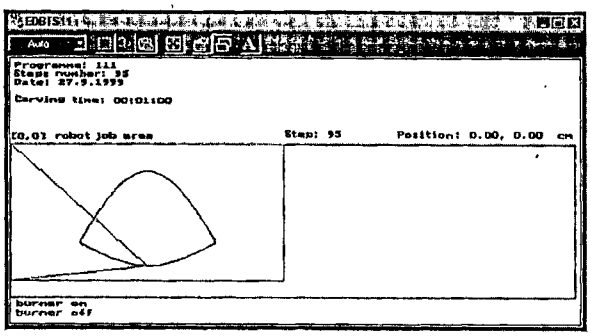

Fig. 4 Simulation of pipeline component cutting in program EDBTS 11

Designed environment for generating of chosen group of task enables creates also programs for pipe - knee parts from requested number of segments, respectively can be completed by other tasks, which will be requested by practice.

5. CONCLUSION

The most used CAD/CAD systems in present time are characterized by following marks: uses new forms of program implementation - property orientated approach (coding language C++ etc.); have modular structure; use mainly 3D modeling and techniques, modeling tasks, construction tasks, simulation and analysis tasks runs parallel (Concurrent Engineering) what helps reduce time of part planning and manufacturing; used data are not only geometrical but also technological and are unambiguous during all process of design complete and accessible for all applications; for data transmission is used new STEP - ISO standard; aided dynamical data exchange (between subjects in system); are opened from side of extending by new modules; it is possible to use them in Internet and intranet, too.

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