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CAD SYSTEM FOR DESIGNING WELDING ROBOTIC STANDS AIDED WITH TECHNOLOGICAL EXPERT SYSTEM

Summary. The paper presents the structure and work of model CAD system for designing welding robotic stands accomplished within research project "Welding CAD/CAM System", No.PB 31/7/91, sponsored by Scientific Research Committee.

1. Introduction

In welding, one of the most important and modern applications of CAD systems is configuration and "off-line" programming of robotic arc and resistance welding work stations. The stand design is arranged into configuration by assembling prepared 3-dimensional models of devices which are put together in the stand. Each element can be taken from libraries, integrally belonging to the system, created in internal graphic editors or "imported" from other CAD programs using standard formats of graphic information exchange, e.g. IGES or DXF. Such programs have real-time motion simulation available for robot and other elements of the stand, fully taking into consideration their kinematics and dynamics which allows programming the operation of the stand precisely. At the end it is possible to generate the finished program for robot's controller, ready to be started immediately. Such systems allow changing program of already existing stands without shutting them off (in fact the time of the stand out of operation is at least four times shorter).

First step in the direction indicated by that type of programs is model Welding CAD/CAM System, created within the research project, accomplished in the Welding Institute in Gliwice and sponsored by Scientific Research Committee. The structure and work of this system is the content of this report.

2. System and its hardware environment

Described system has a hybrid structure. It consists of programs such as databases, expert systems and "classic" algorithmic programs, embedded in the environment of graphic CAD package.

As hardware and software we used computer PC and AutoCAD, which is a typical combination in our country. Computer used was 486DX/33MHz/16MB RAM. The motherboard has an EISA architecture with 32-bit bus. Computer has SPEA vector graphic card based on Texas Instruments processor, aided by 64-bit processor of RISC-i860 type with its own RAM, and equipped with RAM memory for display list . Hard disk memory according to SCSI standard is controlled by so-called intelligent SCSI controller, which in fact is a 386DX computer with its own memory RAM. Owing to this realization the access time to open disk file is about 0.5 ms. The unit is also equipped with co-processor Weitek. As to AutoCAD system (version 11), the additional factors in choosing it were:

- possibility of adding programs written in AutoLISP and C,
- possibility of creating 3-dimensional objects.

3. Elements of welding CAD/CAM system

The system realized within the project consists of:
- AutoSPAW package, which is composed of six main parts:
    - program generating symbols and notation of welds according to proper PN standard,
    - libraries of standardized drawing sheets with tables and with management program,
    - program generating symbols of welds in 3 dimensions,
    - libraries of standard methods of edge bevelling before welding and a supervising program,

Fig. 1 Structure of welding CAD system.

- program generating welding procedure specifications (WPS), according to Euronorm
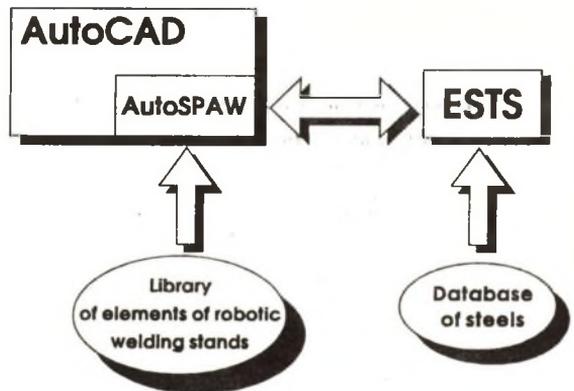
EN-288-2,
- program detecting potential points of collision,
- database of steels,
- Expert System of Technological Support (ESTS),
- library of the elements of robotic stands,
- a number of utility programs for transmitting, converting and filtering data and generating print-outs.

3.1. Database of steels

Database of steel contains all the necessary information for welding engineer about approximately 250 types of steel made in Poland. It has a special operating program, written in CLIPPER 5.01, facilitating usage of data contained in it. This program makes it possible to view the list of steel ordered in groups with simultaneous displaying extended information about each type of steel. For each type of steel it is possible to get information about its chemical composition and its mechanical characteristics. It is possible to quickly find steel with a given symbol. It is also possible to select all steels meeting defined requirements referring to their chemical composition or strength parameters and all steels described in a specific standard.

3.2. Program generating symbols and notation of welds

Program generates symbols of welds in the second level of simplification according to principles defined in proper PN standard. All other variants of weld symbols defined by the standard are also included together with specific dimensions. The program has been provided as a tool for dimensioning construction drawings. It cooperates with Expert System of Technological Support (ESTS) in data exchange. The program has been written in AutoLISP.

3.3. Library of standardized drawing sheets

In fact it is the program generating in AutoCAD's environment standardized drawing sheets with frames and drawing tables for a lot of sizes. Table filling and editing is semi-automatic, which means that the operator gives necessary data and the program arranges them properly along with attributes.

3.4. Program generating symbols of welds in 3 dimensions

With the help of this program you can automatically draw symbols of welds in places of edges to be joined on a 3D drawing made in AutoCAD system. Additionally, the program writes coordinates of weld trajectory to disk file. This data can be corrected in case of need or used directly as entry data for postprocessor generating program for robot's controller.

3.5. Libraries of ways of preparing edges before welding

They contain ways of preparing edges of objects to be joined before welding, provided in proper PN standard. The libraries are managed by the program cooperating with Expert System of Technological Support, which automatically inserts the dimensioned drawing of joint, obtained as a result of consultation with ESTS, to WPS currently worked out.

3.6. Program generating welding procedure specification (WPS)

This program prepares manufacturing instruction of welding WPS according to requirements of Euronorm EN 288-2. It takes the following data from Expert System of Technological Support:
- thickness of elements to be joined,
- type of steel,
- type of bevelling,
- characteristic dimensions of a groove,
- pre-heating temperature,
- parameters of welding for a root pass and filler passes respectively (wire feed rate, welding speed, arc voltage and current).

When the program is working it asks for additional data. The data could be welder's name and surname, technologist's name and surname, plant's name, etc. The program allows you to correct already introduced data. Filled WPS can be stored as a disk file or printed by a printer. The program works under control of AutoCAD system.

3.7 Program detecting potential points of collision

The program which can detect emergency of collision for moving elements of stand was written in "C" language. The program works only with models of pseudo-solid shape and when the program runs only when the module AME of AutoCAD is loaded into RAM. Possible usage of this program in AutoCAD environment is limited because of occurrence of losing information about a resultant block in the course of transferring it from one disk file and inserting to other model as a fragment. If designed 3-dimensional models are not imported from other disk files the program works properly.

3.8. Library of the elements of robotic welding stands

It is a set of basic and peripheral devices used for configuration of robotic welding stands in the shape of 3-dimensional computer models. All models are made with a scale 1 : 1 which means they have real dimensions. They were made according to the original working drawings or they were reproduced from existing objects.

At the moment the library consists of 11 elements and comprises among others the model of IRb-6 industrial robot, two types of controllers, two types of positioners and other elements of typical stands. There will be more items added to the library when there is a need for it.

Those items were made with the help of solid modelling module - AME - of AutoCAD package and they are accessible through the screen menu or special set of icons (item ROBOTICS in pull-down menu).

3.9. Expert System of Technological Support

The aim of Expert System of Technological Support is to ensure that a designer, working in CAD system, has access to technological knowledge essential for making production instruction of welding - WPS - (with the help of the package AutpSPAW), for the object to be welded on a designed robotic stand. In a traditional approach professional advice from an expert technologist is needed. When technological expert system is applied it helps to obtain needed consultation limiting to the minimum distraction of a designer and at the same time the same consultation can be used on many design stands.

Shell system EXSYS Professional was used for making ESWT. It is rule based system extended by simplified frames and elements of table architecture and hypertext and also procedural programming language [EXSYS 2]. Its chaining mechanism can do backward chaining, forward chaining and mixed one. With the help of the programming language you can solve problems requiring special chaining control as for example changing the sequence of rules firing, import and export of data, special ways of presenting results. EXSYS Professional is equipped with the editor of knowledge base making it possible to form rules in a relatively simple way and test finished fragments of the base along with automatic formal validation checking which can be presented in a shape of a chaining tree. In the system there are provided four different ways of processing uncertain data and possibility of introducing by a user his own complete definition of a system of managing uncertainty. It can also use results from the work of the most popular data processing programs (direct access to databases in the form of dBASE III and worksheets compatible with Lotus 123). It is also equipped with a rich set of mathematical functions, arithmetical and relation operators what is particularly important in technical applications.

The ESWT structure is based - with some simplifications resulting from limitations of applied tools - on table architecture. The system has an open character; any program with any functions can be added to the system. It only needs to be equipped with possibility of getting data from a table and if necessary writing there results of work in such a way that they may be read and used by other programs.

There are four basic units cooperating within table organisation of ESWT :
  - AutoSPAW package, writing to the table the data which was placed on a drawing of an object before calling ESTW and reading from it results of consultation,

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- program managing database of steels "STALE", which, after finishing work, writes chosen information about chemical structure and physical properties to the table, from which any program working within ESWT can take the information,
- expert system "PARAMETRY" making it possible to choose, in the light of the valid standards, the most suitable way of preparing a joint, and stating the number of seams and
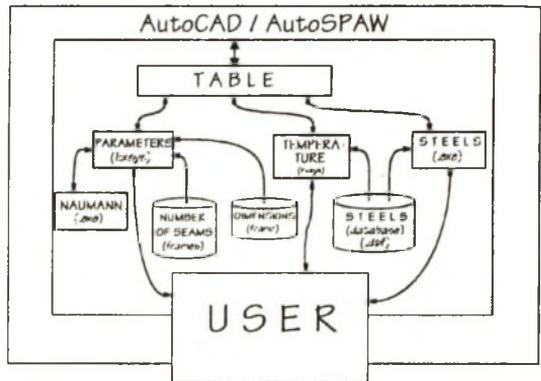

Fig. 2 The structure of ESWT

parameters of welding. Its knowledge base contains at the moment 55 rules making possible proper choice of the way of preparing a joint and stating the most suitable number of seams according to :
- type of a joint (butt or fillet),
- thickness of material and thickness of a fillet weld,
- possibility of access to a joint from both sides (only for butt joints),
- position of welding (at the moment only gravity and horizontal positions),
- total weld thickness.

When above mentioned information is not found in the table, the system asks for required information.

Values of parameters of welding are calculated, individually for a root pass and filler passes, from the Naumann-Schilling algorithm. Obtained values, for the time being final, will be initial values for further reasoning in the future, based on the set of heuristic rules formulated on the ground of the analysis of knowledge of an experienced welding technologist.

- expert system "TEMPERATURA", whose job is to state the pre-heating temperature T_0. Its range of work comprises carbon steels and low-alloy steels, and knowledge base, existing at the moment in outline, is based on the method of defining T_0, worked out by D. Uwer and H. Hone, based on empirical research. This method, which is the result of as much as 10 years of research, is presently probably most thoroughly documented way of solving that problem, and takes into account the greatest number of influencing factors. The range of its application, resulting from the assumed by the authors limitations of the research field, is as follows :
  - the range of yield strengths for steels: 300 - 1000 N/mm2,
  - chemical composition within the range : C - 0,05 do 0,32 %, Si - max. 0,8 %, Mn - 0,5 do 11,9 , Cr - max. 1,5 %, Cu - max. 0,70 %, Mo - max. 0,75 %, V - max. 0,18 %,

Nb - max. 0,06 %, Ni - max. 2,5 %, Ti - max. 0,12 %,
- thickness of the object to be welded :10 - 90 mm,
- the hydrogen content in weld metal, defined according to the standard DIN 8572: HD 1 - HD 20,
- quantity of heat supplied in welding process : 0.5 - 4 kJ/mm.

Details, required by the system in the course of consultation, which can be obtained from the table or from the user, are the following :
- method of welding : manual with covered electrode, automatic GMAW or automatic submerged arc welding,
- parameters of welding or diameter of covered electrode required for defining heat input in the process of welding,
- type of weld (the possible choice is : tack or root weld, fillet weld made in one pass, multi-pass fillet or butt weld); according to the chosen type, the system makes adjustments to the calculated temperature,
- thickness of material to be welded,
- the hydrogen content weld metal, if it is stated (if not, default value HD 10 is assumed).

After finishing consultation with ESWT and returning to AutoCAD, the package AutoSPAW reads the data placed in the table by the described above programs, then suggests that they should be assumed as default data when the WPS is written. Of course, user of the system may not accept that suggestion and introduce his own values. The expert system works here only as an advisor.

4. Recapitulation

The system described in this report seems to be the first in Poland serious attempt of using CAD system and expert systems in welding applications. Interest, which was raised among representatives from industry, indicates usefulness of continuing the research, and additionally because the flexibility of the system which was created allows its adaptability, if not as a whole then in fragments, also for applications not connected to robotics. The results so far obtained lead to considering the usefulness of developing advanced CAD applications based on solid modelling methods using PC computer, even the most sophisticated, and AutoCAD package. Many shortcomings of the latter one have been extensively described in the report of the realization of the project. As far as the hardware is concerned, it can be assumed that only UNIX workstations (types SUN, HP or Silicon Graphics) can give satisfactory working capacity. Of course, PC/AutoCAD configuration is still the most reasonable in more elementary applications.

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Revised by: Wojciech Cholewa