Research

Monika Restecka

IT Systems in Aid of Welding Processes

Abstract: The organisation of work and proper control of both technical and economic process parameters increase productivity. Success is preconditioned by the possibility of quickly adapting a technological process to an ever-changing market situation. The article presents various IT programmes supporting the management, planning, designing and preparing of production, monitoring technological processes and analysing obtained data in an appropriate way.

Keywords: IT welding programmes, monitoring of technological processes;

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The quality of welded structures and increasing process efficiency depend not only on technical aspects of production, but also on designing such quality-related aspects as better work organisation and the use of systems for controlling both technical and economic parameters. Requirements set for producers by, among others, environmental protection and energy consumption optimisation, impose the necessity of controlling production processes. Success is determined by the possibility of quickly adapting technological processes to the ever-changing market situation. Increasingly, intensive pursuits are focused on the optimum management of production processes so that the greatest flexibility at each production stage can be achieved. An important aspect of "smart" management is the quick transfer of updated information between all enterprise departments, ranging from management and planning through production design and preparation, to the very technological process, production, quality control, reporting, data analysis and marketing. The simplification and acceleration of the circulation of information are possible due to appropriate software as

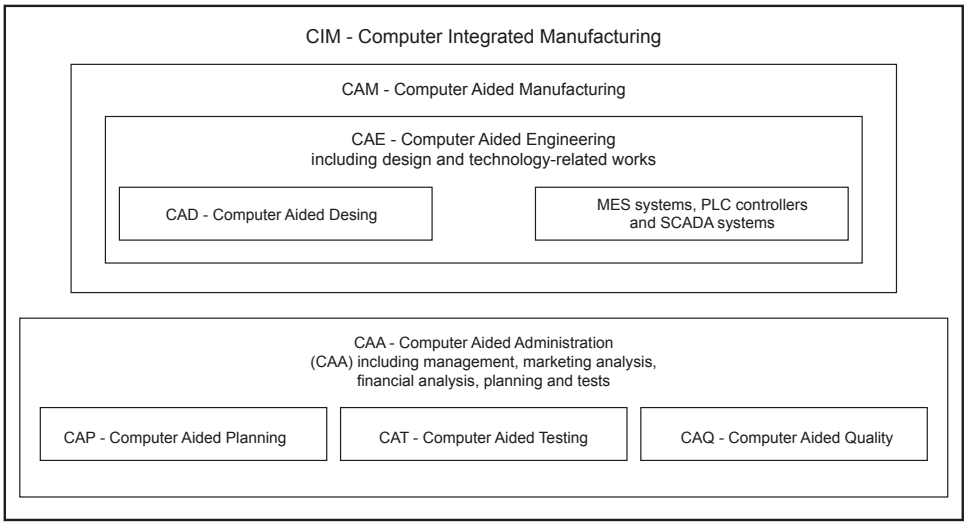

Fig. 1. Computer aided systems

mgr inż. Monika Restecka (MSc Eng.) – Instytut Spawalnictwa, Marketing and Scientific Information Department

well as to automated and robotic production. Such implementations largely depend on policies adopted by a given company, its size and financial potential [8, 28].

Global standards and methods for production planning, i.e. Manufacturing Resource Planning II (MRP II), define the manner in which computer aided production management systems should be created. MRP II combines Computer Aided Design (CAD), Computer Aided Engineering (CAE) and Computer Aided Administration (CAA). CIM (Computer Aided Manufacturing) is an integrated manufacturing system composed of CAD, CAE and CAA. Figure 1 presents the CIM system structure. CIM includes all computer aided activities connected with the production of a given element [11].

Selecting a Proper System

According to surveys conducted by the Control Engineering company, from the point of view of the customer, the most important software selection criterion is the possibility of integrating a purchased programme with other systems used in their company. As many as 85% of users consider this aspect to be the main criterion taken into account when choosing production management systems in their company. As many as 76% of users give emphasis to return-on-investment, whereas 60% emphasize the functionality of given software (Fig. 2).

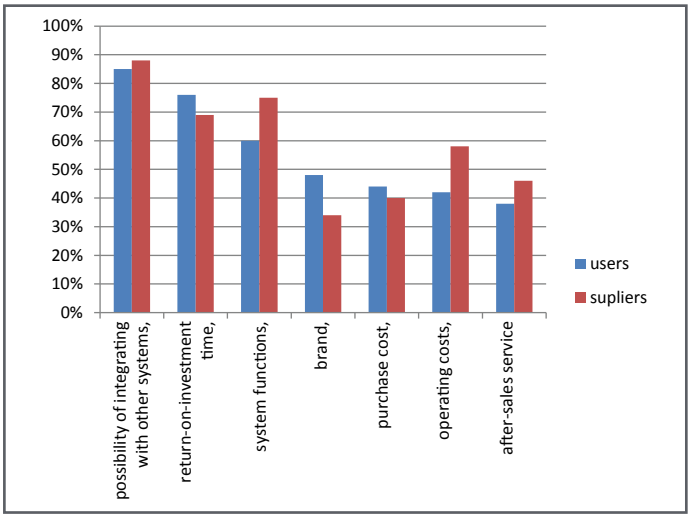

Fig. 2. Main criteria taken into consideration when purchasing software for production management [8]

The needs of users connected with welding process computerisation are diverse, yet it is important to define main tasks set for manufacturing management software. Firstly, a programme should facilitate process planning and design, create simulations, monitor and record parameters as well as archive gathered data in a user-friendly manner. Depending on the company profile, functions enabling data analysis may also appear to be of importance.

The necessity of increasing efficiency without compromising process quality is the main reason for which complex solutions are wanted. Module-structured programmes belong to more interesting solutions as they combine many functions in one integrated system with a steady flow of information. An additional advantage of such a system is the possibility of addressing the needs and requirements of customers in a flexible manner. Well-composed and business-oriented software also enables the extension of software functionality at any time and without changing the design, e.g. programming cost analysis on the basis of recorded welding parameters [8].

Software Types

CAD/CAM Software

One of the tasks of software aimed to aid welding processes is design assistance, e.g. while designing a welding fixture. A computer system tasked with integrating design, construction and manufacturing stages is the CAM system. The main feature characterising the system is converting computer-modelled 2D/3D objects into instructions enabling the manufacture of elements. The software aims at simplifying technological process design. CAM and CAD programmes have similar structures, the only difference being the replacement of a modelling module with a process-related module. Models developed in CAD can be imported to CAM and, next, subjected to further processing in this environment [34].

CAD develops constantly in terms of design and visualisation of created designs. In welding engineering, such systems are used mainly for designing welding fixtures. Software for designing such fixtures is referred to as CAFD (Computer Aided Fixture Design) and includes three areas:

– design verification and planning of activities,
– configuration,
– verification of operation on specific equipment.

CAM also enables the utilisation of computer applications for defining production plans in the area of tool design, CAD model preparation, NC programming and programming of measuring coordinates (CMM – coordinate measuring machine). Design-related tests are performed in virtual reality. Integration consists in collecting information containing data related to the machine itself, tools and operational parameters, followed by the implementation of the model in a specific manufacturing environment [2].

To today, an enormous number of tests concerned with designing complicated fixture, e.g. welding fixtures, has been performed. This implies that CAFD is making its way towards automated and robotic production process design [18, 20, 23].

Presently, this type of integration is used mainly in robotic arc welding processes. Robotic welding off-line programming efficiency depends on the complexity of workpieces as well as on experience and expertise of the software developer in relation to a given welding technology. When a workpiece or fixture changes, complex re-programming becomes necessary. In order to better integrate CAD, CAM and CAPP (Computer Aided Process Planning), it has become necessary to create mapping algorithm-based applications. One of the possibilities involves the use of a robot visual system and appropriate sensors enabling appropriate robot control on an on-line basis during welding. One of the proposals is a universal 6D system for laser scanning-based tracking of welds. Another possibility consists in off-line programming, i.e. robot control designing in virtual reality, followed by generating numeral control (NC) and transferring such a programmed model to welding tasks in a real environment. Tests based on simulations in the CAD environment involved the optimisation of robot trajectory in the Cartesian space. As a result, it was possible to propose a CAD interface for programing welding robots through gathering information from the CAD movement model. Due to the complexity of welded elements, teaching and repeating efficiency turned out to be low. In order to solve this problem, it was necessary to use a mapping function converting designed tasks directly to a real environment. Afterwards, due to movement navigation and weld tracking, a robot can perform welding tasks more automatically. This method provides beneficial solutions (e.g. operation time reduction) for many industries, including welding engineering, and results mainly by integrating CAD, CAPP and CAM [11].

The abbreviated operating plan of fully integrated simulating system software is the following:

– importing data about the model and robot in the 3D system – CAD programmes, e.g. Pro-Engineering, CATIA;
– structural features mapping function;
– performing the welding task in the simulation environment;
– performing off-line programming and computer-aided fixture design [1, 3, 4, 7, 10, 17, 22, 26, 27].

Fig. 3. Simulation of robotic arc welding system [11]

Presently, there are more than a dozen or so 3D CAD packages available on the market. The diversity and availability of such programmes are significant. Exemplary software includes CATIA, Pro-Engineering, GibbsCAM, Cadwork 3DCAD/CAM and many others. Figure 2 presents a robot simulation system in VC++/Open GL software [11].

In order to effectively use the software and convert obtained data into real data, it is necessary to appropriately select performed operations. For this reason, in spite of being supported by complex computer simulation, software is unable to replace the knowledge and experience of a welding engineer [11].

CAE Software

CAE is software for aiding production works connected with computer-aided design including FEM strength-related calculations, for simulating product operation for improvement reasons and for providing assistance in solving structural problems. The accuracy of finite element analysis directly affects the quality, thus the competitiveness of a product. A disadvantage of such an analysis is the fact that it can only be used for making a prototype. The analysis does not provide the possibility of designing a real structure [35]. In the CAE software environment it is very important to properly correlate the model. Proper analyses and correlation between fatigue tests and the simulation require the development and implementation of modules responsible for updating software and optimising the structure [6].

The operation of standard CAE systems can be divided into three stages, i.e. analysis preparation (also referred to as pre-processing), calculations and interpretation of results. Analyses possible to perform using the CAE system include dynamic and static analyses of components and of units using the Finite Element Method (FEM), the kinematic and dynamic analyses of mechanisms, and thermal and flow analyses using computational fluid dynamics (CFD) methods. The CAE applications also enable simulations of mechanical phenomena and simulations of manufacturing processes such as casting, forming and pressing [35].

The main CAE-based programmes used in welding processes are SYSWELD and ANSYS. Instytut Spawalnictwa in Gliwice is in possession of software offered by both renowned companies, i.e. ANSYS (ANSYS Mechanical) and ESI (SYSWELD). Both programmes enable making FEM-based numerical analysis. The ANSYS system is used in widely defined strength analyses, thermal analyses, electromagnetic analyses and analyses of fluid mechanics. The software does not have its dedicated environment intended for modelling welded joints, yet there is the possibility of developing a model taking into consideration thermal and mechanical processes (using the APDL language).

SYSWELD is the software strictly intended for simulating, among others, welding, brazing and weldbrazing processes. The numerical analysis makes it possible to determine a temperature field during the process, the fraction of individual phases and element strains.

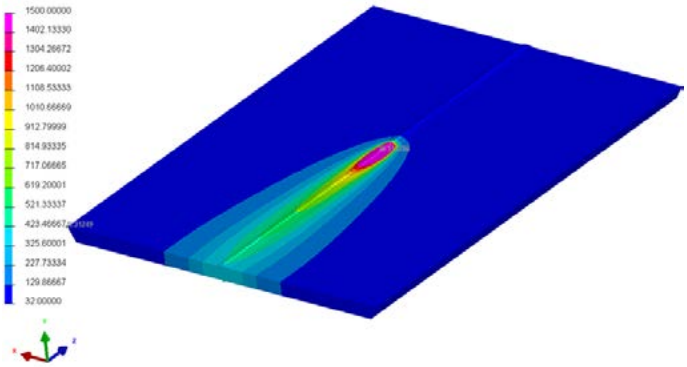

Fig. 4. Temperature field in SYSWELD

The programme also enables simulating the generation of stresses and strains in the material, resulting from various factors. Models and databases of this software make it possible to analyse various steel grades (unalloyed steel, steel alloys, austenitic steel etc.), aluminium alloys, titanium alloys and iron casts [3, 32]. In 2014, Instytut Spawalnictwa performed, among others, numerical analyses of

friction stir welded (FSW) elements of radiators using ANSYS software as well as conducted the analysis of MAG multi-run welding of S355 grade steel plates using SYSWELD.

MES and SCADA Systems

The definition of MES class system proposed by the MESA International organisation says that "the Manufacturing Execution System (MES) aims to provide information enabling the optimisation of production-related processes ranging from the order placement to the delivery of finished products".

In the MES class systems production-related data are gathered automatically. Quick access to updated and reliable data is an invaluable advantage for the scattered enterprises of today. The programme also enables reading out information concerning presently and previously performed tasks [29]. MES aids in planning, improves the effectiveness of existing resources and increases production capacity without compromising product quality. The software also makes it possible to monitor machinery efficiency and production quality. In order to perform these tasks, MES gathers and analyses three types of data:

– past: the system stores and analyses historical data concerning the latest processes,
– now: the system controls and monitors processes in real-time,
– future: the system generates forecasts and schedules processes allowing for possible deviations.

The MES software can be used in 11 areas, i.e. production management (Process Management), performance management (Performance Analysis), production tracking and its genealogy (Production Tracking and Genealogy, Traceability), quality management (Quality Management), data collection and acquisition (Data Collection and Acquisition), document circulation management (Document Control), resource allocation management (Resource Allocation and Status), human resources management (Labour Management), maintenance management (Maintenance Management), production scheduling (Operations/Detailed Scheduling) and distribution of production tasks (Dispatching Production Units) [13]. Figure 5 presents a simplified model of the MES software operation. Many systems available on the market are created in exactly the same or very similar form. The essence of their operation is the integration and availability of databases.

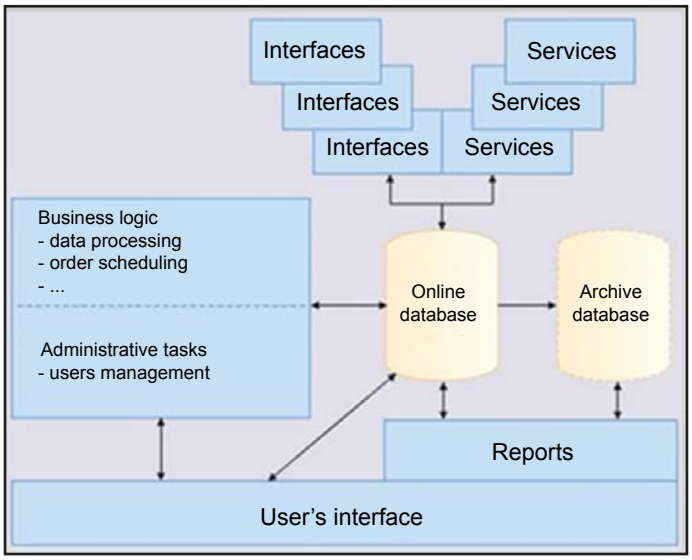

Fig. 5. Operation principle of MES type programmes [30]

MES is a system used for processing information. To some extent, this system is a supplementing link between ERP class systems (Enterprise Resource Planning) and data collected in SCADA type production control systems [33]. The SCADA system is software tasked with controlling and monitoring the operation of individual control elements. SCADA allows quick access to an updated and actual status of actuators and of production devices. In this way, the application supports welding process monitoring. The system also enables quick locations of alerts and automatic response to specific signals, thus providing security. SCADA also enables full visualisation of process statuses, making it possible to present parameters in the form of diagrams and enables data archiving [15,19,29].

Such types of programmes are often used in welding engineering, mainly in

universal applications or in robotic processes (programmes such as Fronius Xplorer, Kuka pcd505, etc., integrated with robotic welding stations provided by a given manufacturer). Another group comprises programmes for monitoring arc welding processes (e.g. the somar system or a cordless multi-station system for arc welding monitoring). Both programmes have similar principles of operation. The software developed and implemented at Instytut Spawalnictwa, i.e. the cordless multi-station system for arc welding monitoring, is used mainly for controlling and assessing welding processes and, on the basis of developed devices and systems, selecting proper process parameters. The architecture of the multi-station system for welding process control is presented in Figure 6:

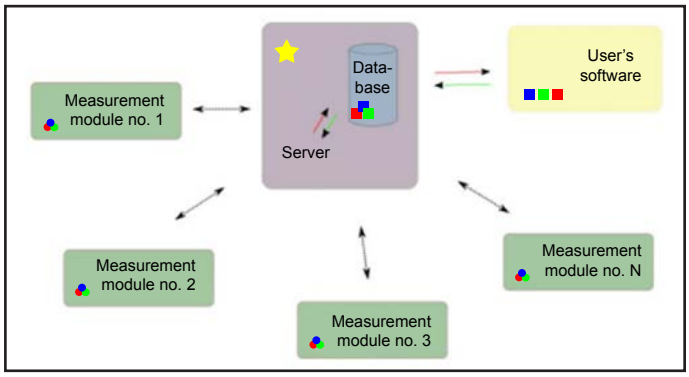

Fig. 6. Architecture of the multi-station system for controling welding process parameters [24]

The programme has a two-layer client–server type structure, which allows data acquisition. The system is divided into individual modules used for specific measurements and tasked with collecting and transferring welding process-related information to the server. The software installed on the server analyses and processes the data and, afterwards, saves them at a designated space on the disc. The software is also provided with the user's interface. Information exchange takes place in a computer network (WiFi, Ethernet).

Due to its module structure, the multi-station system for welding control is universal. The system measurement modules can be installed on any welding machine subjected to the operation of a welding process monitoring system. Measurements are automatic once a welding process has been initiated. Measurements include welding current parameters being of key importance as regards weld quality assessments, i.e. welding current or welding arc voltage. Recorded waveforms enable the determination of derived quantities, which are next used for determining quality indicators for individual welds. Figure 7 presents the user interface with an exemplary arc welding process course.

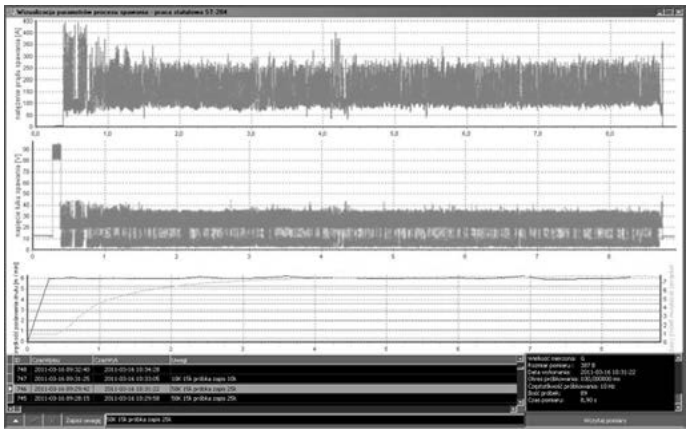

Fig. 7. User's interface [24]

Due to the continuous monitoring of parameters, the system ensures high quality and repeatability of production. Production monitoring is possible on any number of stations, which translates to the elimination or reduction of defects leading to decreased costs [24].

The advantages enumerated by the manufacturer are the following:

- continuous monitoring of production (inspection of every joint made),
- automation of a joint quality assessment process,
- welding process parameter archiving,
- elimination of defective elements from further production stages,
- production process optimisation,
- improved quality of joints,
- increased process reliability,
- decreased number of complaints,
- reduced quality control and production costs,
- fairly easy system adaptation in a manu-

facturing facility,
– module system structure (easy extension of hardware and software), high scalability [24].

CAA Software

CAA (Computer Aided Administration) systems include quality management in a company, as well as support planning and testing. Additional, yet equally important functions of such software are marketing and financial analysis. CAA is composed of tools which help to perform work planning-related tasks. The main system objective is the integration of human activity with means of production in order to perform tasks in accordance with adopted economic criteria. The main CAA applications include production time reduction, implementation of innovative technologies, quick response to market demand and consistency of actual delivery times with scheduled delivery dates [35]. The CAA systems are divided into:

I. CAQ – (Computer Aided Quality) system for supporting quality management – the methods and techniques of this supporting element are concerned with designing, planning, creating measurement processes and developing procedures directly related to quality control (taking into consideration competitiveness in relation to the quality of a given product consistent with related standards, most CAA programmes are provided with an in-built CAQ module responsible for quality). The software provides 100% control and testing. Another advantage of the system is increased efficiency in control processes through inspection integrated with the production process [5, 25, 36].

II. CAP – (Computer Aided Planning) – software for supporting the creation of task structure, introduction of cause-and-effect correlations, visualisation of schedules and determination of the number of existing solutions. The programme also takes into account various types of resources and their costs, allocates resources to tasks and identifies overloaded resources. Solutions are generated the entire time and are at the planner's disposal. Acceptable solutions are saved and selected in order to choose the one best for the company. The software adjusts selection criteria to conditions existing in the company and its environment.

III. CAT – Computer Aided Testing

The CAA system applications in welding engineering can be divided into three groups:

I. Software supporting keeping welders' records and creating documentation (e.g. CAQ)

Programmes which support keeping welders' records and managing qualifications facilitate registering workers as well as generating and printing out reports from basic welder courses, welder training and certificates. Examples of such software are, among others, EVOK developed by ANB (Czech Welding Society) or KSOP (Komputerowy System Obsługi Personelu Spawalniczego – Computer-Aided System for Welding Personnel Management) developed by Instytut Spawalnictwa. KSOP consists of a database including directives, harmonised standards, guidelines and product standards in the part concerning training and qualifying welding personnel and NDT personnel as well as a database of centres and forms of education adjusted to international requirements. The software is an integrated system of "education and certification paths". An Internet application makes it possible to access the database of centres educating according to international requirements and enables continuous development of knowledge by providing the possibility of asking questions on an on-line basis or via the Newsletter [31,32].

The welder training system includes two main processes, i.e. the management of courses and course participants (training centres) as well as the management and creation of documents (certificates and welder's books). Presently, over 100 centres use the KSOP on an on-line basis. The designed and developed graphic interface is user-friendly and does not require a long time to learn and master [21].

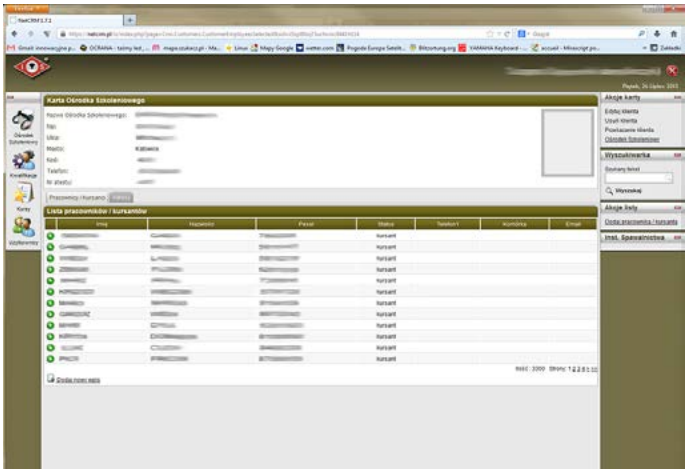

Fig. 8. Screen presenting a training centre sheet with a list of workers/course participants [21]

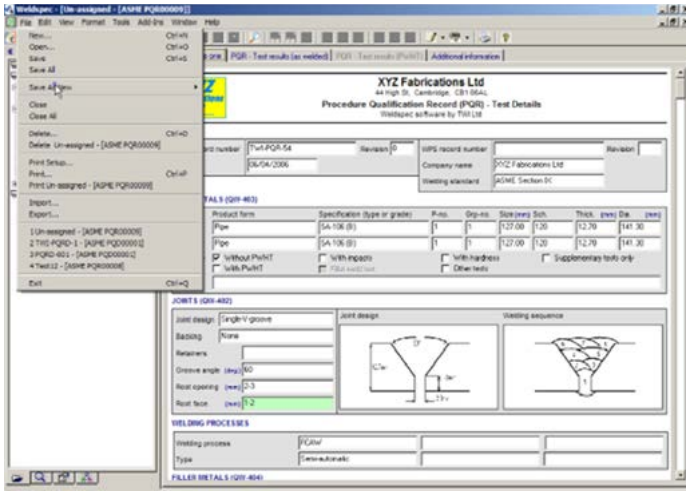

Fig. 9. WeldSpec screen view [38]

Computer-aided quality management system in welding engineering is facilitated by the WelderQual software supporting mainly the management related to issuing documents confirming welding-related qualifications. The programme targets engineers and managers responsible for managing and tracking welder's qualification according to regulations specified in ASME Sec. IX, EN 287, ISO 9606 and AWS D1.1.

The programme offers the following:

- reduction of general costs and increased efficiency in managing welding personnel qualifications,
- consistence with regulations of the ASME code Sec. IX,
- reduction of costs while maintaining qualifications up-to-date,
- reduction of time necessary for finding a welder with required qualifications - due to a search engine with built-in filters of processes, types of joints, materials and other variables,
- many welding processes available,
- possibility of running the programme on a LAN with many users,
- possibility of integrating with other programmes supporting welding processes e.g. Weldspec.

The investment costs related to this type of programme are presented in the table 1.

Another programme supporting welding processes is **WeldSpec**, enabling the creation and management of documentation connected with welding processes. The programme is intended for engineers and other personnel dealing with tracking, developing and managing welding procedures according to the ASME code Sec. IX, EN 288 / EN 15614-1: 2008 and AWS D1.1. Due to the programme companies are able to:

- reduce general costs and increase efficiency in managing welding procedures and welding personnel qualifications,
- save time and reduce costs by providing welding procedures in accordance with the latest regulations.

In addition, the programme facilitates the selection of materials by using a related database. WeldSpec automatically creates technical data (WPS) by reading information provided in PQRS.

The investment costs related to this type of programme are presented in table 2.

Table 1. WelderQuael purchase cost (EUR) [38]

1 user	3 users		Annual subscription	
	Access	SQL	Access	SQL
not applicable	1385	2795	345	695

Table 2. WeldSpec purchase and annual subscription cost [38]

1 user	3 users		Annual subscription	
	Access	SQL	Access	SQL
not applicable	2235	3645	495	895

II. Software supporting welding costs calculations (CAP)

Weld Cost Calc XL – is a programme calculating welding costs for 10 various types of joints (demo version: filler weld). Weld Cost Calc XL is based on Microsoft Excel.

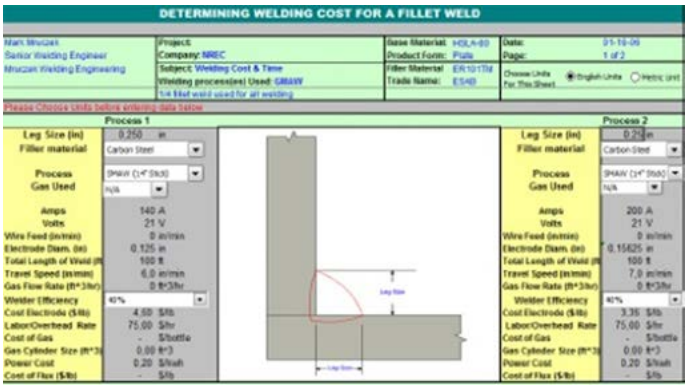

Fig. 10. Joint selection screenshot [31]

While selecting one scheme of a welded joint, it is possible to compare welding costs for two selected methods. For instance, on the right it is possible to perform calculations for method 111 (MMAW), and on the left for method 135 (MAG). This is a very useful application featuring simple and intuitive operation enabling the achievement of a desired goal in a simple way.

The demo version can be downloaded from the website of the programme author (Brothersoft). The full version costs approximately 80 USD. There is also the possibility of purchasing a ready-made estimate. The Esab company offers services in calculating welding costs using the Weld Cost Calc XL programme [31].

Weld Wizard – is a free application by Fronius, used for calculating, among others, cross-sectional areas on the basis of weld geometry, arc burning parameters, spatter and parameters related to electric energy for selected welding processes. In addition, Weld Wizard features a module for simple welding costs calculations and is also provided with a comparing engine. The application can be run on smartphones.

Welding Estimator – programme for precise calculations of making a single joint on the basis of technological designs. Welding Estimator helps adjust materials, labour costs and operating costs for a given welding method. Due to built-in functions, users can save time at the planning stage. The programme also makes it possible to quickly compare production costs. The software is user-friendly and has a step-by-step tutorial.

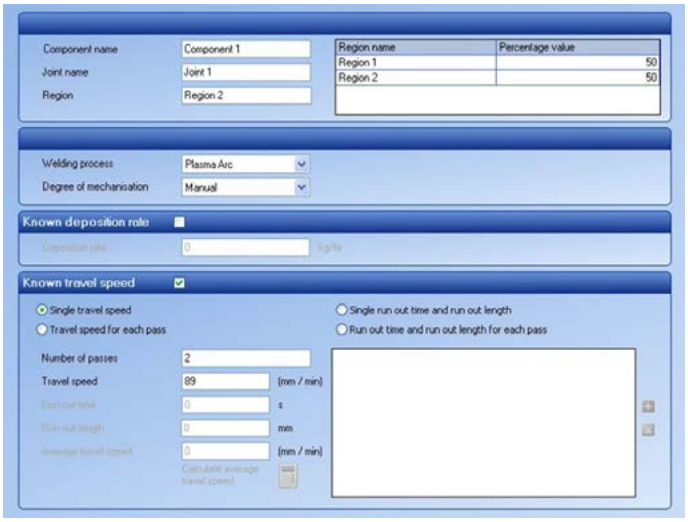

Fig. 11. Screenshot with the Welding Estimator programme panel [38]

Welding Estimator most important functions include the following:

- accurate welding cost calculations,
- adjusting cost factors to a given company and region,
- generation of material-related reports in relation to a given weld,
- operating calculations for a given joint, component or the whole design,
- time-related calculations according to guidelines and data obtained from the process specification.

Welding Estimator advantages are the following:

- programme was developed by welding engineering experts,
- common date of shielding gases and shielding gas mixtures meeting needs of individual users,
- easy to use,
- built-in module for comparing estimates,
- cost calculations for MIG, MAG, TIG, plasma, submerged arc and flux-cored arc welding,

– easily available data throughout the company by generating reports in the PDF format.

The investment cost for a single user amounts to 845 EUR.

Welding Pro – software for welding calculations. The application features a built-in calculator for performing complicated calculations in a simple and user-friendly manner (programme can be used on smartphones). Welding Pro makes it possible to calculate welding costs for all shapes of welds and for all welding methods.

III. Software integrating CAQ and CAP for complex solution in one system

Weldassistant – software for supporting work of chief welding engineers and that of welding technologists. The programme is provided with a large database related to a given technological process, which significantly facilitates work and development of welding procedure specifications. Another available function is simple cost calculation and comparative analyses aimed to optimise costs for a given joint. The programme enables the management of welder qualifications and constant overview of updated information about welders.

The programme is available in several editions:

– free STARTER,

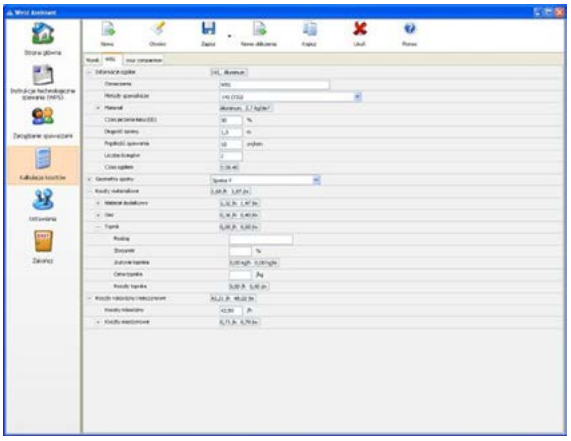

Fig. 12. Cost calculating module [16]

– BASIC–ISO (modules ISO WPS + WPQR),
– BASIC–ASME (modules ASME IX WPS + WPQR),
– BASIC (modules BASIC–ISO + BASIC–ASME),
– PRO-ISO (modules BASIC-ISO + welders' records + cost calculator),
– PRO (modules ISO + ASME WPS) [32].

The table below presents investments costs in relation to the software [16]:

Table 3. Weldassistant software purchase costs [16]

Licence/upgrade	Cost
PRO	
1-st licence	980 Euro
Each next licence	640 Euro
Update from ver. 5 to ver. 6	490 Euro
Update from ver. 4 to ver. 6	640 Euro
PRO-ISO	
1-st licence	680 Euro
Each next licence	440 Euro
BASIC	
1-st licence	680 Euro
Each next licence	440 Euro
Update from ver. 5 to ver. 6	340 Euro
Update from ver. 4 to ver. 6	440 Euro
BASIC-ISO	
1-st licence	380 Euro
Each next licence	190 Euro
BASIC-ASME	
1-st licence	380 Euro
Each next licence	190 Euro

ARC System 3 – module-structured programme developed by the Kemppi company. Each of the modules is responsible for different functions important for the complete support of welding processes. The programme structure is presented in the figure below.

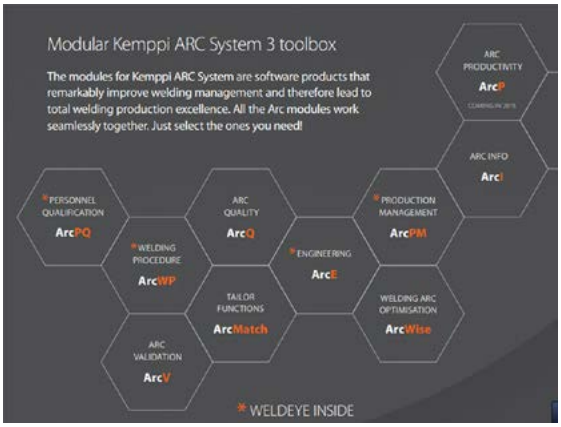

Fig. 13. Module structure of the ARC System 3 programme [15]

Arc System 3 enables recording parameters such as current, voltage, welding rate, filler metal feeding rate and heat input. These parameters affect welding quality and efficiency as well as labour costs.

Among other things, the individual modules are responsible for the following:
- safety,
- weld identification,
- complying with PN-EN 1090,
- welding process control,
- data archiving and analysis as well as reporting and documentation management,
- creating welding procedure specifications (WPS),
- cost management,
- elimination of welding imperfections [15].

Welder Expert – programme supporting welding works, consistent with ASME regulations. The main advantages of the programme are the following:
- full compatibility with the latest version of ASME Sec. IX,
- complete databases of materials (specification SA, SB) and of filler metals (specification SFA),
- issuing welder certificates (WPQ) and certificates for operators of machines for conventional and special processes,
- possibility of entering base materials different to those consistent with the ASME specification,
- generating certificates in pdf and doc formats; a certificate can contain up to two welding processes

Welder Expert price: the purchase cost of one licence is 900 euro net; annual upgrade costs 200 euro + VAT [31].

Weld Pulse – complex software supporting welding processes; addressed at engineers. Weld Pulse has a module-based structure with each module having built-in functions helpful at specific welding process stages:

Module Quick Weld provides information necessary for "quick welding", i.e. electrode type (SMAW), wire type (TIG), temperature, required welding rate, post-weld heat treatment (time and temperature), information related to welding all material combinations consistent with API 582, adaptation of information to qualifications of a given welder (basic level – lower detail level).

Module WPS IX supports creating technological documentation in accordance with the requirements specified in ASME Sec. IX. The module is an extension of the Quick Weld module, in which the user can write a welding specification in accordance with the code requirements. By means of an appropriate creator, the Weld Pulse software provides full service when writing a WPS. Data entered into the form can be edited at any moment.

Module PQR IX consists of a form from which data are automatically transferred to the WPS IX module. The form is fully compatible with ASME.

Material Module provides access to a knowledge base concerning welding properties of materials most commonly used in industry; data are consistent with ASME. Properties specified in the module include mechanical properties, tensile strength, yield point, chemical composition, welding properties, material group number and ASTM description. The module is provided with a function enabling the comparison of materials.

Module Welder-Check IX is responsible for keeping record of welders qualifications. It archives and updates all information necessary for identifying welder qualifications.

Module Welding Cost aids in welding cost calculations. All data can be edited by the user. The module has built-in functions such as time necessary for making a weld, data concerned with making a welded joint, management of many processes, operating costs (gas, energy, labour), full support (back-end) for assumed values etc.

The purchase cost for an individual customer (one licence) amounts to 549 GBP (one-time

Table 4. Comparison of functionalities and investment costs of software supporting welders' records and creation of documents

Programme functions	Programme names			
	EVOK	KSOP	Welder Qual	Weld Spec
Welders' records	X	X	X	
Management of welding personnel qualifications	X	X	X	
Management of NDT personnel qualifications		X		
Creation of tests and examination reports	X	X		
Development of WPS	X		X	X
Database of Training Centres		X		
Consistence with standards	X	X	X	X
Integration with other programmes			X	X
Generating and printing reports	X	X	X	X
On-line access via an Internet browser		X		
Database (i.e. base materials and filler metals, welding methods and positions, etc.)		X		
Cost comparison engine				X
Possibility of running a programme on mobile devices		X		
Cost (EUR)	-	free access to application for centres attested at Instytut Spawalnictwa	1395	2235

cost) for the Spark version. The Arc version is intended only for companies. It is possible to purchase 3 licences in a package for 1999 GBP. After one year of use the annual cost amounts to 499 GBP [37].

The tables above present the functionalities of individual programmes supporting production in terms of efficient and detailed planning and scheduling of production. Particularly in cases of companies processing various types of orders (especially in multi-stage production), planning mechanisms are of key importance as they enable the minimisation of customer's waiting time for ordered products. A vast range of programmes available on the market help optimise the use of production resources by, among

Table 5. Comparison of functionalities and investment costs of software supporting welding calculation costs

Programme functions	Programme names			
	Weld Cost Cal XL	Weld Wizard	Welding Estimator	Welding Spec
Consistence with standards	X	no data	X	no data
Integration with other programmes				
Generating and reports			X	
Welding parameter calculation	X	X	X	X
Welding cost calculation	X	X	X	X
Database of filler metals			X	X
Cost comparison engine	X	X	X	X
Cost factors for a given region			X	
Smartphone application				X
Cost (EUR)/licence	70	0	845	0

Table 6. Comparison of functionalities and investment costs of software supporting combining CAQ and CAP

Programme functions	Programme names			
	Weld assistant	ARC System	Welder Expert	Weld Pulse
Welders' records	X	X		X
Management of welders' qualifications	X	X		X
Development of WPS		X		X
Reading information from PQRS				X
Consistence with standards	X	X	X	X
Integration with other programmes		X		
Generating and printing reports	X	X	X	
Welding parameter calculation		X		X
Welding cost calculation	X	X	X	X
Database of filler metals	X	X	X	X
Cost comparison engine	X			X
Welding process monitoring		X		
Process control		X		
Cost (EUR)/licence	980	-	200	2670

others, managing and recording welder qualifications, huge material base, welding cost calculations etc. The tables also present basic investment costs which need to be borne in relation to specific software. Prices may vary depending on duration, number of licences and implementation degree. For a large number of customers, price is one of the most important factors, yet the greatest restraint while buying a system is the possibility of its integration with the production environment and a low level of IT awareness of the company on one hand, and inadequate knowledge of a given sector by IT companies implementing a given system, on the other.

Summary

Welding engineering-related trends observed for many years include, among others, the progressive automation of repeatable welding processes, for instance using programmable logic controllers (PLC). Also, the use of bar codes or RFID readers is becoming increasingly common. According to various analyses, manufacturers are now more inclined to use methods which aid in solving organisation-related issues, facilitate planning, scheduling and quality control, enable comfortable storage and efficient distribution of products, help in managing equipment and maintaining machinery stock as well as allow reducing production management costs [8].

Analysing the present state and research efforts concerning IT systems in welding engineering, it is possible to observe that in addition to using safety-related modules, this industrial sector will increasingly often use planning process integration (CAP) [9].

This process is becoming increasingly complicated and requires many additional solutions. Due to the fact that enterprise innovativeness is an important indicator of competitiveness and that numerous tests have revealed that the CAP process significantly affects enterprise innovativeness-related success, a new trend in computer-aided production will consist in employing a new tool, i.e. CAI (Computer Aided Innovation). Some tasks aided by CAI are those at the process design stage, assessment of customer needs as well as assistance in creative invention development and during new product market launches [12].

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