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TECHNOLOGY MATURITY STUDIES OF EQUIPMENT FOR WELDING IN A PROTECTIVE GAS ENVIRONMENT[8]

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Abstract: *Today the most rapidly developing method for production of welded structures is the MIG/MAG process. An extensive demand and expanding number of applications have been found in this technology and more particularly in the Impulse Welding with Inverter Multiprocessor Machines. Some of these devices feature Industry 4.0 generation communication components and capabilities. They have embedded welding procedures (WPS) according to ISO 151612, which meet the requirements of EN 1090-1. They also have Spatter Reduction Systems (SRS) that can regulate the additional heat transfer to the carbon and stainless steel material (up to 3 mm thick) to reduce the additional opperations.*

Yet the maturity level of these welding systems is not thoroughly studied. The presentation is focused on the purpose and application of the above technology features from the point of view of their maturity and readiness level for comercial applications. CMM (Capability Maturity Model) philosophy was brought to describe and assess the machines capabilities, application areas and their specific characteristics.

Keywords: *Welding Equipment, Modern Technologies, Welding in a Protective Gas Environment, Technology Maturity, Pulse Welding*

INTRODUCTION

The manufacturing process of composite products mainly consists of welding, soldering and bonding technolodgies. Welding is one of the most widely used technological processes in the industry for the production of monolithic indivisible compounds.

The welding industry faces a complex challenge related to the growing shortage of skilled welders. While this is not a new problem, many welding companies are struggling every day to remain competitive.

According to the American Welding Society, the industry will face a shortfall of about 400,000 welders by 2024 [1]. This is due to both the lack of skilled workers and the aging population worldwide. In the United States, the average age of welders is 57 years.

In response to this challenge for the industry, welding equipment manufacturers are developing innovative technologies to make welding recruitment and training easier and more cost-effective. Some of these technological improvements can also be used to retrain existing employees and improve their skills.

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At this stage, the fastest growing and productive method is that of MIG / MAG weldingis in protective gas environment.

This report compares two varieties of the Industry 4.0 endoved MAG methods (impulse and conventional). The Capability Maturity Model concept for assessment of the welding technologies was developed and pilot implementation of this model based on the review of the trade literature and subjective assessment by professionals was shortly introduced.

EXPOSITION

Inspite of the strong world wide interest in modern methods of welding in a protective gas environment still insufficient knowledge of their technological capabilities and maturity could be observed. This lag is due to the fact that the production of modern welded structures is undergoing continuous development, and the end products are becoming more complex. This leads to increase of the requirements to the welding equipment and subsequent increase of its complexity.

New advanced welding processes offer higher productivity, easy control and management, improved seam quality [2].

Modern multiprocessor welding machines have separate wire feeders, water cooling systems and pulsed welding capabilities. The design is flexible, mobile and highly ergonomic. This type of equipment has the ability to remotely diagnose and control the processes via a PC, tablet or smartphone. Optional synergistic settings, high welding speeds, almost no spray welding regimes are included. In today's "smart factories," industrial welding machines are networked to exchange information and improve their work independently or as an integrated system. All this leads us to believe that we will witness growth in the welding sector following the market for advanced technologies used in industrial production to compensate the lack of manpower [3, 4, 5].

Industry 4.0 innovations are focused on cyber physical systems (CPS), ie. systems that can connect the digital world to the physical, optimizing results through continuous data analysis. In addition the economical and ecological requitemrnts of the modern welding equipment involve increase of the welding efficiency by implementation of robots or by IT assisted operators, lower energy consumption and process solutions with greater care for the environment and for the human sfety. One example is the latest developments in wireless helmets. It allow the glass to be darkened when the arc is switched on by a welding machine. This allows the glass to respond very quickly, resulting in maximum protection for the worker's vision, especially in the case of low-intensity arc [6].

The welding productivity issues are recently addressed by pulsed MIG / MAG welding. It is a variation of the conventional MIG / MAG welding process, in which the current is pulsed. An inverter is used in this technology instead of a transformer. The setting of the welding parameters is stepless, not incremental, as with a conventional power source [7]. The pulse was initially introduced to control metallic transmission at low average current levels by imposing short continuous high current pulses. The cycle consists of applying a repetitive impulse current to a constant background current as shown in the figure below.

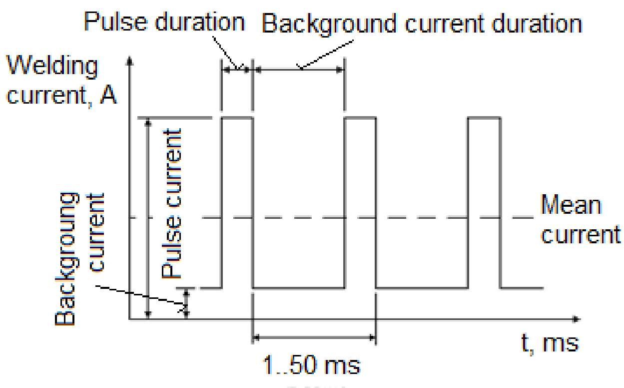

Fig. 2 Graph showing the principle of pulse welding

Modern welding machines allow the use of a wide range of pulse amplitudes, durations and waveforms at frequencies from several hertz to several hundred hertz. The amplitude and duration of the pulse are best combined to melt and separate a single droplet of the same or smaller diameter from the electrode wire, leading to the emergence of synergistic welding currents.

The main advantage of pulsed MIG / MAG welding is that it allows the use of smooth, non-spray welding at medium currents (50-150A), which would otherwise be too low for process the realization.

To evaluate the maturity of this process and to compare its level of technology readiness with that of the conventional welding processes utilize a system called CMM (Capability Maturity Model). The CMM is simple, IT and system oriented method that makes it appropriate for evaluation of the highly digitalised modern welding systems. It was initialy developed to study the ability of government contractors to perform software projects but later was utilized for evaluation of other processes and technologies. It was sucessfuly implemented in the evaluation of the MNT (Micro and Nano Technlogy) processes within the EUMINAFab (Integrating European Research Infrastructures for Micro-nano Fabrication of Functional Structures and Devices out of a Knowledge-based Multimaterials Repertoire) project [8].

According to CMM there are five maturity levels defined along the continuum of the model: (1) Initial; (2) Repeatable; (3) Defined; (4) Managed; (5) Efficient. Description of these levels are presented in Table 1.

Table1.

Maturity levels		Description
Initial	Chaotic, ad hoc, individual heroics, the starting point for use of a new or undocumented repeat process	1. Undocumented. 2. In a state of dynamic change. 3. Driven in uncontrolled and reactive manner by users. 4. Provides a chaotic or unstable environment.
Repeatable	The process is at least documented, repeating the same steps may be attempted	1. Some processes are repeatable, possibly with consistent results. 2. Process discipline is unlikely to be rigorous, but it may help to ensure that processes are maintained under stress.
Defined	The process is defined/confirmed as a standard	1. There are sets of defined and documented standard processes. 2. Subject to some degree of improvement over time. These standard processes are in place. 3. May not be systematically used for the users to become competent and the process to be validated in a range of situations. 4. A developmental stage.
Managed (Capable)	Quantitatively managed in accordance with specific metrics.	1. Using process metrics process objectives can be evidenced across a range of conditions. 2. The suitability of the process in multiple environments and conditions has been tested. 3. Enables adaptions to particular projects without measurable deviations from specifications.
Efficient (Optimizing)	Process management includes deliberate process optimization/improvement.	1. The focus is on continually improving process performance through both incremental and innovative changes.

The utilisation of the CMM requires to assess the processes throughout a set of Key Process Areas (KPA), which form the backbone of the evaluation model. For testing software systems these are focused on: Policy, Standard, Process, Procedure, level overview. In CMM evaluation model of the MNTs the KPAs are structured in three areas: Capability; Dynamics; Documentation. The KPAs were evaluated according to six generic parameters: Quality and Accuracy; Size and complexity (of the produced objects, components, etc.); Materials (which are processed); Efficiency (e.g. speed, cost, time); Processing (e.g. typical technological parameters); Fixturing and Set-up.

In this study, based on the specifics of the welding processes the KPAs are studied trough five indicators: Materials; Efficiency; Technology; Information; Quality and Accuracy. The maturity of the welding processes is evaluated through each of the five indicators using the five-point CMM scale [9]. The description of the welding process Indicators are presented in Table 2.

The assesment of the processes is indicative and has been performed mainly to test theCMM design. The evaluation shows that impulse methods are still on Defined/Managed level of process development. Althogh the process has been tested in multiple environments and conditions (companies with different profiles and scale of production in terms of geometrical sizes and batches, including production of different type of welded structures such as frames, fundaments, plates etc.) it still has lack of information regarding the process capabilities, and the materials aspects of the welding. The process adaptation in terms of technological parameters, automation capabilities, connectivity, Industry 4.0 applications still require additional test for definind the deviations from the requirements. The level of quality achievements (heat affected zone, surface integrity) and efficiency (deposition rates, staff qualification) are rated higher as “Managed” (close to that of the conventional MIG/MAG processes) but this shuld be assessed more precisely and with envolvement of abjective criteria.

Table 2.

Indicators	CMM Level ®	Initial	Repeatable	Defined	Managed	Optimised	Rating	
		1	2	3	4	5	Pulsed	Conventional
Materials	Forms of the materials (e.g. electrodes - wires, rods), type of the materials (e.g. alloys, coatings)			√		√	3	5
Eficiency	Defined welding speed and deposition rates, staff qualification, costs				√	√	4	5
Technology	Technological parameters, automation capabilities, connectivity, Industry 4.0 applications			√ √			3	3
Information	Research on the topic, advertising and promotional materials (printed, internet)			√		√	3	5

Quality and Accuracy	Geometrical parameters (shape, size, etc.), heat affected zone, surface integrity (roughness, defects, splashes, etc.), operational comfort				√	√	4	5

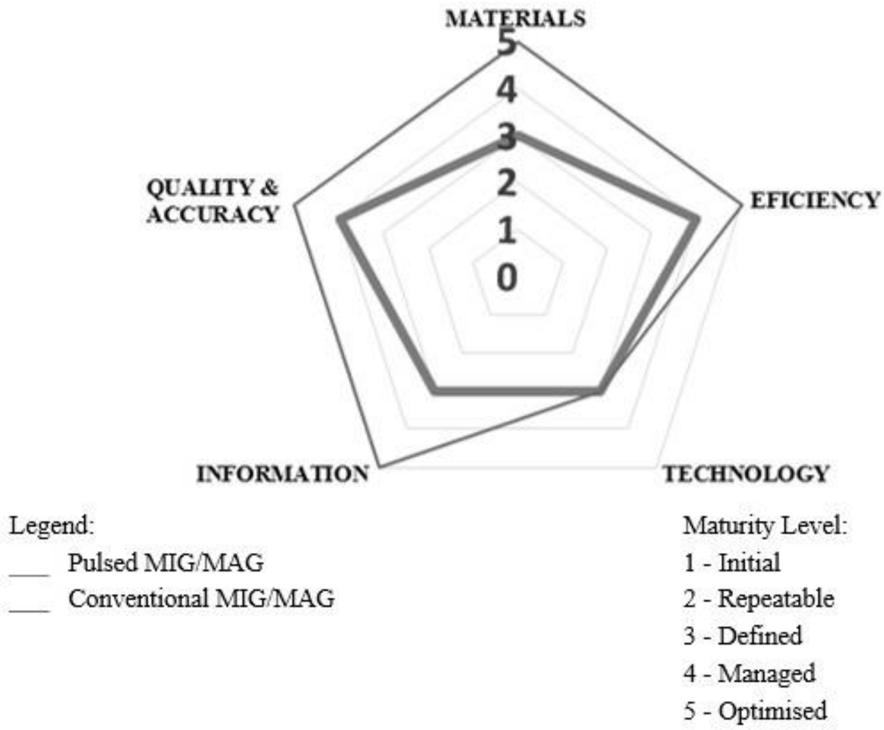

Fig. 3. CMM Levels of pulsed and conventional MIG/MAG welding indicators

The presented maturity evaluation of the pulse and conventional welding processes in protective gas envoirnment (Table 2. and Fig. 3.) is based on the study of literatutre, practical experience, trade information, user's feedback available from the trade companies, and subjective evaluation of the process. The results of this evaluation have to be taken into account cautiously since it does not have a significant statistical scope and should be considered as initial approved attempt to evaluate the proposed model. Standardized survey method techniques will be required to collect representative data in the future. Hardware testing will also be required to assess technical indicators in relation to quality issues, such as surface integrity (adhersion and heat stress), dimensional accuracy (as in penetration and uniformity), and performance in various joint types. These parameters must also be assessed in relation to technical specifications of the equipment (voltage, arc current, arc length, material transfer regime, etc.)

CONCLUSIONS

At present, the most rapidly evolving and commonly used method of welding is MIG / MAG process. Modern welded structures are increasingly complex, and their requirements are increased, which is related to the development and sufistication of the welding equipment. Pulse welding method is one of this innovative processes.

Modern power sources are more compact, lighter but more and more features are included, as well as multiprocessor capabilities. The most important innovative capabilities of welding machines are:

- increased wire feed speed;
- possibility to work with long electrode output;
- wireless connection between the welding source and the safety helmet to eliminate delays in darkening the glass;
- limiting the introduction of additional heat into the spray reduction material;
- programming for work on two levels of welding current in order to limit heat deposition and deformation;
- impulse welding with high speed processing and data exchange, which leads to increased welding speed, reduced deformation and uniform welding;
- synergistic modes to focus the arc and achieve optimum welding at a higher welding speed.

High-performance impulse welding in various models of MIG / MAG welding equipment provides increased productivity, limits the amount of energy input, significantly reduces spray separation, reduces welding deformations, and generally reduces the cost of the finished product. This can rate the maturity level of the pulse MIG/MAG process as “Defined/Managed” but still require additional study with more objective sriteria. Still on the basis of the analyzes made and its significant advantages and the available information, pulsed welding gradualy begins to shift towards the Managed maturity level catching up the conventional welding methods.

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