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DEVELOPMENT OF A MATURITY INVESTIGATION SYSTEM FOR STUDY OF WELDING PROCESSES[4]

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Abstract: *The present work aims to develop and adapt the Capability Maturity Model (CMM), so that it can be used for comparative analysis of modern welding technologies (e.g welding in a protective gas environment, pulse welding, etc.). The indicators to be examined as well as the assessment levels have been determined. The weights of the individual indicators are determined, as well as the methods for data collection and summarization in order to arrive at an integrated assessment of the maturity of a given technology. The system must serve the users of a technology by helping them in the selection and investment process.*

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

INTRODUCTION

The manufacturing processes of joining materials by welding, soldering and gluing are used to assemble a number of components and have a major place in industry today. Among them welding of monolithic non-detachable joints is one of the most widely used. Modern production of welded structures is constantly evolving, due to which the final products become more complex and the requirements for them - higher, which is associated with the development of welding technology [1].

On the other hand the welding industry faces a complex challenge related to the growing shortage of skilled welders. Although this is not a new problem, many welded construction companies are struggling every day to stay competitive. According to the American Welding Society, the industry will face a shortage of about 400,000 welders by 2024 [2, 3]. This is due to both the lack of skilled workers and the aging population around the world. 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 it easier and more cost-effective to recruit and train welders. Some of these technological improvements can also be used to retrain existing employees and improve their skills. At this stage, the fastest growing and productive method is that for welding in a protective gas environment MIG/MAG.

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The new advanced welding processes offer increased productivity, easy control and enhanced quality of the seams. In this respect the issue of the ‘maturity” of this technology and its readiness for wide implementation and substantial investment by the construction companies become very important. Currently, there is a serious interest, including internationally, in modern methods (i.g. using pulse sources) of welding in a protective gas environment, but there is insufficient knowledge of their technological capabilities and maturity.

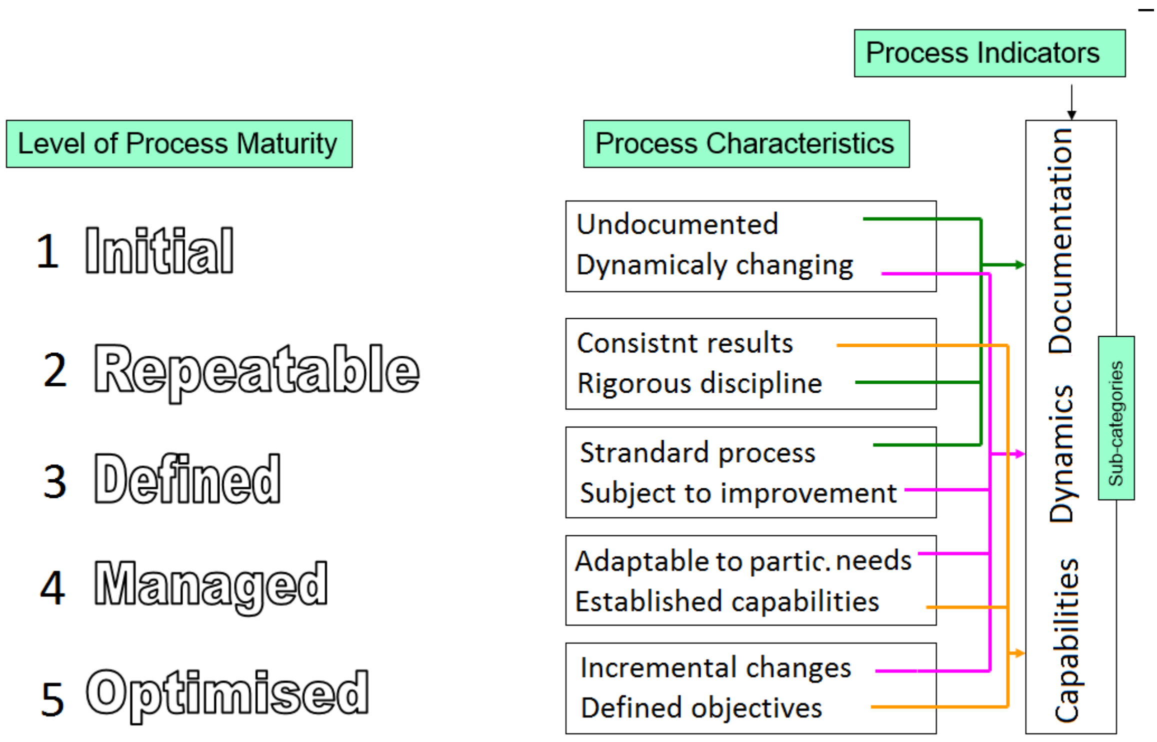

Fig.1 CMM model levels and their characteristics

The maturity of the processes was studied with CMM (Capability Maturity Model). A description of the model is shown in Fig.1. There are five levels defined along the continuum of the model:

Initial - the process is undocumented and dynamically changing;
Repeatable - the process is documented but requires rigorous discipline;
Defined - the process is defined as a standard one;
Capable - the process capabilities are well studied and adapted to particular needs;
Efficient - process management includes deliberate process optimization and improvement.

The CMM was applied for studying the maturity of Micro/nano technologies [4-6] and proved to be informative and easy to implement.

This paper presents some possibilities to study the maturity of the welding technologies and equipment for welding materials. More specifically this work aims to:

(i) adapt the CMM (Capability Maturity Model) so that it can be used for comparative analysis of modern welding technologies;
(ii) define and establish indicators, subcategories to be examined and the assessment levels;
(iii) determine the weight of the individual indicators, as well as to evaluate the methods for data collection and aggregation in order to arrive at an integrated assessment of the technology maturity;
(iv) design a maturity assessment system to serve the users and to assist them in technology selection process;
(v) make a comparative analysis of conventional and pulse MIG/MAG welding technologies.

EXPOSITION

Methodology

In order to determine the maturity of a process it is necessary to define some caracteristics - specific and essential features that describe it in technical, engineering, economic, social and other aspects. Then these indicators must be assessed in relation to three main indicators: Capabilities; Dynamics; Documentation.

It is appropriate to use a survey method to assess maturity. It can be carried out either by compiling a questionnaire to cover the maturity of the individual indicators or by giving a direct assessment of maturity. In our case, we used the second approach. The survey that we presented to a dozen of specialists is presented in Table 1.

Table 1 Process characteristics in the survey with indicative answers in scale of 1 to 5.

Process characrteristics	Conventional MIG/MAG	Impulse	Average score	
1. **Materials** to be welded:				
1.1 Low carbon steels	5	4		
1.2 Aluminium alloys	3	4	1-Conventional	1-Impulse
1.3 Stainless steels	5	4	4,3	4
1.4 Others	1	1		
2. **Eficiancy**				
2.1. Speed of welding	5	2		
2.2. Operators qualification	5	3	2-Conventional	2-Impulse
2.3. Productivity	4	2	4,7	2,3
2.4. Price of the investment	5	2		
3. **Technilogy**				
3.1. Technological parametrs	3	2	3-Conventional	3-Impulse
3.2. Automation capabilities	3	2	3	2
3.3. Industry 4.0 compatability	1	2		
4. **Information**			4-Conventional	4-Impulse
4.1. Avalability of studies	4	1	4	1
4.2. Advertising and promotion materials	2	3		
5. **Quality and assurance**				
5.1. Geometrical accuracy	4	3		
5.2. Heat affected zone	3	1	5-Conventional	5-Impulse
5.3. Surface integrity	3	3	3,3	2,3
5.4. Comfort	3	3		

The object of the analysis is the opinion of employees, managers and owners of small companies, SMCs and large companies on the maturity of pulse welding compared to conventional welding. The surveyed companies mainly weld low-carbon steels, but some of them were also involved in a wider production program. Enterprises differ in volume and variety of production. The surveyed experts have different professional and engineering education and perform different functions in the production process.

Results and analyses

Depending on the qualification and position of the experts in the production process, their assessment of the maturity of conventional welding in a protective gas environment and pulse welding changes from greater confidence in the innovative process in the lower level experts and more conservative assessment in the higher managerial level (Fig.2).

Fig. 2 Maturity level of the processes accoding to the experts with different qualification.

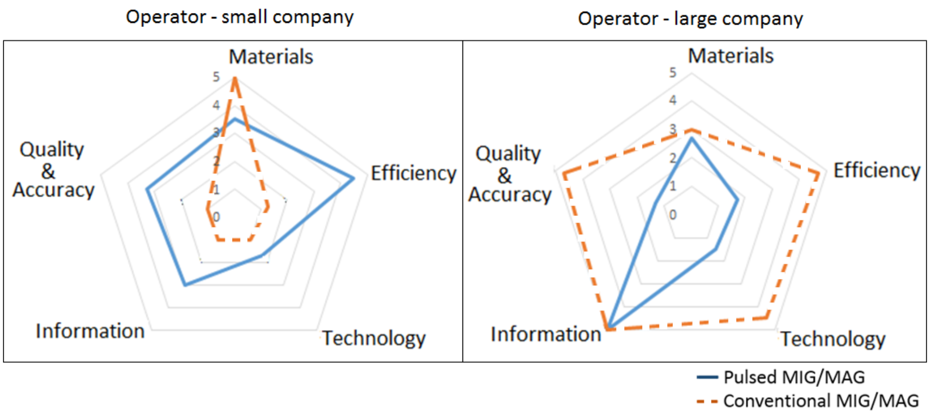

Fig. 3 Survey of different size of companies

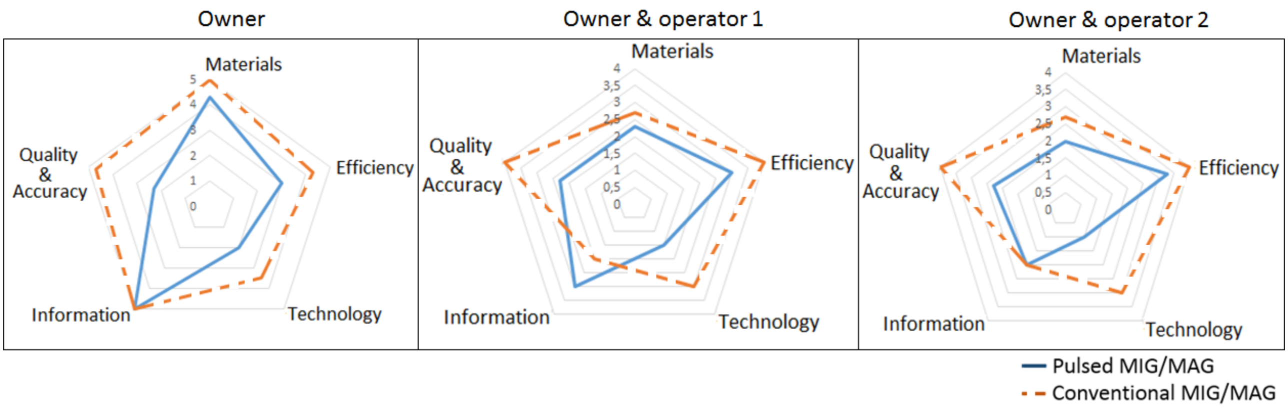

Fig. 4 Maturity level of the welding technologies according to the small company owners.

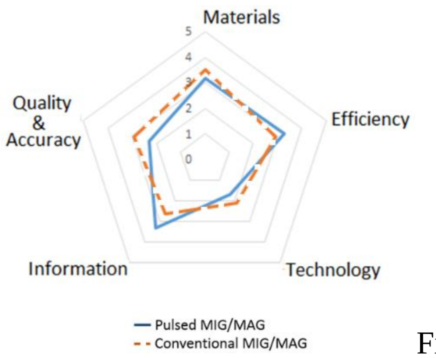

Fig. 5 Overal assessment of the process maturity

The experts from larger companies with larger production scale, located in larger city and dealing with greater variety of materials (aluminum, stainless steel, etc.), asses the maturity of the new technologies (pulse welding) higher than that of conventional MIG/MAG technologies (Fig. 3).

The owners of small companies which are operators at the same time value the innovative method (pulse welding) higher in terms of its maturity compared to conventional welding technologies in a protective gas environment (Fig. 4). It can be assumed that the method of direct assessment to determine maturity of the processes sometimes allows distortion of the assessment. The hgher maturity level is often awarded in terms of increased capabilities, better quality of products, easier operation of equipment, etc., and not regarding the technological "maturity".

The overall assessment (Fig.5) of the "maturity" of conventional MIG/MAG technologies and those with impulse characteristics (obtained by all respondents) are similar - level 3 (Define). This result shows that the impulse technology is rapidly gaining popularity and is in the focus of research and investment politics of the companies and academia. Nevertheless the results should be interpretaed with moderate skepticism since the methodology of direct level assessment applied in this study is prone to distortion of the results because of the misunderstanding of the assessment goals. It is necessary to develop a targeted survey with non-contextualised questions which will give mediated "cumulative" assessment of the various indicators (Materials; Efficiency; Technology; Information; Quality and accuracy), as well as the sub-criteria (Capabilities; Dynamics; Documentation) and the integrated assessment of the maturity of welding technology.

CONCLUSION

(i) The surveyed experts from larger companies with higher production variety (aluminum or stainless steel products) are more familiar with the new technologies and rate them higher.

(ii) In small companies located in smaller settlements, the lack of staff and information slows down investment process and negatively affects the maturity assessment of the modern welding equipment.

(iii) The same is true for companies in the industries engaged in repair and maintenance - regardless of location.

(iv) Employees working in international companies are more familiar with modern equipment.

(v) It is necessary to develop a specific targeted survey, the results of which will give a "cumulative" assessment of the various indicators and sub-criteria, as well as an integrated assessment of the maturity of welding technologies.

Acknoleagments

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