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Characteristics of the Levels of Mechanisation in Arc Welding

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Abstract

Improvement of quality, reduction of the subjective possibilities of faults may be facilitated with the help of the technically rational and economically justifiable mechanisation of productive serial production as well as the use of the wide range of hardware and software IT possibilities. Mechanisation is usually understood as the mechanisation of technological operations that may otherwise be performed by manual operations (human movements and effort). Mechanisation is therefore the substitution, in whole or in part, of manual labour with the help of specialised equipment and the mechanical operation of the various movements. The present article examines the particular features of mechanisation in the field of outstandingly high significance in industrial applications, i.e. arc welding, assisting the forms of training applied in the specialty area.

Keywords: *arc welding, automation, robot.*

1. Introduction

The mechanisation levels of arc welding – the most commonly used type of welding among welding works – may be classified according to the binding formation and positioning movements (**Figure 1**) **[1]**. The specialised equipment shown in the tabular figure as well as the robot are automatic, i.e. fitted with its own drive system, capable of adjusting and moving the welding head with adequate accuracy. While the robot is (re)programmable (program-controlled) in multiple spatial directions and movement paths in a given working range (i.e. by software) the specialised equipment moves on a bound path and direction, i.e. "programmable by hardware". In this way it adaptable to performing other tasks by readjustment or modification.

The figures indicated in the example are the codes for the welding processes in question in accordance with the MSZ EN ISO 4063 standard, in which

– the first part is the heat source (presently the arc),
– the second part is the means of melt protection (self-protecting: coated, cored, submerged; protective gas), and the "behaviour" of the electrode (melting, non-melting),
– the third part serves to designate any additional distinguishing features of the procedure variants. The numerical fields opening downwards indicate the possibility of multiple levels of mechanisation. E.g. in case of the widely used active protective gas wire electrode arc welding - coded 135 - the electrode feeding (filler material feeding) is a priori mechanised. Apart from the manual movement of the welding head (weld torch), specialised equipment or robots are also possible, at the manual or mechanical servicing stages (workpiece feeding).

In the practice of welding – based on **Figure 1** – the following are differentiated:

– manual welding, by which both the performance of welding movements and the workpiece feeding are performed by human effort. The operations are performed, controlled and directed by the welder;

<table>
<tr><td colspan="2">Bonding formation movements</td><td>Bonding positioning movements</td><td colspan="2" rowspan="3">Mechanisation level</td><td colspan="3" rowspan="3">Example of procedure mechanisation</td></tr>
<tr><td>Filler material feeding</td><td>Welding head guidance</td><td>Workpiece feeding</td></tr>
<tr><td>Intermittent or continuous</td><td>With or without oscillation</td><td>With or without equipment</td></tr>
<tr><td>manual</td><td>manual</td><td>manual</td><td colspan="2">manual</td><td colspan="2">111</td><td rowspan="6">141
151
152</td></tr>
<tr><td>mechanised</td><td>manual</td><td>manual</td><td colspan="2">partly mechanised</td><td rowspan="5">114

121
122
123
124
125</td><td rowspan="5">131
135
136
137</td></tr>
<tr><td rowspan="2">mechanised</td><td rowspan="2">mechanised</td><td rowspan="2">manual</td><td rowspan="2">mechanised</td><td>with specialised equipment</td></tr>
<tr><td>using robots</td></tr>
<tr><td rowspan="2">mechanised</td><td rowspan="2">mechanised</td><td rowspan="2">mechanised</td><td rowspan="2">automated</td><td>with specialised equipment</td></tr>
<tr><td>using robots</td></tr>
</table>

Figure 1. *Levels of mechanisation of arc welding.*

- partly mechanised welding, by which the performance of welding movements are partly and the workpiece feeding are fully performed by human effort.
- mechanised welding, by which the performance of welding movements are mechanised and the workpiece feeding is performed manually;
- automatic welding, by which both the performance of welding movements and the workpiece feeding are performed automatically, by machines, leaving practically no need for direct human intervention.

2. Robots and specialised equipmen

Therefore the increase of the level of mechanisation can be achieved by increasing the number of machine movements, reducing the extent of human intervention (human control). Welding using specialised equipment and robots can be categorised as mechanised or automated welding, depending on the mode of workpiece feeding. Some aspects of classifying welding robots are shown in **Figure 2.**

Arc welding equipment at a particular level of mechanisation may be classified according to four basic criteria, which can be used to demonstrate the differences in terms of applicability and level of development (**Figure 3**) **[2]**. The number of the degree of freedom is the number of independently controlled axes of movement and their drive units. For this, 2 types of movement (T = translational, R = rotational) and 3 coordinate axes (along which translation, or around which rotation takes place) can be selected. Of the arm systems, control and sensors of arc welding robots, a systematic overview is provided in **[3]**.

3. Characteristics of the levels of mechanisation

The level of mechanisation is well characterised by the number of operations of which the conditions of mechanisation have been solved concerning the equipment in question. The classification scheme of these operations is shown in **Figure 4**, ndicating the corresponding levels of mechanisation, whose hierarchy and points of connection can be traced in **Figure 5 [4, 5]**.

The equipment implementing the various levels and their main parameters can be summarised as follows:

The zero or baseline level (G0) not shown in the figure is manual welding using coated electrodes (111), and the level of mechanisation of the other levels are benchmarked against this. Also “classified” between the zero and the first level is (G0.5) gravity arc welding (112) which, although using no machine movement has its coated electrode “automatically” melted off with the help of a simple device using the force of gravity.

(G1) mechanised filler material feeding (wire feeding), partly mechanised protective gas

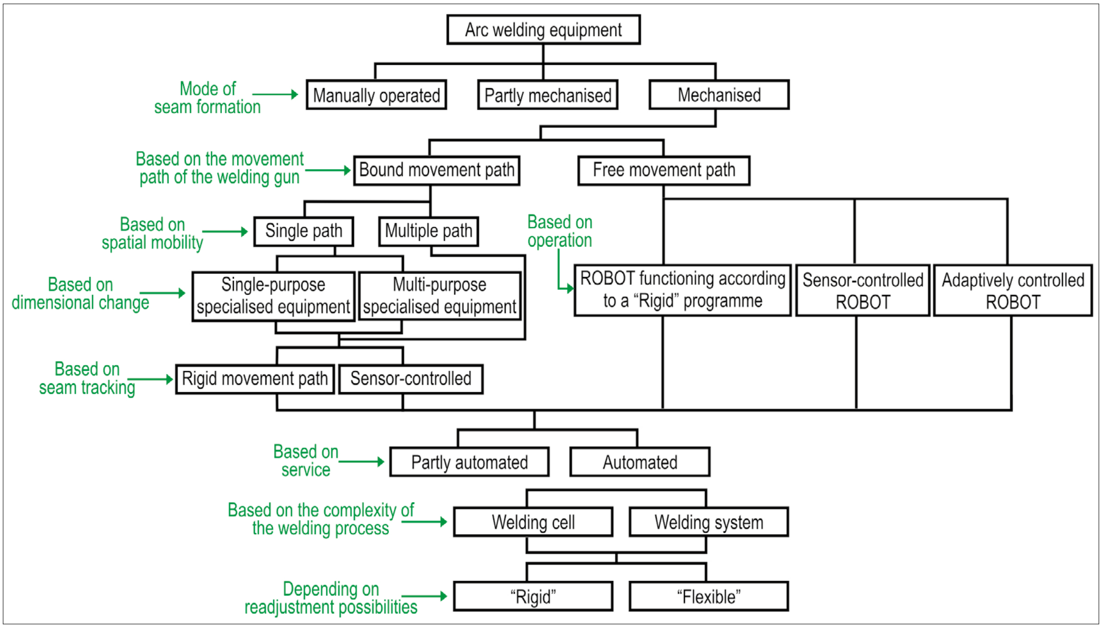

Figure 2. *Classification aspects of welding robots and specialised equipment.*

Scope of application			Mode of seam formation			Service			Degrees of freedom		
Universal	With specialised equipment	Mixed	Manual	Partly mechanised	Mechanised	Manual	Partly automated	Automated	Number	Nature	(Coordinate) system
Multiple designs for workpieces of different sizes	A particular design for a particular workpiece size	A particular design for workpieces of different sizes	Manual filler material feeding with manual welding head guidance	Mechanised filler material feeding with manual welding head guidance	Mechanised filler material feeding with mechanised welding head guidance	Manual workpiece feeding with manual workpiece positioning	Manual workpiece feeding with mechanised workpiece positioning	Mechanised workpiece feeding with mechanised workpiece positioning	1	1R 1T	1 axis, rotating or feeding
									2	2R 1R+1T 2T	2 axis (planar)
									3	3R 2R+1T 1R+2T 3T	3 or more axes (spatial)
									4	4R 3R+1T 2R+2T 1R+3T	Humanoid Spherical SCARA Cylindrical Rectangular Tricept (with orienting movements above 3 degrees of freedom)
									5	5R 4R+1T 3R+2T 2R+3T	
									6	6R 5R+1T 4R+2T 3R+3T	
									7	7R 6R+1T 5R+2T 4R+3T	

Figure 3. *Characteristics of arc welding equipment.*

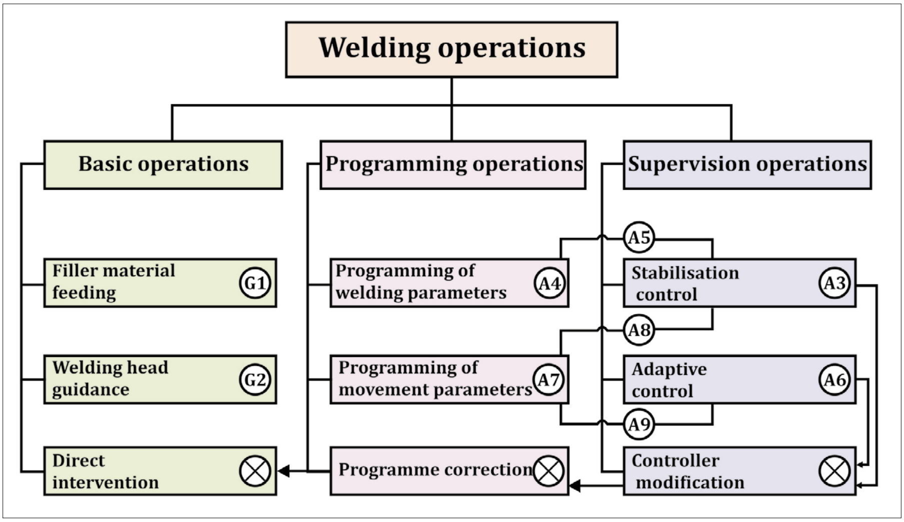

Figure 4. *Division of welding operations in relation to mechanisation.*

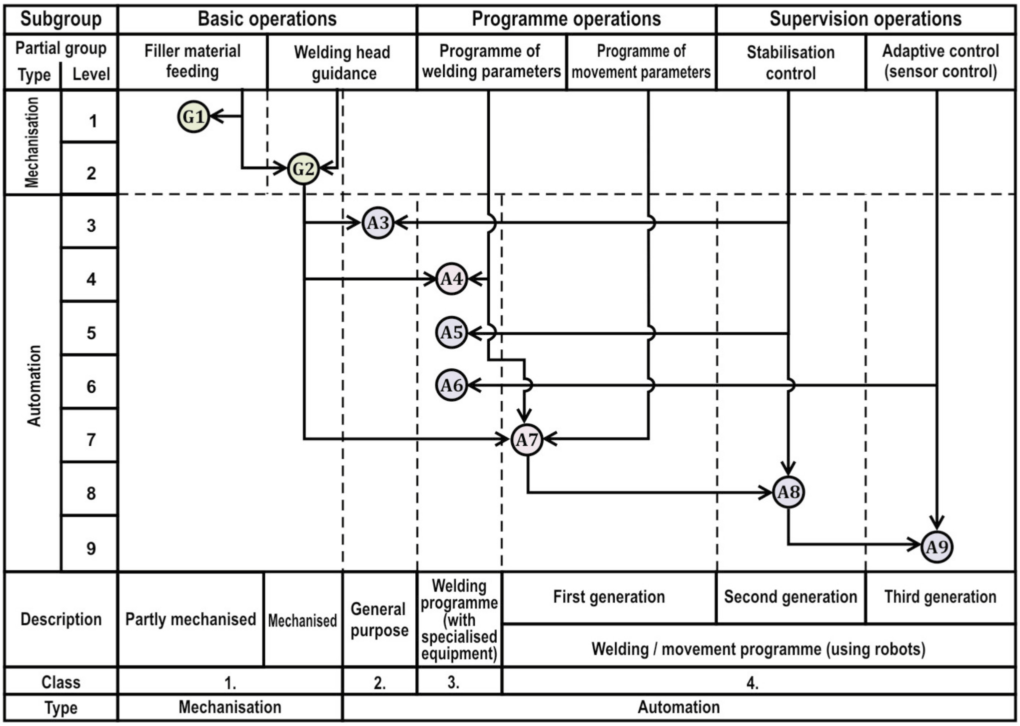

Figure 5. *The levels of mechanisation and their relations.*

arc welding equipment (13, 14, 15) with high melt power and a wide range of applications. It is no longer in use, but there was a mechanised, coated electrode arc welding, classified between the first and second levels (G1.5), where the gravitational electrode feeding was accompanied by a mechanised guidance of the welding head (welding unit).

(G2) mechanised submerged (flux) welding equipment with welding heads fitted onto movement units (12), with parameters adjusted in advance and very high capacities.

(A3) equipment of general use, fitted with arc sensors and arc stabilising control, which – by correcting the changes having taken place in the main welding parameters – ensure continuity of welding, but do not take into consideration the varying welding conditions.

(A4) single-purpose specialised equipment moving along a bound movement path, attributing programmed parameters to the particular path sections, which may be partially or fully mechanised, but are not equipped with sensors.

(A5) single or multiple-head, multi purpose (e.g. for pipes and tanks) specialised welding equipment fitted with arc stabilising control, using programmed parameters, applicable for movement paths of varying positions.

(A6) sensor-controlled multifunctional specialised equipment (with seam location and/or seam following sensors) using programmed parameters, ensuring consistancy of seam quality even under varying circumstances. Naturally, these terms only meet the definition of adaptivity to a certain degree. This level represents a certain boundary of specialised equipment, as the next level is a “quantum leap” into the world of industrial robots.

(A7) first generation robots, capable of repeating the movement according to the program to be currently executed. Their movement is deterministic, and their movement path is “rigid” in the sense that it is independent on changes taking place at the location of work. This is

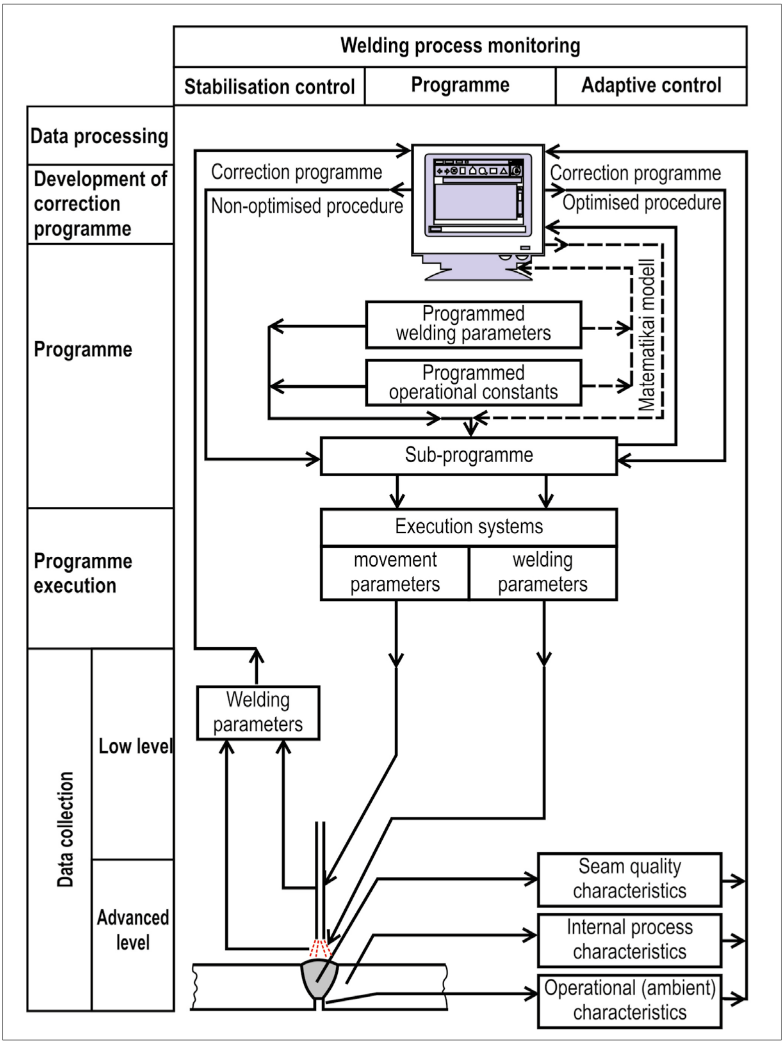

Figure 6. *Welding process monitoring scheme.*

because they do not have devices capable of sensing and modifying their movement programs. A basic requirement of their application is the accurate machining, orientation and fitting of the parts in advance.

(A8) second generation robots that are able to adapt to significant changes at the work location. Their movement is controlled at all times by a direction algorithm, based on the signals of the sensors activated. For the rapid processing of large amounts of information, a high-performance hardware and software suitable for sensor communication are used.

(A9) third generation robots capable of sensing a number of ambient characteristics and adapting to the changes in ambient conditions. These are capable of shape and situation recognition, based on which they are able to make independent decisions with the help of their artificial intelligence. A structural sketch of one such welding process monitoring system can be seen in **Figure 6 [5]**.

Adaptive control on the one hand approaches optimal conditions in case of varying ambient circumstances, and on the other hand, it increasingly prevents subjective errors in the control of the welding process. This naturally requires as many sensors measuring technological and ambient parameters as possible, whose accuracy and sensitivity greatly influence the adequacy of the values measured and used for controlling the process through feedback. From the perspective of the optimising algorithms, the degree of reality of the mathematical models describing the processes is no less significant.

4. Conclusion

From among the means of mechanisation – due to their application characteristics – specialised manipulation equipment and flexibly programmable robots cooperating with the peripherals stand out. Their application increases productivity, the production cycle times are reduced, quality and reproducibility are improved, the flexibility of the production system is increased, monotonous and heavy physical labour can be reduced, and in areas particularly harmful to human health, they can help substitute human activity. The “extent” of their level of mechanisation may be selected based on technical, economic and organisational aspects.

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