THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAŢI
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING,
ISSN 2668-4829 (PRINT) 2668-4888 (ONLINE)

QUALITY ASPECTS IN THE WELDING OF SOME ELEMENTS OF MICRO-MOTORS IN AUTOMOTIVE AND HOUSEHOLD APPLIANCES INDUSTRY

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ABSTRACT

In the automotive and household appliances industry there is a permanent concern to find fast and efficient welding methods and technologies, pressure welding being one of the usual joining methods, due to the minimum qualification requirements, cheap equipment, ease of control, high speed of operation, repeatability and suitability for automation or robotization for inclusion in high production assembly lines. In the paper, quality aspects are described in spot welding of some elements of micro-motors in the automotive industry and household appliances by using tools that allow highlighting the fact that the process is controllable from a statistical point of view, with reference to two micro-motors from the production flow.

KEYWORDS: spot welding, micro-motors, automotive industry, household appliances industry, quality.

1. INTRODUCTION

In recent decades, there has been an evolution of the automotive industry at global and European level, correlated with the increase in the weight of electrical and electronic components in the construction of vehicles, with the aim of improving their performance.

The European Commission estimates that the automotive market will be fully electrified by 2050, as a key contribution to the future of mobility and the technological base of the automotive industry [1,2].

Reducing production costs is one of the imperatives for companies producing components, and aligning with the standards imposed by the major players in the global automotive and household appliances industry is impossible without a clear development strategy, as these two industries annually generate more than 10 billion euros [3].

Companies must consider optimizing processes and workflows, eliminating human errors, optimizing data management and control, and increasing the level of collaboration between internal and external stakeholders.

Moreover, some of the major challenges faced by companies producing automotive components and subassemblies are driven by the need to reduce production costs, speed up design and time-to-market, increase product diversity and complexity without compromises quality.

As for the appliance industry, it is divided into two main sectors: major appliances and minor appliances. The first category includes refrigerators, washing machines, freezers, kitchen stoves etc.

Sales of major home appliances, globally, represent the largest portion of the overall home appliance market, with sales exceeding $300 billion and nearly 700 million units shipped annually [4]. Small appliances, includes products such as food processors, toasters, etc.

It is estimated that the revenue of the global small appliance market will cross the $100 billion mark consistently in the coming years [5,6]. The home appliance market is very competitive with some of the major companies such as LG, Samsung, GE electronics, Whirlpool etc.

Companies are becoming technologically advanced and coming up with innovative features such as integrating their products with IoT to make customers' lives comfortable and convenient [7].

Welding is a means of manufacturing and repairing metal products and is used in each of these two industries, but especially welding is widely used in the automotive industry [8].

Depending on the production series, welding can be done on ordinary machines, performing point by point, using rotating and dividing devices according to the required number of points or, in large series production, on special machines, provided with multiple heads heads that perform simultaneous spot welding.

To prevent welding defects and improve quality, it is important to select the right materials and processes for the application in the welding design phase [9]. Even if the design is adequate, however, defects produced during welding will have a major influence on quality [10].

Weld quality assurance is the use of technological methods and actions to test or ensure the quality of welds and, secondly, to confirm the presence, location and coverage of welds, multiple technical aspects being specified through *QA* (*Quality assurance*) / *QC* (*Quality control*) [11].

In conditions where a technological process is of high complexity, its quality characteristics must be within the specified tolerance limits [12,13]. The quality of components in the automotive industry and household appliances is determined by means of the quality rate figure.

To calculate performance indicators, companies must record, consolidate and prepare the raw data that is generated in the production process and bring it together. Practically, depending on the different types of quality models, it is possible to quickly make comparisons between target and actual values, as well as good and rejected parts. Early identification of systematic deviations can be achieved by means of statistical models, as preventive methods of quality management [14-16].

2. WELDING THE COMPONENTS OF MICRO-MOTORS USED FOR SEAT ADJUSTMENT

In principle, the key characteristics of the micro-motors used to adjust seats in the automotive industry, with a supply voltage of 12 V or 24 V, are varied, including, among others, reliability, low noise level, compact size, magnetic field generated by permanent magnets, high performance, flexibility and high level of automation. The torque motor engages from 0.2 N·m to 0.35 N·m without gear and from 8 N·m to 12 N·m with gear.

Figure 1 shows flange models of the micro-motors for driving the windows, seats and tailgate of passenger cars [17]. The component elements of the flanges are shown in Figure 2, detailed and assembled on the flange [17]. The elements to be assembled are the following: collector brushes; impedance; ground plate; thermal protection.

Fig. 1. *Flanges of micro-motors for driving windows, seats and tailgates of cars [17]*

Fig. 2. *Components of micro-motor flanges [17]*

Figure 3 shows the collector brush with its wire, the brush that has the role of receiving the current pulse when in contact with the micro-motor rotor, in Figure 4 - the ground plate, which is welded to the wire of the collector brush.

Figure 5 shows the thermal protection, whose connection is welded to the wire of the collector brush, protection that ensures short-circuit protection of the micro-motor, as a result of exceeding the working temperature.

Fig. 3. *Collector carbon brush*

Fig. 4. *Ground plate*

Fig. 5. *Thermal protection*

Figure 6a shows the impedance, which has the role of limiting the current and establishing the direction of rotation of the micro-motor, and in Figure 6b - the connection method between the wire of its coil and the wire of the collector brush.

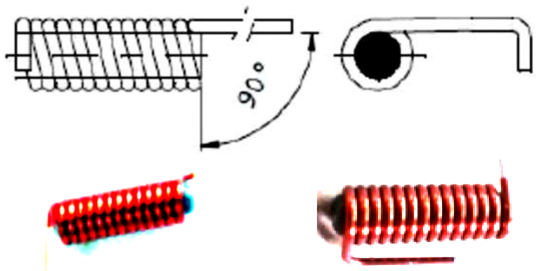


Fig. 6a. *Impedance*

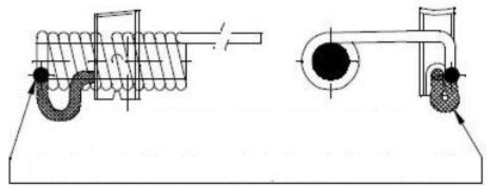


Fig. 6b. *Impedance coil welding with carbon wire*

Spot welding machines are AC welding equipment with pneumatic drive, forced water cooling, and microprocessor control. The system is provided with a fixed and a mobile electrode holder, on which the two electrodes are mounted: the lower electrode is mounted on the fixed electrode holder and the upper electrode is on the mobile electrode holder. The mobile electrode holder is mounted on the rod of the pneumatic cylinder through which the pressing force is achieved. The pneumatic motor for driving the upper electrode holder is equipped with a pressure regulator group, manometer and air filter, ensuring the regulation of the pressing force and, by means of the throttle, the speed of movement of the upper electrode. The pneumatic cylinder is chrome-plated, does not require lubrication and withstands high and long-lasting loads.

2.1. Welded joints

a. Welding the collector brush wire to the impedance wire

The connection of the collector brush wire to the impedance wire can be seen in Figure 7. The wire of the collector brush is laid in the recess of the lower electrode without touching the sides, and then the end of the impedance coil is placed over it, the upper electrode is lowered, and when the pedal is released, the joint is made.

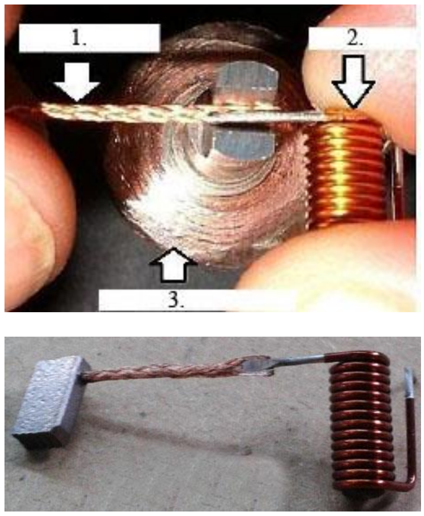


Fig. 7. *Welding the collector brush wire to the impedance wire: 1 - collector brush wire; 2 - impedance coil; 3 - lower electrode*

The parameters of the welding regime are: welding intensity I_s = 3.154 A; welding time t_s = 15 periods = 0.3 seconds; welding force F_s = 4356 N.

b. Welding the connection of the thermal protection with the collector brush wire

The welded joint can be seen in Figure 8.

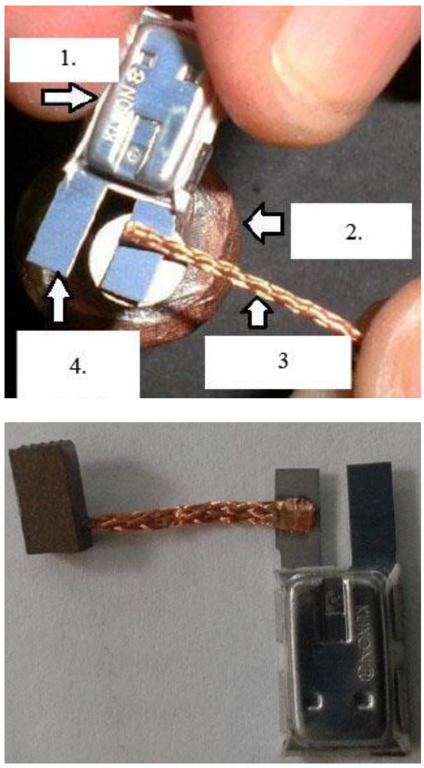


Fig. 8. *Welding the connection of the thermal protection with the collector brush wire: 1 - thermal protection; 2 - lower electrode; 3 - collector brush wire; 4 - thermal protection connection*

The thermal protection connection is placed on the lower cylindrical electrode, then the brush wire is positioned accordingly, the upper electrode is lowered by pressing the pedal and after making contact, by releasing the pedal the two elements are connected.

The parameters of the welding regime are: *Is* = 2.254 A; t_s = 15 periods = 0.3 seconds; F_s = 4356 N.

c. Welding the ground plate with the wire of the collector brush wire

The process begins with placing the ground plate on the lower copper electrode provided with a cutout for its correct placement, positioning the commutator brush wire, lowering the upper tungsten electrode and making the welded joint when the pedal is released. The result can be seen in Figure 9.

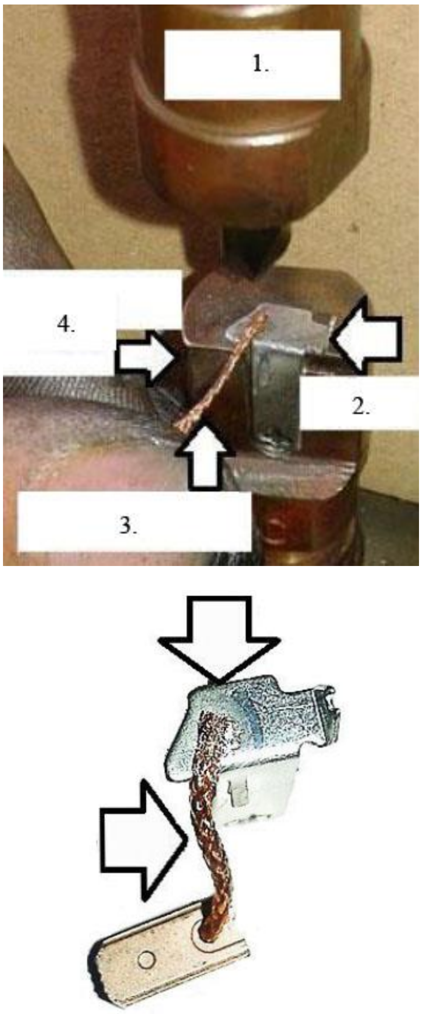


Fig. 9. *Welding the ground plate with the wire of the collector brush wire: 1 - upper electrode; 2 - ground plate; 3 - collector brush wire; 4 - lower electrode*

The parameters of the spot welding machine are shown in Table 1.

Table 1. *Spot welding machine parameters*

Description	*Min.*	*Max.*
Impedance coil-collector brush welding program	0	
Ground plate-collector brush welding program	10	
Welding program thermal protection-collector brush connection	11	
Pressing force [daN]	12	55
Pressing force application time [periods]	2	15
Delay time 1 [periods]	2	4
Current 1 [%]	25	55
Timpul de pauză [periods]	2	5
Delay time 2 [periods]	2	5
Current 2 [%]	31	60
The minimum current [A]	3	1000
The maximum current [A]	6500	9000

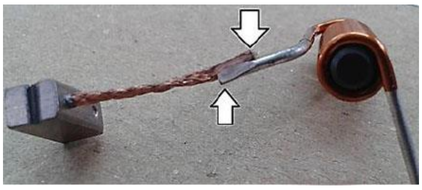
2.2. Quality control of the welded joints

2.2.1. The defects of the welded joints

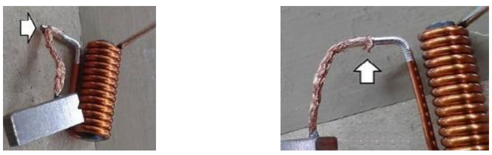
In the welding process of the component elements of the micromotor flanges, defects occur due to the incorrect positioning of the welding components, the premature wear of the contact electrodes, the impurities that reach the contact area, the decrease in the pressing force due to the decrease in pressure in the pneumatic motor circuit, of using an inappropriate regime etc. Due to this, a number of defects can occur.

Figure 10 shows the defects that may occur when welding the end of the impedance coil with the collector brush wire: misaligned weld (a), unwelded impedance wire tip (b) unwelded parts (c).

Figure 11 shows the defects that may appear when welding the ground plate with the collector brush wire: ironed wire (a), wire sticking out of the plate (b) and (c).

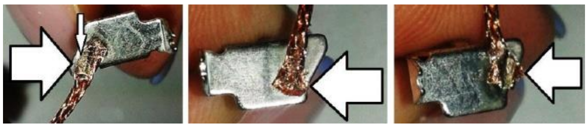


(a)



(b) (c)

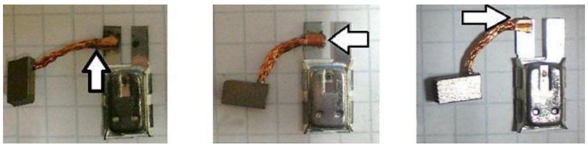
Fig. 10. *Defects in the impedance - collector brush wire joints*



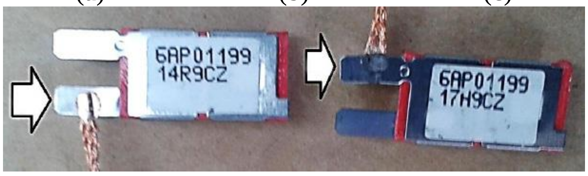
(a) (b) (c)

Fig. 11. *Defects in the ground plate - collector brush wire joints*

Figure 12 shows the defects that can occur when welding the thermal protector plate with the wire of the collector brush: burnt weld (a), welding outside the connection (b), welding at the end of the connection (c), wrong welding of the thermal protector connection (d).



(a) (b) (c)



(d)

Fig. 12. *Defects in the joints of the thermal protection plate - collector brush wire*

2.2.2. Checking the strength of welded joints

Joints made with spot welding machines are rigorously quality checked according to active control plans for the welding operation.

According to the control plans, every hour of work on the welding machine, a shear resistance test is carried out by pulling the welded samples with a weight of 12 N.

In addition, at the beginning of the program, every 4 hours and whenever the machine is worked on, the operator working on the respective machine must carry out a shear strength check on a calibrated device as in Figure 13 , and the 5 joints checked must withstand a breaking force greater than 12 N.

To test for breaking the connection between the commutator brush wire and the impedance coil, fix the carbon wire (right next to the carbon) in the dynamometer, in the lower clamp, then untie the impedance wire a little and fix the welded arm of its impedance in the upper clamp. After fixing the 2 parts, turn the dynamometer handle until the wire breaks and the dynamometer indicator stops at the breaking force.

For the break test of the joint between the wire of the collector brush and the connection of the thermal protection, fix the wire of the coal (right next to the coal) in the lower socket of the dynamometer, then with the connections down, fix the body of the thermal in the upper socket of the dynamometer.

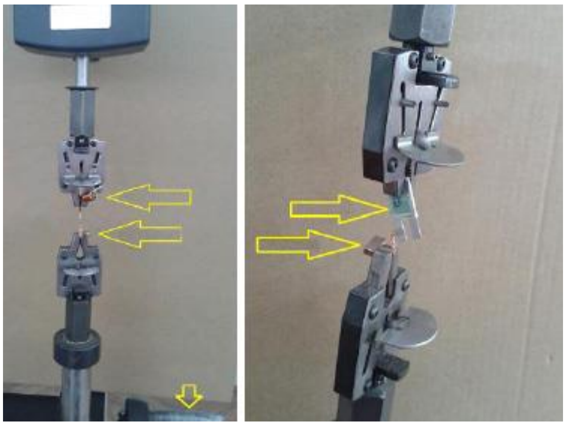


Fig. 13. *Shear rupture test device*

After fixing the 2 parts, rotate the handle of the dynamometer until the wire breaks, and the dynamometer automatically records the breaking force. Measurements were made on 130 samples welded between the collector brush wire and the heat shield connection, which were subjected to the shear failure test. Analyzing the measurement results for the thermal protection-collector brush connection welds, from Figure 14, it can be seen that due to the connection that a soft and flexible element (coal wire) has to make with a hard, flat, metallic element of the thermal protector, the measurements (on a sample of 130 measurements) are found with values ranging from 14 N to 34 N, with most values being around 20 N. The results are considered positive, given that the minimum nominal value is 12 N.

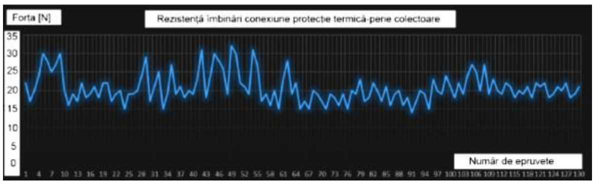


Fig. 14. *Welding resistance analysis thermal protection-collector brush connection*

Analyzing the results of the measurements for the ground plate-wire collector brush welds, from Figure 15, as in the weld analyzed previously, the joint is made between two components, one soft and the other hard (harder than the connection of the thermal protector), so the measurements (on a sample of 140 samples) are found with values ranging from 13 N to a maximum of 31 N, the majority being found around the value of 15 N. The welding between the two elements ground plate-collector brush is a more difficult one due to the material of the ground plate (thicker and harder), which also requires a tensile strength control at 90°. The results are positive, as the nominal minimum value is 12 N.

A joint that gives much more favorable results than the other two types of joints analyzed above, is the welding of the impedance coil - collector brush wire, Figure 16.

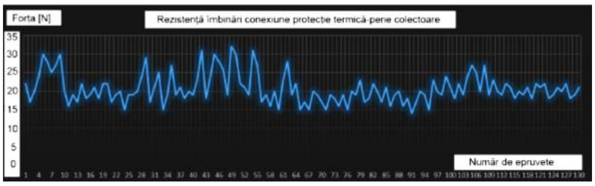


Fig. 15. *Analysis resistance of welding ground plate - collector brush wire*

In this situation, the connection is made between two flexible and soft components, made of the same type of material (copper). It can be noted that, on a sample of 160 welded joints, the weight of the measurements is between 20 and 50 N, the minimum value reached is 17 N and the maximum 5.5 N. And in this situation, the results are positive, because the minimum nominal value is of 12 N.

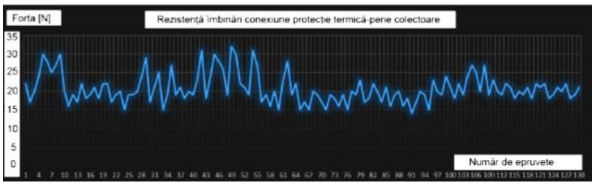


Fig. 16. *Resistance analysis welding impedance - collector brush wire*

To specify that the process is statistically controllable, the maximum and minimum values, the standard deviation, the arithmetic mean, the median and the specification limit values are analyzed through the lens of the process capability index (*Cp*).

To verify the stability of the process from a statistical point of view, the weld strength was considered for 2 types of samples: B2777 (impedance) - B2704 (collector brush - coal) and B2902 (impedance) - B2704 (collector brush - coal), for 60 of tests each, Table 2 and Table 3.

Table 2. *Welding resistance measurements: Assembly B2777 - B2704*

test	[kg]	test	[kg]	test	[kg]	test	[kg]
1	3.9	**16**	3.9	**31**	2.8	**46**	4.0
2	4.1	**17**	3.2	**32**	3.6	**47**	3.2
3	3.7	**18**	3.5	**33**	3.1	**48**	3.8
4	2.9	**19**	2.9	**34**	4.0	**49**	4.0
5	3.3	**20**	3.1	**35**	3.7	**50**	3.8
6	4.0	**21**	3.7	**36**	4.2	**51**	3.0
7	3.5	**22**	4.1	**37**	3.9	**52**	2.8
8	4.2	**23**	3.2	**38**	3.3	**53**	3.6
9	3.7	**24**	3.5	**39**	3.1	**54**	3.1
10	3.3	**25**	4.2	**40**	4.0	**55**	4.0
11	2.8	**26**	4.0	**41**	3.4	**56**	3.7
12	3.1	**27**	3.8	**42**	3.3	**57**	4.2
13	3.5	**28**	3.3	**43**	4.4	**58**	3.9
14	4.0	**29**	3.7	**44**	3.9	**59**	3.3
15	3.7	**30**	3.0	**45**	3.6	**60**	3.1

Table 3. *Welding resistance measurements: Assembly B2902 - B2704*

test	[kg]	test	[kg]	test	[kg]	test	[kg]
1	2.8	**16**	3.5	**31**	3.9	**46**	3.5
2	3.1	**17**	3.2	**32**	2.7	**47**	3.3
3	4.1	**18**	2.8	**33**	3.6	**48**	3.2
4	3.7	**19**	4.2	**34**	4.0	**49**	3.7
5	3.5	**20**	3.9	**35**	4.2	**50**	3.2
6	3.3	**21**	3.5	**36**	3.8	**51**	4.4
7	4.0	**22**	3.7	**37**	3.7	**52**	3.9
8	3.7	**23**	4.2	**38**	3.2	**53**	2.7
9	3.2	**24**	4.3	**39**	4.0	**54**	3.6
10	4.0	**25**	3.8	**40**	4.1	**55**	4.0
11	3.9	**26**	3.9	**41**	3.5	**56**	4.2
12	3.5	**27**	4.3	**42**	2.9	**57**	3.8
13	3.2	**28**	4.0	**43**	3.7	**58**	3.7
14	2.9	**29**	3.6	**44**	3.4	**59**	3.2
15	3.6	**30**	4.4	**45**	4.3	**60**	4.0

From the graphical interpretation of the results, it can be seen that the process is statistically stable, Figure 17 and Figure 18.

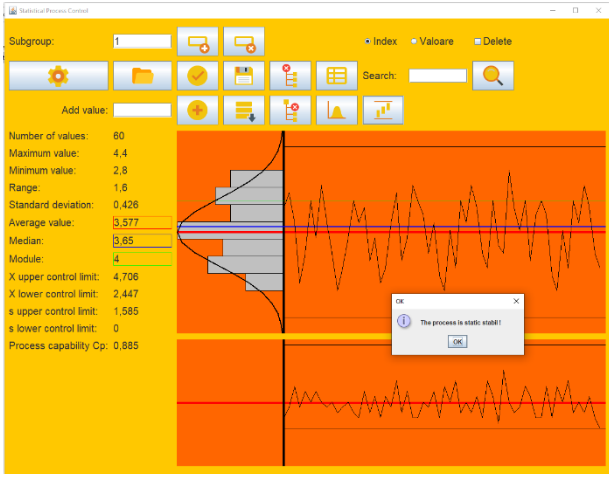


Fig. 17. *Stability of the weld strength verification process: B2777 - B2704*

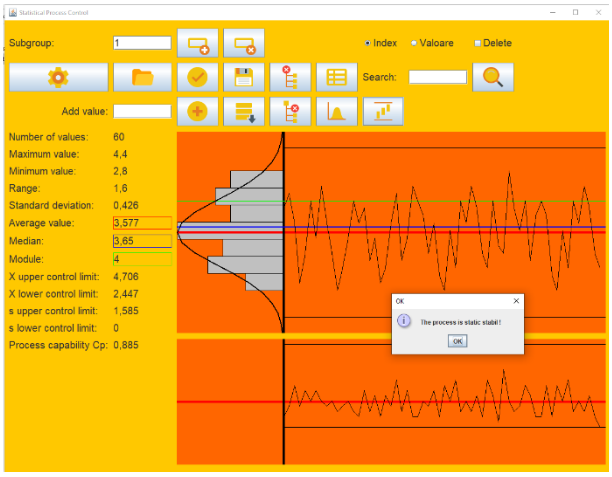


Fig. 18. *Stability of the weld strength verification process: B2902 - B2704*

Tensile/break weld measurements were also considered for the 2 samples types: B2777 (impedance) - B2704 (collector brush - carbon) and B2902 (impedance) - B2704 (collector brush - carbon), for 60 tests each, Table 4 and Table 5.

Table 4. *Tensile/weld break measurements: Assembly B2777 - B2704*

test	[kg]	test	[kg]	test	[kg]	test	[kg]
1	3.2	**16**	4.1	**31**	3.2	**46**	3.6
2	3.7	**17**	3.6	**32**	3.2	**47**	3.2
3	2.9	**18**	4.2	**33**	4.1	**48**	3.1
4	3.0	**19**	2.9	**34**	4.2	**49**	3.7
5	2.8	**20**	4.3	**35**	3.3	**50**	4.2
6	3.3	**21**	4.2	**36**	3.6	**51**	4.0
7	3.4	**22**	3.5	**37**	3.7	**52**	4.24
8	2.8	**23**	2.9	**38**	4.2	**53**	4.41
9	3.1	**24**	3.3	**39**	3.9	**54**	3.3
10	2.9	**25**	3.6	**40**	2.9	**55**	3.6
11	3.1	**26**	4.4	**41**	3.2	**56**	3.7
12	3.6	**27**	4.1	**42**	4.1	**57**	4.2
13	2.7	**28**	3.5	**43**	4.2	**58**	3.9
14	2.6	**29**	3.6	**44**	3.7	**59**	4.4
15	3.7	**30**	3.4	**45**	3.5	**60**	3.3

Table 5. *Tensile/weld break measurements: Assembly B2902 - B2704*

test	[kg]	test	[kg]	test	[kg]	test	[kg]
1	4.1	**16**	3.8	**31**	2.8	**46**	2.9
2	4.2	**17**	3.9	**32**	3.1	**47**	3.1
3	3.3	**18**	4.1	**33**	2.9	**48**	3.6
4	3.6	**19**	4.4	**34**	3.1	**49**	2.7
5	3.7	**20**	4.4	**35**	3.6	**50**	2.6
6	4.2	**21**	4.5	**36**	2.7	**51**	3.7
7	3.9	**22**	4.3	**37**	2.6	**52**	4.1
8	2.9	**23**	4.7	**38**	3.7	**53**	4.1
9	3.3	**24**	3.9	**39**	4.1	**54**	4.2
10	3.2	**25**	3.4	**40**	3.0	**55**	3.7
11	3.1	**26**	3.2	**41**	2.8	**56**	3.5
12	3.1	**27**	3.0	**42**	3.3	**57**	3.6
13	3.0	**28**	2.8	**43**	3.4	**58**	3.2
14	3.2	**29**	3.3	**44**	2.8	**59**	3.1
15	3.1	**30**	3.4	**45**	3.1	**60**	3.5

From the graphical interpretation of the results, it can be seen that the process is not statistically stable, Figure 19 and Figure 20.

Through a complete and reliable quality assurance system, the component elements of the micro-motor flanges are assembled by point pressure on electronically controlled machines, which are further assembled on a flexible line. Welds copper and steel components (collector brush wire, impedance coil, thermal protection connection, ground plate) using assembled tungsten tip electrodes, as well as copper monobloc electrodes and electronically controlled and pneumatically actuated welding equipment.

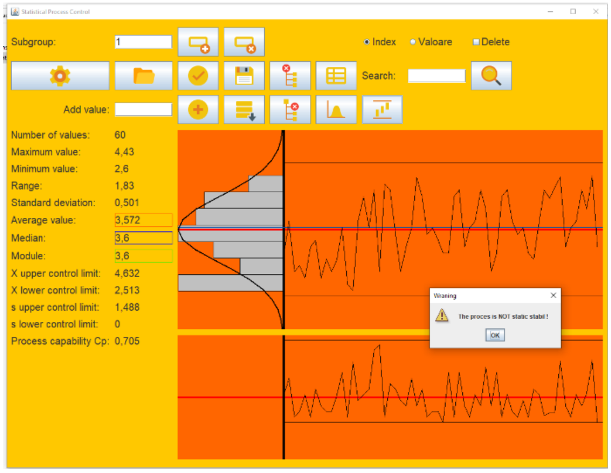


Fig. 19. *Stability of the weld tensile/breakage verification process: B2777 - B2704*

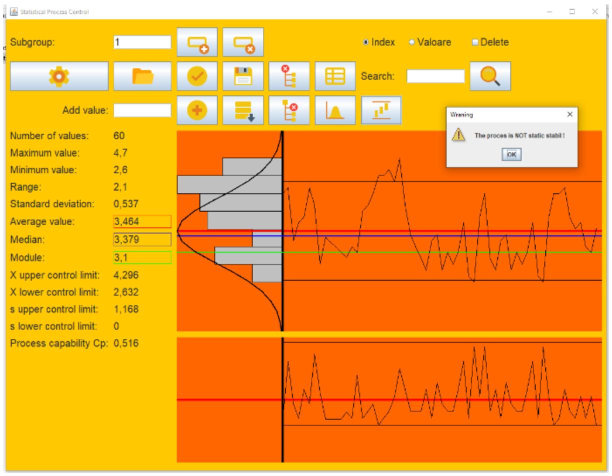


Fig. 20. *Stability of the weld tensile/breakage verification process: B2902 - B2704*

3. QUALITY ASPECTS WHEN WELDING SOME COMPONENTS IN THE APPLIANCES INDUSTRY

3.1. Description of the welding equipment

The equipment that performs the welds automatically is called the MTA MRC500, Figure 21.

The MTA MRC500 is one of the largest robotic spot welding units. The standardized platform is based on a flexible and modular concept that can be adapted to a wide range of processes, from fully automated in-line processes to stand-alone semi-automated processes. The MRC500 can be equipped with any type of welding heads: brazing steel, induction and micro flame. The mechanical structure has been designed to work with a wide range of process equipment, material handling and protection systems.

Fig. 21. *Equipment for automatic welding - MTA MRC500 [18]*

The main technical characteristics of the MTA MRC500 equipment are [18]: welded frame construction; Cartesian robot with 3 axes with optional rotating axis at the head; working area 500x500x200 mm; industrial PC controller with built-in Windows® operating system; intuitive, menu-driven MTA MotionEditor software; positioning repeatability: ±20 µm; speed: *X* și *Y*: < 300 mm/s, *Z* < 150 mm/s, *T* ≤ 3,14 rad/s; selection: HMI; execution mode: autonomous or manual with PLC via I/O interface; actuation of the servomotor axis - rotary axis: stepper motor; pressure: max. 6 bar; protection kit *ESD* (Electrostatic Discharge); parts presence sensor; part height measurement sensor etc.

Heating elements are available for both 80W and 150W welding heads. As these units are subject to high temperatures, they need to be replaced from time to time and as such can be easily swapped out when needed. As a key piece of automatic welding equipment, the wire feeder drives the weld metal into the exact position required by the application. This unit is adaptable to many wire diameters. At the end of the device, the wire is guided through a tube, which, due to continuous contamination of the welding alloy, sometimes has to be replaced.

Welding wires play a significant role in the success of the process. Their main technical specifications are [20]: heating element power: 80W or 150W / 24VAC; steel temperature: adjustable to 450°C; temperature accuracy: ± 5°C (regulation on a 4-20 mA current loop); power controller: 115/230V - 50/60Hz; air pressure: max. 6 bars; dimensions of steel heads: 292 x 225 x 184 mm; welding wire diameter: 0.3 – 1.2 mm. The steel welding head, Figure 22, is composed of two distinct units: the heating unit and the wire feed unit. They are mounted either on a fixed support or on a rotating unit using a rigid clamp.

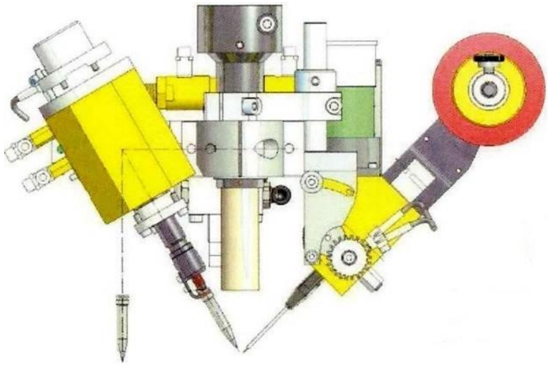


Fig. 22. *Welding head*

The welding tip is fixed to the heating element, the heating unit being mounted on a support, using a rotating cylinder, which allows a soldering position and a cleaning position.

Using its support, the wire feeding robot can be positioned according to requirements. The wire is fed through a guide tube, by combining the actions of a sliding wheel and the pressing rollers. These elements are interchangeable depending on the diameter of the welding wire. The wire feeding unit is equipped with a wire feeding control device.

Figures 23÷25 show some examples of spare parts from the equipment for automatic welding - MTA MRC500.

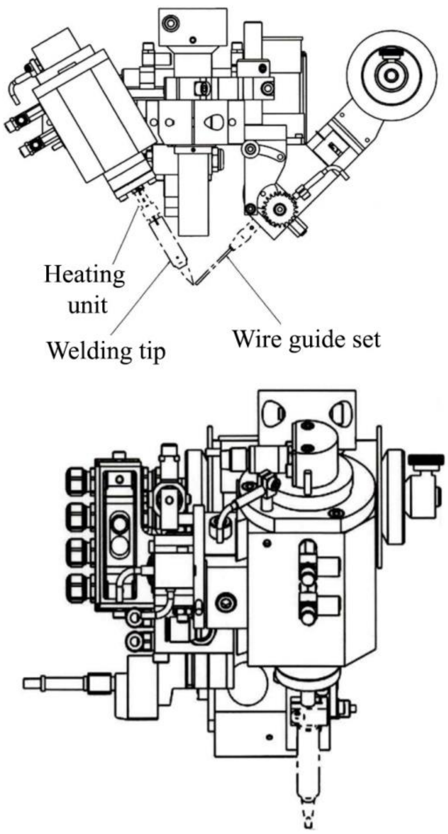


Fig. 23. *Steel welding head*

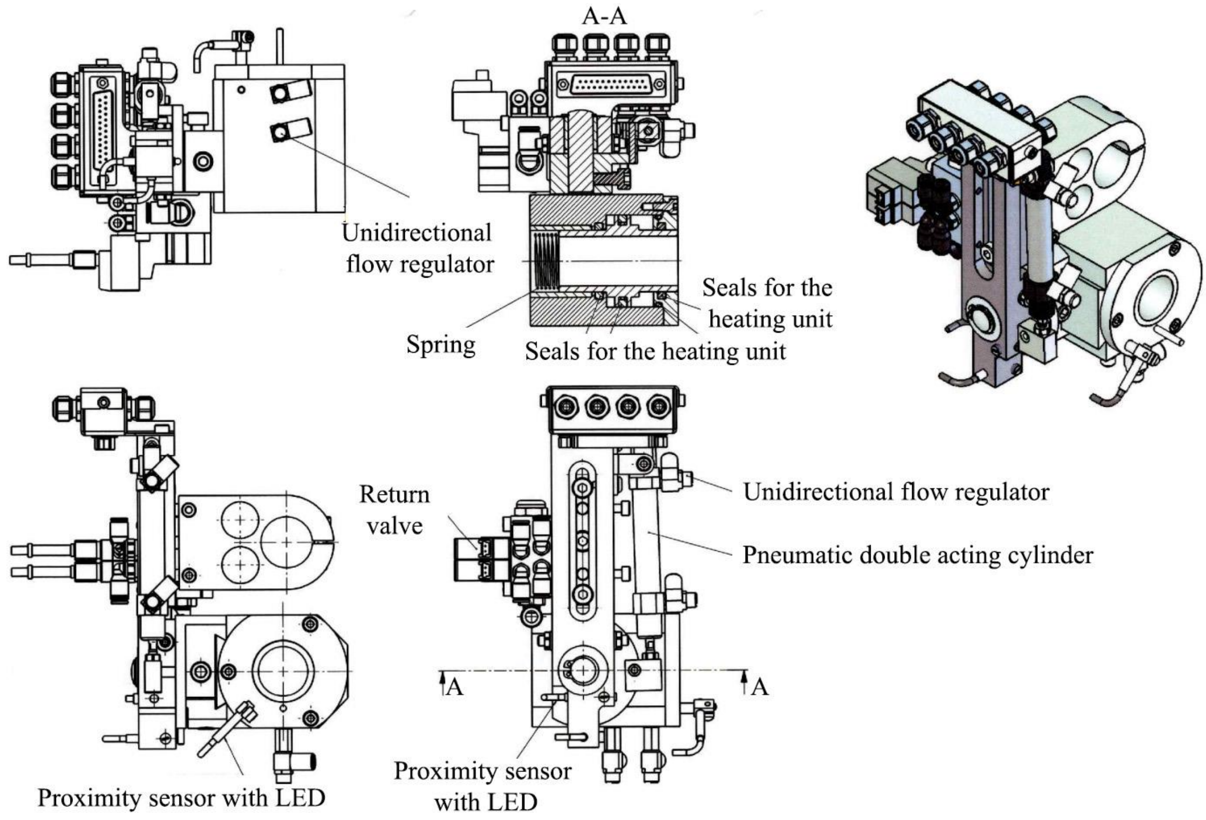


Fig. 24. *Support for heating unit*

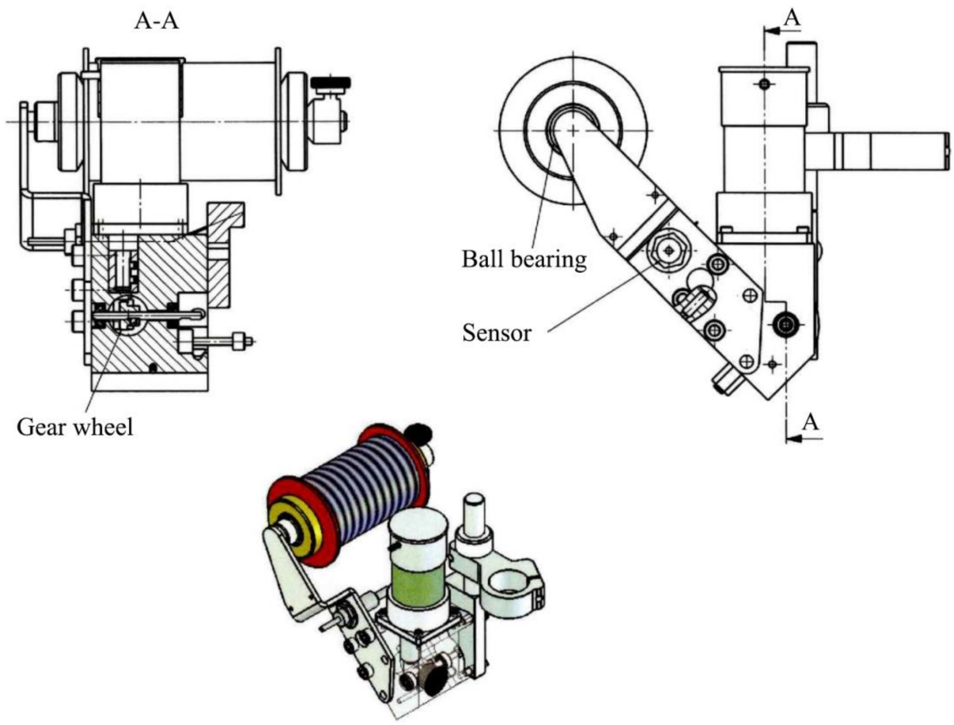
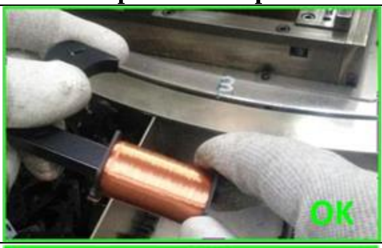
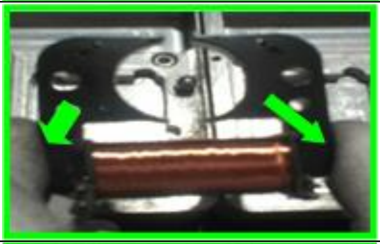
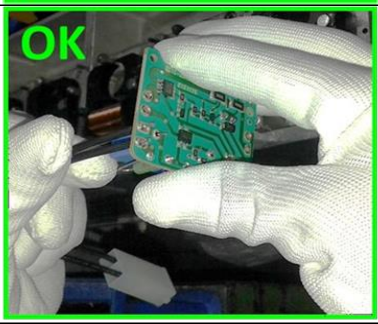
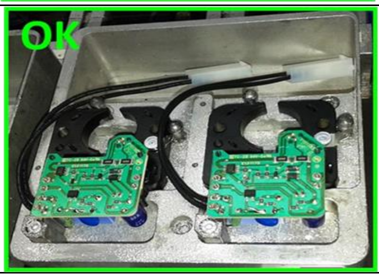
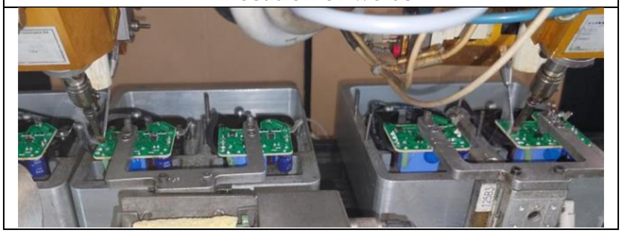


Fig. 25. *Feeder for wire feeding robot*

3.2. Production flow for the assembly of a micro-motor for household appliances

Table 6 shows the assembly flow of a micromotor for household appliances.

Table 6. *Assembly flow of a micro-motor for household appliances*

Process	Description of the process
Coil mounting	
Stators mounting	
Electrical terminal mounting	
Electronic board mounting	
Execution of welds	
	

3.3. Quality control of welds

In welding, quality control plays a vital role in ensuring the production of solid, reliable welds and minimizing rework.

Failure to perform proper quality control during manufacturing can result in welds of varying quality. When welding defects occur, rectification will be required and may delay product delivery to the customer. This can also lead to the loss of the manufacturer's reputation.

Quality Control (*QC*) in home appliance micro-motors is the process of confirming that the product meets specifications. It includes verification and testing of manufacturing procedures as well as final products. The results of these tests are compared to a set of defined acceptance criteria. By performing *QC* tests during production, defects can be identified in a timely manner, allowing product failure to be remedied and, if necessary, adjustments to be made in the manufacturing process to prevent subsequent defective production [20].

The first requirement for quality control is the *Welding Procedure Specification – WPS* [10]. *WPS* is an instruction manual on how to perform specific welds. The following are specified in this manual: welding standard, welding process, welding type, weld preparation, pre- and post-heat requirements, welding position/s, inter-pass temperatures, electrode specification / filling, gas details, range of amperes / voltages, speeds, type of current, polarity, etc.

Quality control can be done before, during or after welding. Quality control prior to actual welding typically includes the following [10]:

- material confirmation to ensure that the mechanical properties and chemical composition conform to the design specification - generally done by looking at material certificates; in certain circumstances, some tests may also be necessary, for example on thick plates, to rule out laminar breakage during/after welding;
- preparation of the joint to ensure that it conforms to the design specification and/or specified welding standard; this includes dimensional and surface cleaning checks;
- joint assembly checks;
- the qualification of the welder.

Quality control during welding usually includes the following:

- checking the preheating temperatures, if they are within the limits of the welding procedure specifications;
- confirmation that the filler material is as specified in the *WPS*;
- other checks: cleaning between passes, weld appearance, etc.

Quality control after actual welding will depend on welding compliance standard, welding class and customer agreement.

Control can be destructive (*DT - Destructive Testing*) or non-destructive (*NDT - Non-Destructive Testing*) [10].

Destructive testing requires the physical destruction of the part or weld to test the weld.

It generally includes sectioning the part and/or breaking the weld.

Generally, *NDT* is performed only on finished fabrication, but *DT* may be required for one or a percentage of test pieces. *DT* is more commonly used for *WPS* qualifications. Common *DT* processes are as follows [10]:

- macro testing - sections are polished, etched and examined under a microscope for defects;
- break test - the weld sample is broken and the broken surfaces are examined for discontinuities;
- tensile test - performed on the welded sample;
- bend test - the sample is bent to a certain specified radius to evaluate the ductility and strength of the weld.

Non-destructive testing (*NDT*) involves testing welds without destroying the welds or parts. Common *NDT* techniques are [10]:

- visual scan - visual check to confirm that the welds are according to the drawings, i.e. the type of welds, the locations;
- visual examination - visual inspection of the weld to check for visible welding defects according to the welding compliance standard;
- testing with penetrating dye (*PT*) - to detect surface defects in welding;
- magnetic particle testing (*MT*) - to detect surface defects or near the welded surface;
- ultrasonic testing (*UT*) - ultrasonic waves to detect internal welding defects;
- radiographic testing (*RT*) - with X-rays to detect welding defects etc.

In the paper, the quality control of the welds was performed automatically with a camera of the Keyence type [20],

Figure 26, which verifies the correctness of the welds made on the plate.

Fig. 26. *Keyence camera for checking the quality of welds [20]*

A report was made specifying that the parts marked with "OK" (conforming) are those that passed both tests and "Non-OK" (non-conforming) are those that did not meet the parameters when tested with the digital measuring device.

A daily record is kept of the number of non-conforming welds compared to the number of conforming welds. If there is a significant increase in the number of non- conforming welds and an increase in the percentage of rejects (maximum 2%), then the quality department, in collaboration with the maintenance department, take the necessary measures to reduce the percentage of defects generated by the equipment for the automatic realization of welds, MTA MRC500.

Figures 27 and 28 graphically represent the evolution of conforming welds from the total of welds from March 2023, respectively the evolution of non-conforming welds from March 2023.

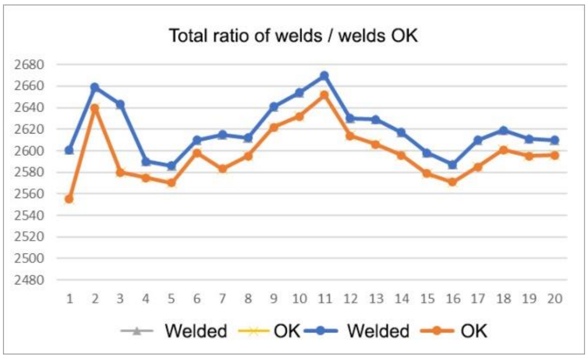


Fig. 27. *The evolution of conforming welds from the total welds in March 2023*

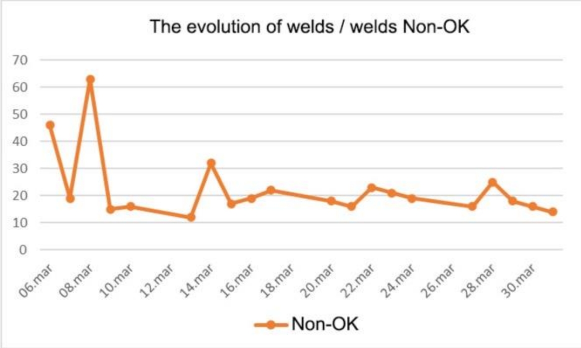


Fig. 28. *The evolution of non- conforming welds from March 2023*

From the graphs presented, it is found that the percentage of defective welds varies between 0.45% and 1.76%, which means that they are below the maximum acceptable defect limit.

4. CONCLUSIONS

Quality assurance and quality control play essential and distinct roles in ensuring streamlined operations and production in companies in the automotive and home appliance industries. Making compliant welds can help companies specializing in various manufacturing processes deliver the highest possible quality products to their customers.

There are a number of codes and standards that apply to welding work.

These standards ensure the quality and efficiency of welds and welding operations and are a major requirement of these industries.

Most companies make the weld quality assurance program a priority requirement for their projects.

The quality of a weld cannot be easily checked. In addition, the welding process relies on a number of variables such as tensile strength, ductility, type of gas and consumables, arc current voltage, etc., which add complexity to producing a weld.

These variables must be carefully monitored to produce a quality result, and weld quality control must be methodical and precise. Determining weld quality requires an experienced and qualified weld inspector and a robust quality assurance program. In all industries and companies, a failed weld can have disastrous effects on workplace safety and, in most cases, on the community and environment.

In addition to the resulting liability, businesses will face significant financial losses arising from manufacturing defects and the associated costly repairs or replacements.

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