Analysis of robotic welding possibilities of a car chassis assembly

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Abstract. The continuous increase of the requirements regarding the quality of the welded joints (elimination of the influence of the human factor) but also the increase of the productivity of the technological processes imposed the analysis of the possibilities of implementing robotic welding processes. The introduction of robotic production lines is an increasingly common thing in the automotive industry. This paper presents the stages necessary for the realization in welded construction of a crossbeam, part of the chassis of a car. The elaborated welding technology aimed to achieve the transition from semi-mechanized welding of the assembly to robotic welding using the MAG (Metal Activ Gas) welding process. The basic material from which the crossbar is made is S355 MC steel, steel for constructions with high mechanical properties. For the robotic welding of the assembly, the design of the device necessary for the orientation and fixing of the components was made. The welding technology developed was validated by performing standard samples that were subjected to visual examination and penetrant testing but also to destructive examinations which consisted in measuring the hardness in the characteristic points of the welding bead and also by measuring its geometric characteristics. Following the analysis of the initial dimensional values obtained, it resulted that the incorrect positioning of the welding head led to the appearance of geometric defects of the welding seams, although the technological parameters of the welding regime were appropriate. After making adjustments on the position of the welding head, accepted characteristics were obtained which led to the decision to validate the welding technology used.

1. Introduction

The continuous and rapid evolution of technological processes has required the development of new technologies and equipment capable of satisfying the increasingly complex requirements of the industrial environment. Welding processes are an important component in the machine building industry, with the advantages of low cost, good performance of connection and easy operation, etc [1-3]. Fusion welding is a process used in the automotive industry to achieve highly required non-removable assemblies, as is the case with chassis components. During welding, the basic materials are subjected to a thermal heating-cooling cycle, which influences their structure and properties. The Metal Activ Gas (MAG) process is one of the most used welding processes with applicability in many industrial fields having the advantages of a high productivity while offering a very good quality of the resulting welded joints. The main technological parameters of the welding regime (welding current,
arc voltage, welding speed) directly influence the geometric characteristics of the resulting welding seams. The position of the welding head in relation to the parts to be assembled influences the shape of the welding bead but also the penetration depth for each component [4-6]. The geometric characteristics of the resulting weld bead can be highlighted with the help of macrographic examination. Following the analysis of the obtained results, recommendations can be made regarding the modification of the values of the welding regime parameters so that the resulting joints comply with the imposed quality requirements.

Increasing demands on the quality of welding seams have required the elimination, as far as possible, of the human factor in welding processes and the use of mechanized or robotic systems. The introduction of industrial robots eliminates the disadvantages of manual or semi-machined welding and meets the new quality and productivity requirements of technological processes [7-9]. Robot programming can be done online or offline and ensures process repeatability under the specified initial conditions [10-13].

The main objective of the paper was to obtain information on the geometric characteristics of welded seams obtained in the case of robotic welding, using the MAG process, of a chassis type car component (fusion line position, weld metal and heat-affected zone) as well as to analyse the interdependence between these characteristics and the technological parameters of the welding regime. Following the analysis of the initial results, recommendations were made regarding the modification of the values of the welding parameters so as to obtain the desired quality level of the welded joints, in order to validate the chosen welding technologies. In the case analysed in the paper, the car chassis consists of several cross members and assembly elements. Each cross member is welded on a robotic workstation following that in the end the final assembly of the car chassis to be performed.

2. Experimental data
A robotic cell was used for the realization of the welded joints which has in its component a two-axis positioner, welding fixture, Air Liquide welding power sources DIGIWAVE 500 and the welding robot Fanuc Arc Mate 120iC (six-axis servo motor), whose working area, indicated in figure 1, ensures the accessibility to all the necessary joining areas.

![Figure 1. Fanuc ARC Mate 120iC working range.](image)

The positioner together with the afferent devices ensures the fastening and fixing of the components of the chassis cross member in order to be joined by welding and with the help of the
external axis of rotation the relative position of the welding head with respect to the components to be joined is ensured. The robotic welding cell used to weld the cross member is presented in figure 2.

![Figure 2. Auto chassis welding workstation.](image)

The main basic materials used to make the components of the car chassis cross assembly (figure 3 and figure 4) were steels: S355MC (fine grain structural steel thermomechanically rolled and special cold forming) for the main structure of the chassis and S355J2H (structural steel for hollow section) for additional components. The filler material used to make the welded joints was solid wire type G3Si1 according to EN ISO 14341: 2020 and the shielding gas used was the mixture type M2.0 according to EN ISO 14175: 2008 [14-17].

![Figure 3. Nominal dimensions of the car chassis cross member.](image)
Figure 4. The welded joints necessary for the realization in welded construction of the car chassis cross member.

The chemical composition as well as the mechanical properties of the materials used to make the welded joints shown in figure 4, according to the standards in force, are presented in table 1 and table 2 [14-17].

| Materials | Weight Percent |
|-----------|----------------|
|           | C  | Si  | Mn  | P  | S  | Al  | V  | Nb | Ti  |
| S355MC    | 0.12 | 0.50 | 1.50 | 0.025 | 0.020 | 0.015 | 0.20 | 0.09 | 0.15 |
| S355J2H   | 0.22 | 0.55 | 1.60 | 0.030 | 0.030 | -   | -   | -   | -   |
| G3Si1     | 0.06-0.14 | 0.80-1.0 | 1.4-1.6 | 0.025 | 0.025 | -   | -   | -   | -   |

Table 1. Chemical composition of basic materials and filler material [14-17].

| Materials | Tensile Strength (MPa) | Yield Strength (MPa) | Elongation (%) |
|-----------|------------------------|----------------------|----------------|
| S355MC    | 950                    | 880                  | 14             |
| S355J2H   | 895                    | 828                  | 10             |
| G3Si1     | 470-600                | 380                  | 20             |

Table 2. Mechanical properties of base materials and filler material [14-17].

For welding the chassis using the MAG process, depending on the thickness of the components, 5 types of joints were used, according to EN ISO 9692/1 [18]. The components were laser cut and mechanically machined to ensure the geometric configuration required for assembly. Two types of joints used to make the welded joints are presented in figure 5, where MB represents the base material.

After the mechanical processing of the joints, the components were fixed in devices and welded in the robotic cell using the working parameters presented in table 3. Some of the resulting welded joints are presented in figure 6.
Figure 5. Types of joints used to weld the car chassis.

Table 3. The parameters used in the experiments.

| No. crt. | Parameter                        | Value       |
|---------|----------------------------------|-------------|
| 1       | Welding current [A]              | 210-220     |
| 2       | Arc voltage [V]                  | 22-24       |
| 3       | Filler material diameter [mm]    | 1.2         |
| 4       | Gas flow [l/min]                 | 18-20       |
| 5       | Travel speed [cm/min]            | 60          |
| 6       | Type of gas protection           | Ar+10%CO₂   |

3. Results

After finishing the welding process, the samples were subjected to visual and dimensional examination [19] and penetrant testing [20]. Following the analysis of the obtained results, it was observed that the samples do not show surface imperfections or that are related to the surface.

In order to avoid overheating of the samples and a possible structural change during cutting in order to perform the metallographic analysis [21], the samples were cut with low cutting speed on a device with continuous cooling.
Following the cutting process, the samples were first cleaned from impurities and then subjected to polishing using different granulations of metallographic paper; the final polishing was made with abrasive diamond paste. In order to reveal structural details the samples were etched with Nital 4% [22].

After the metallographic preparation of the obtained samples, they were examined macroscopically with the help of an optical microscope, photographed and introduced in a computer program for measuring the geometric characteristics of the welded seams. The quality evaluation of the welded joints was made in accordance with the internal norms of the beneficiary. From the analysis of the welded joints obtained (figure 7) it can be seen that some of the samples showed a series of imperfections such as: surface pore, lack of penetration, intermittent undercut, incorrect weld toe, excessive asymmetry of fillet weld. The acceptance criteria for imperfections are presented in table 4. Possible causes of these types of non-conformities were: incorrect positioning of the welding head relative to the welding axis, free length of improper electrode wire or too low value of welding current intensity.

Table 4. Acceptance criteria for the welding imperfections (extras).

| No. | Imperfection                          | Value                          |
|-----|--------------------------------------|--------------------------------|
| 100 | Crack                                | Not permitted                  |
| 2017| Surface pore                         | Not permitted                  |
| 402 | Lack of penetration                  | Not permitted                  |
| 505 | Incorrect weld toe                   | \(\alpha \geq 100^\circ\)     |
| 512 | Excessive asymmetry of fillet weld   | \(h \leq 2\text{mm} + 0.5a\)  |
| 5012| Intermittent undercut                | \(h \leq 0.1t\), but max. 0.5mm |
| 617 | Incorrect root gap for fillet welds  | \(h \leq 0.5\text{mm} + 0.2a\), but max. 3mm |

Figure 7. Metallographic evidence of non-compliant welded joints.

Taking into account the imperfections, a series of changes were proposed to the parameters of the welding regimes: increasing the value of the welding current in the case of thicker components, changing the position of the welding head depending on the geometric configuration of each joint and synchronizing the positioner movement with the welding head in order to ensure better accessibility at the welded joint. After making the proposed changes regarding the values of the technological parameters, the welded samples were remade on a test cross member. After the examinations of all the welded joints made with the improved technology (figure 8) no imperfections were detected, which led to the validation of the welding technologies used in this case. The robotic welding programs made were saved for use in series production.
The analysis of the geometric characteristics of the welded seams, with the help of computer programs, as can be seen from figure 7 and figure 8, provides the necessary information in order to decide their acceptance and the welding technology depending on the required level of acceptance of imperfections, in accordance with an international, national or internal norm, depending on the requirements of the beneficiary.

4. Conclusions

By using qualified robotic welding technologies and by adapting and validating them to the working conditions in the welding workshops, the human factor in the welding process has been eliminated. The introduction of robotic welding has led to high quality welded joints with a much lower chance of imperfections occurrence.

Changes to the welding regime parameters can be easily made and the validated welding technology can be repeated by resuming the working programme. Welding paths can be easily changed by programming the robot online or offline.

The costs of the initial investment necessary to purchase the robotic cell can be amortized quickly by reducing the costs necessary to fix any imperfections that may occur in welded joints due to the human operator, but also by reducing manufacturing times.

With the help of computer programs designed to analyse metallographic images it was possible to make measurements of the geometric characteristics of the welded seams and, by comparison with the values included in the acceptability criteria, the decision was made to validate the welding technologies use in the paper.

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