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SUPER DUPLEX – AHSS WELDING FOR ELECTRIC VEHICLES

Summary. Solutions for planning and improving transport processes often require the modification of existing transport equipment or the development of new equipment to increase its operational range or improve its efficiency. Appropriately introduced modifications contribute to maintaining the smooth flow of the process, enabling transport in a wider operational range. Proprietary solutions consisting of increasing the operational range of the extension arm by incorporating high-strength steels into their structure made it possible to extend the arms of these devices while maintaining the total weight of the device and appropriate high-performance parameters. The solution allows operators to reach places previously inaccessible to these devices, thus eliminating the need to use other devices in the logistics process. An important element of the solution is to ensure the passive safety of the structure; hence, the solution created for the needs of transport logistics required the development of an appropriate process for joining different types of steel. This type of joint is important in the automotive industry, especially in the construction of mobile platforms, because, on the one hand, a light, spacious, and durable structure is required, and on the other hand, this structure should be characterized by good anti-corrosion properties. *The uniqueness of the presented solution* is evidenced by the fact that the developed processes supporting the reduction of the "carbon footprint" were deliberately used to combine elements of two different types of steel: super duplex (SD) steel and advanced high-strength steel (AHSS), which is a technological novelty in combining the discussed steel grades. The CO_2-free gas mixture was selected for technological and environmental reasons in accordance with EU directives, which strongly recommend reducing CO_2 emissions in the automotive industry. *The purpose* of this article is to present a solution for the execution of welded joints, high-strength steels with duplex steels, ensuring the achievement of the desired structures of transport equipment, taking into account the principles of sustainable development and striving in this area to reduce CO_2 in technological processes. The main methods for checking the quality of the welded dissimilar joint were based on the tensile, bending, and impact toughness tests. The results are very promising, and the obtained correct joints are characterized by high mechanical properties suitable for constructing mobile platforms in the automotive industry. *The presented solution supports* activities for sustainable development and logistics in transport. The proposed solution to modify transport means will improve the functionality of

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this device. The solution was developed to address the need to implement the transport processes of the examined organization.

1. INTRODUCTION

Welded structures can be used for mobile platforms, other various means of transport, and passenger vehicles, as well as car bodies and the frames of trucks and buses [1]. Certain vehicle components may come into contact with corrosive agents such as chemicals. SD and AHSS are used in the structures of supports of electric vehicles (Fig. 1) or mobile platforms [2, 3]. Stainless steels have already found practical use in many car structures, for example:

- hydroformed dashboard covers
- complex body structure reinforcements
- front cross members
- car seat elements
- many body elements related to increasing safety in the event of a collision
- bumpers
- controlled crumple zones
- vertical posts
- door reinforcements and many other elements

Fig. 1. SD and AHSS elements and joints in electric cars [4]

The global goal of reducing the weight of vehicles, regardless of the type of drive, is mainly achieved by replacing structural steel with high-strength steel, including stainless steel [5-8]. Generally, the weight of vehicles is reduced by reducing the wall thickness of steel elements.

In this field, high-strength and stainless steels constitute a substitute for low-alloy structural steels with lower tensile strength and lack of the required corrosion resistance.

Therefore, high-strength steel grades are also increasingly used to design transport equipment and machines (Fig. 2). These transport machines have various functions in warehouse work. They are used to place and remove heavy goods from the shelves. They are also used to control orders and inventory.

Lifts are also helpful in activities related to the maintenance and repair of individual parts of the room, as well as in construction and finishing works. Thus, it is clear that lifts are an important part of working in warehouses and other such spaces. High-strength steels make it possible to construct the structures of machines characterized by the following:

- increased lifting capacity while maintaining the total weight of the structure,
- reduced cross-section of the profiles used in relation to low-alloy steels,
- reduced total weight of the structure elongation of thin-walled profiles while maintaining an appropriately high level of safety, including the stability of the structure and its strength

Fig. 2. Examples of the transport machines used in magazines and building transport infrastructure processes

Extending the operating arm of transport machines and equipment while maintaining their lifting capacity allows goods and people to be moved in a wider operational range, which is often crucial for logistics processes (e.g., in warehouses).

2. RESEARCH PROBLEM

In the audited organization, during activities related to the improvement of logistics processes, a team was appointed, which, as part of brainstorming and 5 Why analysis, determined that the extension of the mobile platform arm by at least 30%, and thus, the increase of its operational range should translate into a reduction of costs in the company by increasing the flexibility of the operating device (a device with a larger operating range and comparable dimensions). It was recognized that in transport processes, such a solution enabled relatively easy modification of the path leading in the logistics processes of the analyzed organization without the need to substitute other devices. Until now, changes in products on the line and their distribution in the warehouse have forced the retooling of machines and the change of trolleys or booms or the operation of several devices simultaneously. The introduction of a device with an increased lifting capacity and operational range should, therefore, speed up logistics processes and eliminate the need for multiple transport equipment. Adjusting the length of the arm of the device should contribute to improving work ergonomics.

Solving the logistic problem requires the development of appropriate material and technological concepts along with the adoption of the following assumptions:

a) The total weight of the modified vehicle cannot be higher than the weight of the existing vehicle.
b) The modified device must have a folding arm and cannot increase the dimensions of the vehicle's load-bearing structure because only then will it be possible to easily integrate it into the existing logistics processes without the need to provide additional maneuvering space.
c) The device must ensure the elimination of the second conveyor device in the process, which will realistically reduce floor space requirements and the time required to rent and install a second, larger device.

When modifying the transport equipment and ensuring the fulfillment of logistical objectives, it was necessary to consider the environmental and structural safety objectives. The increase in ecological awareness and the adoption of design principles consistent with the principles of sustainable development require an analysis of the materials used in terms of their impact on the natural environment. This approach analyzes the impact of all factors related to the extraction, processing, use, and recycling of a given material. In this approach, stainless and high-strength steels are particularly recommended. This is due, among other things, to the low demand for primary energy during steel production and especially the low CO_2 emission of the production process compared to competitive aluminum or magnesium alloys. Despite their robust ability to reduce the weight of the vehicle structure, magnesium and aluminum alloys have a substantial negative impact on the natural environment at the initial stage of obtaining aluminum and its processing into an engineering material [9-11]. The CO_2 emissions of the aluminum or magnesium production stage are three times greater than those of steel, including stainless and high-strength steels. Compared to classic unalloyed steels, stainless steels do not require additional anti-corrosion protection during use. As a result, during operation, they do not generate additional CO_2 emissions related to the production of coating materials and anti-corrosion protection of the welded structure. For ecological reasons, we decided to use high-strength steels in the developed solution. Based on the literature and the authors' experience with high-strength steels, we drew the following conclusions:

a) The use of materials with better strength properties should also ensure the passive safety of the structure.
b) The use of high-strength steel grades gives a real opportunity to make thinner profiles of the structure, which reduces the total weight of the structure when using the same length of profiles or maintains the weight of the structure when using elongated profiles.

An important element of the solution was the development of an appropriate technology for combining new steel grades with duplex steels used in modified equipment. The technology must ensure that the correct joints are obtained with the right strength properties and are in line with achieving sustainable development goals.

The article aims to present a solution for the execution of welded joints, high-strength steels with duplex steels, ensuring the achievement of the desired structures of transport equipment, taking into account the principles of sustainable development and striving in this area to reduce CO_2 in technological processes. We checked whether these steels are welded and whether it is possible to reduce or even eliminate CO_2 as a shielding gas.

3. MATERIALS AND WELD METHOD

Austenitic-ferritic steel (S32750) was combined with martensite steel (DOCOL 1100 M) using the metal active gas (MAG) method under different welding parameters. On the one hand, a material with high corrosion resistance and good strength (super duplex steel) was combined, and on the other hand, a material with a very high strength of 1300 MPa (DOCOL 1100 M steel) was utilized. Welding two different types of steel is very complicated because both types have different structures and, therefore, welding requirements. One material has an austenitic structure with a delta ferrite content, and the other material has a martensite structure. Table 1 presents the mechanical properties of tested materials for dissimilar welding.

The data in Table 1 show that the two utilized grades of steel have very different properties. Martensite steel has a much higher tensile strength (UTS) and elevated yield point (YS) than super duplex S32750 steel.

Moreover, martensite steel has a much higher coefficient of thermal expansion than super duplex steel. Another difference is that super duplex steel has a higher thermal conductivity than martensite steel. All physical differences make the MAG welding of both grades of steel a difficult process. The aforementioned properties of both materials result from their different compositions (Table 2).

Table 1

Tensile strength of tested materials

Steel grade	YS, MPa	UTS, MPa
S32750	530	840
DOCOL 1100 M	920	1080

Table 2

Chemical compositions of the tested grades of steel

Steel	**C, %**	**Si, %**	**Mn, %**	**P, %**	**S, %**	**Al, %**	**Cr, %**	**Mo, %**	**N, %**	**Ni, %**	**Ti, %**
S32750	0.011	0.92	1.12	0.013	0.011	0.01	25,7	3.92	0.29	6.91	-
DOCOL 1100 M	0.11	0.13	0.23	0.014	0.002	0.03	0.03	0.05	0.02	0.02	0.22

Table 2 shows that the chemical compositions of the two materials are not the same. It is very difficult to select additional welding materials (shielding gases, wires) and the correct process parameters. It is necessary to properly select the right combination of welding parameters (current and voltage, appropriate shielding gas mixtures, as well as appropriate parameters of process speed or preheating temperature) and maintain the right regime during the process in order to ensure a joint with the best mechanical, physical, and chemical properties.

When performing dissimilar welding, attention is usually paid to three factors:

a) choice of electrode wires
b) shielding gas mixtures
c) preheating

The most important general recommendations for separate welding of duplex steel and AHSS steel include [12] ensuring high cleanliness of the joined elements. The surface of the welded steel must be free from grease and traces of paint, rust, and other contaminants that may affect the quality of the weld and the correct selection of electrode wires, ensuring appropriate corrosion resistance and mechanical properties.

Choice of electrode wires

The austenitic wire 309LSi was chosen for the dissimilar MAG welding of super duplex S32750 steel with martensite DOCOL 1100 M steel. The electrode wire was selected based on the popular Shaeffler chart so that the chemical composition of the weld was as close as possible to the chemical composition of the wire. No other electrode wires were tested because the wire selected by the authors met all expectations. This article focuses on selecting shielding gases that give the joint good mechanical properties. Shielding gases do not contradict the suggestions of European directives assuming CO_2 reduction in industrial processes due to the carbon footprint. Neither grade of steel has good plastic properties, so they were welded with 309L Si austenitic wire only (Table 3).

We decided to prepare welding samples that were 3 mm thick without any chamfering. The 309LSi wire diameter in both cases was 1 mm. At the beginning of the welding process, the current and the voltage parameters were suggested:

- welding current: 116.7 A
- arc voltage: 22.4 V

Other important welding parameters were chosen as follows:

- welding speed: 363 mm/min,
- shielding gas flow: 15.2 dm^3/min.

Table 3

Electrode wire–composition

Wire	C, %	Si, %	Mn, %	Cr, %	Mo, %	Ni, %	Ti, %	P, %	S, %
309LSi	0.02	0.85	1.8	24	0.2	14	0.001	0.02	0.02

Shielding gas mixtures

The main aim of this study was to modify the shielding mixture in the MAG process containing Ar with air. We decided to introduce elevated nitrogen and oxygen content.

In line with the adopted assumptions, CO_2-containing mixtures were abandoned in order to reduce the carbon footprint.

The joints were made with several combinations. The most important element of investigation included checking the preheating temperature and selecting the proper shielding gas mixture for the MAG welding process containing:

- Ar-0% air
- Ar-1% air
- Ar-2% air
- Ar-3% air

The CO_2-free gas mixture was selected for technological and environmental reasons in accordance with EU directives, which strongly recommend reducing CO_2 emissions. So far, the process of welding high-strength steels has been based on welding in an argon-carbon dioxide shield for several reasons. The addition of CO_2 affects the shape of the weld and allows a joint with a controlled geometric appearance of the weld to be created, which translates into the transfer of stresses in the structure. Metal inert gas (MIG) welding in pure argon is rarely recommended [6].

Preheating

Preheating before welding both grades of steel is not usually required but may be done depending on the specific application requirements and material specifications. The decision to preheat before welding depends mainly on the following factors [13-15]:

- Material thickness: When welding thick super duplex steel components, preheating before welding can help reduce the risk of deformation and reduce thermal stresses in the weld.
- Avoidance of cracks: In some situations, preheating before welding can help reduce the risk of weld cracks, especially when welding components with complex geometry or prone to deformation

Since the weld thickness was 3 mm, classic welding was done without preheating (ambient temperature 293 K (i.e., 20°C)) and with the preheating temperature of 423 K (i.e., 130°C) before welding. The dimensions of the sample were 300×200×3 mm.

4. INVESTIGATION METHODS

After the welding process, some non-destructive tests (NDTs) and destructive tests (DTs) were carried out to assess the quality of the joints.

These tests were carried out in accordance with standardized test methods described in the relevant standards. The test conditions and samples were prepared and adapted to the guidelines presented in the standards. Therefore, a detailed description of the test process is not given here. Below are the standards that can be followed to reconstruct the test.

Initially, these NDTs were carried out:

- VT – a visual test corresponding with → PN-EN ISO-17638) standard
- MT – a magnetic particle test corresponding with → PN-EN ISO-17638 standard

Then, these DTs were carried out:

- Nitrogen and oxygen amount in weld metal deposit (measured on the LECO ONH836 analyzer)
- tensile strength → EN ISO 527-1 standard

- bending test → EN ISO 7438 standard
- impact toughness → ISO 148-1 standard

5. RESULTS AND DISCUSSION

The dissimilar joints were made using one type of electrode wire, three different shielding gas mixtures, and two different thermal conditions. In total, eight different welds were made, labeled E1 to E8 (Table 4).

Table 4

Samples designations

Sample	Shielding gas	Welding temperature, K
E1	Ar	293
E2	Ar-1% air	293
E3	Ar-2% air	293
E4	Ar-3% air	293
E5	Ar	423
E6	Ar-1% air	423
E7	Ar-2% air	423
E8	Ar-3% air	423

NDTs were performed for all samples (E1–E8) after the welding process. Most of the samples (E1, E2, E3, E6, E7) were defect-free (column rows marked in green), but some samples (E4, E5, E8) were made incorrectly (column rows marked in grey). The NDT results, with comments on the observations during inspection, are presented in Table 4.

It was found that the preheating temperature influenced the possibility that defects would occur. The selection of shielding gas mixture was also important. It was observed that 3% of the air in the gas mixture did not give good results. The next part of the research focused on the air content in the shielding gas mixture, which directly translates into the nitrogen and oxygen content in the weld. We decided to carefully check the relationship between the nitrogen content in the gas mixture and the nitrogen content in the weld metal. For this purpose, tests were carried out on the Leco-ONH-836 device. In this part of the investigation, we decided to check only joints that did not have defects (marked row with green color in Table 4). The nitrogen amount in the dissimilar weld S32750/DOCOL 1100 M is presented in Table 5. It was observed that the composition of the gas mixture influenced the amount of nitrogen and oxygen in the weld. The oxygen content in all tested samples was similar, but an increasing tendency was observed. The nitrogen concentration increased more as the air content in the shielding gas mixture increased.

Table 5

Nitrogen amount in the weld metal

Sample	**Nitrogen in weld metal, ppm**	**Oxygen in weld metal, ppm**
E1	50	355
E2	60	375
E3	65	385
E6	60	370
E7	65	380

Then, we checked the mechanical properties of the samples, assuming that the nitrogen content in the weld would significantly increase the strength. Table 6 shows the tensile strength (UTS) of the joints.

Table 6

Tensile strength of joints

Sample	UTS [MPa]
E1	470
E2	485
E3	502
E6	512
E7	520

The data from Table 6 indicate that it is possible to achieve high tensile strength (of the dissimilar super duplex stainless steel with martensite steel) joint over 500 MPa (table rows marked in green). Next, a bending test was carried out. Measurements were taken from the face and the root sides of the joint. A bending test was performed at ambient temperature. The observation and results of this test are presented in Table 7.

The bending test results were very positive, as very few samples presented cracks. This confirms the beneficial properties of the thin-walled dissimilar joint. In dissimilar joints, it is easier to obtain good strength properties than plastic ones, which is why the bending test result is very valuable.

In the last part of the research, we decided to check the impact toughness of the SD-AHSS joint. However, thicker sheets were needed to conduct impact tests. For this purpose, additional 8-mm-thick joints were made with a V-bevel. The joint was made in a multi-pass manner under similar conditions as before. Then, 5-mm-thick impact tests were made. Impact toughness tests constitute illustrative information because they were performed separately for thicker sheets. The analyzed joints corresponded to the thermodynamic conditions, allowing for the best tensile strength (analogous to Table 6) to be obtained. In total, five different welds were made (Table 8).

Table 7

Bending test of dissimilar weld

Sample	Face side	Root side
E1	No cracks	Small cracks
E2	No cracks	No cracks
E3	No cracks	No cracks
E6	No cracks	No cracks
E7	No cracks	No cracks

Table 8

Sample designations for impact toughness tests

Sample	Shielding gas	Welding temperature, °C
F1	Ar only	20
F2	Ar-1% air	20
F3	Ar-2% air	20
E6	Ar-1% air	130
E7	Ar-2% air	130

Impact toughness tests were performed at -30°C and -40°C to check whether joints similar to SD-AHSS meet impact toughness classes 3 and 4, respectively. In the welding literature, degrees Celsius are mainly used to test impact toughness; Table 9 presents these impact toughness (KV) values in customary units. The test results are presented in Table 9.

The data in the table show that preheating is necessary when good plastic properties are important, as measured by meeting the 4th class of impact toughness. For joints F1, F2, and F3, for which no preheating was performed, impact toughness class 3 was met (i.e., the impact toughness was above the limit of 47 J at a temperature of -30°C), but impact toughness class 4 was not met. For joints F6 and F7, the best plastic properties were obtained, as the impact toughness class 4 was met, and the impact toughness was above the limit of 47 J at a temperature of -40°C.

Table 9

Impact toughness of dissimilar SD-AHSS welds

Sample	KV [J] measured at -30°C	KV [J] measured at -40°C
F1	48	39
F2	50	42
F3	54	43
E6	77	61
E7	62	53

These results confirm that the newly developed method of welding dissimilar joints allows correct joints without welding defects to be made. With properly selected parameters of the roofing process, these joints are characterized by good mechanical properties, as confirmed by the research results concerning impact toughness, tensile strength, banding test, and impact toughness. The positive results of the research provided the basis for creating a prototype of a pillar boom arm, which was characterized by increased length compared to the existing one.

6. PROTOTYPE OF A MODIFIED TRANSPORT DEVICE ARM

The positive laboratory test results provided the basis for adapting the newly developed process of joining structural elements of different types of steel to the real conditions of the production of mobile platforms.

Fig. 3. Preparation of modified profiles

For this purpose, a welded mobile platform arm was made using a newly developed technology. The design takes into account the elongation of the profiles by 30% compared to those used so far, obtaining a 9-m structure in place of the 7.5-m structure (Figs. 3 and 4). In the previous structures made of low-alloy steels, the thickness of the joined elements was about 3 mm higher. If a comparable density of steels is used with steels introduced in the course of modifications to the structure, the weight of the new 9-m structure is comparable to the weight of the previously produced 7.5-m structure. A scheme of the newly developed structure is shown in Fig. 4.

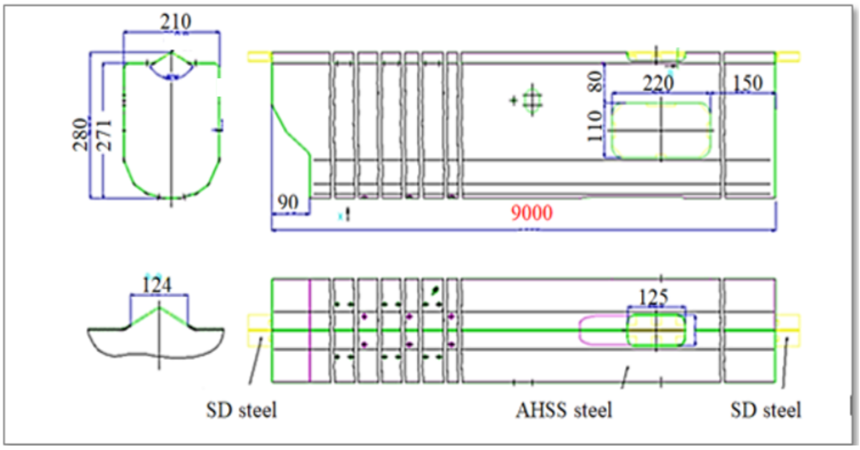

Fig. 4. Extending the column arm by 30% of its previous length

The analysis of the obtained results allows us to conclude that:

- The use of the newly developed welding process allows super duplex and AHSS steels to be successfully joined to make a mobile platform structure.
- The obtained structure (Fig. 4) has been extended by 30% while maintaining the current total weight of the structure in question. The total length of the arm was 9 m.
- The newly developed method made it possible to make a prototype of a welded structure of a mobile platform; thus, it is suitable for making this type of welded structure.
- The method can be successfully used to join various elements made of high-strength and super duplex steels.

A modified device, characterized by a folding, extendable arm, with a total weight that did not increase. The device does not require the dimensions of the vehicle's load-bearing structure to be increased, making it easy to integrate into existing logistics processes without the need to provide additional maneuvering space. In addition, the elimination of a second conveyor device with increased dimensions and weight in the production process reduces the need for floor space. Properly selected equipment in logistics processes ensures that Lean Manufacturing goals are easier for the organization to achieve. The presented solution made it possible to extend the mobile platform arm by 30 % and thus increase its operational range. The solution should contribute to the implementation of plans related to the improvement of logistics processes in the analyzed organization because all the assumptions presented by the company have been achieved. The device has undergone additional certification tests (including stability tests conducted by external companies).

The developed solution can be adapted to other design solutions in terms of modification of transport equipment. However, each time, it requires appropriately selected current-voltage parameters and preheating temperature, which is determined by both the thickness of the walls of the structure and the quality of the material supplied to the process. In the automotive industry, steels used in vehicle production are subject to dynamic changes as manufacturers strive to reduce the weight of vehicles, improve their efficiency and safety, and meet increasingly stringent emission standards. The automotive industry utilizes sustainable and ecological processes and materials. Car manufacturers are increasingly turning to steel that is produced more sustainably (e.g., using renewable energy or with a greater share of recycling). Due to the technology of obtaining steel (often from so-called recycling), the material in the delivered state may differ slightly in chemical composition. The slight differences in the chemical composition of steel are not significant for the quality of steel, but these differences are significant for welding processes. Therefore, welding processes require technological tests and possible modification of welding parameters. These trends show that steel in the automotive industry is evolving towards increasing strength while reducing weight, as well as improving resistance to corrosion and environmental influences.

7. CONCLUSIONS

The presented solution of transport logistics processes combined with the modification of transport equipment, with the use of original inventions, is an important achievement for civil engineering and transport. Dissimilar joints of different steel grades are crucial in the automotive industry. The paper presents the results of the modification of transport machine arms using the new advanced high strength steel and metal active gas welding process. The applied solutions and modifications improved the operational range of the pole boom while maintaining the safety of the structure. The solution was developed for the needs of the industry and was a response to the security requirements regarding the improvement of transport processes of people and goods.

This paper is intended for the automotive industry, where there is an increasing demand for various types of dissimilar SD-AHSS welds. Welding advanced high strength steel with super duplex stainless steel is challenging due to their different physical, chemical, and mechanical properties. It requires special measures to avoid problems such as cracks, deformations and corrosion. Such new material and technological requirements are needed in the construction of electric means of transport. Electric vehicles should be as light as possible and made of materials that are both very durable and resistant to corrosion. In the production of electric vehicles, it is important to respect EU directives and demands regarding CO_2 emissions. Below are the two main recommendations made after the present investigation:

1. The appropriate additional material (welding wire, electrode) with a chemical composition appropriate to connect AHSS with super duplex steel should be chosen. It is recommended to use materials with high nickel and molybdenum content to ensure adequate corrosion resistance and compatibility with the duplex structure. For this reason, we decided to choose austenitic wire.
2. Preheating and interpass temperature should be controlled. AHSS may be sensitive to high temperatures, which may lead to a loss of strength. Therefore, the preheating temperature should be kept to a minimum (usually 100–150 °C), and in the case of super duplex steel, it may be slightly higher but should still be controlled.
   For this reason, preheating at 130 °C was tested.

Both in the construction of motor vehicles and in the broader construction of various types of means of transport, this type of connector will be needed to ensure high-quality products. As noted in the introduction of the article, there is a growing trend of interest in SD steel, AHSS, and dissimilar SD-AHSS connectors in the automotive industry. Dissimilar welding is difficult due to the different structures and properties of both materials when joined. At the same time, we decided to follow EU directives that recommend limiting CO_2 emissions due to the carbon footprint. We decided not to use CO_2 as a shielding gas or as a component of the argon gas mixture. For this purpose, argon and air with variable contents were used as a gas mixture. It is important to carefully select the process parameters. Therefore, for the purposes of this article, eight variants were considered to demonstrate what the preheating temperature should be and what composition of the shielding gas mixture should be treated as the best one. In the beginning, NDTs were performed, which showed that an air concentration that is too high in the argon gas mixture is unfavorable because it causes welding defects and incompatibilities. Therefore, we decided to check the nitrogen and oxygen content in the tested joints as a function of the variable air content in the shielding gas mixture. It was found that the content of oxygen and nitrogen increases with increasing air content in the shielding gas mixture. Then, tensile strength testing was performed only for those joints for which no welding defects or inconsistencies were observed. The results of the tests of the tensile strength of dissimilar SD-AHSS joints showed that it is important to use preheating before welding because it affects the mechanical properties of the joint. Then, bending tests were performed to check whether the joints had good plastic properties. The samples were bent from the face and root sides, and no defects or inconsistencies were found. In order to obtain additional information about the plastic properties of the joint, impact toughness tests were performed. For this purpose, other (thicker) sheets were used but welded in similar conditions as before. Impact toughness tests were performed at temperatures of -30°C and -40°C. Impact toughness tests showed that preheating for dissimilar welding is recommended, which translates into obtaining high class 4 impact toughness for the joints.

In the course of the research, it was found that:

- All welding parameters should be selected very precisely.
- The most important parameters of dissimilar welding are the preheating temperature and the chemical composition of the shielding gas mixture. The best welding results were obtained when the preheating temperature was 130 °C and the shielding gas mixture contained Ar-1% air.

Warehouse lifts bring many benefits, making work in warehouses and logistics centers more efficient. They allow for work at considerable heights, enabling easy and quick access to high-bay storage racks. The lifts move quickly, even with the basket raised, saving time on work. Instead of the costly replacement of the equipment owned by the organization, we decided to modify the lift arm to achieve a greater operational range of the device and eliminate the additional lifting device rented by the company used in the process.

Based on the research, the following conclusions were drawn:

1. It is possible to modify the arm of the transport machine by using high-strength steel profiles and the welding process that has been developed.
2. The connection of high-strength steel profiles into the design made it possible to extend the arm by 30% and, thus, increase the operating range of the transport machine.
3. Using profiles with thinner walls and higher strength compared to the original design made it possible to maintain the total weight of the structure.

An important achievement of the development is the production of a prototype of a conveying device using the newly developed technology of gas-shielded welding with reduced CO_2 content. For environmental reasons, using CO_2 as a shielding gas should be limited due to the carbon footprint.

The presented solution ensures the achievement of the desired structures of transport equipment, taking into account the principles of sustainable development and striving to reduce CO_2 in technological processes.

The solution used to modify the transport means will improve the functionality of this device. The assumed extension of the operating arm by 30% was achieved. A solution was developed to address the need to implement the transport processes of the examined organization.

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