MIG MAG Robot Welding in Research and Education

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Abstract— **As the number of welding experts as well as the cost of automation is decreasing, the application of robotics is gaining significance in this field. The aim of the paper is to introduce the automation of the production of a particular part as a use case for university studies and experimental setup for further research. The part was previously hand-welded, but the increasing annual order number made automation necessary. The paper introduces a new welding jig utilizing a robotic arm.**

Keywords—MIG MAG welding, robot welding, welding design, welding programming, digital education

I. Introduction

As digital education is increasingly gaining ground [1]–[3], state-of-the-art topics like robust engineering solutions [4]–[6], predictive maintenance [7]–[10] or industry 4.0 [11], [12] need new concepts for the structure of the university curriculum. Thus, a further challenge of this aspect is the modification of the laboratories to meet these new requirements.

Welding plays a special role in robotics. Beyond positioning the correct path planning has an extremely large effect on the quality of the seam. The design of the welding jig, choice of the appropriate sensor technology [13]–[15] and the programming of the robot arm is a challenge for education as there are a lot of safety requirements for which a common robotics laboratory is not properly prepared.

The second section of the paper describes the basics of the problem of a welding robot like fixing the workpiece, coordinate systems of the robot arm or welding. The focus of the third section is the design of the welding jig mentioning those topics which might be important in education. The fourth section introduces a simulation environment for robot programming and the updates needed after transferring the program to the robot controller.

II. Problem Description

During the design, the following design steps were done:

- positioning of the workpiece
- design of the welding jig
- programming of the robot

Determining the position of the workpiece is fundamental. When positioning, we must pay attention to fixing the degrees of freedom of the workpiece, which means that it cannot be moved in any direction. Rigid bodies have six degrees of freedom, as shown in Fig. 1. These freedoms are the displacements along the x, y, z axes and the rotation about these axes.

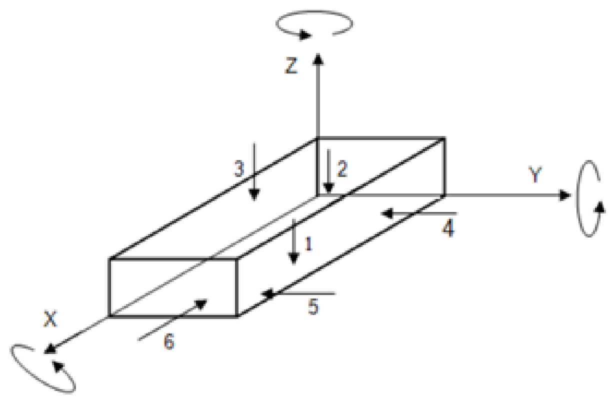

Fig. 1: 6 degrees of freedom [16]

In Fig. 1 we also see 6 points, which symbolize at which points the surfaces of the body are supported and thus all degrees of freedom can be taken away. This way it can be achieved that the body cannot move. In our case, this is a very important factor so that the position of the workpiece is fix in the device in such a way that it does not move in either direction during welding. [16]

After determining the position of the workpiece, the next step was to design the fixation. When mounting, it is important that the part does not move during welding and does not suffer from deformation or surface damage. In addition, it must even be considered that no large surface damage remains in the finished piece in the end, do not have imprints or scratches larger than accepted. When designing the clamp, the surfaces suitable for the clamp must be selected. This depends on the shape of the workpiece, the rigidity, the location of the positioning elements and supports and, in our case, it is also a crucial aspect that the welding robot can approach the paths of the seam.

Solid knowledge of the different coordinate systems used in robot programming (see Fig. 2) is also essential for university studies.

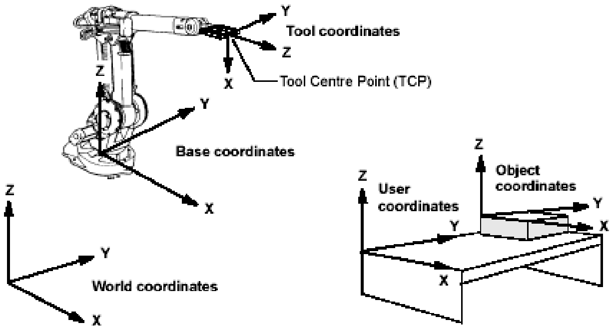

Fig. 2: Coordinate systems [17]

III. Welding Jig Design

The workpiece (see Fig. 3) consists of two parts, a bent "U" profile and a plate. Both parts are made on a laser cutting machine and one is then bent on a bending machine. In the case of welding, the point is that the plate is welded to this "U" profile at a certain height. The first design step is the development of the welding jig. Numerous requirements must be considered:

- main dimensions
- tolerances
- type of welding seam
- location of welding seam

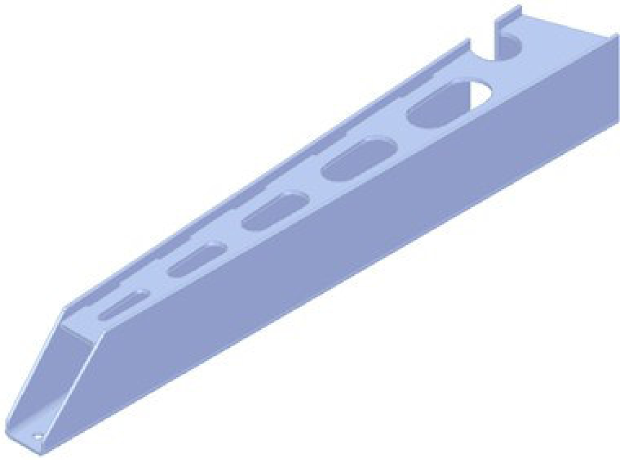
Fig. 3: Workpiece

The whole device is based on a S355MC 10mm thick steel plate, which is a commonly used commercially available material. The seats and bumpers are made of C45 material. The closed section in the middle of the device is a 100x80x4 closed section made of S235JR material. The other two smaller parts of the moving support were also made of S235JR material in a size of 60x20x2. Clamps are used to fix the parts. In order to make both a right-hand and a left-hand piece of the part, which means that the two are mirror parts of each other, a jig has been designed on which both parts can be made at the same time. It was also necessary to have a moving support on which, on the one hand, the plate part was to be welded to the profile and, on the other hand, to hold against the clamps used to fix the part on its side. The table is 1000 mm high and was assembled from 80x80x4 closed sections. The palette is welded to this table (see Fig. 4).

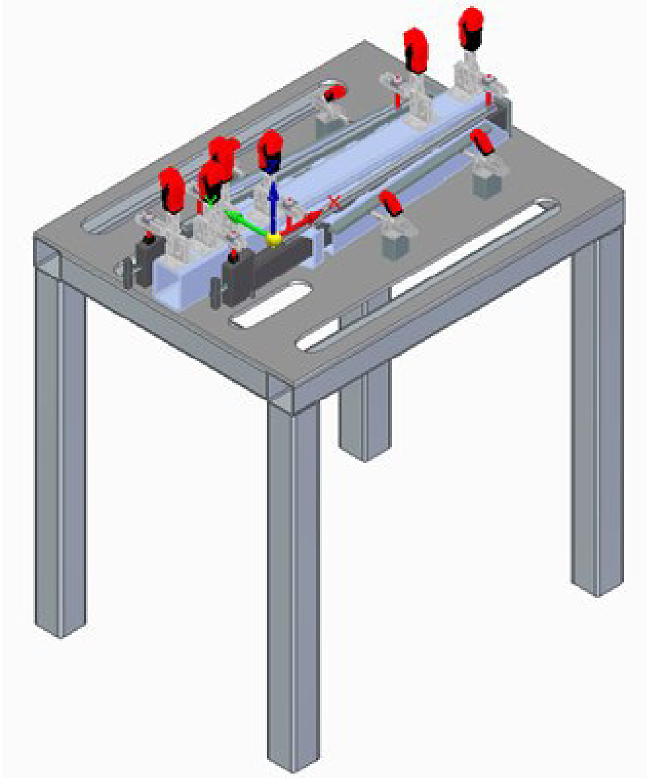
Fig. 4: Welding jig

The first version of the welding jig can be seen in Fig. 5. A common use case of welding jig design can be demonstrated on this part where the moving support is positioned parallel to the central closed section.

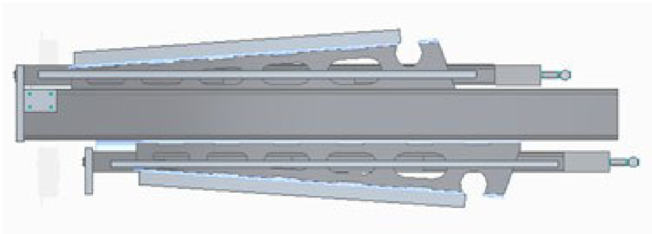
Fig. 5: First version of the welding jig

All the parts are fixed properly considering the first requirement concerning the welding jig, nevertheless the welding robot cannot reach all the necessary positions on the workpiece, therefore it would not be possible to weld. That is why it was necessary to change its position as shown in Fig. 6. For this reason, the front bumper was also milled so that the moving support could collide completely on it. Thus, the robot can make the necessary movements also near the closed section.

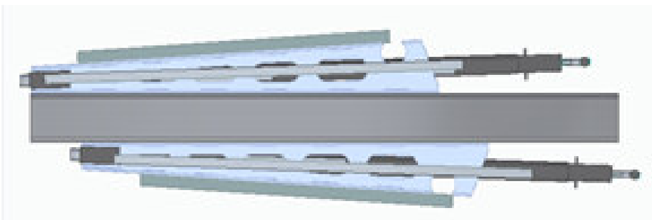
Fig. 6: Second version of the welding jig

IV. Testing in Simulation Environment

3D simulation program called Roboguide was used as simulation environment. In this program we can program the robot and test the finished robot programs in a safe simulation environment.

The program was used for two goals. The first goal was to make sure that the device is suitable in the sense that the robot will have access to all the parts that need to be welded and there will be no collision with the device anywhere. The most problematic position of the welding jig from this point of view is the farther side of the workpiece. Fig. 7 shows that this is accomplished and there is no collision.

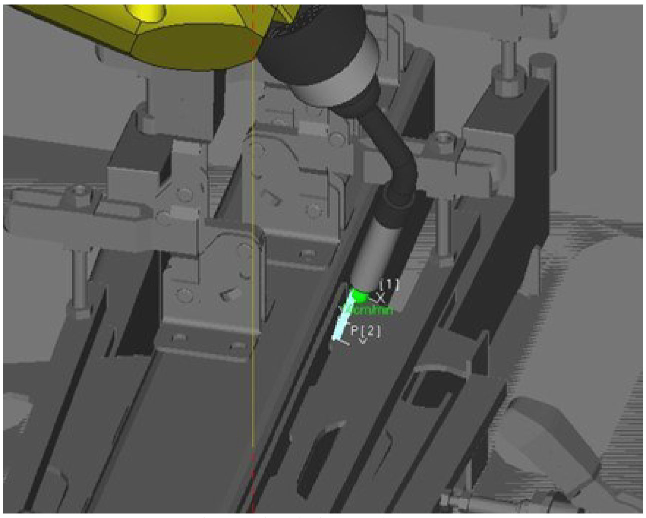

Fig. 7: Simulation environment

Fig. 8 shows an error code. This error code was encountered several times during testing. It means the robot supposed to move to a point it could not reach. That was why there was still a bit to adjust on the device or the position of the device. When placing the device, it was designed in the robot cell, care must be taken to ensure that the robot arm reaches every point to be welded.

Fig. 8: Error code

The second goal was to program the robot in the simulation environment. The purpose was to implement the welding sequence in a safe environment. The possible collisions or bad seams are not crucial in a virtual environment. After this step, the program can be transferred to the real robot controller, where only the relevant position registers must be updated for the real environment of the robot cell. Then the program must be run in test mode and it must be checked that everything runs properly and there are no collisions.

For the programming, the teach in method was applied from point to point and recorded each point for the robot, making sure not to collide with the elements of the device. Since the program was ready in advance, it was easy to update the program. Nevertheless, there were questionable cases where the robot movements were repeatedly run between two points to see if it is possible to fit in the given tight spaces.

Programming was started by setting the basic data. The robot controller is built so that the welding parameters, such as current, voltage, wire feed speed etc., can be set and they are saved in a so-called JOB which can be called during programming to set the predefined parameters.

V. Conclusion

The paper introduced a use case for robotic welding design with educational and research purposes. The design process can be presented form the first steps till the working robot cell starting from a computer laboratory and finishing in the workshop. The proposed environment facilitates the education of several engineering field. The paper introduces a curriculum for the following topics:

- fixing 6 DOF of a workpiece
- coordinate systems in robotics
- welding jig design
- robot programming in simulation environment
- application of the simulation results in the real robotic environment

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