Automated assembling of single fuel cell units for use in a fuel cell stack

C K Jalba¹, A Muminovic¹, C Barz² and V Nasui²

¹Ulm University of Applied Sciences, Production Engineering and Production Economics, Prittwitzstraße 10, 89075, Ulm, Germany
²Technical University of Cluj-Napoca, North University Centre of Baia Mare, Victor Babes str., no. 62A, 430083 Baia Mare, Romania

E-mail: klausjalba@t-online.de

Abstract. The manufacturing of PEMFC stacks (POLYMER ELEKTROLYT MEMBRAN Fuel Cell) is nowadays still done by hand. Over hundreds of identical single components have to be placed accurate together for the construction of a fuel cell stack. Beside logistic problems, higher total costs and disadvantages in weight the high number of components produce a higher statistic interference because of faulty erection or material defects and summation of manufacturing tolerances. The saving of costs is about 20 – 25 %. Furthermore, the total weight of the fuel cells will be reduced because of a new sealing technology. Overall a one minute cycle time has to be aimed per cell at the manufacturing of these single components. The change of the existing sealing concept to a bonded sealing is one of the important requisites to get an automated manufacturing of single cell units. One of the important steps for an automated gluing process is the checking of the glue application by using of an image processing system. After bonding the single fuel cell the sealing and electrical function can be checked, so that only functional and high qualitative cells can get into further manufacturing processes.

1. Introduction
A fuel cell is a galvanic cell which converts the chemical reaction energy of a continuously supplied fuel and an oxidizing agent into electrical energy (Figure 1).

While a lot of heat is generated during the oxyhydrogen reaction (Figure 2), the reaction between oxygen and hydrogen can be controlled in the fuel cell (Figure 3). As a final product, is generated in the fuel cell in addition to water and heat electrical energy.
Figure 1. Functional principle of the fuel cell [1]

Figure 2. Boiling gas reaction [1]

Figure 3. Controlled electrochemical reaction in the fuel cell [1]
The strength of fuel cells lies in the high-energy density compared to other power storage units. This explains the early interest of the military and space travel in this technology.

Governments are now also interested in the development of fuel cells for ecological reasons. For this reason, projects for the further development of this technology are also being provided in Germany. An institution that is involved in this development is the Center for Hydrogen Technology and Solar-Technology (ZSW) in Ulm, Germany. One of the Daimler Research Centers is also located in Ulm and cooperates intensively with ZSW [2].

Daimler developed prototypes of smaller vehicles with fuel cells, which are already available in series; aim to test the size, the weight and the cost of the fuel cell and the appropriate storage of the hydrogen. Daimler presented for example the A-Class and B-Class vehicles with fuel cells (Figure 4). In Hamburg and Stuttgart, hydrogen-powered buses are tested in normal operation.

Fuel cell technology is at a relatively early stage. In order to replace this technology in the long term with other technologies such as the internal combustion engine, fuel cells must become considerably cheaper.

Figure 4. Fuel cell vehicle, Mercedes C-class

Figure 5. Assembly line for fuel cells [3]
Because the production of polymer electrolyte membrane (PEM) fuel cell stacks was largely done manually and because it was assumed that by the large number of components, assembly tolerances or material errors had to be expected a higher statistical susceptibility and therefore could cause higher processing costs, one of the aims of this project at the University of Applied Sciences in Ulm, Germany in cooperation with ZSW, was the development of automated manufacturing processes with robots for the medial sealing of membrane electrode assemblies (MEA) with bipolar plates to single cell units. On the other hand, was the next aim the optimization of economic production of fuel cells and quality control by industrial image processing. The individual cells produced and tested in this way should be stored in magazines or provided on assembly carriers (Figure 5) [2].

The first part of the research project describes assembling solutions and the automatic production of individual cells under robotic use. The second part of this paper describes economic advantages and benefits with the new production method.

2. Assembling fuel cells
A fuel cell consists of the following components:
- Electrolyte (membrane), which provides ion transport and separates anode and cathode.
- Electrodes; here take place the electrochemical reaction.
- EME (Electrode Membrane Unit): "heart" of the fuel cell.
- Gas diffusion layers; are necessary for the supply and distribution of the reaction gases.
- Bipolar plates; are fine channels in the plates and ensure the supply and distribution of hydrogen and oxygen. In addition, they serve as "electron-collectors".

![Figure 6. Parts of a 6 V fuel cell stack [3]](image)

![Figure 7. Glue bead with robot [4]](image)
In the case of stack mounting, firstly is positioned the base plate. At next is assembled a current tap plate. Depending on the size of the fuel cell, the individual cells are then mounted. Thereafter, a further current take-off plate and an end plate are mounted (Figure 6).

By the laboratory tests were used the weight and cost-saving direct adhesive application (Figure 7). The individual cells must be separated from each other by adhesive beads. The sealing function of fuel cells can be done either by a metal carrier with sealing beads or by application of the sealing beads directly to the main components.

For this purpose, was used a dispenser system for applying the adhesive seal (Figure 8). The dispenser system was integrated into the robot cell. For quality control was installed an image processing system with camera and PC.

![Dispenser system for applying the adhesive seal](image)

**Figure 8.** Dispenser system for applying the adhesive seal [3]

For the adhesive hardening, final component inspection and further assembly to finished stacks was implemented a conveyor with carriers and an identification system (Figure 5).

Due to these technical measures were made a lot of modifications: to adapt the grippers, to change the programs from the integrated PLC and the sensor technology and to modify the valve control.

The integrated image processing allows, for example, that boards with a defective glue bead have to be removed before the stack is mounted [5], [6]. The height of the adhesive must not exceed 0.7 mm and must be uniform. Otherwise, problems arise with the joining and the tightness of the cell.

The system allows also through the implementation of the identification unites and the optical recognition system the documentation of every single cell or leakage test result. But also can provide data to create statistics for the general evaluation of the production process: the number of produced cells, required time for each assembly cycle, statistic about failure parts, etc. [7-9].

The complete assembly process from the material supply carrier to the fuel cell stack was led from an industrial robot. It was used a KUKA KRC-15/2 Robot with a gripper change system, a linear gripper and a suction gripper.

The layout of the robot station (Figure 9 and 10) shows the transfer cycle with the material supply and the transport route for mounted fuel cell stacks.
In the tests, it was found that the assembly of the metal seal (Figure 11) is unnecessary when the adhesive bead is applied. The metal gasket does not increase the tightness of the fuel cell. Thus, the production becomes more economical.
Figure 11. Supplying the robot with fuel cell parts

The following table shows the material cost difference of the mounted cell with and without metal gasket (Figure 12).

Figure 12. Additional costs for the assembly of metal gasket

Depending on the size of the cell, the material costs of the metal frame cover are up to 25 percent of the other parts of the fuel cell. In addition, there is the separate supplying of the sealing frames in the mountings as well as the required assembly time.

3. Conclusions
The tests performed showed that fuel cells and fuel cell stacks can be mounted with industrial robots. With the developed robotic station, can be assembled even smaller production units. For larger units is recommended to produce with more assembling robots. For fast movements like peak and place movements can be used 4-axis SCARA Robots.

Through the use of the described automation and savings on the product (removal of the metal support gasket), the production can be more economically. In the case of very large unit numbers, shorter assembly times as well as lower material costs lead to competitive advantages and price reductions of the end products.
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