FIT-4-AMANDA

Future European Fuel Cell Technology: Fit for Automatic Manufacturing and Assembly

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Approved by	Dr. Anna Molinari (UNR) – Project Coordinator	2017-06-15
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Publishable Executive Summary

Fuel cell technology has shown its ability of being a reliable energy source for stationary, maritime and mobile applications. By its use, energy supply can be realized without CO_2 and particle emissions and without wasting fossil resources. One of the major obstacles for a break-through of the fuel cell technology in the mobile application field, however, is related to their relatively high costs in relation to well established fossil based energy sources, such as gasoline or diesel based drives trains. This is mainly due to the use of non-standardized components, whereas the production of which is often not automated and hence expensive. The problem can be identified on multiple levels: electrochemical active components of the fuel cell stack, peripheral components of the fuel cell system, and eventually on the level of stack- and system assembly.

In mass manufacturing, one of the key factors for cost-effective production of any goods is related to effects of the "economy of scale" and the ability of producing high quantities in short time at appropriate quality. Mass manufacturing is defined as the production of large quantities of the same products using interchangeable, standardized parts and assemblies for a non-predetermined period of time. For this, extensive machinery in the form of extremely specialized production lines are needed.

The major aim of the Fit-4-AMandA project is to establish a manufacturing machine with an automation grade of more than 90% capable of producing ready-to-operate fuel cell stacks in one assembly line at a theoretical quantity of >10'000 Stacks/year. With a manufacturing capability like this, the production- or processing costs of a fuel cell stack is believed to be lowered by more than 75% to a level that is competitive with the established technology in the market (detailed numbers see proposal).

Work Package 2 ("Redesign current stack and stack components for mass production and design-to-cost") with its goal of a redesigned stack PM400 (to achieve lower cost and higher manufacturability) is the prerequisite for designing a fully automated manufacturing machine. The stack component redesign will be followed by a product validation process to ensure the specified stack performance is met.

The consortium has identified critical stack components (listed below), which have to be redesigned to decrease the time and effort required in stack assembly, specifically piling/stacking of individual cells. The redesign is mainly influenced by the physical capabilities of the mass manufacturing machine (MMM), which will be developed by USK. Secondly, key components for cost reduction have also been identified.

This work has to be performed in parallel to Work Package 1 ("Definite setting of the technical requirements"), focusing on the review of the technical specifications of PEM fuel cells and currently available business studies. Cross interference of both work package will result in an optimal mass producible stack with enhanced performance.

As the first step, it is of utmost importance to define the specifications for an automated stacking machine. These specifications result from the technical parameters of the stack PM400 and its core components, as well as from the requirements of the targeted mobile application. This collection of specification data is the core of the deliverable D2.1.

Combining a consequent design-to-cost and design-to-manufacture approach while maintaining the very high quality standard of the core components and the stack assembly is one of the major challenges at this point. However, at this stage it is not necessary to fix properties regarding the final performance of the stack, as there would be parameters such as lifetime degradation or power characteristics. It is rather parameters concerning the outer dimensions and shape, as well as the basic stack design in terms of number, kind and processing method of components, which have to be defined at this stage. Due to the large number of parties involved in this process and the high impact of the deliverables onto the final machine, great care and high accurateness is crucial at this step.

The result of the deliverable is the specification of the stack parameters, on which then machine design has to be based. The most important points at stack level are:

- stack size / number of cells
- footprint of the cells (outline)
- thickness of the bipolar plates
- bipolar plate material
- bonding / joining method of anode and cathode half plate
- CCM/GDL concept (die cut CCM and FAST GDL and 7-layered MEA with sub-gasket)
- sealing concept of the active area (Anode <-> GDL/CCM/GDL <-> Cathode)
- dimensions of the MEA and active area
- design of MEA and BPP (areas for robotized handling/grabbing)
- restraining concept
- concept of current collectors

Not directly related to the final stack design, but also important points of interests are at this stage are the following topics, which have also been defined in this document:

- solution for component supply (packaging, protective sheets)
- diagnostics for reject parts and faulty assembly
- possible FAT procedures of the final stacks
- space requirements of the machine vs. available space at the production facility
- automated application of tracing codes

The results of the deliverable are the basis for the next steps in Work Package 4 (“Development, Manufacturing and Testing of technology and machine system for the automated assembly of fuel cell stacks”) with its main goal to develop the automated mass manufacturing machine. Also it will be of strong influence of the further progress of WP 1 and the deliverable D2.2 of WP2, allowing to reach the milestones MS1.1 (“Specifications and technical requirements for WP2,3,4 defined”) and MS2.1 (“Redesigned stack prototype meeting new specifications related to costs, manufacturability and mass production”).

Contents

1. Introduction

The target of this document is to define the specifications for an automated stacking machine (plant), resulting from the technical parameters of the Proton motor stack products. The following bullet points describe the recommendations to the mass manufacturing machine as an obliging outline:

- Although the Project Fit-4-AMandA targets only the stack PM400 for a later use in a mobile fuel cell system, the plant is supposed to cope with both Proton Motor stack formats: PM200 V6 (current PM product) and PM400 V4 (in development).
- The subassembly „Bipolar Plate“ (BPP) is supposed to be jointed in the plant, whereas the respective bonding process of both half plates is not defined in detail yet (task Proton Motor).
- As a target of the project F4A a 7-layer “Membrane Electrode Assembly” (MEA) of EWII will be used, which features a ready-assembled membrane and gas diffusion layer. The corresponding sealing solution between this MEA and the BPP is not existent yet and needs to be developed by Proton Motor.
- As a fallback solution, the plant is supposed to cope with the PM standard technology, which does not feature a 7-layer MEA. Here, the MEA subassembly must be assembled in the plant, whereas the „Catalyst Coated Membrane“ (CCM) and the „Gas Diffusion Layer“ (GDL) need to be jointed. This process must be wheather- or environment independent.
- The plant is supposed to stack the subassemblies BPP and MEA (= 1 cell) up to the defined stacking size/height. At the moment, these are 96 cells, which is also the F4A project target. If possible, the option for stacking 240 cells should be considered for future stack developments.
- During the stacking process another component is supposed to be added in a cell: the voltage tapping. For this, a respective cavity is provided in the BPP. This step can be done during stacking of the stack, or during handling of the BPP half plates in the BPP bonding process.
- The plant is supposed to finish the stack with the „End Plates“ (EP), which comprise the media connectors. This subassembly needs to be fitted to the stack with a defined clamping force and fixed with a tie rod system.
- In addition, the plant must be capable of fixing a so called „Anode Module“ (AM) to the upper EP, which comprises the most important sensors and actors of the hydrogen media loop.
- In-Line testing for quality assurance needs to be performed by the plant. Following tasks have been identified to be of importance:
  - 100% testing of BPP half plates for hair cracks (before bonding process)
  - 100% testing of gas tightness of BPP subassembly (after bonding process)
- An End-of-Line test under operation with hydrogen has been defined not to be part of the plant, since the operative effort would be far too high. An integration of a full sized test bench operating on hydrogen into the plant – which would be necessary – will go beyond the available resources of time, money and space. Reasons are:
  - End-of-Line testing is time intensive (>1h), it significantly exceeds the targeted cycle time for stack assembly. Thus, a number of parallel working End-of-Line test benches need to be operated following stack assembly to maintain the target of 10’000 stacks/y. This cannot be realized in one plant.
  - What happens if the test fails? The plant is not capable of disassembling the manufactured stack, or “repairing” it. This has to be done in a post processing station anyway. Hence, there is no advantage of integrating the End-of-Line test into the plant.

The hard technical details of the stack, its components and its assembly processes are confidential data and property of Proton Motor. They are being shared with USK on a basis of the NDA and the related Consortium Agreement, but shall not be made accessible to the public. Hence, they are integrated into a confidential appendix to this document, which will be submitted separately.

2. Technical

2.1 Space requirements

The following figure provides the available space in the Proton motor Production facility. It becomes obvious, that ca. 150m² are available for setting up the plant. The room height is approximately 4m. This will eventually be needed, since the necessity of stacking a stack version of up to 240 cells is desired, and the electric cabinets as well as the acclimatization module will most likely be mounted on top of the assembling modules.

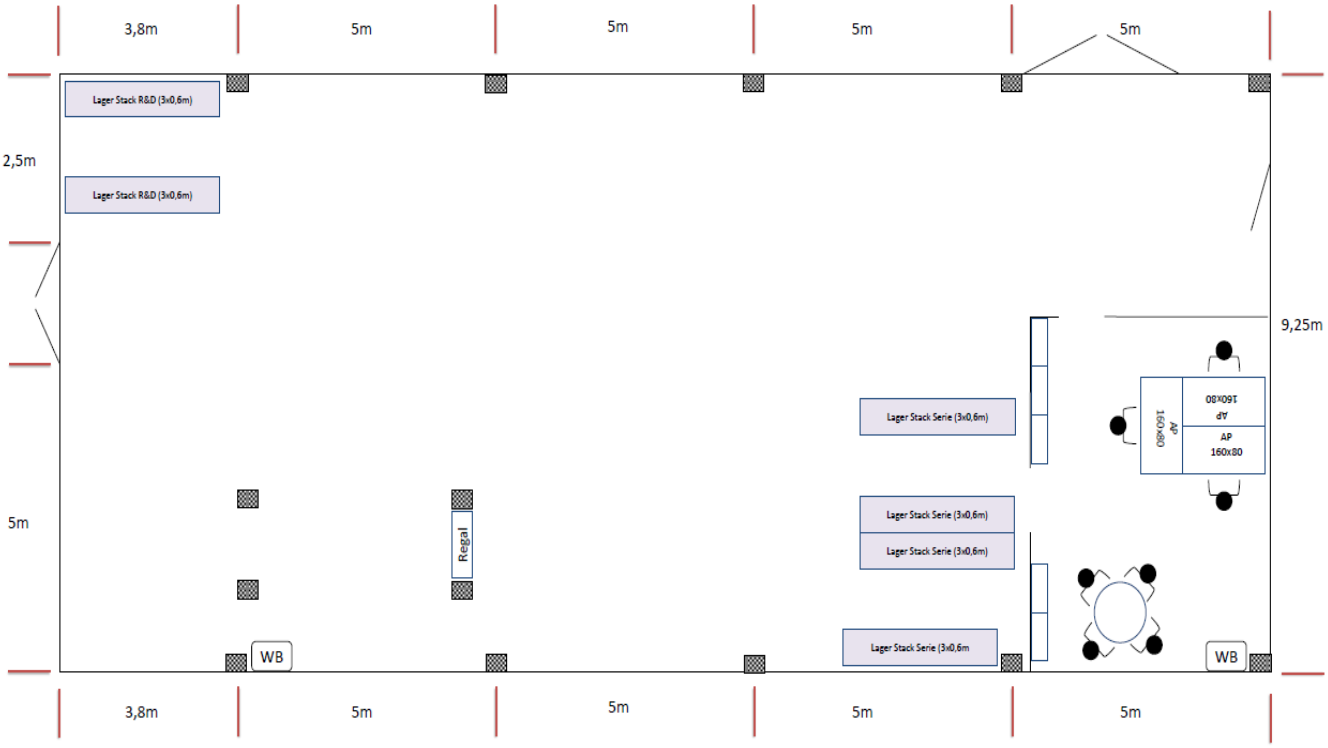

Figure 1: Ground plot of the available space at the Proton motor Production facility

Based on D4.1, some suggestions have already been made by USK on how the plant could be designed according to the requirements of the PM stack technology. These are distinguished by using one or two robotic grabbers, respectively, leading to faster or slower cycle times for cell stacking.

Theoretically, both estimations allow for the targeted quantity of stack output. However, only the stacking procedure is accounted for here. The bottleneck might later be the bonding- and testing procedures, leading to significantly higher times for cell assembly than 5 or 10 seconds. Also the space requirement is yet to be completed with the peripheral modules of the plant (energy supply, acclimatization, connections, etc), which are not shown in the figures.

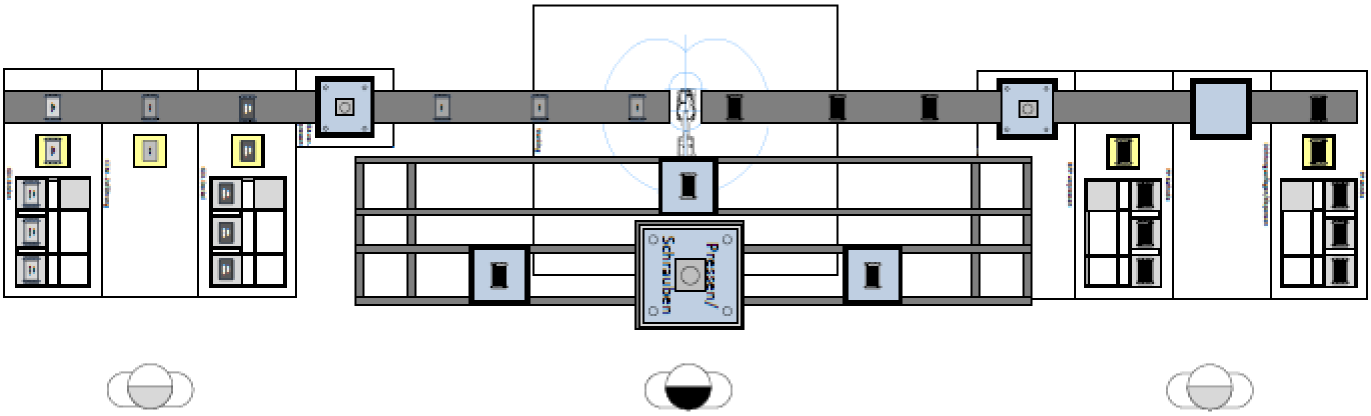

Figure 2: USK draft plan of plant based on 1 robot → 10 seconds for stacking a cell

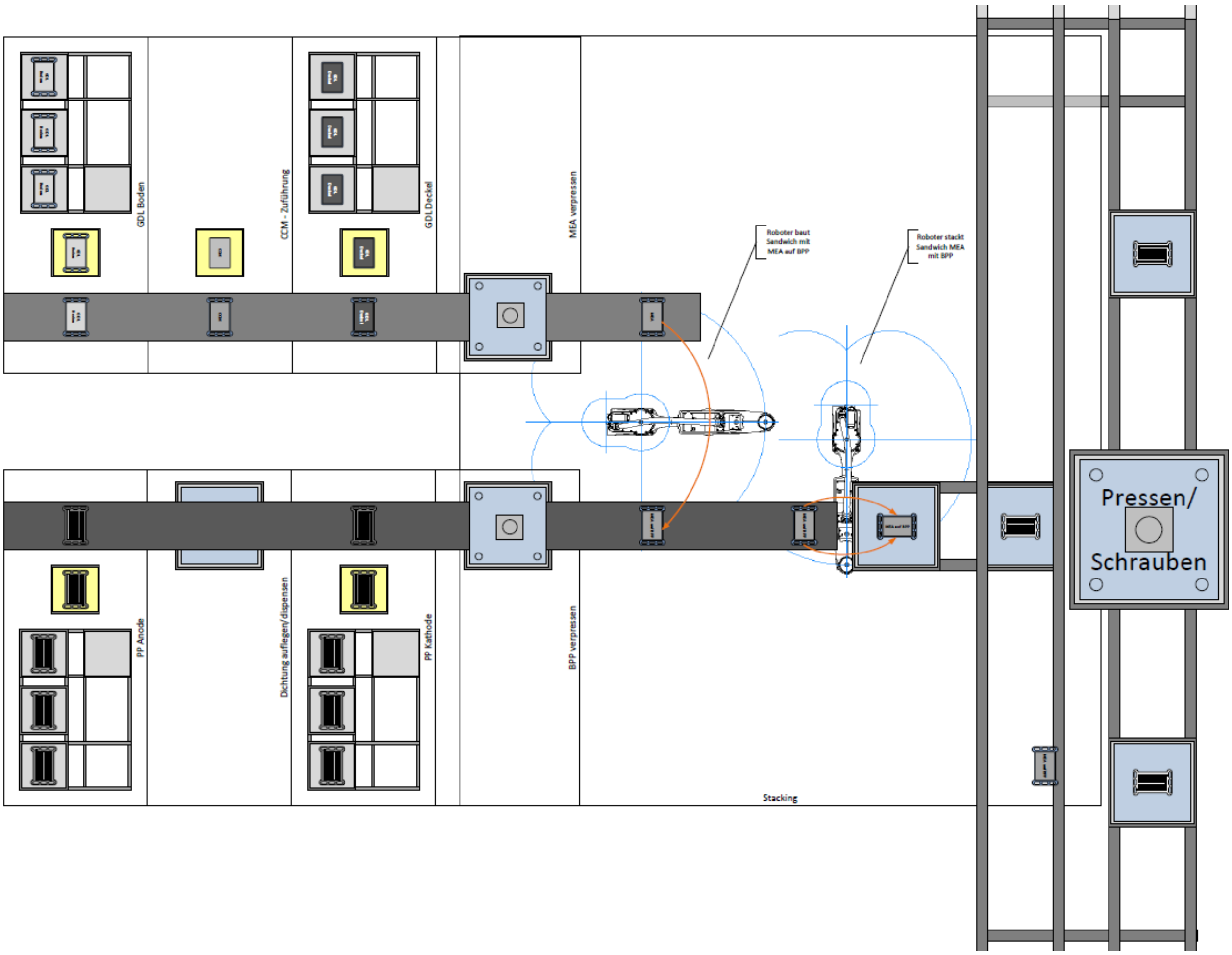

Figure 3: USK draft plan of plant based on 2 robots → 5 seconds for stacking a cell

2.2 Open Technical Points

A number of technical processes or parameters for the stack assembly are still unsolved. Mostly, these are the points in which the Proton motor stack design had to be changed from its today's standard to fit an automated process in the machine, or to achieve a certain cost down. Proton Motor has to invest in resources to achieve technical solutions for these points until the due date of D2.2 in November 2017.

These points are:

- a MEA sealing is to be developed, to be able to process the EWII 7-layer MEA (not PM standard)
- a BPP bonding procedure needs to be developed, which is quick-hardening (e.g. UV-sensitive) and detachable (not PM standard)
- the concept for integrating the voltage tapping is to be validated (not PM standard)
- plate springs need to be integrated into the end plate subassembly instead being part of the tie rods as today
- rim BPP need to be combined with the current collectors, otherwise a time intensive "sorting step" needs to be inserted into the material supply process
- the PM200 stack concept (today: Z-flow w/o anode module) needs to be adapted to the PM400 style: U-flow, anode module, voltage tapping, etc.
- unclear if an alignment feature has to be created for joining the GDL and die-cut CCM (PM Standard), since the hinge of the GDL will not be part of the stack design optimized for automated production.
- TUC has to develop a method for hair crack detection in BPP half plates
- TUC has to develop a method for gas tightness testing of the bonded BPP modules
- the part suppliers have to implement tracing features on their parts

3. Risk Register

Risk No.	What is the risk	Probability of risk occurrence	Effect of risk	Solutions to overcome the risk
1	functional requirements of stack cannot be reached with necessary modifications on stack design	low	high	more resources in redesign of stack
2	validation shows that modifications on stack technology do lead to less stack performance	medium	medium	flexible machine design, more resources for machining processes,
3	bonding procedure for BPP does not work	medium	high	more time resources for redesign of solution
4	sealing concept for MEA does not work	medium	high	more time resources for redesign of solution
5	Plant will be too large to fit the PM production premises	low	medium	reasonable outsourcing of tasks like End-of-Line tests, or splitting of plant
6	automated processes in the plant will lead to high number of defective parts/components	high	low	careful re-adjustments of the respective processes
7	setup of plant according to specifications will take more time than planned	medium	low	intensify the communication between USK and PM
8	the plant suppliers do not implement tracing features on their parts, or the parts grow expensive due to this feature	medium	low	rework the overall tracing concept

4. Acknowledgement

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Project partners:

#	Partner	Partner Full Name
1	UNR	Uniresearch BV
2	PM	Proton Motor Fuel Cell GmbH
3	EWII	EWII Fuel Cells A/S
4	USK	USK Karl Utz Sondermaschinen GmbH
5	Fraunhofer	Fraunhofer gesellschaft zur foerderung der angewandten forschung E.V.
6	TUC	Technische Universitaet Chemnitz
7	UPS	UPS Europe SA

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