Production and automation for fuel cells and components

R&D supporting industrial processes

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Development focus cost reduction: Manufacturing and assembly

Manufacturing Targets & Challenges

Final Assembly
- Standard assembly processes
- Easy and fast assembly
- Standardized components
- Industry known activities

Stack Assembly
- Stapeling processes
- Low stack up tolerance
- Low rework rate
- Leak tight assembly

MEA and Bipolar Plate Manufacturing
- Well formable materials
- Fast curing polymers
- Robust parts against handling damage
- Fast coating technologies
- Robust joining technologies

Keywords:
- standard
- easy
- fast  → cost
- robust  → quality

source: Dr. Dieter Steegmüller, Daimler, F-Cell 2011
Development focus cost reduction:
Key factors for reliable fuel cell products

A fuel cell stack is built using $10^2 - 10^3$ parts

For market penetration of fuel cells in significant numbers standardised, easy, fast and robust production is essential, meaning:

- High quality of the single component
- Reduction of the human influence factors
- Reaching reproducible pieces and products
- Including traceable parts
- Full documentation, verification
- Product Lifecycle Management
- Topics of recycling have still to be addressed
Component production: Membranes, GDL, MEA

- Catalysts layer is printed on GDL or membrane
- Hot pressing / bonding / laminating of GDL and membrane is standard
- Sub-gaskets are standard for series products
- Sub-gaskets help optimising automation and increase life time of fuel cell stacks
- Roll to roll processes are established at MEA manufacturer sites worldwide

source: Coatema Machinery GmbH
source: Honda 2010 (T. Brachmann / Hysys)
source: 3M Deutschland GmbH USA, 2011
source: Youtube / Ballard PowerSystems (Ballard, 2012)
source: Youtube / Province of BC (Mercedes / Burnaby 2012)
Component production:
Gaskets

- Gaskets are necessary on MEA side, cooling side and at the media connectors.
- Most crucial is the sealing at the MEA:
  - Gasket as part of MEA (Freudenberg Fast GDL, 9 layer MEA etc.)
  - Gasket on bipolar plate (printing, dispensing, injection moulding)
Component qualification: Gaskets

Batch wise
- chemical stability of material
- material leaching of components
- adhesion

During processing
- viscosity
- supervising contour

After processing
- form, geometry, placement
- height, tolerances

offline 3D analysis

Line scan: quick check of geometry
Component production: Bipolar Plates

- Bipolar plates are the mechanical cell frames and the main media carrier.
- Two main technologies: metal or compound plates.
- Compound plate production:
  - Hot pressing
  - Rolling
  - Milling
  - Injection moulding

Source: GrafTech, Danan, Schunk, Eisenhuth, ZBT.
Significant parameters influencing the quality of the bipolar plate are:

- material
- cooling time
- injection volume flow
- ejection speed
- temperature of form

Inline quality observation by

- analysis of machine & process parameters
- article analysis

Source: IPE/ Uni DUE
Quality assurance inline to the production process

- optical fault detection allows contact-free analysis of components
- reflexions caused by lateral side / dark field illumination
  → surface quality and hair cracks
- laser line illumination → thickness profiles
- quality characteristics:
  - sprue brim
  - overall dimensions, thickness, planarity/parallelism
  - flow field structure
  - burrs, capillary cracks
  - groove depths
- fast and secure process (Cycle time 4.3 sec.)
- 100 % testing is possible
Quality assurance batchwise in parallel to the production process
example bipolar plate & gaskets

Ex-situ accelerated ageing (H$_2$SO$_4$ @80°C or H$_3$PO$_4$ c=85% @ 180 °C)

Mechanical testing

Surface properties

Electrical characterization

Permeability testing
Traceablity
example bipolar plate

- Traceability refers to the completeness of the information about every step in a supply chain
- **Step 1**: Recording of any relevant process and material data
- Data base structure and route cards are essential
- For feedback and for analysis of fault causes in the final product clear production numbers are essential
- **Step 2**: Marking / signing of components
  Data Matrix Code or Real Numbers / Text
Stack production
Cell and Stack assembly

- Stacking of cell components
  - MEA
  - Gaskets
  - Bipolar plates / halfplates
- End-Plate Integration
- Compression / Fixing
- Approval

source: Youtube / ProvinceofBC 2012
source: Youtube / BallardPowerSystems 2012
source: KuKa / ZSW ~2007
source: Honda 2010
source: FIX / ZBT 2011
source: Honda 2010

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Assembly of Stacks  
dependent from bipolar plate technology

- Option 1: A bipolar plate having anode gas channels on one side and cathode gas channels on the other side
  - usually with metal foil plates (welded)
  - bonded half plates
  - real bipolar plates without cooling
- Components Plate, Gaskets, MEA have to be stacked individually
- Handling of MEA and pliable parts is difficult

![Diagram of Assembly of Stacks]

Halfplate  |  Cathode Flow field  |  Bonding, Gaskets etc.
Halfplate  |  Anode Flow field  |  MEA
Assembly of Stacks
dependent from bipolar plate technology

- Option 2: Two Halfplates form one single cell
- Advantages:
  - The cell can be riveted / fixed
  - The cell can be tested individually regarding leakage
  - Stack assembly manual possible
Assembly of Stacks

Traceability and quality testing in production process

1. **Traceability**
   - BPHP kennzeichnen

2. **Traceability**
   - Zwei BPHP aus Magazin entnehmen

3. **Traceability**
   - Zwei BPHP auf WT setzen

4. **Traceability**
   - Flow-Field - Dichtung drucken

5. **Traceability**
   - Dichtungs - geometrie - kontrolle

6. **Traceability**
   - Flow-Field - Dichtung aushärten

7. **Traceability**
   - O-Ring Dichtung dispensen

8. **Traceability**
   - Dichtungs - geometrie - kontrolle

9. **Traceability**
   - O-Ring - Dichtung aushärten

10. **Traceability**
    - Materialprüfung Verwendungszeitkontrolle

11. **Traceability**
    - Temperatur - kontrolle

12. **Traceability**
    - Übergabe an Bereich Zellmontage / Magazinierung

13. **Traceability**
    - Zwei BPHP auf WT setzen

14. **Traceability**
    - Eine BPHP um 180° wenden

15. **Traceability**
    - Eine MEA auf BPHP auflegen

16. **Traceability**
    - Einzelzelle bilden

17. **Traceability**
    - Zelle mittels zweier Nielen fügen

18. **Traceability**
    - 1. Endplatten - BG mit Gewinde - stangen zuführen

19. **Traceability**
    - 2. Endplatte - BG zuführen

20. **Traceability**
    - Stack entnehmen (manuell)

**Gasket assembly**

- Zwei BPHP um 180° wenden
- O-Ring Dichtung dispensen
- Dichtungs - geometrie - kontrolle
- O-Ring - Dichtung aushärten
- Materialprüfung Verwendungszeitkontrolle
- Temperatur - kontrolle
- Übergabe an Bereich Zellmontage / Magazinierung

**Cell assembly**

- Zwei BPHP auf WT setzen
- Eine BPHP um 180° wenden
- Eine MEA auf BPHP auflegen
- Einzelzelle bilden
- Zelle mittels zweier Nielen fügen
- Übergabe an Bereich Stackmontage / Magazinierung

**Stack assembly**

- 1. Endplatten - BG mit Gewinde - stangen zuführen
- 2. Endplatte - BG zuführen
- Stack entnehmen (manuell)
- Stack magazinieren (manuell)

**Notes:**
- BG = Baugruppe
- BPHP = Bipolarhalbplatte
- MEA = Membrane - Electrode - Assembly
- WT = Werkstückträger

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Bipolarplatten kennzeichnen
Ein- und Ausschleusung Bipolarplatten
Flow-Field-Dichtung drucken
Flow-Field-Dichtung aushärten
2 Bipolarplatten wenden
O-Ring-Dichtung dispensen
O-Ring-Dichtung aushärten
Übergabe und Einschleusen Bereich Zellmontage
1 Bipolarplatte wenden
Auflegen einer MEA und Bilden einer Zelle
Zelle zu einer Einheit fügen
Übergabe an Bereich Stackmontage/ Magazinierung
Montage und Prüfung des Stacks

ZBT production technology development: Layout of the prototype production line at ZBT
Summary and cooperation offer

- Automated production is a key factor for quality in fuel cell production
- Only at significant numbers it is also a cost factor
- Inline process control and traceability concepts ensure production quality
- Different steps of component and stack production have been demonstrated and are available for industrial use
- ZBT as R&D provider is able to assist on production analysis
- Prototype production line to develop production processes for automated series production is available
- Main targets are low cost production, high quality, repeatability and traceability
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