DIGIMAN

DIGItal MANufacturing and Proof-of-Process for Automotive Fuel Cells

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Project Overview

- Call year: [2016]
- Call topic: [FCH-01-1-2016 Manufacturing technologies for PEMFC stack components and stacks]
- Project dates: [01/01/2017 – 30/06/2020]
- % stage of implementation 01/11/2019: [100%]
- Total project budget: [3 486 965 €]
- FCH JU max. contribution: [3 486 965 €]
- Other financial contribution: [0 €]
- Partners:

Partners

Technical leader
AC64 pre-existing manufacturing line
Proof of Process
AC 64 tests

Intelligent Energy

Stack specification
Stack manufacturing know-how

TOYOTA

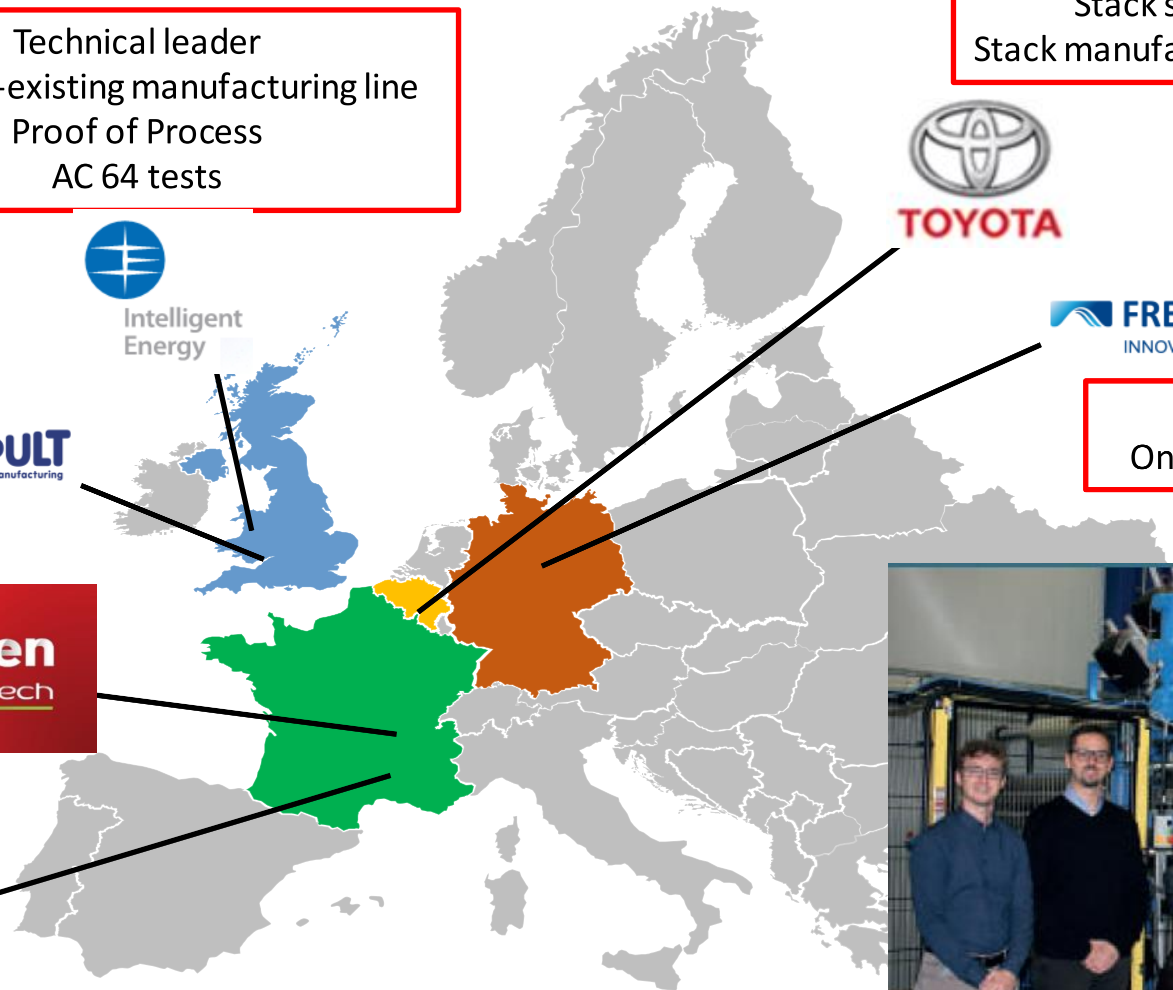
FREUDENBERG
INNOVATING TOGETHER

GDL manufacturing
On-line automated visual inspection

Cell assembly PoP
Blueprint design
Digital twin

WMG THE UNIVERSITY OF WARWICK

CATAPULT High Value Manufacturing



Coordination
GDL characterization
Single cell performance
Analysis of GDL ‘non-uniformities’

liten ceatech

PRETEXO

Administrative support

Project aims & outcomes

- **Aim:** develop a **blueprint design** for next generation fully automated cell assembly & testing of **IE's AC64** air-cooled fuel cell stacks

- **Programme outcomes:** demonstrated **operational** and **supply chain cost reductions** via seamless integration of digital manufacturing techniques (Industry 4.0 compliant) and advanced manufacturing technology, with a **fully automated uplift** to pre-existing semi-automated assembly processes.

- **Progress vs SoA:** (i) Digital Quality Control of GDLs, (ii) Digital Engineering of Future Assembly, (iii) Digital Process Improvement

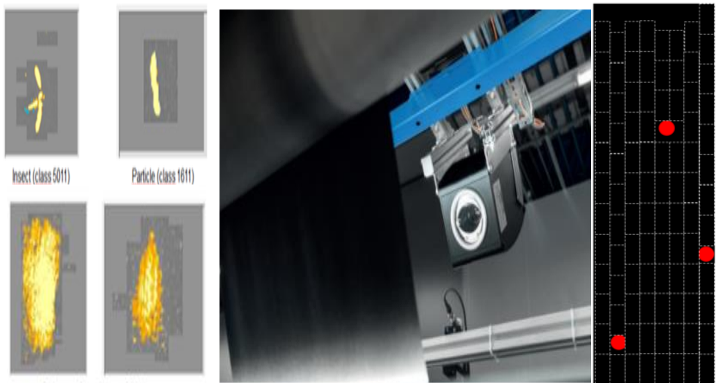
Project aims & outcomes

- **Blueprint design:** allows build-to-print machine readiness with scalable production capacity to **more than 50,000 fuel cell stacks per annum.** The simulated **digital twin** shows that, via digital process engineering, a blueprint can be designed/configured which that is **50% less costly** in terms of capital expenditure and **66% more efficient** in terms operational costs than its conventional counterpart.

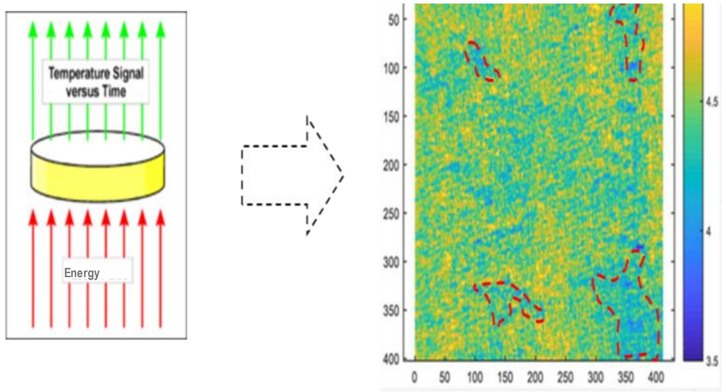
- **Project operations:** raised the manufacturing readiness level (**MRL4 to MRL6**) by introducing enhanced design for manufacture, automated assembly, inspection and test processes, coupled with advances in quality standards for materials acceptance; **cycle time assembly < 5 sec**; material utilisation > 99%

Research highlights

- **Digital Quality Control & Converting**
  - ✓ <u>Processes developed for digital QC for GDL roll-stock:</u>
    - ❑ Auto optical scanning for visible defects
      - ❖ Includes digitally codified defect protocols
    - ❑ Digital thermal diffusivity scanning for heterogeneities
      - ❖ Includes methods for linking digital boundary limits to empirically derived homogeneity data

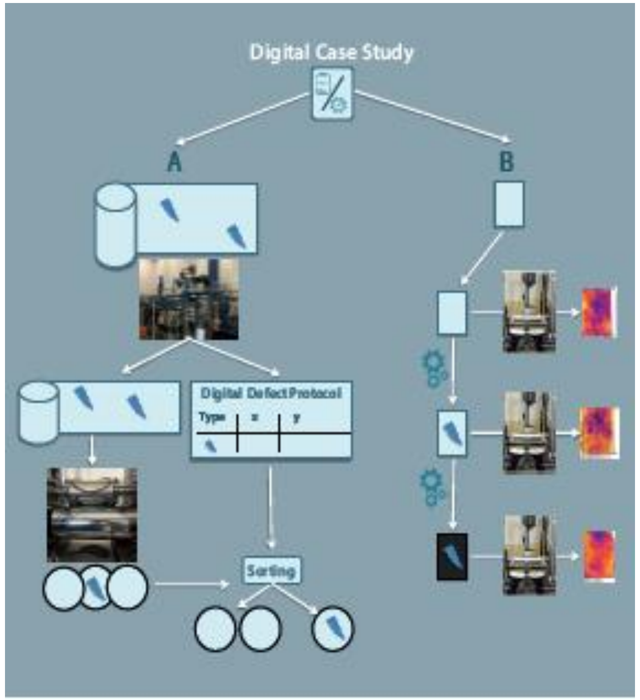


Digital Defect Classification – Vision System – GDL Defect Detection & Mapping



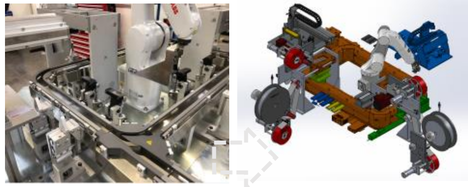
GDL Thermal Characterisation – Digitisation & Mapping of Heterogeneities

✓ <u>Digital converting methods</u> validated via case studies

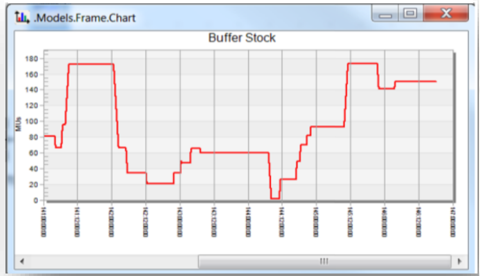


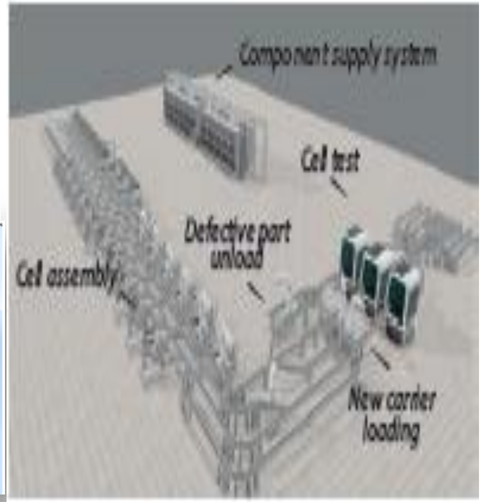
Research highlights

- **Cell Assembly Proof of Process Development (PoP)**
  - ✓ **PoP Demonstrator** within IE's production environment was completed
  - ✓ Validation product stacks were assembled and passed handover test, at **MRL6**
  - ✓ PoP Demo 3D CAD models digitally twined & validated via Virtual Engineering Simulations (VES)
  - ✓ **Discrete Event Simulation models** (DES) of the blueprint design were populated with operational performance data from the PoP Demo operation and various layout scenarios modelled to achieve the project KPIs



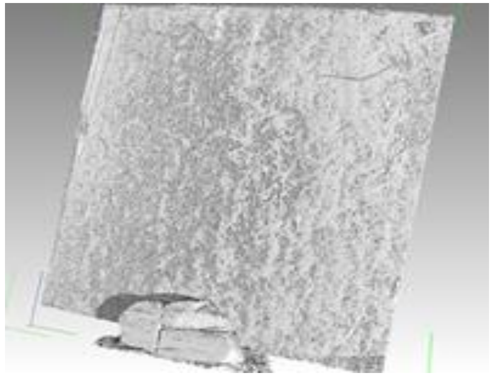
Proof of Process Demonstrator > Blueprint Design





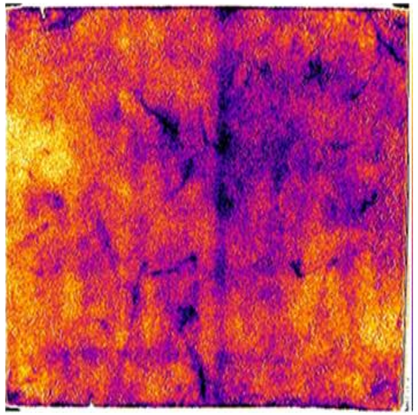
Research highlights

- **Digital Materials Characterisation of GDL**
  - ✓ The project has clearly shown that depending on shape, size, type, operating conditions, flow-field design, anode / cathode location, **GDL defects** can significantly influence stack performance.
  - ✓ **X-Ray Tomography** is appropriated to detect unexpected heterogeneities such as MPL thickness but too long for quality control
  - ✓ **Thermography techniques** have been identified & validated as suitable for enhancing digital QC and converting (sorting) into known-good, ready to use GDL components



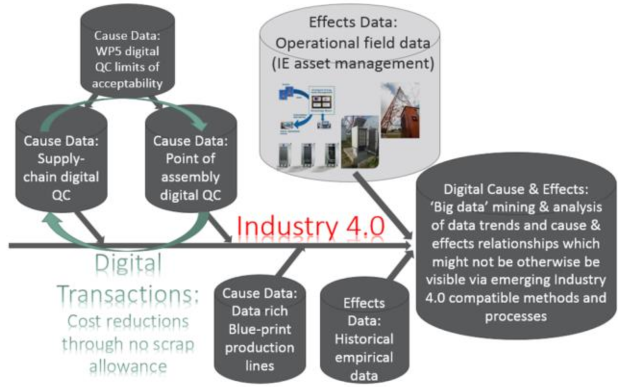
X-Ray Tomography of GDL

GDL non-uniformities not visible by optical approach but visible by thermography techniques

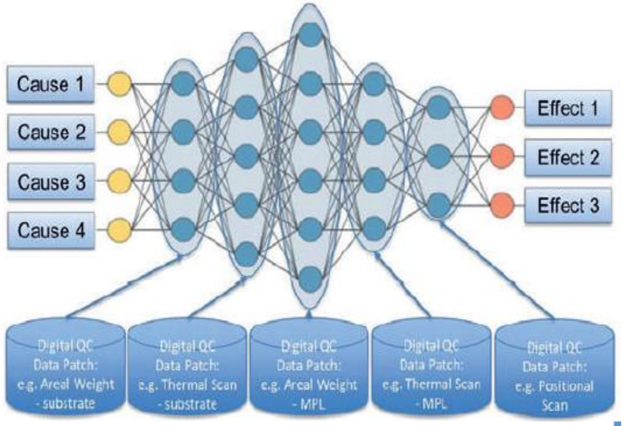


Research highlights

- **Development of QA strategies relevant for the transport sector compatible with ISO/TS 16949**
  - ✓ Physical models have been developed that link digitised cause data (e.g. scanned measurements of component alignment & GDL roll-stock) with stack performance data

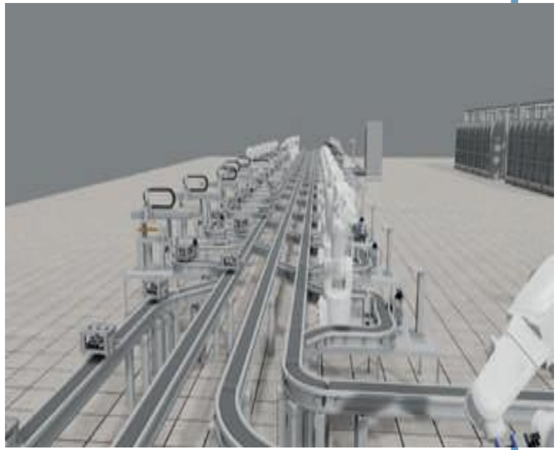


- **Digital Manufacturing**
  - ✓ Industry 4.0 compatible communication protocols based on neural networks
  - ✓ These deep learning algorithms will facilitate the mining of 'big data' and digital cause & effects. This can then feed autonomous process control for both:
    - ❑ Downstream cell and stack assembly
    - ❑ Upstream component production (e.g. GDL roll-stock)



Research highlights

- ✓ **All KPIs have been reached**
- ✓ Delivery of a **blueprint design** for a fully automated, build-to-print ready, production line capable of producing over **50,000 stacks per annum**.
- ✓ Validation of the build-to-print readiness of the blueprint design to the mandatory **MRL6**
- ✓ Development of **digital cause and effects model** & tool constructs as used to analyse the data which verified MRL6 attainment of the full auto assembly processes via a Proof of Process demonstrator.
- ✓ Validation of the **cell assembly cycle time target of less than 5 seconds**, meaning that the uplift to full automation from Intelligent Energy's incumbent semi-automation has delivered a five-fold improvement.
- ✓ **Validation**, via in–situ small and large stack test activities of the MRL advancement ensuring that any changes in cell architecture, materials characterisation and assembly / test processes have not been detrimental to the AC64's performance and meet the **KPI target of 0.7 A/cm2 @ 0.7V BoL.**



European Hydrogen Week

EXPLOITATION and IMPACT

❑ IE:

- ✓ Exploitation of 4kW fuel cell system via 2-wheel **scooters** based on IE's air-cooled architecture (AC64…), partnered with **Suzuki**
- ✓ Fleet trial of five fuel cell scooters with **Metropolitan Police scooters** based at Alperton (Northwest Traffic Unit)
- ✓ **30-100kW** range extender & primary power for automotive, aerospace and rail transportation
- ✓ **IE-Drive:** high power evaporatively cooled stacks for heavy duty auto, rail, marine and stationary power.
- ✓ **IE-Solar:** lightweight fuel cell solutions offering long flights times compared to traditional lithium batteries.
- ✓ **IE-Lift:** low powered air-cooled modular solutions targeting stationary power, MHE (Materials Handling Equipment), telecoms and construction.

❑ FRE: Improved GDL QC for high volumes support:

- ✓ High value for the customer due to improved information
- ✓ Improved performance of assembled fuel cell systems and thus possibility to push fuel cell technology further
- ✓ Possibility for downstream automatization
- ✓ Optimization of production quality, speed and thus volume

European
Hydrogen
Week

#PRD2021
#CleanHydrogen

FCH

European Commission