Advanced materials and innovative structural concepts

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With (reference) to ICAF National Reviews

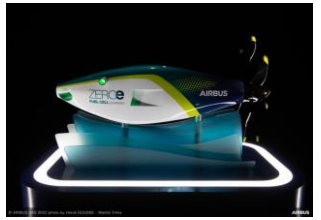
ICAF
International Committee on Aeronautical Fatigue and Structural Integrity

General trends

- Industry needs and trends
  - **Reduction** of development **cost and time**, lead times, life cycle cost
  - **Sustainable technologies** & recycling, aiming towards climate neutral
  - **Digitalization** (virtual testing, digital twins, digital design tools, integrated digital environment…)
  - **Robust supply chain** & **automated** industrial **production** capabilities

- Challenges related to structural integrity
  - Lighter, **high performance** materials and more efficient assembly processes
  - Material qualification and **quality** assurance, NDT etc.
  - **Reduced testing time** (by virtual testing, digitalization)
  - Material behaviour **modelling**
  - **Environmentally friendly** materials, manufacturing processes and surface treatments **without hazardous** ingredients

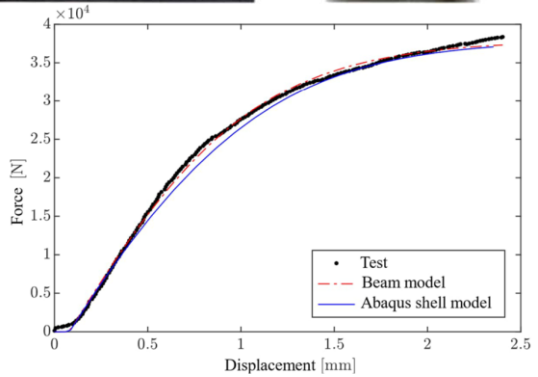
General trends cont.

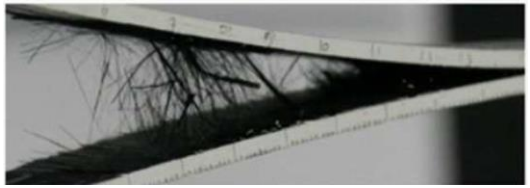


- Decarbonisation rel. to i.e. EU “Green Deal”
  - **Sustainable Aviation Fuel (SAF)**
    - SAF is a proven alternative fuel → reduce life cycle CO_2 emissions by up to 80%
    - 100% SAF uptake by 2030 @ Airbus → no major material or structural challenges
  - **Hydrogen technologies** for Zero Emission
    - Hydrogen combustion propulsion and Hydrogen fuel cells to be matured by 2025 (zero-emissions aircraft to market by 2035) → major challenges for materials, testing and certification
  - **Circularity** → Ecodesign, recycling, secondary materials
  - **Wing efficiency** → R&T projects: Wing of Tomorrow, Ultra-performance Wing
  - **Next generation engines** → Focus at engine producers, but structural impact to be evaluated
  - **Smart Air Traffic Management** solutions → no impact on structure

Composites

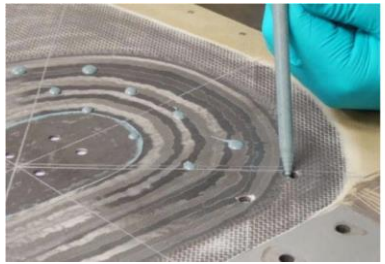
- Testing and modelling
  - Bolted joints (Swe, Fin, NL, Jp)
  - Impact
    - Modelling of low velocity impact (Fin, Can)
    - CAI damage measuring using AE (NL) and DIC (Aus)
  - Delamination
    - Delamination interaction modelling (Fin)
    - ENF R = -1 (Fin)
    - Fibre bridging (NL)
    - Hybrid carbon-glass fibre composites (Bra)
  - High strain rate testing (Fin)
  - Damage modelling
    - Interaction of inter- and intralaminar damage (It)

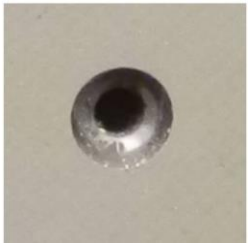




Composites

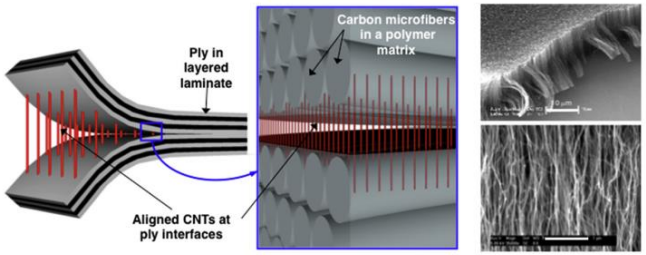
- NDI
  - Laser ultrasonic testing (LUT) (Aus)
  - Line scan thermography (LST) (Aus)
- Repair
  - Adhesively bonded repair (Fin)
  - Vacuum infusion repair (of BMI, NL)
  - Bolt hole repairment EPOCAST potting (Swe)
- Thermoplastics (NL)
  - Durability of thermoplastic welded joints
  - Thermoplastic orthogrid fuselage



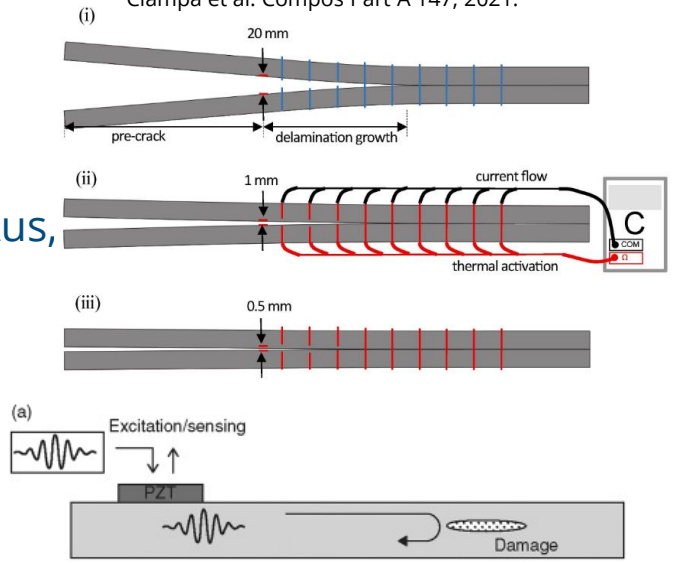


Composites

- Multifunctional materials/structures
  - Carbon nanotubes (CNT) (KTH, Swe)
    - Improvement of interlaminar strength
    - Lightning protection
    - Strain and temperature sensing
  - SHM using optical fibres (It)
  - Shape memory alloy (SMA) tufted composites (Aus, UK)
  - GW (Guided wave)
  - Structural batteries
  - Integrated antennas

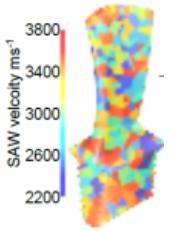


Ciampa et al. Compos Part A 147, 2021.

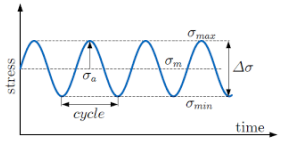


Kim et al. Sensor technologies for civil infrastructures, 2022.

Advanced Materials



- New Materials, Processes & Analysis Methods
  - Material optimization and crystal plasticity modelling for additive manufacturing (AU)
  - Measuring the single-crystal elastic stiffness matrix of polycrystalline materials by SRAS (UK)
  - Unique Materials for Advanced Aerospace Applications (UMA3). → Compare the use and the mechanical behaviour of powder metallurgy and additive manufacturing technologies. (I)
  - Bioinspired architectured ceramics (CA)



- Fatigue Behaviour & Fatigue Life Prediction
  - Fatigue life prediction of Silafont-36 using Fatigue Toughness (CA)
  - Dwell fatigue life prediction of Dual Phase Ti by microtexture characterization (JP)
  - Life prediction model for Ceramic Matrix Composite with Cooling Hole (JP)
  - Predict fatigue life on a CFRP/Aluminium alloy hybrid joint (JP)
  - Fatigue knock-down factors of One up drilling processes → Al/CFRP, Titanium/CFRP (I)
  - Corrosion effects on fatigue behaviour of 7457-T7351 (I)

- Mitigating Critical Materials
  - REACH compliant surface treatments replacing Cr VI (I)
    - Hard Chromium Plating process → Thermal spraying (HVOF)
    - Cadmium Plating process → Zinc-Nickel Plating
  - Chromate-free paint primers (UK)

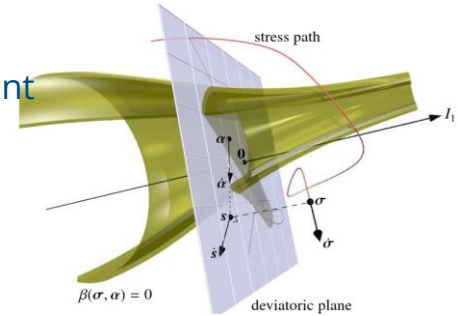
Qualifying Additive Manufacturing (AM) Parts

As the determination of the allowables is done using generally accepted statistical methods for aircraft materials, it is possible to start building a data bank of material properties at an early stage. (FIN)

Load bearing capabilities of additive manufactured test bodies have to be assessed in detail due to AM intrinsic peculiarities. (G)

Additively Manufactured (AM) Metals and Polymers

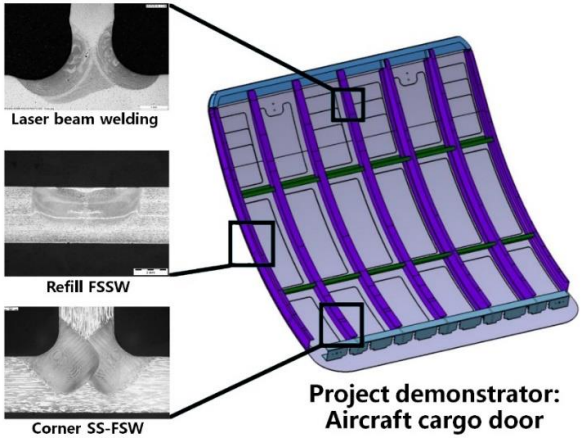
- Material qualification and quality
  - Certification of flying AM (powder bed fusion) parts (Al and Ti) → MRO F/A-18 (CH)
  - Certification of AM Ti64 parts for primary structure (CA)
- Behaviour related to treatment/microstructure?
  - Laser Powder Bed Fusion Ti64 with post-heat treatment (CN)
  - Relationship between internal defects, microstructure, role of defects Ti64 AM was evaluated by fatigue and fracture mechanics (JP)
  - Laser powder bed fusion (LPBF) of NiTi alloy using elemental powders: the influence of remelting on printability and microstructure (PL)
- Fatigue assessment and modelling
  - Prediction of fatigue life of functionally graded AM Ti64 to 7075 T6 (CA)
  - Topology optimization with a continuous-time, high-cycle fatigue constraint (S)
- Composites and 3D cellular structures
  - 3D printed continuous fibre composites, auxetic structures (AU)
  - 3D printed sandwich core material



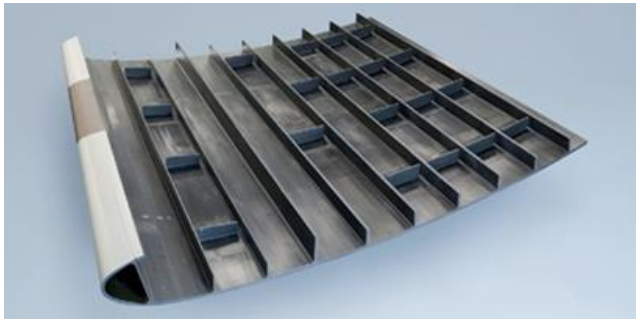
Innovative structural concepts

- FSW, FSSW, Laser heating
  - Clean Sky 2, Oasis
  - Comparison of FSW of 2219 T851 (forged, plates, combi) (I)
  - Fatigue cracks in laser-treated AA2198-T851 (BR)
  - LSP of 2024 FSSW joints (G)
  - FSW process control, optimization & NDT by data science
  - R&T towards increased welding speed → ramp up (G)
- Local improvement & Repair
  - Laser Shock Peening (2024) (G) & Cold Spray
- Integrated composite structure
- Clean Sky 1/2/Clean Aviation (EU)
  - Smart Fixed Wing Aircraft
  - Hydrogen aircraft & hybrid electric aircraft

Clean Sky 2, Oasis



http://www.cleansky-oasis.eu/



https://image-building.de/en/overview-of-smart-fixed-wing-aircraft-2/;
https://www.clean-aviation.eu/programme-overview-and-structure

Summary

Limited inputs on materials & structures for Hydrogen powered or electric flying

- Focus on Additive Manufacturing
  - Development of new alloys, mainly for and through AM
  - Characterization & post-treatment to support optimization of AM parts
  - Qualification & certification strategies for secondary and primary parts
- Fatigue characterization on advanced materials, structures & joints
- Processes to improve joined structures & fulfill REACH requirements
  - Laser Shock Peening, combined with laser heating & cold spray
  - New surface treatments
- Composites
  - Improving testing and measuring methods
  - Damage modelling
  - Multifunctional structures, sensors etc.

Thank you very much for your attention!

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