Enabling Multi-Functional Performance through Multi-Material Additive Manufacturing

March 2023
Newsletter 3 | Article no. 1

Distributed optical fiber sensing for structural health monitoring of metal parts

Intro

The Multi-FUN project team conducts research to develop metal parts with sensing and data transfer capabilities for structural health monitoring and process control techniques.

InPhoTech proposed to implement sensing capability and conduct distributed measurements using metal-coated optical fiber embedded in metal parts using WAAM (Wire and Arc Additive Manufacturing) process. The project team has the following challenges:

- Providing thermal shielding properties for optical fiber required to withstand temperatures occurring during the metal deposition process. The melting point of WAAM technology is ~1200˚C which is destructive for a regular optical fiber,
- Designing an effective method of embedding optical fiber into WAAM printed parts,
- Measure temperature and strain using a fiber sensor.

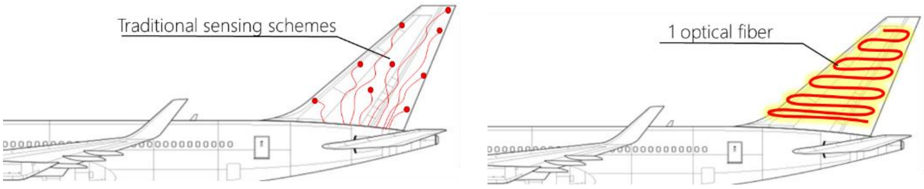

Fig.1. Comparison of traditional measurement schemes with distributed optical fiber sensing.

InPhoTech proposed metal–coated optical fibers that are known for their high resistance to extreme temperatures exceeding 1000 °C and for their superior mechanical properties enabling them to survive in harsh environments ensuring protection from external mechanical influence.

Coating and embedment solution

Researchers tested various metal coatings such as Au, Cu, Ni or their combinations. Trials were focused on evaluating the embedding process and mechanical properties of WAAM printed parts with embedded metal-coated optical fiber.

Optimal metal coating and embedment methods were developed. The tensile and yield strength of the metal part with the embedded metal-coated optical fibers was examined.

These parameters have not deteriorated the examined metal part in comparison with similar metal (aluminium) part without the embedded optical fiber.

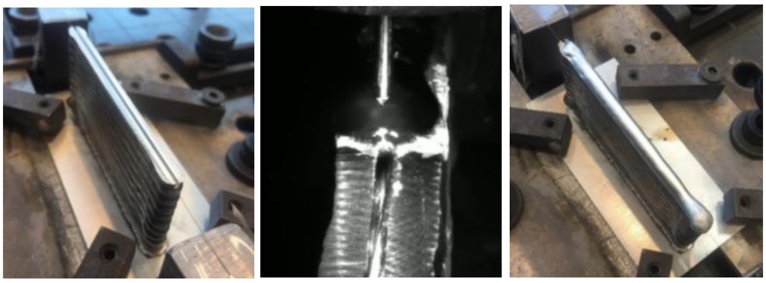

Fig.2. Aluminium part sample with metal-coated optical fiber: before, during and after embedding process.

Optical sensing capabilities

Temperature and strain over the embedded metal-coated optical fiber were successfully measured using Optical Frequency Domain Reflectometry (OFDR). Sensor response to temperature and strain change is linear.

Additionally, a comparison between analytical and experimental temperature and strain sensitivities of the metal-coated optical fibers was investigated - optical reply determined experimentally is consistent with the result of the analytical predictions. Calibration procedures were developed.

Fig.3. Aluminium component with embedded metal coated optical fiber during 3-point bending tests.

Conclusions and Product outlook

An effective method of metal coating thermal shielding for optical fiber and its embedding into WAAM printed parts was successfully developed

- Optimal metal coating for optical fibers was selected,
- Optical fibers were not destroyed during the integration process and they retained their optical properties,
- Embedment does not cause defects in the aluminum structure.

Research proved that such parts can be used as temperature, strain and vibration sensor.

As a next step, research results will be verified and presented in a demonstrator for aerospace industry in the form of a bulkhead panel.

Developed technology brings the concept of Structural Health Monitoring (SHM) into metal parts. Embedded metal-coated fiber optic sensor is able to measure strain and temperature distribution with very high spatial resolution which allows new predictive maintenance strategies, reduce weight of parts as well as reduce maintenance costs.

Follow us:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862617 – MULTI-FUN