Metal-coated optical fiber embedment in WAAM aluminium parts for distributed temperature sensing

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Metal – coated optical fibers are known for its high resistance to extreme temperatures exceeding even 1000°C [1] and superior mechanical properties enabling them to survive in harsh environments (protection from external mechanical influence) [2]. These factors are becoming more commonly explored within the topic of smart materials which are gaining the interest in the means of structural health monitoring. Materials with embedded sensors as metal – coated optical fibers can be inserted in 3D printed metallic parts. This research has focused on distributed temperature sensing by metal – coated optical fibers embedded in an aluminum alloy walls deposited by Wire Arc Additive Manufacturing (WAAM) method. Within the trials of embedment, different metal coatings of optical fibers were tested (such as Au, Cu, Ni, or their combination) and their impact on the embedding process was evaluated. Additionally, the influence of the fibers and process parameters on WAAM insertion quality and fiber integrity were investigated. The best results were obtained for the Ni – coated optical fibers with almost regular boundary between aluminum and nickel coating surface within the examined fiber structure. Furthermore, the tensile strength of the metal part with the optical fibers embedded was examined. Based on the analyzed data, the mechanical properties of the samples decreased in comparison with monolithic aluminum samples without the optical fibers' embedment, but the influence on yield stress was negligible. Discussion on possible improvements and alternatives to introduce in high strength aluminum alloys was also presented. Nevertheless, the successful distributed temperature measurements by the Optical Frequency Domain Reflectometry (OFDR) in WAAM aluminum wall part are demonstrated for different metal – coated optical fibers embedded in A5356 and A2319 alloys. For each conducted measurement, a calibration process resulting with a temperature sensitivity of the embedded optical fiber and the temperature recorded by the OFDR system were presented. Additionally, a comparison between analytical and experimental temperature sensitivities of the optical fibers were investigated. The outcome of this research proves the potential of the distributed temperature sensing powered by 3D printing for structural health monitoring in vast areas of the market including the heavy industry, aerospace industry or energy industry.

[1] Biriukov, A. S., et al. "Strength and reliability of metal-coated optical fibers at high temperatures." *MRS Online Proceedings Library* 531.1 (1998): 297-300.

[2] Li, Jie, et al. "Optical fibers for distributed sensing in harsh environments." *Fiber Optic Sensors and Applications XV*. Vol. 10654. SPIE, 2018.

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