A Methodical Approach for the Integration of Foil-Type Strain Gauges in PBF-LB/M Components

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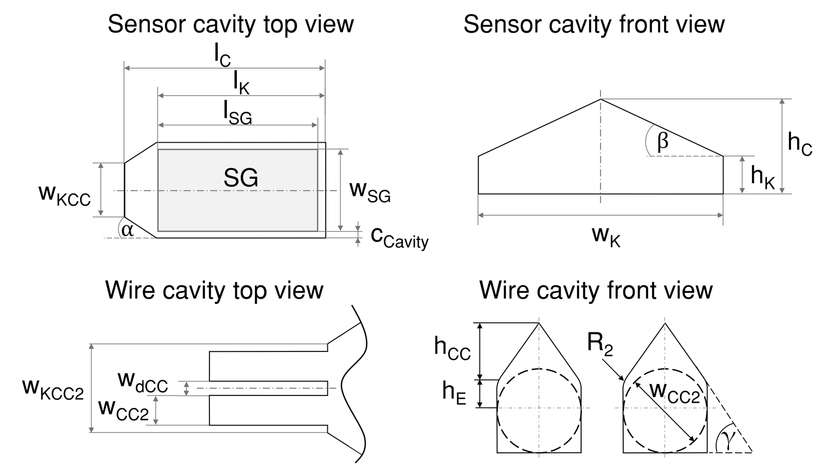
Motivation

- **PBF-LB/M enables the integration of sensors** through its layer-by-layer manufacturing process, allowing placement near critical regions of interest while providing protection from environmental influences.
- **Strain gauge (SG) integration** in PBF-LB/M components **using adhesive bonding** has not been previously demonstrated.
- Research Objective: To establish a **reliable** and **low-cost approach** for in-process integration of SGs in PBF-LB/M components.
- **Key challenges** addressed:
  - Temperature monitoring at the integration site
  - Design of sensor and wire cavities
  - Selection of an adhesive ensuring reliable strain transfer
  - Surface preparation to ensure sufficient bonding strength
  - Development of manual integration procedures within the PBF-LB/M environment

Main results

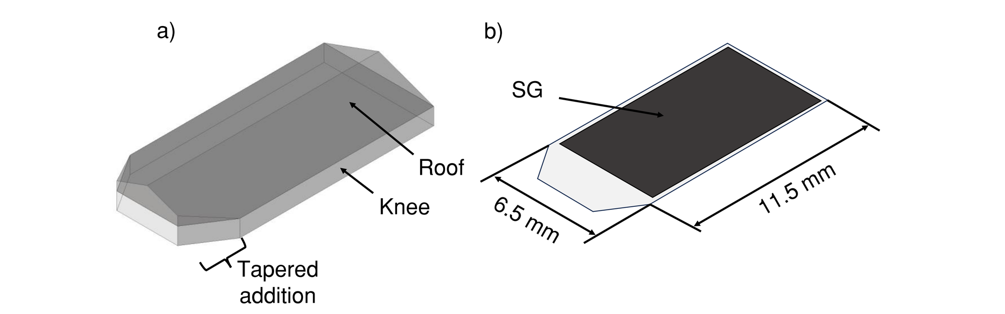
- **Integration methodology** for bonded SGs in PBF-LB/M components was developed.
- **Build plate temperature** was the **main factor influencing** integration-site temperature; laser parameters had minor impact.
- **Method validated through tensile testing**, showing accurate and repeatable in-situ strain measurements.



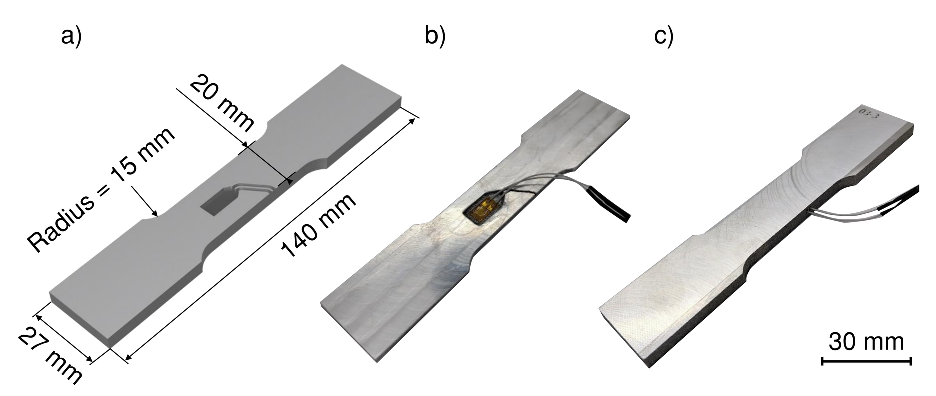
Geometric variables for the design of the sensor and wire cavity

Variable	Description	Variable
α	taper angle	$\alpha = 33°$
β	roof angle	$\beta = 20°$
γ	wire cavity roof angle	$\gamma = 55°$
d_{wire}	diameter of wire	$d_{wire} = 0.60$ mm *
h_C	sensor cavity height	$h_C = h_K + \frac{w_K \times \tan\beta}{2}$
h_{CC}	wire cavity height	$h_{CC} = 1.8$ mm
h_E	wire cavity height extension	$h_E = 0.9$ mm
h_K	knee cavity height	$h_K = 1.0$ mm
l_{SG}	SG length	$l_{SG} = 10.9$ mm *
l_K	SG length with clearance	$l_K = l_{SG} + c_{Cavity}$
l_C	sensor cavity length	$l_C = l_K + \frac{w_K - w_{KCC}}{2 \times \tan\alpha}$
n	number of wire cavities	$n = 2$
c_{Cavity}	clearance around the SG	$c_{Cavity} = 0.3$ mm
w_{CC2}	width of each wire cavity	$w_{CC2} = d_{wire} + 0.6$ mm
w_{dCC}	width of area between wire cavities	$w_{dCC} = 0.6$ mm
w_K	width of the cavity	$w_K = w_{SG} + c_{Cavity}$
w_{SG}	SG width	$w_{SG} = 5.9$ mm *
w_{KCC2}	front width of the sensor cavity	$w_{KCC2} = 2 \times w_{CC2} + 4 \times 0.3$ mm

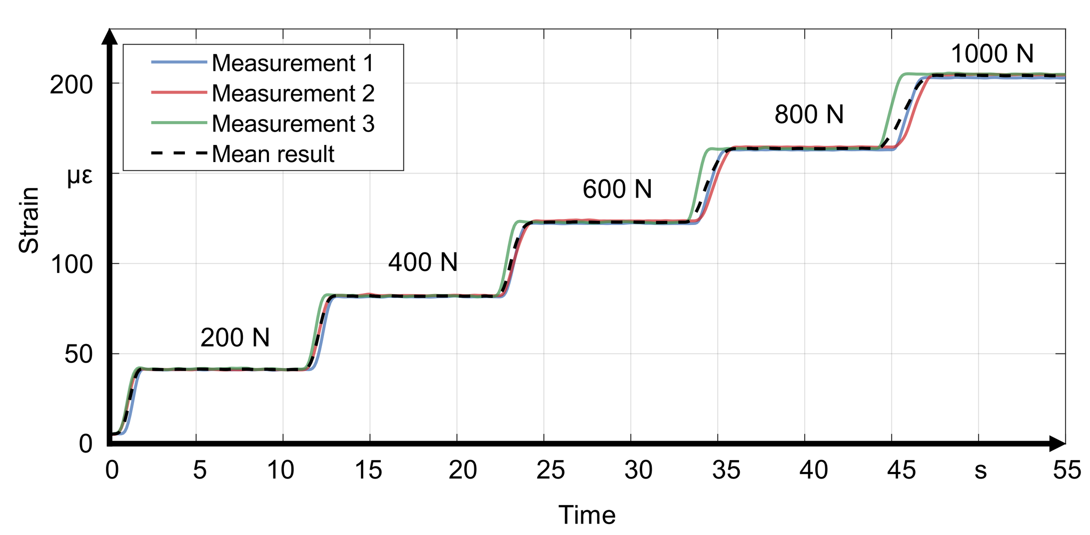
Recommended geometric variables for the design of the sensor and wire cavities, with dimensions derived from the SG 3/350 CLY43-3L-1M at the marked positions (*)



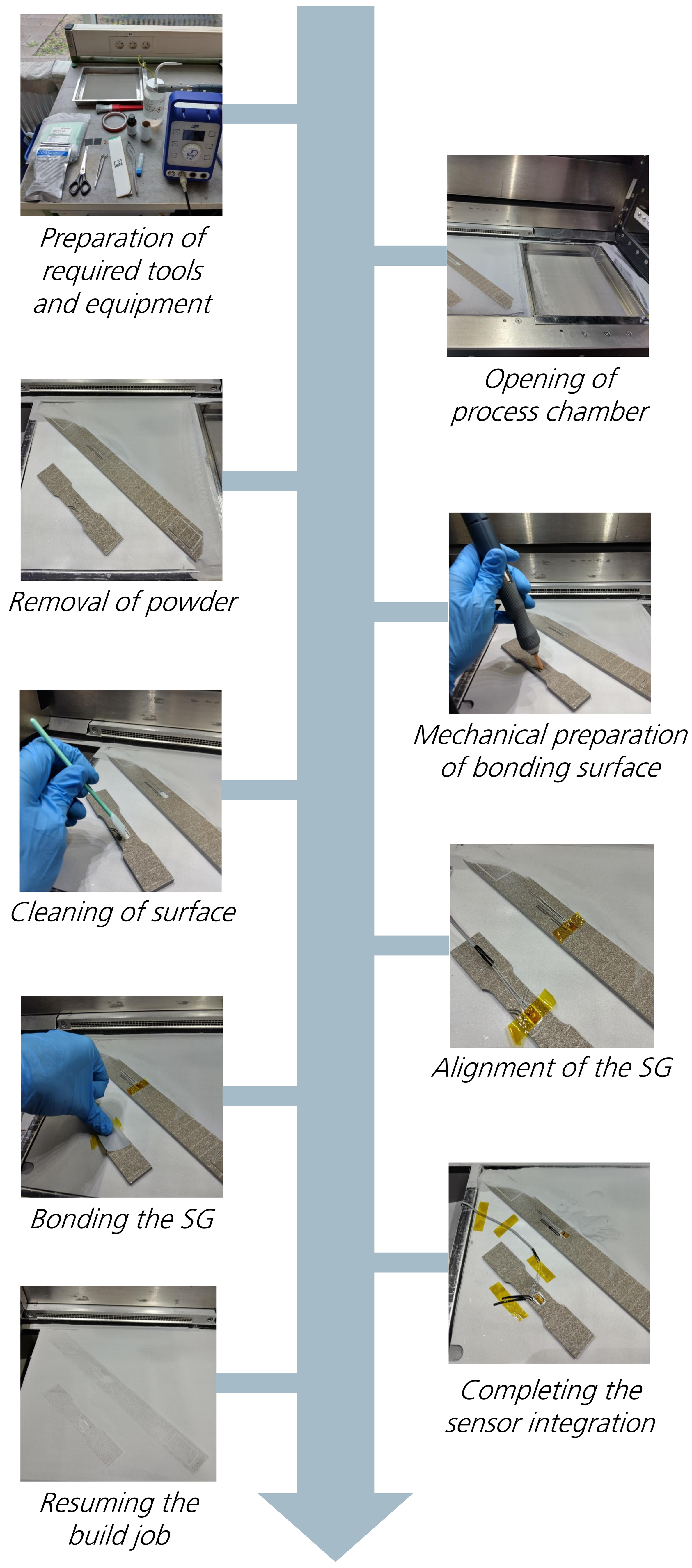
Schematic view of the sensor cavity with: a) the separation in a roof and a knee cavity, and b) the position of the SG inside the cavity



a) Schematic representation of the sectioned tensile sample with geometry specifications, b) milled cross-sectional view illustrating the SG integration position, and c) milled PBF-LB/M manufactured tensile sample with integrated SG



Stepwise tensile test ranging from 200 N to 1000 N, repeated three times, with the mean of all measurement results represented by a dashed black line



Manual integration procedures: Recommended steps during the build interruption and the manual integration of the SG

Conclusion

- **Non-weldable SGs successfully** integrated into **tailored sensor cavities** in PBF-LB/M parts using fast-curing cyanoacrylate adhesive
- **Improved sensor protection** achieved through **encapsulation** within the component
- **Minimal process modifications required**, fully compatible with standard PBF-LB/M setups and powder presence
- **Method adaptable** to **various SG types** and likely to **different materials**, requiring only minor design and process parameter adjustments

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