Title: Assessing Thermal Deformation Risks in Electronic Repairs: Bridging Simulation Gaps for Enhanced Reliability

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Abstract: The rapid evolution of electronics repair methodologies, especially in industrial and batch processing contexts, necessitates a thorough understanding of thermomechanical stress and its associated mechanical deformations. Rework operations, whether conducted manually or through automation, combined with the materials and structural design of the components, lead to uneven temperature distribution across the component. Conventional simulations typically assess the heating effects across entire components, overlooking the localized thermal stresses encountered during specific rework or repair interventions. This limitation may lead to underestimations of mechanical strain and thermal propagation, potentially undermining the long-term reliability of repaired electronic components.

The study, carried out by Valeo's Circular Economy Laboratory, addresses this gap by exploring differential outcomes between global heating simulations and localized thermal analyses during repair processes. Through a series of controlled experiments and simulation techniques, critical discrepancies in thermal stress distribution during isolated repair procedures were identified. Key findings indicate that localized heating generates non-uniform thermal gradients and mechanical deformations, aspects often overlooked by existing simulation models, posing potential risks to the structural integrity of components post-repair.

To enhance predictive accuracy, a protocol was developed and validated, incorporating a simulation framework that takes account of localized thermal profiles and their mechanical impacts. This framework enables precise identification of heat-sensitive zones, facilitating targeted thermal management strategies and adaptation of repair parameters. Such improvements are essential for maintaining the mechanical properties and performance of components after rework, thereby aligning with sustainability and circular economy principles by extending the operational lifespan of electronic components.

The implications of this research are significant for both industry and academia. By providing a more accurate method for thermal-induced deformation risk evaluation during electronic repairs, tools are offered to manufacture and repair to address reliability concerns. Additionally, this work opens avenues for the further refinement of simulation tools and methods that align with the practical demands of electronic repair, thereby, supporting product longevity and resource efficiency—a core tenet of the circular economy.

The findings presented not only highlight current limitations but also propose a practical approach that can be integrated into standard repair protocols or simulation practices. This innovation underscores the importance of revisiting traditional modeling assumptions in light of real-world repair conditions to foster sustainable manufacturing practices and align with energy and environmental goals.

Keywords: thermal deformation, electronic repair, reliability analysis, localized thermal effects, circular economy, mechanical stress simulation, sustainable manufacturing, thermal management, simulation accuracy, repair protocol optimization.