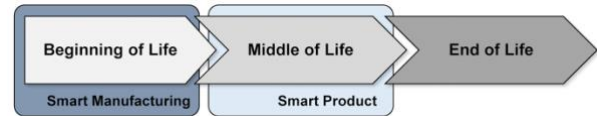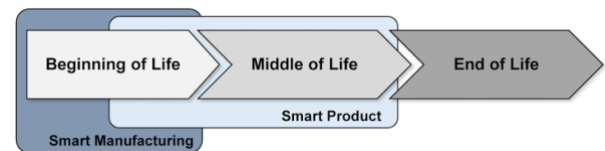Thorsten Wuest

Self-sensing Smart-connected Products in Smart Manufacturing Systems

The Status Quo: Our world is changing rapidly in the wake of the fourth industrial revolution. Connectivity, data, and the *Internet of Things* are everywhere, from our homes to our factory floors. ***Smart-connected products*** with integrated sensors are cheap and omnipresent from shoes to watches,

Today's key Industry 4.0 concepts along the product lifecycle

cell phones to modern appliances. The data collected by smart-connected products during the usage phase (the middle-of-life stage, MoL) offers tremendous value to service providers as well as manufacturers to improve product design and customization/personalization. However, these benefits have yet to be fully leveraged. Currently, only traditional sensors that are integrated within the ***smart manufacturing system (SMS)*** are leveraged in the manufacturing of smart products during the beginning-of-life stage, BoL.
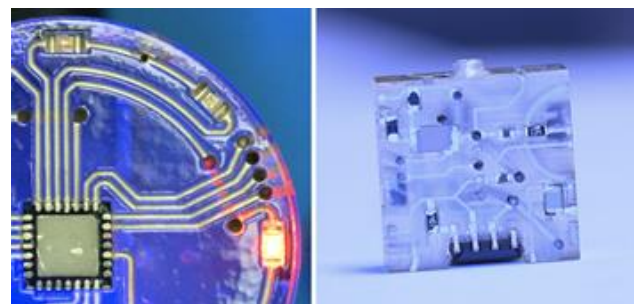
The Problem: While both lifecycle phases are data-driven, to date, smart products (MoL) and the smart manufacturing of these products (BoL) are not aligned. The sensing capabilities of the smart products are activated only after the manufacturing process is completed. Simultaneously, machine tools and sensing equipment in the SMS collect external process measurements of the to-be-manufactured smart product; however, these measurements are limited to an 'outside' perspective. Ultimately, the ***sensing and communication capabilities of the smart product itself are not leveraged during the manufacturing process*** to augment the existing sensor environment. Several

Radically expanding the Smart Product paradigm to SMS

challenges exist to explain why the features of a smart product are not utilized during the manufacturing of said smart product. First, the manufacturing process of every product, including smart products, begins with raw materials and involves a series of different processes – including those involving high temperatures and deformation (e.g., forging or casting). In order for the product to be considered a smart product, the ***sensor system needs to be operational and able to communicate***. This functionality generally requires complex processes including assembly, software installation, and the application of a battery, which may outweigh the benefits of additional data during manufacturing.

The Vision: We propose to ***radically extend the smart product concept earlier in the life cycle*** leveraging the value-adding in-situ sensing capabilities of the smart product to measure preliminary manufacturing data during the BoL. 3D printing can now serve as the foundational process for building multi-functional structures as smart products. ***The potential value of expanding the manufacturing data perspective with real-time, in-situ data collection by the manufactured product itself is transformational.*** Particularly, manufacturing processes that depend on high-fidelity process data to achieve the desired outcome will tremendously profit from not only additional data points but data from within the structure itself - previously impossible without destructive methods. With 3D printing leveraged to directly manufacture structures with integrated sensing, unprecedented data can

3D printed sensor systems

now be measured during manufacturing of next generation smart products.

The ***technical feasibility of this breakthrough innovation*** depends on the product itself and the manufacturing process. However, mapping the viability of this approach over a number of processes for several different products

Technical feasibility of adding sensing capabilities during BoL in SMS

highlights profound opportunities in the later phases of the SMS. Combined with a judgement of the economic benefits, the value proposition for a specific smart product and SMS can be determined.

Substantial work remains and ***inter-disciplinary research is required to tackle this problem and make this unconventional transformative vision a reality!***