Contribution ID: **8** Type: **not specified**

Conceptual Digital Twin Framework for Quality Assurance in the Injection Molding Industry: Technical and Digital Skill Perspectives

Thursday, 25 May 2023 13:20 (20 minutes)

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In order to maintain a competitive edge in the market, companies strive to improve the quality and performance of their products while also minimizing downtime and maintenance costs. One of the ways to achieve this is through the use of Digital Twins (DTs), which are enabled by the fourth industrial revolution. Hence, DTs can serve as a powerful tool for implementing the necessary quality assurance (QA) processes. Schol- ars developed domain-specific DT-driven QA frameworks such as for the aerospace industry [1], semiconductor manufacturing [2], and metal sheet assembly processes [3]. However, while DTs have shown great promise as a tool for QA, current DT-driven QA frameworks do not provide guidelines for addressing the unique challenges of the injection molding industry, which include a highly complex process chain, collaboration and com- munication silos, and the need for enhanced quality assurance tools. To alleviate these challenges, this paper proposes a DT-driven quality assur- ance framework for injection molding. The purpose of the framework is to guide manufacturers in how to setup a DT for injection molding quality assurance that (i) meets the QA needs across the mold lifecycle (ii) can be constructed from meaningful data available in industry, (iii) has the re- quired personnel with the digital skills to build, operate and maintain the DT, (iv) adds value to the company on economic and social dimensions. We deliberately focus our analysis on digital skills as DTs rely heavily on data, and hence being able to read, analyze, interpret, and communicate data is crucial for achieving the full potential of a DT. The framework was developed by the Design Science Research (DSR) methodology in collaboration with a leading Danish injection molding company and DT experts. The DSR method can be used to develop design artifacts and en- sures the academic and industrial relevance. The DSR method consists of three elements: (i) environment, (ii) knowledge base, and (iii) design arti- fact. The environment defines the problem space and business needs. The problem space in this work resides in the three injection molding lifecy- cle phases: engineering, mold manufacturing, and injection molding. The knowledge base contains literature and existing information to ground the development of the design artifact, i.e., DT-driven QA framework. In this research, the knowledge base consists of digital skills transformation literature, an unstructured review of DT frameworks, and expert interviews from the DT domain. The design artifact, in this paper the DT frame- work design, describes the iterative process of creating and evaluating the framework design. Inputs to the design artifact are the requirement coming from the environment and fundamental knowledge derived from the knowledge base. The DT-driven QA framework was evaluated by a combination of literature review and expert inputs. The final framework was validated by a combination of academic literature and expert inputs. Overall, we developed a conceptual DT-driven QA framework tailored to the specific requirements of injection molding companies that can help those companies to take full advantage of the DT technology. Besides the DT framework, this paper makes an academic contribution by outlining the linkage of digital skills and technical requirements of building, using and maintaining the DT.

References

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Session Classification: Contributed session "Digital Twins for Quality and Reliability"