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Digitalization & Standardization: as enablers for the future of industrial hydraulics

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Abstract

The industrial hydraulics sector is undergoing a profound transformation driven by evolving customer expectations, commoditization, digital mindsets, automation pyramid restructuring, and demands for rapid time-to-benefit. This paper highlights five key trends and outlines strategic opportunities to address them, emphasizing a necessary shift from component-centric to system-oriented thinking. Analysis of recent conference topics reveals a progression from initial component digitalization to connectivity, data-based services, and finally to system integration, all converging to meet demands for sustainability, resilience, and increased automation. Three practical use cases – Digital Machine Engineering, Hydraulic Hub, and CytroConnect – exemplify proactive responses to these trends, showcasing how digital twins, accessible knowledge platforms, and predictive maintenance are being implemented. A core argument is advanced that effective cross-manufacturer collaboration, essential for navigating these complexities, critically depends on the adoption and active development of common standards. The Asset Administration Shell (AAS) is introduced as a pivotal enabler for seamless, vendor-independent interoperability. The paper concludes by stressing the imperative for industry-wide engagement in standardization initiatives (e.g., VDMA, IDTA, ZVEI) and proposes future advancements like the Asset Orchestration Platform (AOP), all built upon the foundational role of the AAS to ensure the continued competitiveness and innovation leadership of fluid power technology.

Keywords. Digitalization, Industry 4.0, Digital Twin, Asset Administration Shell (AAS), Standardization, Cross-Manufacturer Collaboration, System Thinking, Interoperability, Fluid Power Technology

1. INTRODUCTION AND OBJECTIVES

The industrial hydraulics sector is currently undergoing significant transformation, driven by several interconnected trends that present both challenges and substantial opportunities.

Firstly, we observe a shrinking pool of traditional hydraulic knowledge alongside the **unjustifiably declining reputation of hydraulics, which is perceived as a mature technology.** Furthermore, **rapidly evolving customer expectations** driven by B2C user

experiences set the benchmark for B2B customer requirements. This trend opens an opportunity to innovate by developing user-friendly software solutions, we can simplify hydraulics. Furthermore, leveraging deep application knowledge and the expertise of internal system integrators, combined with insights from data-driven use cases in the consumer market, will be vital for future success.

Secondly, the industry faces increasing **commoditization, Hardware-as-a-Product (HaaP) models, and regulatory protectionism.** To counter the diminishing differentiation on component level, companies have the chance to provide solutions that offer added value across the entire product life cycle. By leveraging a leading market position, businesses can foster deep customer integration and commitment and actively shape the regulatory landscape through strong market presence and networks.

Thirdly, there's a clear emergence of an **increasingly digital mindset among customers.** A new generation of clients is entering the market with less traditional application knowledge but with distinct digital expectations. This shift creates an opportunity to learn from the success of data-driven business models prevalent in the consumer market. Moreover, monetizing hydraulic know-how and software (SW) solutions will be a key strategy for growth.

Fourthly, we are witnessing the **opening of horizontal layers within the automation pyramid.** By leveraging hydraulic know-how, it is possible to expand customer relationships within the ecosystem, independent of hardware and ecosystem. Proactively co-creating ecosystems with strategic partners and integrating vertically will be essential to capitalize on this trend.

Finally, there is an overarching **demand for fast time-to-benefit.** Shorter life cycles are becoming the norm, with the "China speed" benchmark dictating rapid development and deployment. The opportunity here lies in accelerating the digitization of internal processes to boost efficiency. Additionally, developing adaptable hardware platforms and shifting flexibility into software will be critical to meet the urgent need for quick results and innovation.

2. STATE OF WORK

The main topics of presentations at conferences in recent years reveal a clear trend. Around 2020, the primary focus was on component digitization – how can sensor data be acquired and initial digital functions implemented in valves or systems. In 2022, the discussion shifted towards connectivity and initial data-based services. The aim was to network components and generate initial added value from the acquired data, such as simple condition monitoring. Conferences around 2024 increasingly addressed system integration and efficiency improvements. The focus was on how networked components interact within a system to, for example, increase energy efficiency or improve overall equipment effectiveness (OEE). Today, we must converge these lines of development to address major industry trends: the call for greater sustainability (e.g., through decarbonization), the need for resilient systems, and the increased demand for automation driven by the shortage of skilled workers. This article uses three concrete use cases to demonstrate how these trends can be addressed and

derives from this the compelling need for industry-wide, standards-based cooperation. [1][2][3]

3. METHODOLOGY AND RESULTS

3.1. View of components

We provide three practical examples in this chapter, showcasing how we have proactively responded to and integrated the prevailing trends.

Use Case 1: Digital Machine Engineering – Efficiency from the Start
This approach drastically cuts development and commissioning times by enabling continuous digital development and simulation of entire machines, including hydraulics. A digital twin of the machine is assembled from component digital twins, allowing validation of system behavior and control logic before physical assembly. This significantly reduces errors, costs, and time-to-market, building on advances in component digitalization and system integration.

Use Case 2: Hydraulic Hub – Digitalizing and Accessing Knowledge
The Hydraulic Hub is an online platform offering 24/7 access to knowledge, data, and processes for hydraulic components for service technicians and maintenance personnel. It bridges the gap between the physical and digital world, allowing users to access data sheets, maintenance instructions, and spare parts lists via unique identifiers (e.g., QR codes). AI-powered "Smart Diagnostics" aid in rapid fault identification, addressing the skilled labor shortage and trend towards data-driven services by digitally preserving and applying expert knowledge.

Use Case 3: CytroConnect – From Reaction to Anticipation
CytroConnect is an IoT solution enabling condition monitoring and predictive analytics for hydraulic systems. By analyzing real-time operational data (pressure, temperature, oil condition), it prevents unplanned downtime and allows for proactive maintenance planning. Learning algorithms assess component health and predict remaining lifespan. CytroConnect exemplifies predictive maintenance and increased plant availability, responding to the demand for greater resilience and productivity

3.2. Necessity of system orientation

The necessity to shift from component-centric to system thinking arises primarily from the increasing complexity of modern engineering projects and organizational structures. While component-based approaches optimize individual parts, they often fail to account for how these components interact and influence the behavior of the larger system. This can lead to unforeseen consequences, suboptimal performance, and the creation of new problems while attempting to solve others.[4]

System thinking, in contrast, offers a holistic understanding by considering the interdependencies and relationships among various components, stakeholders, and the environment. [4] This broader perspective enables better decision-making, as engineers can identify underlying causes of issues rather than just addressing symptoms, anticipate unintended consequences, and align technical choices with overall strategic objectives. [4]

It fosters greater resilience, adaptability, and the ability to innovate more effectively by revealing critical connections and the "bigger picture," ultimately leading to more robust and sustainable solutions.[5]

3.3. Standards: Enabling Seamless Cross-Vendor Systems

In today's complex industrial landscape, cross-manufacturer collaboration has become indispensable, and its effectiveness is intrinsically tied to the adoption of standards. Without agreed-upon standards, collaborative efforts between different manufacturers would be severely hampered by issues of incompatibility and miscommunication.

Firstly, standards ensure interoperability. When multiple manufacturers contribute components or systems to a larger solution, standards provide a common language and set of rules for how these diverse elements should interact. This allows for seamless integration, preventing the need for costly and time-consuming custom adaptations between every new combination of products.

Secondly, standards enhance efficiency and consistency. By establishing common practices, protocols, and quality metrics, standards streamline workflows across different organizations. This reduces ambiguity, errors, and redundant efforts, leading to faster development cycles and higher quality outcomes for all collaborators.

Thirdly, standards foster trust and transparency. A shared understanding of expectations and requirements, facilitated by standards, builds confidence among collaborating parties. It clarifies responsibilities, simplifies quality control, and allows for greater accountability, strengthening the partnership. [6]

Finally, standards enable scalability and innovation. With a standardized framework, new partners can be integrated more easily, and new technologies can be developed and adopted without disrupting existing systems. This accelerates innovation by allowing manufacturers to build upon a stable, common foundation rather than reinventing core functionalities with each project. In essence, standards act as the crucial connective tissue, transforming disparate components from various manufacturers into a cohesive and functional system.

3.4. The Asset Administration Shell

The Asset Administration Shell (AAS) is a standardized digital representation, or digital twin, of a physical or virtual asset, playing a crucial role in Industry 4.0. It acts as a digital identity card, structuring and providing all relevant information and functionalities of an asset throughout its entire lifecycle.

The primary benefit of the AAS is to enable seamless integration and communication between machines, equipment, and IT systems, regardless of the manufacturer. This fosters true vendor-independent interoperability, breaking down data silos and facilitating efficient and secure data exchange across different systems and company boundaries. By providing a common, machine-readable database and standardized interfaces, the AAS supports real-time data transmission, advanced analytics, and the development of new business models,

ultimately leading to optimized processes, increased efficiency, and greater flexibility in industrial production. [7] [8]

4. BRIEF INTERIM SUMMARY AND APPEAL

The preceding chapters underscore the critical necessity of collaboration to effectively navigate and address emerging industry trends. This collaborative imperative inherently dictates the joint development of common standards. Organizations must actively engage in standardization efforts within relevant industry associations. For instance, contributing to bodies like the VDMA, which considers standardization a core task for corporate management and promotes the competitiveness of the mechanical engineering industry , or the IDTA, which focuses on maintaining data protection standards and facilitating secure international data transfers Similarly, participation in the ZVEI, which sees standardization as an essential integrative task for bringing together stakeholders and accelerating the digital and green transformation , is crucial. Furthermore, formalizing commitment through signing a Letter of Intent (LoI) with organizations like the ZVEI further solidifies the dedication to such shared standardization goals. Active involvement in these and similar initiatives is not merely beneficial but essential for ensuring interoperability, fostering trust, enhancing efficiency, and ultimately driving innovation across the industry. [9] [10]

5. OUTLOOK - ORCHESTRATION OF ASSETS WITH THE AAS

For the Asset Administration Shell to reach its full potential, tools must make its use simple and efficient for a multitude of use-cases. One such tool is the Asset Orchestration Platform (AOP). This platform leverages the Asset Administration Shells (AAS) provided by component suppliers to radically simplify the integration (or "onboarding") of components into systems and the coupling of systems with each other, e.g., in a production process. Instead of manually sifting through data sheets and individually integrating a proprietary protocol, the AOP reads a component's data and capabilities directly from its AAS and orchestrates its interaction within the system – a "plug-and-produce" approach for industrial applications.

6. SUMMARY

Fluid power technology demonstrates its innovative strength through the consistent development of digital solutions. Systematic monitoring of trends and their driving factors (like in chapter 1 described) is essential to serve as a basis for deriving necessary strategic measures. The path to a successful future is clearly defined and based on three inseparable pillars:

Defining the standard together: With AAS, driven by IDTA and Fluid 4.0, the standard for the digital twin has been defined.

Consistently using the standard: Use cases such as Digital Machine Engineering and solutions like the Hydraulic Hub and CytroConnect, supported by tools like AOP, translate the standard into practice.

Collaboration: Industry-wide cooperation to establish these standards ensures the competitiveness and innovation leadership of the entire sector.

By embarking on this path together, fluid power technology is ideally equipped for a successful and profitable future.

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Biographies

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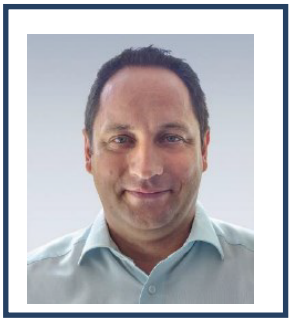
Prior to Bosch Rexroth he was responsible for the development of hydraulic pumps and motors within Parker Hannifin. He earned his Ph.D. degree in engineering at the Fraunhofer-Gesellschaft.



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