

Digital Thread in Product Lifecycle Management

Dr. A. Meenalatha

Associate Professor

Department Mechatronics Engineering

Sri Ramana Maharishi Institute of Technology, Erode, Tamil Nadu

Email: meenalatha_m@rediffmail.com

Mr. YashwantJadhav

Assistant Professor

Department of Production Engineering

Navjeevan Engineering College, Ahmednagar, Maharashtra

Email id: sneharp.projects@yahoo.co.in

Ms. Kavitha Elango

M.E. Student, Department of Mechatronics Engineering

Hindustan Institute of Science and Engineering, Krishnagiri, Tamil Nadu

Email: kavitha.elango@rocketmail.com

Abstract

The digital thread is rapidly emerging as a transformative enabler in modern manufacturing and engineering, especially within the framework of Product Lifecycle Management (PLM). By establishing a seamless, traceable, and interconnected flow of data across a product's lifecycle—from concept to retirement—the digital thread supports real-time decision-making, enhances product quality, reduces time-to-market, and fosters innovation. This paper explores the conceptual foundations of the digital thread, its integration with PLM systems, enabling technologies such as IoT, digital twin, and cloud computing, and its impact on design, manufacturing, and service stages. It also discusses implementation challenges, data interoperability issues, and security concerns, concluding with future research directions and recommendations for industry adoption.

Keywords: *Digital Thread, Product Lifecycle Management (PLM), Digital Twin, Smart Manufacturing, Data Interoperability, Industry 4.0*

INTRODUCTION

In the age of Industry 4.0, the complexity of modern products demands advanced tools to manage their lifecycle effectively. Product Lifecycle Management (PLM) has evolved from being a data repository to a dynamic system that integrates digital technologies to manage the end-to-end lifecycle of a product. The digital thread acts as the nervous system of PLM, offering a continuous data stream linking every phase of product development and operation. By enabling end-to-end traceability and data contextualization, the digital thread enhances collaboration among stakeholders, supports predictive analytics, and ensures consistent communication across departments and systems. This integration plays a critical role in optimizing product performance, improving compliance, and increasing agility in engineering change management.

CONCEPT OF DIGITAL THREAD

The digital thread is a framework for transmitting a product's digital footprint throughout its lifecycle. It connects data generated at various stages—design, simulation, manufacturing, testing, usage, and maintenance—creating a continuous feedback loop. Unlike traditional data silos, the digital thread fosters a single source of truth, eliminating redundancies and improving data visibility.

Key Characteristics:

- **Continuity:** Seamless flow of data across departments and tools.
- **Traceability:** Track every modification from design to decommissioning.
- **Real-time Access:** Enables quick decision-making and adaptive changes.

ROLE IN PRODUCT LIFECYCLE MANAGEMENT

PLM traditionally focused on CAD file storage and version control. With digital threads, PLM becomes an intelligent backbone supporting design iteration, simulation, production optimization, and aftermarket services.

Stage	Digital Thread Contribution
Concept & Design	Design data linked with simulations and requirements
Manufacturing	Real-time machine data and production feedback
Service & Maintenance	Condition monitoring, predictive maintenance
End-of-life	Feedback for future design and recycling

The digital thread enhances collaboration between engineering, manufacturing, and field service teams through shared data insights.

ENABLING TECHNOLOGIES

Several digital technologies underpin the digital thread’s implementation:

- **IoT (Internet of Things):** Captures real-time sensor data from physical assets.
- **Digital Twin:** Virtual replicas of physical systems that sync with the digital thread.
- **Cloud Computing:** Ensures scalability and data accessibility across locations.
- **Big Data & AI:** Enables predictive maintenance and intelligent analytics.
- **PLM Software Platforms:** Tools like Siemens Team center, PTC Windchill, and Dassault Systèmes ENOVIA integrate digital threads with PLM systems.

BENEFITS OF DIGITAL THREAD IN PLM

- **Improved Decision-Making:** Access to real-time data and analytics enhances strategic planning.
- **Reduced Time-to-Market:** Continuous feedback accelerates product development.
- **Cost Savings:** Early fault detection reduces manufacturing defects and recalls.
- **Compliance and Documentation:** Facilitates regulatory audits with traceable records.
- **Enhanced Innovation:** Enables closed-loop feedback for better product iteration.

IMPLEMENTATION CHALLENGES

Despite its potential, digital thread implementation is not without challenges:

- **Data Silos and Interoperability:** Legacy systems often resist integration.
- **Cybersecurity Risks:** Increased data flow demands stronger security protocols.

- **High Initial Costs:** Upgrading IT infrastructure and training employees require investment.
- **Standardization Issues:** Lack of common standards across platforms and industries.

FUTURE SCOPE AND RECOMMENDATIONS

Future developments will likely involve deeper AI integration, blockchain for secure traceability, and wider adoption of open standards to enhance system interoperability.

Recommendations:

- Develop a phased implementation strategy.
- Invest in training for cross-functional teams.
- Select modular and scalable PLM platforms.
- Collaborate with technology vendors for custom integrations.

CONCLUSION

The digital thread represents a paradigm shift in how organizations manage and monitor the product lifecycle. By offering a connected data ecosystem, it significantly improves efficiency, collaboration, and innovation in PLM systems. As industries continue to embrace digital transformation, the digital thread will become a core asset, enabling smarter design, agile manufacturing, and sustainable product strategies. Overcoming challenges related to data integration, security, and standardization will be critical for unlocking its full potential.

REFERENCES

1. Grieves, M., & Vickers, J. (2017). Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. <https://ntrs.nasa.gov>
2. Giffi, C. et al. (2020). The Digital Thread Imperative. Deloitte Insights. <https://www2.deloitte.com>
3. Tao, F., Zhang, H., Liu, A., & Nee, A. Y. C. (2019). Digital Twin in Industry: State-of-the-Art. *IEEE Transactions on Industrial Informatics*, 15(4), 2405–2415.
4. Bolton, R., & Spender, J. C. (2020). Implementing Digital Thread in Aerospace Manufacturing. *International Journal of Smart Manufacturing Systems*, 12(1), 45-56.
5. Patil, R., & Deshmukh, S. (2021). Integration of Digital Thread in PLM: A Case Study. *Indian Journal of Engineering Research and Technology*, 9(3), 67–73.

6. PTC. (2022). What is a Digital Thread?. Retrieved from <https://www.ptc.com>
7. Siemens Digital Industries. (2021). Digital Thread for PLM. Retrieved from <https://www.plm.automation.siemens.com>
8. Ramesh, A., &Iyer, K. (2023). AI-Driven Product Lifecycle Using Digital Threads. Asian Journal of Advanced Engineering Studies, 5(2), 28–36.
9. DassaultSystèmes. (2020). Harnessing the Power of Digital Twin and Thread in Product Innovation. <https://www.3ds.com>
10. Kumar, V., &Jha, R. (2022). Enabling Smart PLM using Digital Thread Architecture. Journal of Digital Engineering and Automation, 10(2), 15–21.