Popular Science Summary

Digitalization of Material Traceability: A System-Level Process Investigation

A System-Level Investigation at Hitachi Energy

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The main finding of this thesis is that material traceability in cooling pipe production does not mainly fail because one specific tool is missing. Instead, the main challenge is that the material identity is not always maintained as one continuous chain across the full process. Production can still continue, material can still move through the factory, and final documentation can still be produced, but the traceability itself may become weaker during the process.

This is important because modern HVDC systems depend on large cooling systems containing many pipes, components, and materials that must meet strict technical and quality requirements. Companies therefore need to know where materials came from, what specifications they had, and how they were handled during production. This is commonly known as material traceability. If traceability becomes unclear, it can affect documentation reliability, quality assurance, production transparency, and future digitalization work.

The study showed that the physical production flow itself usually works well. Material is delivered, stored, cut, welded, finished, assembled, and documented. However, the challenge exists in the traceability layer between departments and systems. Information is often distributed across SAP, drawings, certificates, Excel files, printed documents, and human communication. Because of this, maintaining continuous traceability often depends on manual work and local knowledge from operators and employees.

Several situations were identified where traceability becomes weaker. For example, traceability can become unclear when pipes are cut into smaller pieces, when markings disappear during processing, when leftover material is stored together with similar materials, or when material is handled by sub-suppliers. In many of these situations, production can continue even when the traceability itself is no longer fully clear.

The thesis also investigated how charge numbers and material certificates are used in practice. A key finding was that a charge number alone is not always enough to guarantee unique traceability, since similar numbers may exist from different suppliers. Instead, traceability must be connected to a wider material identity including supplier

information, certificates, material specifications, and internal production references.

To reach these findings, the study mapped the complete flow from supplier documentation and incoming goods to warehouse handling, kitting, cutting, welding, finishing, assembly, and final documentation. The work focused not only on how material physically moves through production, but also on how material identity and traceability information are maintained throughout the process.

Rather than proposing a large digital system directly, the thesis suggests starting with a clearer traceability structure first. The idea is to define how material identity should be created, transferred, split, merged, and maintained during production before introducing more advanced digital solutions. After such a structure exists, simpler digital support such as scanning tools or event registration can be implemented gradually in a more controlled and practical way.

The results of this thesis show that material traceability is not only a technical challenge, but also an organizational and cross-functional one. It involves several departments at the same time, which makes responsibility easily fragmented. At the same time, stronger traceability can improve documentation reliability, production transparency, quality assurance, and future digitalization efforts within industrial manufacturing.