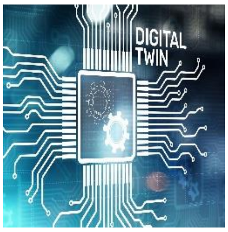
HybridDigital project overview



Project duration: 01.01.23 - 31.12.25

MSE - Material

Metals/Alloys: Steel

Composites: Carbon-fibre reinforced polymer

Other: Hybrid materials

MSE - Application areas

Process optimization: Faster process parameter selection by avoiding trial and error approaches. Enhance material properties (e.g. stiffness) by selecting suitable processing parameters.

Material prediction: Multiple sources based on which material properties are predicted (experimental data, simulated data -> input for ML). Predicted: Stiffness, Modulus, Fatigue behaviour.

Improved information along life cycle: Quick identification of complications in the process chain to avoid production downtime if necessary.

Quality control: Identify potential causes for differences from expected performance (e.g. mismatching autoclave temperatures).

MSE - Product Lifecycle

Raw materials: Quickly obtain expected material properties early in the design process to avoid cost-intensive adjustments afterwards.

Refining/Processing: Parameters for processing.

Manufacturing: Avoid production downtime.

MSE - Material properties

Mechanical: Tensile Strength, Fracture Surface Analysis, Acoustic measurements.

Thermodynamic: E.g. adhesive curing temperatures.

Structural: Fatigue, deformation.

Coupled: E.g., ply layup

MSE - Approach

Experiments: Standardised test for the tensile, fatigue and bonding strength with different standards like ISO, DIN and ASTM.

Computer Simulations: Structural deformation, acoustic behaviour & static and cyclic strength.

Machine Learning/Statistical/Big data: Train ML Model with structured data (from experiments and simulation).

Coupled: ML algorithms take as an input experimental and simulated data.

MSE - Material scales

Mesoscale

Continuum/Macro-scale

General - Centrality of FAIR

Interoperability: Each hybrid material consists of its different components. Predicting the performance of a hybrid material requires combining the data of individual constituents (e.g., CFRP stiffness) from different sources (e.g., CFRP stiffness from simulations or experiments). A clear and interoperable naming and description system has been shown to be crucial for successfully combining all datasets for further processing (e.g. ML).

General - Types of data

Raw data: Spreadsheets (e.g. tensile test/fatigue test results), Images (e.g. fracture surfaces), Acoustic Measurements, Text-Based (e.g. material specifications).

Processed data: Simulation Results (e.g. node deformations).

General - Documentation and publishing of data

General data repositories: Raw Data Storage: Azure Blob Storage.

Code repositories: File-/Data-transformation scripts: Gitlab.

Other repositories: FAIR Data: Triplestore (GraphDB)/OWL-Format

Ontologies - Aspects of digitalization

Data transformation using ontologies: Drop result file of experiment x/process steps y at azure -> auto-parse and structure material/process properties. Drop result from simulation (deformation/acoustics) -> auto parse and structure information. Automatically transform raw files to FAIR data, whereas the FAIR data then drive several workflows (e.g. material performance prediction using ML).

LLM integration: Studies with mappers (unstructured data to taxonomy) and auto-create taxonomy.

Ontologies - Levels of structured data handled

Ontologically described data (RDF data): Will be the result of the project.

Ontologies - Existing ontologies used

MSE ontologies: PMDco

Complimentary ontologies: BFO, CCO

Domain-specific ontologies: Hybrid Materials Ontology

Other ontologies: Manufacturing Ontology

Ontologies - Tools for ontologies

Editors and Collaborative tools: Protégé, drawio

Visualization tools: GraphDB visualizer

Triple Stores and interfaces: GraphDB

Formats and Languages: Python based, OWL

ML/LLMs: ChatGPT, Mistral

Workflows - Types of workflows

Data acquisition from experiments: Every stakeholder drops their data to the azure blob storage for further processing. Dropped file in Azure Blob Storage should be automatically parsed and transformed to FAIR Data (GraphDB).

Machine-learning: Run ML on FAIR data queried from triplestore (e.g. to correlate surface preparation and resulting material properties).

Computer simulation pipelines: E.g. structural deformation & acoustic behaviour. Results from simulations (e.g. stiffness of hybrid material) are automatically parsed and transformed to FAIR data.

Workflows - Workflow priorities

Better documentation.

Workflows - Workflow challenges

Integration of tools: High amount of necessary coordination

Semantic representation: Complexity of representation

Workflows - Levels of workflow implementations

Pre-defined but extendible workflows: Modular approach seeks to distinguish parsing and transforming into single scripts for generating FAIR data.

User friendly interfaces: Planned: GUI for exploring predicted materials performances.

Workflows - Publishing of workflow-related elements

Workflow modules: Single python files

Workflows - Use of PMD workflow store

Publish own workflows/modules: Publish scripts to transform raw data to FAIR data.

Workflows - Tools for workflows

Workflow management: Python Based (flask) with Custom Angular Frontend

Simulation/CAD tools: FEM (Simcenter 3D)

Tools for ontologies/RDF data: GraphDB

ML/LLMs: Tensorflow, Scikit-learn

IT & Security - Computational demands

Usage of HPC resources: Fraunhofer IGCV computing cluster for front & backend

IT & Security - Data-federation

Public: Process- and Material data will be published as OWL-File(s).

IT & Security - Software user interface

Web-service (GUI): Planned: Frontend to browse process and material data.

IT & Security - Tools for IT-architecture and security

Data back-ends: Azure Blob Storage

Use of PMD-Tools

Workflowstore **PMDco**