Plan Overview

A Data Management Plan created using DMPonline

Title: Formation mechanisms of functional coating on porous refractory surfaces via gas-dynamic cold spraying

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Project abstract:

Refractory performance is often limited by the penetration of gaseous and liquid products into the surface layer and deep into the volume through pores, leading to degradation, gas emissions, and costly maintenance. The proposed research focuses on developing a novel method for modifying the porous surface of refractory materials using cold gas-dynamic spraying (CGDS) of ceramic particles ranging from 100 nm to 10 µm in size. The core innovation lies in adapting CGDS—typically used for metals—to coat porous ceramics, thereby creating functional multilayer or composite coatings that improve tightness, wear resistance, and resistance to thermal cycling. The project combines experimental and computational approaches: experimental work includes characterising coated refractory materials (e.g., porosity, gas permeability, hardness, and bonding strength) using tools such as SEM, nanoindentation, and microtomography. Computational Fluid Dynamics (CFD) and Finite Element Method (FEM) simulations will be used to understand particle behavior during impact and pore interaction.

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Formation mechanisms of functional coating on porous refractory surfaces via gas-dynamic cold spraying

Data Summary

Will you re-use any existing data and what will you re-use it for?

Yes, existing data will be reused to complement the experimental and computational components of the project. Specifically:

- **Material property databases** (e.g., thermal conductivity, Young's modulus, and density of ceramic materials) will be reused to inform simulation inputs and validate FEM and CFD models.
- **Literature-based experimental results** on CGDS processes and refractory coatings will be consulted to benchmark coating performance metrics such as porosity reduction, hardness increase, and thermal resistance.
- **Simulation benchmarks and open-access models** related to particle impact dynamics and gas flow in porous materials may be reused to validate and cross-check the outcomes of the custom-developed simulation tools.

What types and formats of data will the project generate or re-use?

The project will generate both experimental and computational data, as well as re-use existing materials data and reference models. Specifically:

- **Experimental Data:**
  - *Raw and processed data* from materials characterisation (e.g., porosity, gas permeability, hardness, bonding strength).
  - *File formats:* .txt, .xlsx, and .csv (from nanoindentation, permeability tests, etc..)
  - *Image data* from Scanning Electron Microscopy (SEM), stored in .tif format, and micro-computed tomography (µCT), stored as volumetric .voxel data or surface meshes in .stl format.
- **Computational Data:**
  - *Simulation results* from Computational Fluid Dynamics (CFD) and Finite Element Method (FEM) models.

What is the purpose of the data generation or re-use and its relation to the objectives of the project?

The purpose of data generation and re-use is to support the development, optimisation, and validation of a novel method for modifying the porous surfaces of refractory materials using cold gas-dynamic spraying (CGDS) of ceramic particles. The data directly aligns with the project's key objectives in the following ways:

- **Experimental data** (e.g., porosity, gas permeability, hardness, bonding strength) will be

generated to evaluate the effectiveness of CGDS coatings in improving surface tightness, mechanical durability, and resistance to thermal cycling.

- **Image data** from SEM and microtomography will be used to analyse the coating's morphology, layer structure, and pore sealing effectiveness.
- **Computational simulation data** from FEM and CFD will support the understanding of particle impact behaviour and pore interaction dynamics, which are essential for optimising spray parameters and predicting performance.
- **Re-used material property data** and published benchmarks will be employed to initialise simulations, validate numerical models, and compare experimental outcomes with state-of-the-art results.

What is the expected size of the data that you intend to generate or re-use?

The expected total volume of data generated during the project is approximately **150–300 GB**, broken down as follows:

- **Experimental data:**
  - Text-based results from material testing (e.g., nanoindentation, gas permeability): ~1–2 GB.
  - SEM image data: ~20–40 GB depending on resolution and number of samples.
  - Microtomography (CT) scans: ~50–100 GB, due to high-resolution voxel and STL formats.
- **Computational data:**
  - FEM and CFD simulation output files: ~30–60 GB.
  - Scripts, source code, and model configurations: <1 GB.
- **Documentation and metadata:**
  - Lab notebooks, notes, and reports: <5 GB in total, mainly in .pdf, .txt, and eLabFTW database entries.

What is the origin/provenance of the data, either generated or re-used?

The **generated data** will originate from:

- **Experimental measurements** performed directly by the project team using in-house equipment at RPTU, including:
  - Nanoindentation and mechanical testing devices,
  - Scanning Electron Microscopy (SEM),
  - Micro-computed tomography (µCT),
  - Cold gas-dynamic spraying (CGDS) setup.
- All experimental procedures and results will be documented using *eLabFTW*, an electronic lab notebook hosted on RHRK's secure infrastructure, ensuring traceability and version control.
- **Computational data** will be produced through custom CFD and FEM simulations developed during the project. Model parameters will be based on literature values, experimental data, and validated against open-access benchmarks where available.

The **re-used data** will come from:

- **Peer-reviewed scientific literature** on refractory materials, CGDS processes, and porous ceramics.

- **Open-access materials property databases** such as MatWeb or manufacturer-provided datasheets.
- **Benchmark models and validation cases** from published simulation studies or reputable academic sources.

To whom might your data be useful ('data utility'), outside your project?

The data generated in this project may be valuable to a range of stakeholders and researchers beyond the immediate scope of the MSc project:

- **Materials scientists and engineers** working on refractory ceramics, coatings, or surface modification techniques may benefit from the experimental data on porosity, permeability, and mechanical properties of coated materials.
- **Researchers in cold gas-dynamic spraying (CGDS)**, especially those exploring its application beyond metals, will find the coating performance data and adapted process parameters highly relevant.
- **Computational modelling communities** involved in Finite Element Method (FEM) or Computational Fluid Dynamics (CFD) simulations can reuse validated models, scripts, and boundary conditions related to particle impact dynamics and gas transport in porous media.
- **Industrial partners in high-temperature or corrosive environments** (e.g., metallurgy, energy, chemical processing) may benefit from insights into improving refractory performance and extending maintenance intervals.
- **Open-access repositories and academic platforms** will enable further use in education, training, and comparative research.

FAIR data

2.1. Making data findable, including provisions for metadata: Will data be identified by a persistent identifier?

Yes, all publicly shared datasets, including final research outputs and supporting materials, will be assigned **persistent identifiers (PIDs)**, such as **Digital Object Identifiers (DOIs)**. These will be issued through the institutional repository **KLUEDO** at RPTU, which ensures long-term accessibility and stable referencing.

Each dataset entry will also include detailed **metadata** describing its content, origin, format, authorship, methods, and licensing terms. Metadata will follow widely accepted standards (e.g., Dublin Core, DataCite) to support interoperability and discoverability in catalogues, search engines, and academic databases.

2.1. Making data findable, including provisions for metadata: Will rich metadata be provided to allow discovery? What metadata will be created? What disciplinary or general standards will be followed? In case metadata standards do not exist in your discipline, please outline what type of metadata will be created and how.

Yes, **rich metadata will be created and provided** to ensure that the data generated during the project is easily discoverable, understandable, and reusable by others. Metadata will be included both within the institutional repository (KLUEDO) and in the eLabFTW electronic lab notebook used throughout the research process.

2.1. Making data findable, including provisions for metadata: Will search keywords be provided in the metadata to optimize the possibility for discovery and then potential re-use?

Yes, **search keywords will be included in the metadata** to enhance the discoverability and reusability of the datasets. Keywords will be carefully selected to reflect the core scientific and technical aspects of the project. The keywords will be added during dataset submission to the **KLUEDO** repository and within the **eLabFTW** entries to support internal searchability. Keywords will follow standard academic and domain-specific terminology to maximise visibility in institutional, national, and international data catalogues.

2.1. Making data findable, including provisions for metadata: Will metadata be offered in such a way that it can be harvested and indexed?

Yes, metadata for all publicly shared datasets will be offered in a structured and interoperable format that supports **harvesting and indexing** by external services. The **KLUEDO** institutional repository at RPTU complies with the **Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)**, which enables automated access and indexing of metadata by search engines, academic databases, and metadata aggregators (e.g., BASE, OpenAIRE).

Metadata will follow the **DataCite** and **Dublin Core** standards, ensuring compatibility with common indexing platforms and enabling global visibility. This approach supports the **FAIR principles**, particularly the “Findable” and “Accessible” components, by making research data easily discoverable via persistent identifiers and well-structured metadata.

In addition, metadata recorded in **eLabFTW** will be exportable and can be linked to final datasets, providing continuity between internal research documentation and published outputs.

2.2. Making data accessible - Repository: Will the data be deposited in a trusted repository?

Yes, all final datasets and supporting materials will be deposited in **KLUEDO**, the **certified institutional repository** of RPTU (Rhineland-Palatinate Technical University). KLUEDO is a **trusted, long-term archive** managed by the university library, ensuring data integrity, access control, and long-term preservation.

2.2. Making data accessible - Repository: Have you explored appropriate arrangements with the identified repository where your data will be deposited?

Yes, appropriate arrangements for data deposition have been confirmed with KLUEDO, the institutional repository of RPTU. KLUEDO is the recommended and supported platform for long-term research data storage at the university and provides guidance for students and researchers depositing data.

2.2. Making data accessible - Repository: Does the repository ensure that the data is assigned an identifier? Will the repository resolve the identifier to a digital object?

Yes, the institutional repository KLUEDO at RPTU assigns a persistent Digital Object Identifier (DOI) to each dataset deposited. This ensures that every dataset has a unique, stable, and citable reference.

The DOI is automatically linked to a landing page that includes the full metadata record and provides direct access to the dataset (or metadata and access conditions, if an embargo or restriction is applied). This allows the identifier to be resolved to a digital object using standard DOI infrastructure (e.g., via https://doi.org), supporting long-term access, citation, and reuse.

This process fully complies with FAIR principles and ensures that data deposited in KLUEDO remains discoverable, accessible, and permanently linked to its metadata and associated documentation.

2.2. Making data accessible - Data:

Will all data be made openly available? If certain datasets cannot be shared (or need to be shared under restricted access conditions), explain why, clearly separating legal and contractual reasons from intentional restrictions. Note that in multi-beneficiary projects it is also possible for specific beneficiaries to keep their data closed if opening their data goes against their legitimate interests or other constraints as per the Grant Agreement.

The majority of the project's research data will be made openly available through the institutional repository KLUEDO at RPTU, in line with FAIR principles and open science practices.

2.2. Making data accessible - Data:

If an embargo is applied to give time to publish or seek protection of the intellectual property (e.g. patents), specify why and how long this will apply, bearing in mind that research data should be made available as soon as possible.

N/A

2.2. Making data accessible - Data:

Will the data be accessible through a free and standardized access protocol?

Yes, all data made publicly available will be accessible through free and standardized access protocols. The institutional repository KLUEDO at RPTU provides open access to datasets via the HTTPS protocol, ensuring secure and universal accessibility without the need for specialized software or subscriptions.

2.2. Making data accessible - Data:

If there are restrictions on use, how will access be provided to the data, both during and after the end of the project?

N/A

2.2. Making data accessible - Data:

How will the identity of the person accessing the data be ascertained?

For the majority of datasets, which will be made openly available without access restrictions, no user identification will be required. Anyone can access, view, and download the data through the KLUEDO repository via a public DOI link using standard web protocols (e.g., HTTPS).

2.2. Making data accessible - Data:

Is there a need for a data access committee (e.g. to evaluate/approve access requests to personal/sensitive data)?

No, there is no need for a data access committee in this project.

2.2. Making data accessible - Metadata:

Will metadata be made openly available and licenced under a public domain dedication CC0, as per the Grant Agreement? If not, please clarify why. Will metadata contain information to enable the user to access the data?

Yes.

2.2. Making data accessible - Metadata:

How long will the data remain available and findable? Will metadata be guaranteed to remain available after data is no longer available?

All research data deposited in the institutional repository KLUEDO at RPTU will be preserved and remain available and findable for the long term, consistent with the university’s data management and digital preservation policies.

2.2. Making data accessible - Metadata:

Will documentation or reference about any software be needed to access or read the data be included? Will it be possible to include the relevant software (e.g. in open source code)?

No.

2.3. Making data interoperable:

What data and metadata vocabularies, standards, formats or methodologies will you follow to make your data interoperable to allow data exchange and re-use within and across disciplines? Will you follow community-endorsed interoperability best practices? Which ones?

To ensure interoperability and facilitate data exchange and reuse within materials science, engineering, and computational modelling disciplines, the project will follow established and community-endorsed standards and best practices:

- **Metadata standards:**
  - *DataCite Metadata Schema* for dataset description and repository archiving, enabling cross-disciplinary discovery and citation.
  - *Dublin Core* for general metadata interoperability and indexing by search engines and aggregators.
  - *Open Researcher and Contributor ID (ORCID)* identifiers for author attribution.
- **Data formats:**
  - Experimental data will be stored in widely-used, non-proprietary formats such as **TXT, XLSX** (for tabular data), and **TIFF** (for imaging).
  - 3D imaging and geometry data will be saved in **STL** or **voxel** formats, common in materials and engineering research.
  - Simulation data and scripts will be stored in plain text formats (e.g., TXT, CSV) and documented with sufficient metadata for reuse.
- **Methodologies and practices:**
  - Data and metadata will be structured following the FAIR principles (Findable, Accessible, Interoperable, Reusable).
  - Use of persistent identifiers (DOIs) and rich metadata to enhance interoperability.
  - Compliance with guidance from the Research Data Alliance (RDA) and community recommendations for materials science data management.
  - Consistent use of controlled vocabularies and terminology drawn from materials science and coating technology to improve semantic interoperability.

2.3. Making data interoperable:

In case it is unavoidable that you use uncommon or generate project specific ontologies or vocabularies, will you provide mappings to more commonly used ontologies? Will you openly publish the generated ontologies or vocabularies to allow reusing, refining or extending them?

Yes.

2.3. Making data interoperable:

Will your data include qualified references [1] to other data (e.g. other data from your project, or datasets from previous research)?

[1] A qualified reference is a cross-reference that explains its intent. For example, X is regulator of Y is a much more qualified reference than X is associated with Y, or X see also Y. The goal therefore is to create as many meaningful links as possible between (meta)data resources to enrich the contextual knowledge about the data. (Source: https://www.go-fair.org/fair-principles/i3-metadata-include-qualified-references-metadata/)

No.

2.4. Increase data re-use:

How will you provide documentation needed to validate data analysis and facilitate data re-use (e.g. readme files with information on methodology, codebooks, data cleaning, analyses, variable definitions, units of measurement, etc.)?

To ensure that data can be accurately validated and effectively reused, comprehensive documentation will accompany all datasets. This includes:

- **Readme files** detailing the experimental and computational methodologies, data collection procedures, and project context.
- **Descriptions of data processing and cleaning steps** , including scripts or workflows used for analysis, to provide transparency and reproducibility.
- **Version histories and changelogs** to track data updates and corrections over time.
- **Metadata records** that include links to related publications, software, and tools used in data generation and analysis.
- Use of the **eLabFTW electronic lab notebook system** to record experimental protocols, intermediate results, and analysis notes, ensuring structured and searchable documentation throughout the research process.

2.4. Increase data re-use:

Will your data be made freely available in the public domain to permit the widest re-use possible? Will your data be licensed using standard reuse licenses, in line with the obligations set out in the Grant Agreement?

Yes.

2.4. Increase data re-use:

Will the data produced in the project be useable by third parties, in particular after the end of the project?

Yes, the data produced during this project will be **fully usable by third parties** , both during and after the project's completion. To ensure this:

- Data will be curated and documented following **FAIR principles** (Findable, Accessible, Interoperable, Reusable).
- Standard, open file formats (e.g., TXT, XLSX, TIFF, STL) will be used to facilitate compatibility with common analysis tools.
- Comprehensive metadata and documentation, including methodology descriptions and codebooks, will accompany the datasets.
- Data will be deposited in the institutional repository **KLUEDO**, which supports **long-term preservation, persistent identifiers (DOIs), and open access**.
- Where applicable, datasets and associated research outputs will be linked to **open-access scientific publications**, further enhancing usability and citation.

2.4. Increase data re-use:

Will the provenance of the data be thoroughly documented using the appropriate standards?

Yes.

2.4. Increase data re-use:

Describe all relevant data quality assurance processes.

To ensure the integrity, accuracy, and reliability of the data generated in this project, several quality assurance processes will be implemented throughout data collection, processing, and storage:

- **Calibration and validation of instruments:** Experimental tools such as SEM, nanoindentation devices, and microtomography scanners will be regularly calibrated according to manufacturer specifications and laboratory standards to ensure precise measurements.
- **Standardized protocols:** Experimental procedures and computational simulations will follow standardized and well-documented protocols to minimize variability and enhance reproducibility.
- **Data verification:** Raw data will be systematically checked for completeness and consistency immediately after acquisition, including verifying file formats and metadata accuracy.
- **Replicates and controls:** Experimental tests will include replicates and control samples to assess measurement variability and identify outliers.
- **Software validation:** Computational models (CFD, FEM) will be benchmarked against known cases or literature data to verify accuracy before production runs.
- **Version control:** All datasets, scripts, and analysis workflows will be managed using version control systems to track changes, support reproducibility, and prevent data loss or corruption.
- **Backup and storage:** Data will be securely backed up regularly on institutional servers, with redundant copies stored to prevent loss due to hardware failure or human error.
- **Review and documentation:** Data quality and processing steps will be documented in the eLabFTW electronic lab notebook and reviewed by supervisors to ensure compliance with project standards.

2.4. Increase data re-use:

Further to the FAIR principles, DMPs should also address research outputs other than data, and should carefully consider aspects related to the allocation of resources, data security and ethical aspects.

In addition to data management following FAIR principles, the project will also address the management and sharing of other research outputs, such as:

- **Research publications and reports:** Experimental and simulation results will be disseminated through open-access scientific journals and reports deposited in the institutional repository KLUEDO, ensuring wide visibility and long-term preservation.
- **Software and code:** Scripts and computational models developed during the project will be documented, version-controlled, and published openly where possible, facilitating reuse and transparency.

Regarding **allocation of resources**, the project will leverage institutional support for data management, including:

- Technical infrastructure from the university's computer center for data storage and backups.
- Support from RPTU's data management teams and student assistants for metadata creation and data curation.
- Use of existing platforms such as eLabFTW and KLUEDO, reducing the need for additional costly infrastructure.

Data security measures include:

- Storage on secure university servers with regular backups and access control.
- Compliance with GDPR and institutional IT security policies to protect any sensitive information, even though this project does not handle personal data.
- Controlled access settings in KLUEDO for any restricted datasets, with monitoring of access logs.

Ethical considerations:

- The project does not involve human subjects or personal data; therefore, there are no specific ethical risks associated with data privacy or consent.
- All research will adhere to RPTU's code of research integrity and ethical guidelines, including proper attribution and responsible data sharing.
- Transparency will be maintained by documenting all methods and ensuring reproducibility.

Other research outputs

In addition to the management of data, beneficiaries should also consider and plan for the management of other research outputs that may be generated or re-used throughout their projects. Such outputs can be either digital (e.g. software, workflows, protocols, models, etc.) or physical (e.g. new materials, antibodies, reagents, samples, etc.).

Beyond data, the project will generate and potentially re-use several other research outputs, including:

- **Digital outputs:**
  - **Software and code** developed for simulations (CFD, FEM) and data analysis will be version-controlled, documented, and deposited alongside datasets in the institutional repository KLUEDO or in dedicated code repositories (e.g., GitHub), ensuring transparency and reusability.
  - **Experimental protocols and workflows** will be recorded in the electronic lab notebook system (eLabFTW) and made accessible to support reproducibility and knowledge transfer.
- **Physical outputs:**
  - **Coated refractory material samples** and related experimental specimens will be labelled, catalogued, and stored securely in laboratory facilities following institutional safety and handling protocols.
  - Samples will be preserved for possible future use or further characterization, in compliance with RPTU's material management policies.

The management of these outputs will adhere to institutional standards and best practices to ensure

they remain traceable, accessible, and usable for verification, future research, or potential collaboration partners.

Beneficiaries should consider which of the questions pertaining to FAIR data above, can apply to the management of other research outputs, and should strive to provide sufficient detail on how their research outputs will be managed and shared, or made available for re-use, in line with the FAIR principles.

The project will extend the **FAIR principles** (Findable, Accessible, Interoperable, Reusable) beyond datasets to all other research outputs, including software, protocols, and physical samples:

- **Findable:**
  - Digital outputs such as software, scripts, and experimental protocols will be assigned persistent identifiers (e.g., DOIs) where possible and catalogued in institutional repositories (e.g., KLUEDO, GitHub).
  - Physical samples will be labelled with unique identifiers and recorded in laboratory inventory systems.
- **Accessible:**
  - Digital outputs will be openly accessible through trusted platforms with standardized access protocols (HTTPS).
  - Physical samples will be available upon request under clear conditions defined by institutional policies.
- **Interoperable:**
  - Software and workflows will be documented using widely accepted standards and formats to facilitate integration and reuse across disciplines.
  - Metadata describing physical samples (composition, treatment, provenance) will use community-recognized vocabularies to enhance interoperability.
- **Reusable:**
  - Comprehensive documentation (e.g., README files, protocols, code comments) will accompany digital outputs to support reproducibility.
  - Physical samples will be stored under conditions ensuring their preservation and future usability.

Allocation of resources

What will the costs be for making data or other research outputs FAIR in your project (e.g. direct and indirect costs related to storage, archiving, re-use, security, etc.) ?

The costs associated with making data and other research outputs FAIR-compliant in this project are expected to be moderate and primarily covered through existing institutional resources.

How will these be covered? Note that costs related to research data/output management are eligible as part of the Horizon Europe grant (if compliant with the Grant Agreement conditions)

N/A

Who will be responsible for data management in your project?

The primary responsibility for data management lies with the principal investigator (PI), who will oversee data collection, documentation, quality assurance, and archiving.
They will be supported by:

- RPTU’s university data management team providing guidance on best practices and compliance with institutional policies.
- The computer centre, ensuring secure storage and backup of digital data.
- Student assistants helping with metadata creation, data entry, and routine curation tasks.

How will long term preservation be ensured? Discuss the necessary resources to accomplish this (costs and potential value, who decides and how, what data will be kept and for how long)?

Long-term preservation of research data and outputs will be ensured through institutional infrastructure and clear planning.

Data security

What provisions are or will be in place for data security (including data recovery as well as secure storage/archiving and transfer of sensitive data)?

Data security in this project is ensured through a combination of institutional infrastructure, best practices, and clear procedures:

- Secure storage and access control:
  All data will be stored on RPTU’s secure institutional servers, which offer controlled access, password protection, and role-based permissions to prevent unauthorised use.
- Backups and data recovery:
  Regular automated backups are managed by the university’s computer center, with redundant storage systems in place to enable full data recovery in the event of hardware failure, accidental deletion, or corruption.
- Archiving:
  Final datasets and project outputs will be archived in the certified institutional repository KLUEDO, which offers secure, long-term digital preservation with persistent identifiers and version control.
- Sensitive data:
  While this project does not involve personal or sensitive data, all data transfers will still follow secure protocols (e.g. encrypted file transfer, VPN access) to maintain confidentiality during collaborative work and external sharing.
- Physical security:

Laboratory notebooks, physical samples, and lab equipment will be stored in access-controlled facilities within RPTU.

Ethics

Are there, or could there be, any ethics or legal issues that can have an impact on data sharing? These can also be discussed in the context of the ethics review. If relevant, include references to ethics deliverables and ethics chapter in the Description of the Action (DoA).

No.

Will informed consent for data sharing and long term preservation be included in questionnaires dealing with personal data?

No.

Other issues

Do you, or will you, make use of other national/funder/sectorial/departmental procedures for data management? If yes, which ones (please list and briefly describe them)?

No.