

THE BENCHMARK DATABASE OF EXPERIMENTS, NUCLEAR, AND TECHNOLOGICAL DATA FOR HYBRID FUSION SYSTEMS WITH VARIOUS TYPES OF BLANKETS

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ABSTRACT

- The development of three independent databases is being carried out by research teams of NRC «Kurchatov Institute»:
 - 1. Benchmark experiments for the verification of transport codes and evaluated nuclear data libraries;
 - 2. Evaluated nuclear data libraries (ENDF/B, ROSFOND, etc.), integrated into the VISTUD hardware-software system for their storage, processing, and visualization;
 - 3. Properties of functional and structural materials intended for the design of hybrid facilities;
- The developed databases are planned to be integrated into a unified management system.

BACKGROUND

The fusion neutron source (FNS) concepts under development at the NRC «Kurchatov institute» are based on a tokamak-type magnetic confinement system for DT plasma, equipped with a blanket containing nuclear materials. In the design of a FNS, a key aspects are: 1. simulation of neutron irradiation effects on the structural and functional materials of the facility; 2. verification of the obtained modeling results with experimental data; 3. selection of structural and functional materials according to their properties and service conditions. Structuring of benchmark experimental data, material characteristics, and evaluated nuclear data library files within a management system will facilitate the efficient and more safe development of technical solutions in the design of FNS and provide all project participants with access to up-to-date information.

IMPLEMENTATION

BENCHMARK EXPERIMENTS DATABASE

- The following facilities were employed for experiments:
 - NG-24 neutron generator with a fusion-like spectrum and an intensity of 1×10^{11} n/s;
 - I-2 linear particle accelerator with a beryllium target irradiated by protons with an energy of 20.8 MeV and an intensity of 6×10^{11} proton/s.
- Several types of micro-models of fusion blankets were used:
 - the "pure" NG-24 spectrum (without a blanket);
 - a molten salt blanket (0.52NaF 0.48ZrF₄) with thermal and fast neutron spectra;
 - solution-based blankets;
 - beryllium target irradiated by protons.
- Numerical simulations were performed using various transport codes (KIR, MCNP, SuperMC, PHITS) and nuclear data libraries JEFF-3.3, JENDL-4.0/5, ENDF/B-VIII.0, ROSFOND-2010, FENDL-3.0, TENDL-2019, IRDFF-II.

EVALUATED NUCLEAR DATA DATABASE

- For a design of hardware—software system Visualizer of Fusion—Controlled Data System (VISTUD) a modern technological stack was used: SQL (PostgreSQL), Python, and C++;
- The VISTUD system consists of subsystems for management, data storage, computation, user interaction, and auxiliary infrastructure.

MATERIAL PROPERTIES DATABASE

• The database is populated with information from open sources and from research and development results.

OUTCOME

BENCHMARK EXPERIMENTS DATABASE

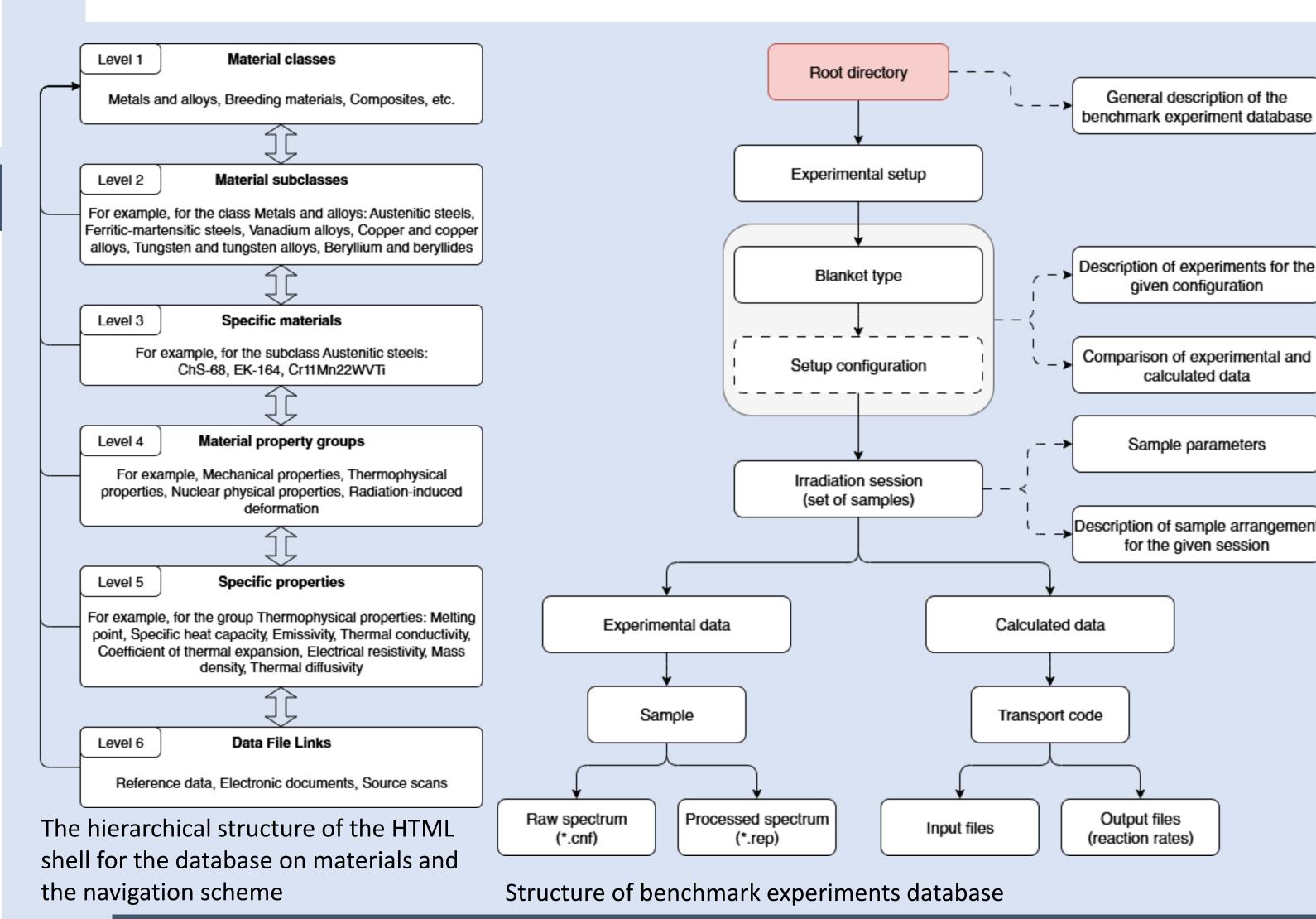
More than **800 values** of threshold reaction rates – (n,2n), (n,p), (n,pn), (n, α), (n,n' γ), and (n, γ) – have been measured for 17 samples: $^{63(99.5\%),65(99.7\%),nat}$ Cu, nat Ni, nat Zr, 27 Al, nat Ti, 59 Co, nat Mg, nat Fe, nat Cd, nat In, $^{64(99/4\%)}$ Zn, 197 Au, 93 Nb, 169 Tm, 232 Th. The database containing measurement and simulation results, description of experiments, numerical models and results of the comparative analysis has been designed. An HTML-interface has been developed for database access, also alternative interface based on Anytype app has been used.

EVALUATED NUCLEAR DATA DATABASE

VISTUD system is designed for the storage, transformation, analysis, and visualization of existing neutron fusion data. The general architecture, design, and prototype of the VISTUD system have been developed. The database has been partially populated using the ROSFOND library.

MATERIAL PROPERTIES DATABASE

Data on 16 alloys has been collected. The database has 6 levels of its structure to navigate a user. It comprises 7 groups of material properties: mechanical, thermophysical, corrosion, radiation-induced deformation, interaction with hydrogen and helium, nuclear physical properties, and magnetic properties.



CONCLUSION

- A benchmark experiment and material properties databases have been developed while VISTUD system is currently at the stage of user interface development and refinement of the remaining subsystems;
- The databases are being continuously expanded with new data, and tools for their processing are under development;
- The resulting system will support the efficient and more safe development of technical solutions for hybrid reactor design.

REFERENCES

- [1] TITARENKO, Yu.E. et al., Verification of nuclear data libraries used to design molten salt blankets of a fusion neutron source, Annals of Nuclear Energy 211 (2025) 110983.
- [2] TITARENKO, Yu.E. et al., Benchmark Experiments for Verification of Nuclear Data Libraries for Designing Fusion Blankets, Fusion Science and Technology 78 7 (2022) 549.
- [3] TITARENKO, Yu.E. et al., Benchmark Experiments Methodology on Base the Neutron Generator NG-24M and Micromodels of the Fusion Neutron Source (FNS), Problems of Atomic Science and Technology, Ser. Nuclear And Reactor Constants 2 (2023) 60.