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

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The development of hybrid fusion facilities requires the modeling of neutron interactions, as well as thermal, chemical, and mechanical effects on installation components and materials. The accuracy of such modeling is strongly determined by the nuclear data libraries used, the computational methods employed, and the specified material properties (composition, mechanical, thermal, and chemical characteristics). Practical experience underscores the necessity of a comprehensive dataset, including various benchmark experiments. These datasets can be categorized into three primary directions within a unified database:

(a) Benchmark experiments for the verification of transport codes and nuclear data libraries used in calculations of hybrid system blankets and in the assessment of the activation of structural and functional materials;
(b) Existing neutron fusion data (e.g., ENDF, ROSFOND), integrated into the developing VISTUD software and hardware platform for storage, transformation, and visualization;
(c) Properties of structural and functional materials for hybrid systems, including mechanical, thermophysical, and corrosion properties, as well as data on radiation-induced deformation and interactions with hydrogen and helium.

In the absence of high-intensity fusion neutron sources, benchmark experiments (the first category) were conducted using the NG-24 neutron generator and proton accelerator with a Be target. The NG-24 operated at an intensity of 1×10^{11} neutrons per second. The Be target was irradiated by protons with an energy of 20.8 MeV and an intensity of 1×10^{12} protons per second.

To verify computational results, threshold reaction rate measurements were performed for (n,2n), (n,p), (n,pn), (n,α), (n,n´γ), and (n,γ) processes across 17 samples, including both natural and highly enriched isotopic compositions: $^{63(99.5\%),65(99.7\%),nat}$Cu, ^{nat}Ni, ^{na}tZr, ^{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.

Currently, the developing database includes data for micro-models of fusion blankets of various compositions: a “clean” NG-24 spectrum (i.e., “without a blanket”); salt-based and solution-based blankets; as well as experiments involving a Be target [1-3].

For each type of experiment, the database provides the following information:

- Experiment description and blanket geometry, including the arrangement of irradiated samples;
- Measurement results, including γ-spectra of irradiated samples and the corresponding processed data;
- Detector specifications, and the parameters of their absolute efficiency;
- Simulation results, gained by various versions of transport codes such as KIR, MCNP, SuperMC, and PHITS, and different libraries (JEFF-3.3, JENDL-4.0, ENDF/B-VIII.0, ROSFOND-2010, FENDL-3.0, TENDL-2019, IRDFF-II, JENDL-5). These results are presented in the form of input and output files;
- Comparative analysis of experimental and computational results for irradiated samples, presented using statistical factors that assess the predictive capabilities of the transport codes and nuclear data libraries.

The database was developed using HTML-based interface that easily can be integrated into web site. As an alternative interface for the database the Anytype platform was used. The database has a hierarchical structure, enabling users to easily locate the required experiment and all associated information.

For the second direction of the unified database, the VISTUD Software and Hardware Complex (Visualization System for Fusion-Controlled Data) is under development. This system is designed for the storage, transformation, and visualization of neutron fusion data by leveraging modern nuclear data libraries (e.g., ENDF, ROSFOND [4]) and data conversion codes (such as GRUCON [5], NJOY, and others), as well as tools for data analysis and visualization.

At present, the general architecture and design of the VISTUD complex have been completed, and a prototype has been implemented. Partial population of the evaluated fusion data database, based on ROSFOND, has already been performed. Interfaces for interaction with the control module have been developed for all subsystems.

The development plan includes the creation of a multi-threaded control module and a web-based user interface for fully functional interaction with the VISTUD complex, as well additional subsystems and modules for data analysis, export, and visualization, enabling the comprehensive presentation of fusion data and the results of their analysis, with full integration.

The ultimate goal of the project is to establish a scalable software and hardware complex that incorporates all created fusion databases and providing authorized access to users.

As part of the third direction of the unified database – developing a database of the properties of structural and functional materials for hybrid systems – the following components have been developed:

- A hierarchical structure of the database;
- Data formats;
- Codification of database elements;
- Templates for preparing data for entry into the database;
- Tools for database population and user access to its contents;
- A methodology for database population, employing a quality control principle at each stage of data processing to ensure data integrity, formatting, and codification;
- An HTML-based interface for easy navigation through database sections and subsections, facilitating user access to required data.

The database is populated by compilation data sourced either from publicly available resources or from the results of research and development (R&D) of Russian projects. Currently, entries have been made for the properties of industrially developed reactor-grade chromium-nickel austenitic steel ChS-68, promising low-activation chromium-manganese austenitic steel such as Cr11Mn22WVTi, and low-activation vanadium alloy V-4Ti-4Cr.

The authors anticipate that the database will serve as a valuable resource for specialists involved in the development of fusion neutron sources and “clean” fusion reactors, contributing to advancements in the field of controlled fusion.

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