Material Design Integration Tutorial

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There is a strong interaction between operating and loading conditions of systems or components, their respective engineering realization and materials selection. Various facets shall be addressed. For fusion DEMO in-vessel components (IVC), there are:

- Systems' requirements, operational requirements, engineering design descriptions
- Operational and loading conditions, harsh environment,
- ➢ Taken together these impose requirements and criteria on material selection and
- ➢ Where socio-economic policies further reduce candidates and options considerably.

Typically the flow of information is channelled through "design description documents" (from engineering to materials) and vice versa via "material assessment reports, materials property handbook (MPH) and associated design criteria (DC)" and associated limiting properties.

For materials the current status of structural materials and requirements on future options shall be addressed, in particular, the ideas from material development, characterization, increasing manufacturing maturity towards verification and validation for DEMO specific application.
The first-part of this tutorial provides background information on blanket concepts, basic requirements, candidate materials, and current trends in R&D. Further, the performance of these candidate materials is briefly summarized and discussed. With this background, the focus will be put on a detailed presentation of the relevant aspects in materials technology.

A. Introduction & Overview
    - basic and operational requirements, blanket concepts
    - material classes
    - developments – past & present
B. Materials Performance
    - metallurgy
    - basic properties
    - irradiation damage
C. Materials Technology
    - technical readiness level
    - production
    - semi-finished products
    - machining (conventional, future options)
    - joining
    - coating (corrosion, T-permeation)
    - materials testing (engineering data)

In the second-part the focus is on materials-engineering integration and interaction.
Considering the development of a component "material design integration" has different aspects and as well different task and function in the various steps of the next-step DEMO project. Development of a helium or water cooled breeder blanket options will serve as examples.

1) Engineering of a system along with first basic decisions and selection imply requirements on temperature window, and physical and mechanical properties of materials. A family of materials can be pre-selected and then further "designed", i.e. optimized according to specific needs. Typical examples of this process are RAFM steel breeder blankets. Serious operational and performance limits

likely are not only set by the base structural material properties and its degradation under n-irradiation, but rather by technological issues as “joints” or the need for coatings (thermal and/or electrical insulation, tritium and/or corrosion barriers).

2) Starting from well characterized material and “some conceptual design ideas”, the engineering challenge involves making optimal use of it. During the design process various types of analyses for proper identification of any potential loading conditions and failure paths are required. MPH and DC are the guiding documents and input.

3) Development of specific design criteria might be the most efficient and economic approach to improve, both, performance and safety of IVCs. In essence this key to success needs

- To (really!) understand material behavior and degradation of properties,
- To identify failure modes (material as well as structural), cause and progress of damage,
- To identify the most critical failure paths (hence btw: assigning priorities of projects and directing funding properly)
- To know synergetic effects, i.e. to understand where interactions enhance damage rates, but also to know of potential beneficial effects of irradiation hardening.

Therefore, knowledge and experience based on a deep understanding of microstructure evolution needs to be combined with micromechanical modeling on one hand side as well as, at the component level, comprehension of response to loads, proper and effective modeling and robust structural analyses on the other hand side.

This tutorial will be open to registered ICFRM attendees free of charge. Lecture slides and tutorial materials will be provided to attendees.