TECHNICAL MEETING ON COMPATIBILITY BETWEEN COOLANTS AND MATERIALS FOR FUSION FACILITIES AND ADVANCED FISSION REACTORS

CODES AND STANDARDS TO SUPPORT DESIGN

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SOME CHALLENGES TO ADAPT NUCLEAR CODES AND STANDARDS TO INNOVATION

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INTRODUCTION

The current situation regarding energy leads to reconsider the position of the nuclear production as a solution to face the future. Especially regarding the so-called “GEN IV” reactors, or the Advanced Modular Reactors (AMR), a new pulse is now given for their development. Under the umbrella of innovative reactors, all the concepts are not at the same level of industrial maturity and the question is raised to applicability of the existing codes to the new potential fleet of reactors.

In this article, we will make a short review of different innovative concepts (innovative coolant type reactors such as sodium, lead-bismuth, molten salt or fusion installations). A focus will be made on the main mechanical components and the questions raised by their standardization. We will see that, for mature concepts already standardized, it is still possible to improve the existing and that the new type of reactors leads to work in depth on the way to extend or rewrite a code for these applications (but some doors have already been opened to facilitate this work).

INNOVATIVE REACTORS, A WORLD OF DIVERSITY

If pressurised water reactors are quite standardised even in their more advanced versions, it is not the case for the advanced reactors where a strong diversity of concepts and components can be encountered. The reactors of the next generation, called generation IV (GEN IV) are categorised in 6 categories:

- Gas-cooled fast reactor (GFR);
- Lead-cooled fast reactor (LFR);
- Molten salt reactor (MSR);
- Super-critical water reactor (SCWR);
- Sodium-cooled fast reactor (SFR);
- Very-high-temperature reactor (VHTR).

The fusion technology reactors has to be added to the previous ones (the data regarding fusion are based on the DEMO project (Demonstration fusion power plant pre-conceptual design study conducting in Europe [10]).

Their main characteristics can be summarized in the Table 1 below (extract from [1] [10]):

TABLE 1. GEN IV REACTORS AND FUSION REACTORS MAIN PARAMETERS

Type	Coolant	Temperature range	Pressure range
GFR	Helium	490°C/850°C	90 bar
LFR	Pb / Pb-Bi	400°C/550°C	~1 bar
MSR	molten	565°C/ 700°C	<0.1 psi
SCWR	salt	above 374°C	> 22.1 MPa
SFR	high pressure water	500–550ºC	~1 bar
VHTR	Sodium	between 700 and 950°C	Dependent on process
FUSION[1]	Water	295-328°C	15.5 MPa

1 different existing concepts, illustration with the water-cooled lithium lead concept

We can see a large panel of pressure, temperatures and coolant that can appear as a real obstacle to standardisation.
Another issue is also the different level of maturity of the concepts. If some of them like sodium fast reactors have a relevant feedback of industrial reactors, it is not the case for other concepts that have to be implemented on the nuclear market.

WHAT ARE THE CHALLENGES REGARDING CODES AND STANDARDS

In Europe, under the umbrella of the European Commission initiatives SNETP and ESNII, a workshop has been launch (CEN WS 64) in 2009 to bring together all the relevant stakeholders in order to develop, the European code for the design and fabrication of mechanical equipment for innovative nuclear installations.
The process put in place in the workshop was to share with the different stakeholders an existing code (in this case, the RCC-MRx code [3]) and to evaluate the possibility for innovative projects (GEN IV, AMR, fusion etc…) to use it.
The third phase of the CEN WS 64 recently came to a end iand a next phase is announced (2023-2026), which shows the strong interest of the codes and standards adaptation to the users needs.
The previous phases already allowed to identify major gaps in the adequacy of current codes to innovative reactors needs ([4][5]) and already we can establish a long lists of needs:

— Innovative operating conditions: the high/very high temperatures and pressures or the extension of duration up to 60 years of the SFR lifetime highlighted the lack of material data and knowledge for these operating conditions.
— Innovative coolant: historically, codes have been developed for Sodium coolant reactors (ASME division 5 [6], RCC-MRx), lead or molten salt coolant types raise questions on the applicability of the rules to this kind of coolant.
— Innovative material: innovative coolant and optimization of performances of the components drove research and developments on materials to find a new product that can solve corrosion, ageing or embrittlement. It includes also new processes such additive manufacturing, leading to different materials.
— Place of digitalization: More and more numerical tools are available on the market, not only for design calculations but also in support to non-destructive examination, to welding , to quality assurance recording…A strong effort has to be put in the standards to review the existing practices in regards to digitalization.

— Harmonization: bellow this generic term, it is the relevance of methodologies or requirements, historically based on the prevention of the pressure risks, to other kind of predominant damages as creep for instance.
— Link with non-nuclear standards: if this topic is not specific to GEN IV and questioned already for GEN II to III [7], it is especially sensitive for AMR where the transposition of biggest reactors classification in terms of classified/non-classified and level of classification is not obvious. In the same way, codes are focused essentially on the level 1 components ensuring a high level of quality and quality insurance. For others kinds of reactors, it could have some needs to have more detailed requirements and guidelines for lower level components that however play a crucial role in the installation.

POSSIBLE STRATEGIES

Two main strategies are available to get a standard answering to dedicated needs: to adapt existing texts to these needs or to create a new standard.
In the case of the GEN IV reactors family, the effort has been made to gather in an ISO document [2] the essential technical requirements that can be shared between the several concepts. The ISO standard emphasizes that codes and standards are the safer way to design mechanical components and thus it is essential that they are adapted to the GEN IV specificities.
Even if modifications are already implemented and work is on-going, the applicability of the code to the GEN IV reactors needs is not covered as far as a lot of inputs coming from the projects themselves have to be provided. For the time being, it is very important to evaluate the impact of the environment on the materials and the components, in line with the targeted lifetime.
It is also very important to evaluate the applicability of the requirements (safety, regulatory or technical) to the innovative reactors. Different initiatives are on-going, we can mention the European project HARMONISE [8] started in 2022 that has as objective to evaluate the possibility to go to an harmonised licencing path for GEN IV reactors, including the codes and standards aspect, or the IAEA initiative NHSI [9].
Regarding fusion needs, the trend is more to develop a dedicated reference, as the dedicated division 4 in ASME. Nevertheless, these developments should be connected to other codes or standards as the industrial fabric is familiar to existing rules.
In all cases, in an objective of economic efficiency, it is essential to make the most of existing synergies, in particular regarding standardisation resources.

CONCLUSION

For the next generation of nuclear reactors, small or big, we can reasonably think that there is no need to create new codes to answer to the needs and that an adaptation of the existing ones (especially those already developed for Sodium Fast Reactors) is a convenient solution. However, this adaptation needs a large amount of inputs from the projects themselves and may necessitate a rewriting of the existing to answer to this new generation needs.
It appears that we have to define new tools or new way to standardize and that a strong collaboration of the different stakeholders is of course necessary to ensure that the codes meet the needs of the users and to face the challenges of the innovative concepts.

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