6 Task force reports

Advanced Manufacturing and Material Engineering Task Force

In addition to being deployed as base-load power in large, centralized grids, nuclear power plants are increasingly likely to complement variable energy sources in distributed, localized and sometime remote grids. For nuclear energy to compete in this new paradigm, the industry must now focus on certain key characteristics. For example, designs with built-in, enhanced safety features and designs that focus on lower upfront capital costs, as well as those with shorter construction schedules, would allow nuclear power to obtain the social license required to operate and compete on the basis of overnight capital costs, and not simply based on the levelized cost of energy (LCOE). In addition, attributes such as non-electric applications (e.g. district heating, industrial process heat, clean hydrogen and synthetic fuels) and flexibility (e.g. load following) must now be considered for nuclear energy in these emerging, low-carbon energy systems.

Generation IV reactors are particularly suited to these requirements, and the last decade has seen a substantial rise in the number of active Gen-IV reactor designers and vendors worldwide. They typically involve:

- smaller, scalable designs, both in terms of size and output;
- simpler and compact modular designs that allow factory assembly and easier transport to construction sites;
- designs that focus on lower upfront capital costs and shorter construction schedules;
- designs with built-in enhanced safety features (passive/inherently safe designs);
- standardized designs to support volume production levels and a fleet approach to deployment;
- higher outlet temperatures and steam production for industrial applications (e.g. hydrogen production, water desalination, district heating, mining and resource extraction);
- designs with load-following flexibility to enable deployment in smart grids and hybrid energy systems.

Innovation in the nuclear supply chain, particularly in the areas of advanced manufacturing and materials engineering, is necessary if these advanced reactor technologies are to be delivered on time and on budget. However, nuclear design codes typically dictate that only qualified materials and processes can be used. Getting new materials or new manufacturing processes qualified can be a long and tortuous process. Furthermore, current developments in advanced manufacturing are occurring much faster than the ability of most to introduce new materials and methods into design codes, potentially stifling innovation and hampering deployment. These issues need to be addressed if advanced reactors, integrating innovative materials and components, are to be brought to the market in reasonable time frames.

The GIF Advanced Manufacturing and Materials Engineering Task Force (AMME TF) was therefore formed in order to better characterize and address these issues. As an initial step, the task force undertook a survey investigating the status of advanced manufacturing for nuclear reactor development and construction. The main outcomes of the survey can be summarized as follows:

- most advanced manufacturing methods were considered opportunities by potential end users;
- the techniques identified as having the greatest potential were cladding and surface modification techniques, welding and joining, and additive manufacturing;
- a total of 90% of respondents identified the greatest obstacle to adoption as being the approval of codes and standards organizations.

The survey also highlighted the evidence for strong support in collaborating at the international level on:

- establishing codes and achieving regulatory acceptance;
- organizing joint workshops as a means to design, initiate and promote joint activities;
- collaborating on materials and component/structural performance assessments to enable regulatory acceptance.

A well-attended Advanced Manufacturing Workshop was held at the Nuclear Energy Agency in Paris in conjunction with the R&D Infrastructure Task Force (RDTF) meeting on 18-20 February 2020. The purpose of the workshop was to identify both areas and methods where collaboration could lead to a reduction in the time to deployment of advanced manufacturing for advanced reactors. Workshop participants, from reactor vendors, nuclear supply chain firms, regulators, national laboratories and R&D providers enabled broad representation from across the nuclear industry, and the cross-functional breakout sessions were particularly engaging and successful. The output from the six breakout groups was discussed in the final session of the workshop, and final conclusions

were established. The overall recommendation of the workshop was that collaborative activities should be actively encouraged in three main areas:

- Qualification
  - codes and standards development;
  - a new qualification modality (e.g. real time process qualification);
  - an increased need for component testing.
- Demonstration and deployment
  - materials property database structure and content;
  - specific component testing;
  - round robin activity, e.g. generic intermediate heat exchanger (IHX) component.
- Design and modelling
  - collect experience and experimental data (feed data-driven methods);
  - share practices for inspection and design optimization;
  - resolve modelling and simulation benchmark problems.

There was strong support from the community for the AMME TF to continue its effort and organize follow-up workshops in due course. The future direction of the task force was discussed at the 43rd Experts Group and 49th Policy Group meetings. The AMME TF was encouraged to further develop its terms of reference (TOR), consistent with the workshop's recommendations.

Although progress in 2020 was affected by COVID-19, new TOR were drafted to refine the task force's objectives, define a new task force structure and provide action plans for the next 24 months. Following the 44th Experts Group and 50th Policy Group meetings, the reviewed TOR were approved in late 2020. Consequently, the task force will expand its activities and membership, and will conduct its activities through the three sub-working groups described below.

Requirements Capture Sub-Work Group

A key outcome of the February 2020 Advanced Manufacturing Workshop was the requirement to communicate and consult with the wider community to ensure the task force's success. The initial AMME TF survey was very successful in both identifying the needs of the community and raising awareness of the activities of the task force. These tools for requirements capture will thus be regularly used to update the task forces aims and outcomes. Community engagement will be pursued through regular targeted surveys enabling the task force to monitor stakeholder requirements, provide opportunities for stakeholder involvement and report progress on its activities. The next AMME TF survey is scheduled for 2021.

Qualification, Demonstration and Deployment Sub-Work Group

New approaches and methods for qualification of manufacturing processes, materials or components are key to the timely deployment of advanced manufacturing methods and materials. Although different AMME technologies may require different approaches, there are likely to be commonalities. Therefore, the first focus of the working group will be to identify these commonalities by sharing experience across different reactor systems, AMME technologies and national qualification approaches. The second focus of this working group is to elaborate on the qualification of specific components/materials or processes by studying their real or projected demonstration and deployment. As a final goal, a roadmap and guidelines for the development and implementation of qualified nuclear advanced manufacturing will be developed.

Design and Modelling Sub-Work Group

The February 2020 workshop underlined the need to capture and share processes and methodologies for ensuring product quality, and more specifically to: 1) collect experience; 2) share practices for inspection and design optimization, and 3) develop modelling and simulation benchmarks. This working group will consider three different categories of modelling: software and modelling assisted design, best practices for inspection and design optimization and organization of modelling and simulation benchmarks. In addition to requirements and the efficient use of modelling into materials and component accelerated development, qualification process has also been identified in the roadmap to meet these requirements.

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Chair of the AMME TF, with contributions from AMME members