Recent Progress of Low Aspect Ratio Machines

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Research on the properties of the Spherical Torus for development of fusion science and technology encompasses a broad effort across several experimental devices. This proof-of-principle program is focused on studying high-temperature plasmas at very low aspect ratios. The two largest experiments, NSTX and MAST, are addressing critical physics issues at the $I_p \sim 1$ MA level. This allows exploration of the potential of the concept for a cost-effective contribution to fusion energy development both as a fusion concept in its own right and as a means of advancing key tokamak physics concepts at geometric extrema.

Smaller experiments in the US are focused on specific ST-related and/or fusion issues. The HIT program is developing and testing the coaxial helicity injection approach for startup and current drive. CDX-U is testing Li-liquid limiters and progressing to a full Li-wall tokamak test. The PEGASUS program is exploring the extreme near-unity aspect ratio regime to establish the limits of ST parameter space.

High beta plasmas are readily achieved in ST experiments, with $\beta_N > 5$ being achieved through increasing plasma control and improved confinement with H-mode operation. While tokamak-like confinement is achieved, the absolute values are seen to be higher than standard ITER scaling.

Some critical issues for future development include noninductive plasma startup, sustainment, and energy exhaust. Electron Bernstein Wave heating and current drive is being actively pursued in both the largest and some smaller experiments. Helcity injection, neutral beam current drive, and RF drive schemes are all under investigation for future application. Studies of H-mode and divertor operation in STs are revealing new insights into power flows during ELMs and ELM structure itself.

These experiments are generating relevant experience with the technical challenges of constructing and operating tokamak-like devices at near unity aspect ratio. The large electromechanical stresses in the centerstack region, plus the lack of space in that region, require both new engineering and scientific approaches to generating and sustaining the plasma.

Based on the progress to date, initial considerations of the design of a performance-extension ST experiment are underway in the U.S. A device of a scale comparable to that envisioned for a component test facility would require R ~ 1.5 m, Ip ~ 10 MA, and pulse lengths of 5 – 50 sec to provide the required physics basis, and could be considered in parallel with larger efforts in the international fusion program.