Progress Meeting
Monaco Fellows 2010-2012
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ABSTRACTS

Modelling and Advanced Control of Cryogenic Systems

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The ITER cryogenic system will be constructed to achieve low-temperature conditions for the magnets and the associate pumping systems of ITER Tokomak over a wide range of plasma scenarios. As a major component of cryoplant, the helium refrigerator is dedicated to provide cooling power at different temperature levels, e.g.4.2K, 4.5K, 50K and 80K, with large heat loads variation and high repetition rates.

This work studies the mathematical modelling schemes and several advanced control strategies for helium refrigerator. The aim is to develop required process controls that guarantee the overall reliability, availability and safety of refrigerator plant. Both time-domain system identification and frequency-domain system identification techniques have been proposed to determine mathematical models that could simulate the dynamical response of the refrigerator.
With the obtained models, the improved PID control, Internal Model Control (IMC) and Feedforward Control (FC) have been designed. The theoretical studies on the stability, the robustness and comparative analysis of each control are also provided. Dynamic simulation on a simplified refrigerator has been conducted to assess the derived models and the proposed control algorithms. It is shown that the models derived based on the frequency identification are applicable and the IMC gives superior performance. Primary analysis on a 'predesigned' ITER refrigerator was also conducted, for which the advanced control will be exploited. Practical tests on down-scaled installations will also be expected.

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Application of the parareal algorithm for temporal parallelization of plasma Simulations

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Parallelization is a necessity for reducing the wall clock time of computationally demanding simulations. With space parallelization attaining saturation in processor use and with the availability of resources as in modern super computers, time parallelization ushers in a new avenue. The Parareal Algorithm [1], which parallelizes the time domain, has garnered attention in recent times.

This algorithm has already been successfully applied to fully developed plasma turbulence simulations which are high dimensionally chaotic initial value problems [2]. It is a unique approach to solving partial differential equations. Prior to turbulence, the algorithm had been successfully applied to relatively simpler problems.

This presentation will briefly review the parareal algorithm followed by applications in recent plasma simulations utilizing the "Parareal Framework" recently developed at ORNL as part of the SWIM-IPS project. An outline of my on-going research to implement the algorithm to more ITER-relevant codes (CORSICA) will also be discussed. This will explore the possibility of time efficient simulations at ITER, for example, where relatively long pulses need to be simulated in short wall clock time.

References:

1) J. Lions et al., CR Acad. Sci. I – Math. 332 (7)(2001), pp.661–668.

2) D. Samaddar et al., Journal of Computational Physics 229 (18)(2010), pp.6558-6573.

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Current Sharing Temperature of NbTi SULTAN Samples Compared to Prediction Using NbTi Strand Single Pinning Mechanism Parameterisation

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In the past, the PF Conductor Insert Coil test campaign has found that the coil limits were identical to the sum of the strand performances in the cable at the location of the peak magnetic field [1]. In this paper, the single strand behaviour of NbTi with the relevant, short full-size ITER conductor tested at the SULTAN facility will be compared.

Single pinning mechanism parameterisation of the Chinese NbTi strand to be used in the ITER Poloidal Field (PF) coil, Correction Coil (CC) and feeder busbars has been obtained based on the Bottura scaling law [2] using critical current data measured by NIST. The determination of the scaling parameters using a Kramer-type regression method will be described. The critical temperature (T_c) of a single strand at the operating current and field as determined by the parameterisation and the current sharing temperature (T_{CS}) of a few short full size conductor samples tested at the SULTAN facility will be compared. The validity and limitation of the estimation will be discussed. The estimated-T_{CS} dependence on various (superconducting critical as well as geometric and volumetric) parameters will be assessed. Errors propagated from critical current (I_c) measurements of the strands and parameters fitting, and other uncertainties will be quantified.

References:

[1] D. Bessette, L. Bottura et al. in IEEE Trans. Appl. Supercond. 19 3 (2009) 1525-1531

[2] L. Bottura in IEEE Trans. Appl. Supercond. 10 (2000) 1054-1057

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Simulating ITER advanced operation scenarios using a free-boundary transport simulation code, CORSICA

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This research work aims at exploiting advanced plasma operation scenarios for ITER, such as the hybrid and steady-state modes, including all the relevant physics and engineering constraints.
An advanced free-boundary transport simulation code, CORSICA, has been used to study the feasibility of the proposed operation scenarios and to better optimize them within ITER design parameter ranges. Several realistic source modules for heating and current drive, such as NB, EC, IC and LH, are either upgraded or newly added to the CORSICA code, and its integrated discharge modelling capability has been continuously improved. As a first step, ITER hybrid mode operation scenarios have been studied focusing on achieving physics goals, such as the fusion power multiplication factor, Q, and plasma burn duration. Various current ramp-up and ramp-down conditions, and pre-magnetization of the PF coils have been tested to investigate issues related to engineering constraints, such as the coil voltage, current, force and field limits.
Various combinations of auxiliary heating and driven current sources have been applied to examine several physics issues, such as the plasma current density profile tailoring, enhancement of the plasma energy confinement and fusion power generation. A study on ITER steady-state mode operation scenarios has been recently initiated and the improved tokamak discharge modelling capability achieved in this research work would be useful for supporting ITER PCS and IM projects.

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JOREK Modelling of ELM Triggering by Pellets in DIII-D and Implications for ITER

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Operation of ITER in the Q_{DT}=10 reference inductive scenario is based on the H-mode regime with controlled ELMs. One of the schemes to control ELM is the injection of frozen deuterium pellets. Although ELM size reduction by pellet injection has been demonstrated in present experiments, uncertainties remain regarding its optimization for application in ITER (pellet size, launch velocity and injection geometry) as well as its integration with other ITER operational requirements.

The presentation will show a first attempt at the quantitative validation of the ELM triggering prediction by JOREK (Nonlinear MHD simulation code) with experiments in DIII-D.
In these experiments reliable triggering of ELMs by pellets was demonstrated with cylindrical pellets of 1.8 mm diameter injected from the LFS (vertical and horizontal trajectories) at a frequency of 14 Hz in ITER similarity discharges. Comparisons with predictions from JOREK will be employed to determine the minimum spatial resolution required for modelling and/or the identification of renormalization guidelines for modelling/experiment comparisons, as well as to predict for DIII-D : a) the minimum pellet size/penetration leading to the triggering of ELMs, b) the transient power fluxes to PFCs associated with pellet triggering of ELMs and c) the effect of the pellet injection geometry on ELM triggering, in particular, injection of pellets near the Xpoint region (i.e. the ITER reference injection geometry for ELM triggering) to be explored in future DIII-D experiments. Implications of this JOREK modelling/experiment comparison with DIII-D for the triggering of ELMs by pellets in ITER will be discussed.

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