Prediction of magnetic island dynamics with neural networks

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Magnetic reconnection is a physical process involving conductive plasma flows and leading to a topology modification of the magnetic field. It can be a major obstacle to the good realization of fusion experiments. In particular, self-generated large magnetic islands and/or Neoclassical Tearing Mode (NTM) in tokamaks can lead to the destruction of the plasma confinement. Such islands are metastable in large devices and, thus, both, control and dynamics prediction in fusion devices is a key question [1].

Neural networks have been used in the past [2] to identify important parameters which influence the seeding process of islands. However, many mechanisms can seed magnetic islands and it is not uncommon, in experimental devices, to ignore the seeding mechanism.
In this work, we focus on the possibility to use neural networks to predict island dynamics and more specifically to assess if they can be used to predict their final size and, thus, the hazards involved. We test this question by using a *minimal* MHD model which generates magnetic islands and we confront results with neural network predictions.

In that context, theoretical studies was devoted to nonlinear calculations of island sizes at saturation [3, 4, 5]. However, numerical simulations have shown that this approach has noticeable restrictions in parameters space. Discrepancy between models and numerical results have been observed and theory is falling when mechanisms far from low order resonnant surfaces, identified in [6], are at play.

In our MHD problem, the input parameters space corresponds to the equilibria magnetic field an current profiles space. Indeed, in a previous study [6], we have shown that transport parameters and complex transcient phenomena do not influence the asymptotic characteristics of islands. Thus, neural networks have been trained on the basis on more that ten thousand random equilibrium magnetic profiles. We have performed the corresponding nonlinear MHD simulations corresponding to these profiles to extract relevant informations such as asymptotic island sizes. The efficiency of predictions and the nature of the neural networks is discussed. The possible links with underlying physics is emphasized. Noteworthy, we investigate if whether or not, when providing relevant physical mechanisms in the network, the predicition is improved.

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