Effect of inboard gas puffing on H-mode in COMPASS-D

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Introduction

Control of particle and heat transport through the plasma edge is one of the key issues in optimisation of the H-mode regime. The requirement to sustain high core plasma density and low dilution factor means that a substantial influx of neutral gas is needed. However, it is generally observed that the maximum fuelling rate has a limit determined by the collapse of the edge transport barrier. This paper reports on exploratory experiments on COMPASS-D in order to find whether an improvement can be achieved simply by changing the location of gas puffing.

Experimental conditions

Inboard midplane gas puffing has been installed in addition to the existing system at the outboard midplane (see Fig. 1). This allows comparison of discharges when fuelled from two extreme points relative to the magnetic curvature. Experiments are performed in deuterium, in single null open divertor plasmas (\(a=0.17\)m, \(R=0.56\)m, \(\kappa=1.7\), \(\delta=0.4\)). Most of the studies concentrated on the L- to H-mode transition in Ohmically heated plasmas. The walls were conditioned between shots using a glow discharge in...
helium for 5 minutes. The inboard gas puff inlet was observed using a video camera. The images in visible light (see Fig. 1) show that the ionisation source is localised in comparison with the poloidal extent of the plasma.

**Reduced L-H density threshold**

The fuelling efficiency from inboard and outboard has been assessed by application of rectangular waveforms on the piezo valves and comparing the rate of change of line-averaged density $\frac{d\langle n_e \rangle}{dt}$. In L-mode, no significant difference in fuelling efficiency has been found. Similar experiments in ELM-free H-modes were not yet conclusive as the sufficiently large gas puff usually triggers the H-L transition.

During these feed-forward experiments we have observed first signs of asymmetry between inboard and outboard fuelling. With outboard fuelling the density increases but the plasma remains in L-mode. The transition to H-mode occurs only when the gas puff is switched-off late enough to allow the density to exceed the H-mode density threshold [1]. With inboard gas puff, however, the transition to H-mode occurs during the phase when the valve is open. This asymmetry is also observed when the gas puff is applied to plasmas just at the L-H transition (dithering or transitional ELMs). Outboard gas puff results in transition back to L-mode while the inboard gas puff stimulates the L-H transition.

Most of the experiments were performed with valves in a feed-back loop so that the line averaged density at the L-H transition could be accurately controlled. Figure 2

![Figure 2. Comparison of two Ohmic discharges with feedback density control, one with inboard and one with outboard gas puffing.](image-url)
compares two such discharges. The plasma with inboard gas puff shows the L-H transition at \( t=120\text{ms} \) as indicated from the \( D_\alpha \) emission while using the outboard gas puff, the discharge stays in L-mode despite having the same density at that particular time.

Figure 3 summarises the L-H transition on a \( P - n_e \) diagram for both feed-forward and feed-back density control. It is seen that the fuelling from the inboard midplane extends the operation window for H-mode towards the lower densities. In particular the minimum line-averaged density required for transition to ELM-free H-mode is approximately \( \sim 40\% \) lower in comparison with discharges with fuelling from the outboard midplane (\( 5 \times 10^{19} \text{m}^{-3} \) compared to \( 8 \times 10^{19} \text{m}^{-3} \) at \( I_p=190\text{kA}, B_T=1.2\text{T} \)). Simultaneously the power at the transition is also lower by the same factor so that the data points lie approximately on the same line - close to the scaling deduced from the international database [2]. The outboard piezo valve has been used in all cases during the breakdown and the valve change-over introduces some variations of the plasma current waveforms during the ramp. These, however, do not correlate with the observed fuelling asymmetry.

Limited data with ECRH (\( 1\omega_{ce} \)) shows no strong effect of gas puff position on the L-H transition so far. This could be related to the increased recycling observed around the antenna mirror when the plasma-to-antenna distance is not optimised.

**Discussion**

These results are quite unexpected. Firstly, it is usually assumed that poloidal asymmetry of the ionisation source due to gas puffing can not be achieved except when the regions are physically separated i.e. puffing in the private flux region v.s. puffing in the main chamber. Our observation of the gas inlet shows, however, that the ionisation source is in fact strongly poloidally localised. A second common assumption is that puffing into a region of larger

![Figure 3](image-url)
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[4] S You et al., submitted to Contributions to Plasma Physics