High beta experiments on JET in preparation of JT60SA

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1.Introduction

High beta discharges with dimensionless parameters collisionality (ν^*) and normalized Larmor radius (ϱ^*), and also normalized beta (β_N) relatively close to the JT-60SA scenarios hybrid and advanced were realized on JET. In particular the JET poloidal Larmor radius ϱ_P^*=0.036 and bootstrap fraction f_{BS}=0.6 were close to JT60-SA values. So the discharges realized on JET are expected having similar confinement properties as in JT60SA[1]. Since the maximum normalized beta $\beta_N MAX \approx A^{-1/2}$, is dependent on the aspect ratio A, the equilibrium properties at high beta on JET (A=3.2) would be similar as in JT-60SA(A=2.7). Strategy of the experiments was to explore high normalized beta (β_N) values, MHD effects at different BT (Toroidal Magnetic field on axis) and find an optimal set of parameters for discharges with mild MHD. Deuterium plasmas were realized in a **variant of the hybrid-advanced scenario** at BT = 1.7, 2, 2.4 T, Ip = 1.4 MA, elongation k = 1.6, and high triangularity $\delta \approx 0.4$, q95=4-6, and central safety factor q0>1.2 at NBI (Neutral Beam Injection) start, with NBI power P_{NBI} = 16-25 MW, no ICRH (Ion Cyclotron Resonant Heating). Shots at BT=2.4T were realized in third Deuterium-Tritium (DTE3) campaign. The deuterium dataset is new: the pulses at BT=1.7/Ip=1.4MA have the same charateristics of 2014 Hybrid power scan at high δ[2], but there is an extension in the range of NBI power to P_{NBI} =25MW. While pulses at BT=2.4T are executed at higher q95 (q95>5) with respect to the yr 2014 advanced pulses[3]. Two scans were carried out : i) a NBI power scan, affecting

β_N and ii) a NBI start time scan, affecting the central safety factor q0 at the time of NBI onset, which is a key ingredient for MHD stability of the high beta phase. Main results of the experiments are: i) Good confinement properties and relatively high β_N values; the normalized beta achievable increases with input power, $\beta_N \approx 3.7-4$ for BT/Ip=1.7T/1.4MA(JPN 102422) ; ii) Good control of q0 at the beginning of the main heating phase with NBI starting time t0_NBI depending on the toroidal magnetic field value, as investigated in JET hybrid[2] and advanced scenarios; iii) Maximum $\beta_N \approx 2.5-2.7$ with relatively mild/stable MHD in the hybrid-advanced scenario at BT = 2.4 T and q0 > 1 (pulse#103116 and 103117). Preliminary transport analysis has been done using Bohm-gyroBohm , QuaLiKiz , CDBM. The measured ion and electron temperature profiles and neutron fluxes are reproduced by CDBM code at all the magnetic fields. The paper is organized as follows : in sec.2 the experiment is described and the usefulness of the JET experiment for preparing the high beta scenarios in JT-60SA is discussed ; in sec.3 The main experimental results are presented : i) the max β_N versus the NBI heating power ii) the MHD characteristics ; iii) the confinement improvement factor and the plasma energy content versus β_N ; in sec .4 the conclusions are drawn.

2.JET experiment and similarity with JT-60SA

The 'similarity' principle states that tokamak plasmas are equivalent from the point of view of confinement if they share the same values of the dimensionless parameters (β, ϱ^*, ν^*, q) [1]. From the point of view of confinement, in 'similar' Tokamak plasmas the plasma parameters are linked by the following scalings (A = aspect ratio, R = major radius, M = main ion mass, B = magnetic field on axis, Ip = plasma current [1]) see Table I .

$n = M R^{-2} A^{2}$
$T = M^{1/2} R^{-1/2} A^{7/4}$
$Ip = M^{3/4} R^{-1/4} A^{-1/8}$
$B = M^{3/4} R^{-5/4} A^{15/8}$

Table I

In case of similarity of JT-60SA/JET (which share the same major radius, and at a fixed ion mass) the magnetic field and current of similar discharges is depending on the aspect ratio following the scaling: $B \approx A^{15/8}$ and $Ip \approx A^{-1/8}$. This means that to get similar discharges (between JET (A = 3.2) and JT-60SA (A = 2.7)) we must choose the magnetic field B and the current Ip as follows: $B\_JET/B\_SA = (A\_JET/A\_SA)^{15/8} = 1.37$;$Ip\_JET/Ip\_SA = (A\_JET/A\_SA)^{-1/8} = 1.02$. The present JET experiment at (BT/Ip) = (2.4T/1.4MA) can be used for studying the confinement (and the MHD stability) of the JT-