2.2 Development of pellet fuelling system in HL-2A tokamak

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Pellet injection is considered one of the most important methods to control the plasma pressure and current profile. Improved energy confinement has been observed in many tokamaks with centre pellet injection since 1980s. For increasing the plasma density and studying edge localized modes (ELM) mitigation, a new pellet fuelling system based on the extrapolation technology which was proposed by Mitsubishi Heavy Industry has been developed successfully under the contract 06CMIA130RU/JJ between Pelin Laboratory and Southwestern Institute of Physics (SWIP), and set up in the low field side (LFS) of the HL-2A tokamak (\( R = 1.65 \text{ m}, r = 0.4 \text{ m} \)) in 2009. As shown in Fig. 1.

![Schematic drawing of pellet fuelling system in the LFS of the HL-2A tokamak](image)

Fig. 1. Schematic drawing of pellet fuelling system in the LFS of the HL-2A tokamak.

The HL-2A device is a medium size tokamak with a closed divertor. And it is operated in the following parameter range:

- plasma current \( I_p = 200 - 400 \text{ kA} \),
- toroidal magnetic field \( B_t = 2.2 - 2.6 \text{ T} \),
- line-average electron density \( n_e = (1 - 6) \times 10^{19} \text{ m}^{-3} \),
- electron temperature \( T_e = 1 \text{ keV} \).

The specification has been determined from the experimental data using the old pellet injector which is based on the in-situ condensation technology and developed by Pelin Laboratory in 1996 for SWIP. The new pellet fuelling system should meet the required performance given in Table 1 below.

The pellet fuelling system is designed to produce 1 - 40 solid pellets of hydrogen/deuterium in one injection cycle. It consists of six main parts:

1) Vacuum system, which includes two independent subsystems and can pump the corresponding spaces to \( 10^{-3} \text{ Pa} \) and \( 10^{-2} \text{ Pa} \) below, respectively.

2) A closed-cycle helium cryorefrigerator of 1 W power at 4.2 K, which is used for cooling of the injector and pellet production.

3) A pellet size regulator, which is used for extrusion of ice ribbon with different dimensions.

4) Electromagnetic cutter, which is used to cut the ice ribbon to pellets with high frequency (up to 30 Hz).

5) Gas supply system, it can provide the pellet material of \( \text{D}_2 \), \( \text{H}_2 \) and propellant gas of helium.

6) Control and diagnostic system.

<table>
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<th>Table 1 Required performance for the HL-2A pellet fuelling system</th>
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<td>Pellet material</td>
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<td>Duration of one injection cycle</td>
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The pellet fuelling system in HL-2A tokamak is now in the phase of engineering commissioning (the images of the pellets - in-flight are shown in Fig. 2). The appropriate pellet size, injection frequency, the interaction between pellet and plasma,
and other refuelling problems are studied. During the 2010 spring experimental campaign of HL-2A, the deuterium solid pellets were injected into the plasma and we got some preliminary results (See Fig. 3). It symbolized that the new pellet fuelling system put into operation. In the next experimental campaign, more pellet fuelling experiments will be done.

![Image of pellets in-flight](image)

**Fig. 2.** Pellets in-flight in HL-2A fuelling system.

A new pellet fuelling system based on the extrusion technology has been developed successfully and set up in the low field side of the HL-2A tokamak. During our 2009 - 2010 experimental campaign, we made some commissioning tests for the fuelling system and injected the deuterium pellets into the plasma with the typical parameters as follows: pellet size with the diameter = 1.3 mm and length = 1.3 - 1.7 mm, number of pellet $N_p = 3 - 5$, frequency of injection $f = 10/20$ Hz, Velocity of pellet $v_p = 200 - 300$ m $\cdot$ s$^{-1}$ by helium propellant gas with pressure of 0.6 - 1 MPa. The injection reliability is more than 90%.

![Waveforms of OH discharge with one deuterium pellet fuelling](image)

**Fig. 3.** Waveforms of OH discharge with one deuterium pellet fuelling.

(a) Plasma current $I_p$, (b) Line-average electron density $n_e$, (c) Electron temperature $T_e$, (d) $H_2$ radiation intensity, (e) Heat radiation intensity.