Fusion Engineering and Design 130 (2018) 69–75

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Measurement of velocity and reliability of 50 Hz pellet injector for EAST

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ARTICLE INFO

Keywords:
Pellet injector
Velocity
Reliability
PI-50
EAST

ABSTRACT

Cryogenic deuterium pellet injection is one of important techniques for edge localized mode (ELM) mitigation for successful operation of ITER in the future. A high frequency, 50 Hz, pellet injection system (PI-50) based on screw extrusion forming ice and pneumatic acceleration has been built and developed for ELM mitigation for EAST. As velocity and reliability of launching frozen pellet are of importance to ELM mitigation, a diagnostic system including video cameras is installed on this pellet injection system to acquire the pellet's velocity and monitor the quality of pellet. With the help of this diagnostic system, the velocity and reliability of PI-50 system have been measured successfully. The reliability of PI-50 is more than 85% when the launching frequency is 50 Hz, which means this system can be used for ELM mitigation on EAST in the future. PI-50 system has been installed on EAST at present and is expected to be involved physics experiment in next campaign on EAST.

1. Introduction

Toakmak for magnetic confinement fusion needs fueling continuously during operation. Cryogenic deuterium pellet injection and gas puffing are expected to be used as primary fueling technical in future reactor [1]. Gas puffing is a fundamental fueling technical which feed neutral gas from the edge of plasma. Because high temperature in scrapped-off layer (SOL) ionizes hydrogen isotopes, lots of fueling ions following magnetic field line are dumped on divertor plates and finally pumped out as neutrals by vacuum system. As a result, particles entering core plasma have a large decrease and the efficiency of fueling is very low. However, cryogenic pellet injection has a high efficiency, which is necessary for achieving high fusion gain. The fact that lifetime of pellet can be extended due to neutral gas shielding around it has been demonstrated [2]. Thus, the cryogenic pellet can survive the SOL and has a penetration on the core plasma. Many fusion devices have carried out experiments for high density plasma operation beyond the gas puffing limitation using cryogenic pellet injection, such as DIII-D [3], ASDEX [4], JET [5], and LHD [6]. In addition, the experiments for edge localized mode(ELM) mitigation [7–9], L-H transformation [10,11], and disruption mitigation have been also performed applying cryogenic pellet injection [12]. In these experiments, the velocity and reliability of launching frozen pellet are of importance to acquire expected experimental results. So measurement of velocity and reliability of launching pellets must be done in detail.

Fully non-inductive steady-state H-mode plasma was extended over 60 s for the first time on EAST [13], which is the first full superconducting tokamak with advanced divertor configuration in the world. To achieve a longer pulse steady-state operation, it is necessary to avoid a large transient local heat load on the divertor induced by ELM [14]. Pellet injection is one the most effective methods for ELM control in present tokamaks and will also be applied on ITER [15]. So EAST has been developing a high frequency pellet injection system PI-50 for ELM mitigation. Since active triggering of ELM requires a density perturbation in the gradient region, the speed of pellets must be controlled. In order to make a good use of PI-50 for ELM mitigation on EAST in the future, the launching velocity and reliability of pellets have to be measured. At present primary engineering test has been completed on this system and basic test results have been obtained [16]. On the basis of former results we have investigated the launching pellet velocity and reliability systematically.

In Section 2, the components of the pellet injector and diagnostic block will be introduced. The operation and test results will be described in Section 3. Then the results will be discussed in Section 4. Finally, the summary and our future will be provided in Section 5.

2. Injector and diagnostic block

The injector of PI-50 system, built on the basis of screw extruder and pneumatic accelerator, is a device for production and repetitive

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https://doi.org/10.1016/j.fusengdes.2018.03.049
Received 8 November 2017; Received in revised form 12 March 2018; Accepted 19 March 2018
Available online 28 March 2018

Table 1
Essential design parameter of PI-50 system.

Pellet material	Pellet shape	Pellet diameter (mm)	Pellet length (mm)	Injection frequency (Hz)
H_2, D_2	Cylinder	1.5	1.2, 1.5, 1.8	from 1 to 50

*Pellet length can be changed by replacement of the extruder nozzle at room temperature.

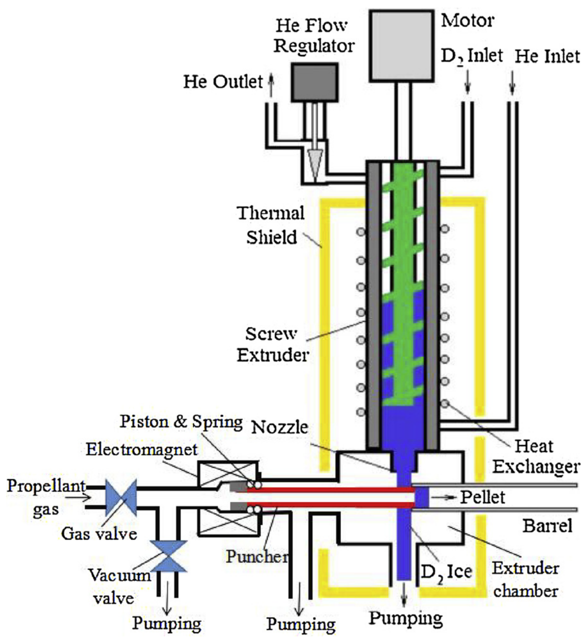

Fig. 1. Schematic drawing of a pellet injector module.

injection of ice pellets frozen from hydrogen or deuterium gas for ELM control of the EAST tokamak. Its essential design parameter is shown in Table 1. It has three major components: two same modules of pellet injection system (left module is called A, right module is called B), gas supply system, and set of electronics with local control system. This system can operate either from 1 to 25 Hz with one injection module. When these two modules work at the same time, a maximum frequency of 50 Hz can be achieved. Both of the modules are inserted into a vacuum chamber. Each module consists of a screw extruder for solid hydrogen isotope ice production surrounded with a thermal screen to protect the extruder from heat radiation, a helium flow regulator for temperature regulation and stabilization, a pellet fabrication and acceleration system, including puncher for solid hydrogen isotope pellet formation and valves for pellet acceleration. Helium is used as propellant gas for pellet acceleration. And schematic drawing of the signal module is shown in Fig. 1. A 1.5 mm size cylindrical pellet can be fabricated from the rod moving at 50 mm/s with maximum frequency of about 25 Hz taking in mind 25% ice waste during pellet formation. And the pellet has an adjustable length that can be 1.2, 1.5, or 1.8 mm. The nominal number of atoms in each pellet is approximately 1.2×10^{20}, 1.60×10^{20}, and 1.91×10^{20}, respectively. Waste parts of ice rod are sublimated and evacuated with residual propellant helium by vacuum system.

During process of pellet formation and acceleration, a gas valve is opened and pressurized propellant gas pushes forward a piston with a puncher. The extruded ice rod is cut off a small piece by the puncher inside the extruder chamber. Accordingly, a pellet is formed and transferred into the barrel. Meanwhile, a part of propellant gas penetrates through a capillary duct inside the piston and puncher into the gun barrel and accelerates the pellet. Shortly after the puncher movement the vacuum valve is opened and gas behind the piston is evacuated by a vacuum pump. Finally, the piston is returned to the initial

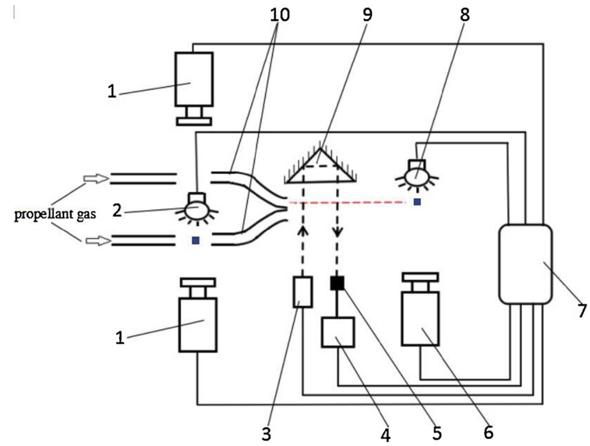

Fig. 2. A structure scheme of the diagnostic block.
1 – extruder video cameras, 2 – extruder light, 3 – laser, 4 – photo detector, 5 – optical fiber, 6 – pellet video camera, 7 – diagnostic block controller, 8 – flash, 9 – prism, 10 – gun barrel.

position by an electromagnet and a spring until the next injection cycle. The newly designed pellet formation and acceleration system can reduce the amount of gas into the barrel and extruder chamber. When propellant gas is at 3×10^5–5×10^5 Pa, gas load into the barrel and extruder chamber is reduced to (0.4–0.7) Pa m3/shot and (0.1–0.2) Pa m^3/shot, respectively. So the gas load coming out of the barre is 0.4–0.7 Pa m^3/shot. And the gas into the barrel is pumped out by a two-stage differential pumping system after it accelerates the pellet. And the system's second differential chamber which will be connected to the tokamak is approximately at 10^{-4} Pa, so the propellant gas will have little impact on the plasma.

To monitor the quality of ice rod and acquire the pellet's velocity and picture, a diagnostic system including video cameras, as shown in Fig. 2, is designed and installed. The observation of ice rods extruded by the screw extruders is provided by two same video cameras. The video cameras are fixed on the vacuum chamber oppositely and their model is *Infinity CS-420HD*. A diagnostic chamber is attached to the flange of the vacuum chamber as shown in Fig. 3. The pellet velocity and photo

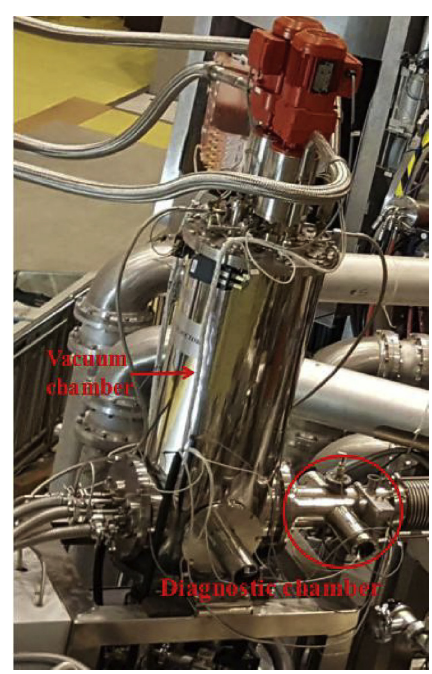

Fig. 3. Diagnostic chamber attached to the vacuum chamber.