§21. Direct Energy Conversion System for D-^{3}He Fusion

Tomita, Y., Shu, L.Y., Momota, H.

A novel and highly efficient direct energy conversion system is proposed for utilizing D-^{3}He fueled fusion. In order to convert kinetic energy of ions, we applied a pair of direct energy conversion systems each of which has a cusp-type DEC and a traveling wave DEC (TWDEC).

After escaping from burning plasma, the perpendicular energy of the charged particles with respect to the magnetic field is converted to the parallel component by a reduction of magnetic field. At the entrance of the cusp-type DEC of "ARTEMIS-L," the typical Larmor radii of electrons and thermal ions are 6×10^{-4} m and 3×10^{-2} m, respectively. Because of the small Larmor radius and small mass of electrons, they go along the constant magnetic flux surface and are introduced to the first line-cusp. The thermal ions which energy is characterized to be few hundreds keV, pass through the first line-cusp. The higher magnetic field at the second line-cusp compared with the first line-cusp leads the thermal ions to the second line-cusp. On the other hand, the orbit of fusion protons with energy of 15 MeV is hardly affected by this cusp-magnetic field and they pass through these line-cusps. The coil radii and currents of the inlet and outlet of the cusp-type DEC are determined to be 5.3 m with 0.5 MA.T and 4.2 m with 2.1 MA.T , respectively . In this case, the distances of line-cusp coils are 4.2 m and 6.4 m. From the consideration of particle orbit traces included with the energy distributions, a classification fraction of incident particles is tabulated in Table 1.

Table 1 The classification fraction of incident particles to the cusp type DEC.

	electrons	thermal ions					fusion protons
		D	^{3}He	^{4}He	p	T	
introduced to line-cusp #1	> 0.99	0	0	0	0	0	0
introduced to line-cusp #2	< 0.01	0.96	0.48	0.64	0.90	1.0	< 0.01
pass through cusps	< 0.01	0.04	0.52	0.36	0.10	0	> 0.99

More than 99% of electrons are introduced to the first line-cusp. On the other hand, because of higher energy, majority of fusion protons passes through these line-cusps. A part of thermal ions is introduced to the second line-cusp, but the rest passes through these cusps. As a result, in the first line-cusp there are only electrons and in the second line-cusp there exist only thermal ions.

The 15 MeV fusion protons, which pass through cusp-type DEC, are guided to the traveling wave direct energy converter, which consists of a modulator and a decelerator. At the modulator, a traveling electric field is excited by grid meshes with a spacing of 1.2 m installed in the proton beams. The velocities of incident proton beams are modulated to form bunched protons at the down stream by this traveling electric field of 1 MV/m with a phase velocity of 5.3×10^7 m / s which corresponds to the velocity of 15 MeV incident protons. The applied maximum voltage to the modulator is 0.82 MV. The modulated proton beam performs a proton beam bunching at 11 m down stream from the modulator. The energy of the bunched beams is recovered by the decelerator, which utilizes a principle of a "LINAC". Namely, the bunched proton beam excites an electrostatic wave on a grid mesh array and this electrostatic field decelerates the bunched protons. The maximum voltage of 0.42 MV is applied to the decelerator. The grid meshes at the modulator and the decelerator are installed with a spacing of 1.33 m. This grid pipe with 18 mm diameter and 1 mm thickness is cooled by the water with a pressure gradient of 1.2 MPa/10m. This pressure difference restrains the temperature increment at the outlet of a grid pipe to the value of 30℃ and the stress of grid pipes is as small as 40 MPa. Taken into consideration of bombardment of fusion protons to the grids and the energy recovery at the end collector, the conversion efficiency of the traveling wave DEC is estimated as high as 0.76 (Fig.1).

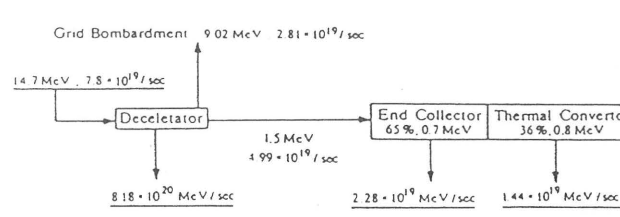

Fig.1 The energy flow diagram of traveling wave DEC.