THE MULTI-PHYSICS ANALYSIS OF DUAL-BEAM DRIFT TUBE LINAC

Tao He*[1,2], L. Lu [1], L. yang [1,2], W. Ma [1], L.P. Sun[1], X.B. Xu[1], L.B. Shi[1], C.X. Li[1], Y. He[1], H.W. Zhao[1]

[1] *Institute of Modern Physcis (IMP), CAS, Lanzhou, China*

[2] *University of Chinese Academy of Sciences, Beijing 100049, China*

(1) INTRODUCTIONS

The DB-DTL prototype is proposed to validate the feasibility of multi-beam accelerator in middle energy region. The main parameters are listed in Table.1. The DB-DTL will operate as pulse injector with the capacity of accelerating proton from 0.56 MeV to 2.5 MeV. The 35.83 kW normalized power dissipation of DB-DTL dissipated on the cavity internal surface will heat the cavity and cause cavity temperature rise and structural deformation, which will lead to resonant frequency shifting. The cooling water takes away the power to resolve this problem. In this paper, detailed multi-physics field simulation of DB-DTL is performed by using ANSYS multi-physics, which is a coupled electromagnetic, thermal and structural analysis

Table 1: DB-DTL Prototype Main Parameters

Parameters	Value
Particle	H^+
Operation	pulsed
Frequency (MHz)	81.25
Current (mA)	1
Input/output energy (MeV/u)	0.56/2.56
Maximum gap voltage (kV)	387.50
Transmission efficiency (%)	35.0
Power dissipation (MW)	35.83
Kilpatrick factor	2.10
Shunt impedance (MΩ/m)	100.01

(2) MULTI-PHYSICS ANALYSIS

As shown in fig.1 [1], the multi-physics analysis is a coupled electromagnetic, thermal, structural and frequency shifting analysis. The ANSYS workbench [2] and CST Microwave Studio (MWS) [3] are employed in the simulation. The total cavity power loss is firstly calculated with the MWS and the distribution of RF thermal loss on the cavity internal surface is simulated with the ANSYS High Frequency Structure Simulator (HFSS), which will be coupled to the next thermal analysis. The thermal solution will generate cavity temperature map based on cavity internal surface heat flux, which is applied to calculate the structural stresses and deformations. The last step is to calculate the resonant frequency shift according to the deformations. Through multi-physics analysis, appropriate parameter of cooling-water is chosen to satisfy the requirement for cavity operation of DB-DTL. The deformation and stress of cavity and corresponding resonant frequency shifting should be within a proper range.

The electromagnetic simulation results in MWS show that cavity resonant frequency is 81.24993 MHz. The normalized power dissipation is 35.83 kW and the shunt impedance is 100.01 MΩ/m. As shown in fig.2, the octahedron cavity model is chosen for easily assembling, which includes 8 ridge waterways and 5 wall waterways. Fig.3 shows the distribution of the cavity power dissipation, which will be applied to following thermal simulation. The simulation results of multi-physics analysis show that the temperature rise, deformation, stress and resonant frequency are beyond a proper range, which indicate the cooling system is impracticable to CW operation of DB-DTL, as plotted in Table.2. Actually, the DB-DTL will operate at pulse with 1/1000 duty without cooling water in future for shorting funds. Therefore, the maximum loadable power test of DB-DTL is studied. The simulation results show that the maximum loadable power of DB-DTL is 18 kW*5/100 with cooling water and 18kW*1/100 without cooling-water, respectively, as illustrated in fig.4.

Considering 18*1/100 power dissipation, the simulation results of DB-DTL without cooling-water is shown in Fig.5, which include the distribution of temperature, deformation and stress. The maximum temperature is 32.735 0C located at eighth drift tube and the minimum temperature of drift tube is 29.588 0C. The maximum deformation is 68.018 μm on the external surface and the displacement of drift tubes are between 7.55 μm and 30.231μm. The maximum stress is 62.876 MPa located at fixed supporting flame. The stress distribution of DB-DTL cavity is within a proper range. The deformation of DB-DTL cavity will cause frequency shifting. The frequency shifts were calculated with the HFSS code based on the deformation results. The frequency shift is −16.8 kHz compared with the initial frequency. The resonant frequency shifting for cavity deformation is tuned by tuners with 9.65 kHz/mm frequency tubing ability. The simulation results of 18 kW*5/100 power dissipation with cooling water is plotted in Table.2. The maximum deformation is located at eighth drift tube. These simulation results indicate that the DB-DTL meets the design goals with 1/1000 pulse operation mode.

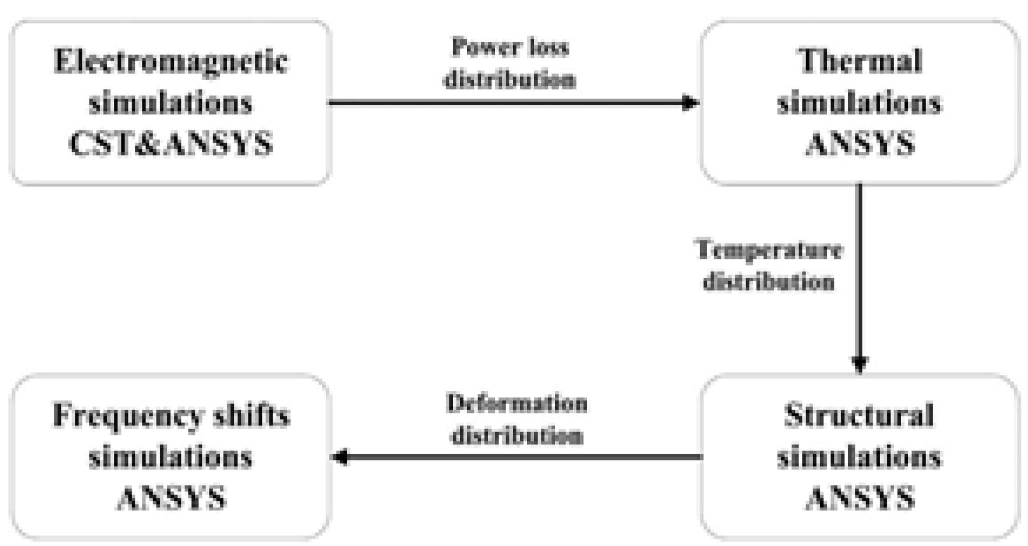

Fig.1: Multi-physics analysis scheme with CST and ANSYS.

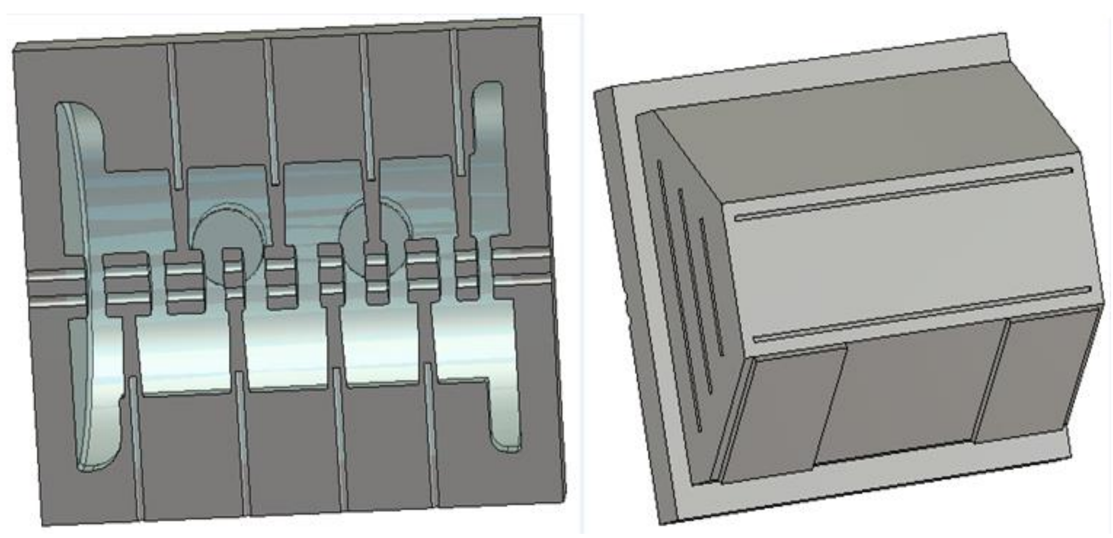

Fig.2: Structure model of DB-DTL.

Table 2: Simulation results of CW and pulse (5/100) operation mode

Parameters	*C W*	*Pulse(5/100)*
Power dissipation	*18 kW*	*18 Kw*8/100*
Maximum Temperature (^{0}C)	*550.22*	*46.511*
Maximum Deformation (mm)	*1.8114*	*99.635*
Maximum Stress (MPa)	*230.95*	*29.247*
Frequency shifting (kHz)	*-685.8*	*-38.1*

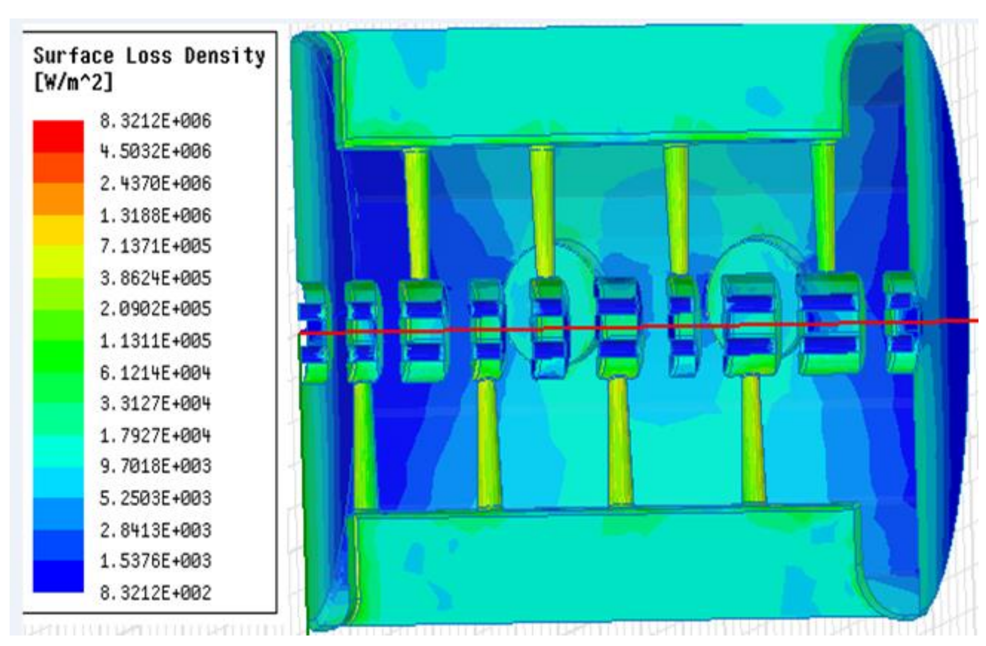

Fig.3: Power loss distribution of DB-DTL cavity.

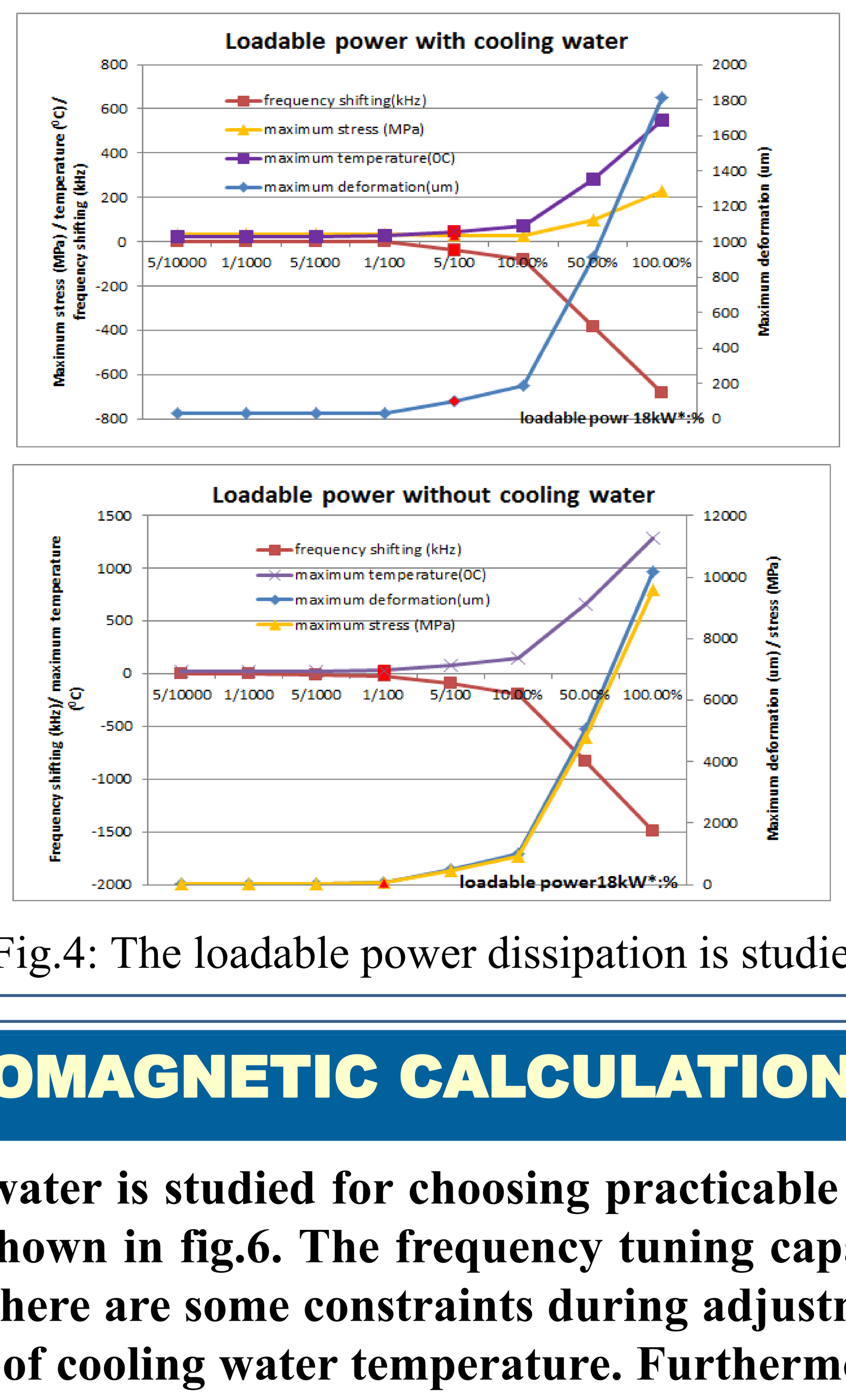

Fig.4: The loadable power dissipation is studied.

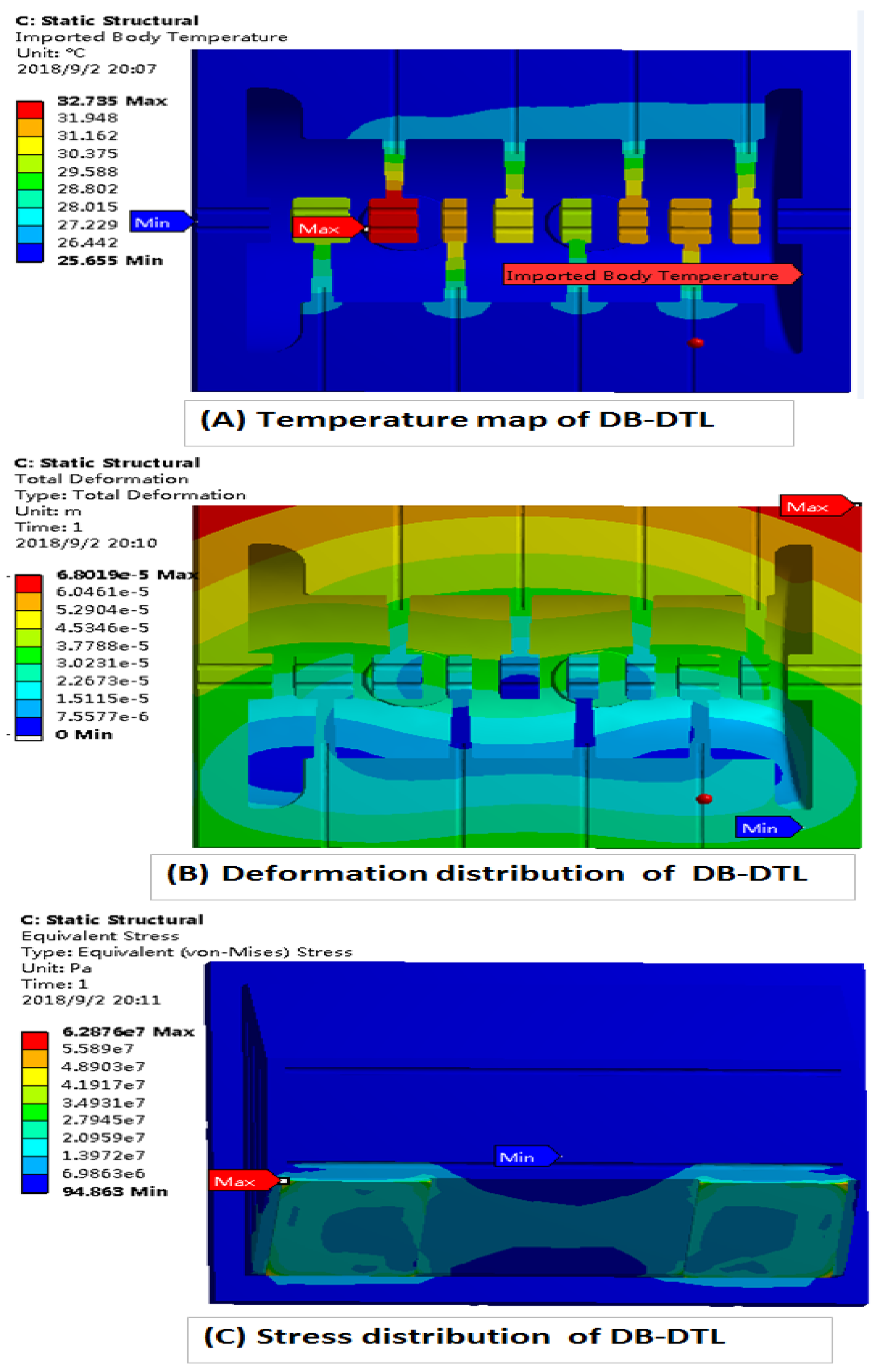

Fig.5: The temperature map, deformation and stress distribution of DB-DTL with 1/100 pulse operation.

(3) ELECTROMAGNETIC CALCULATION AND FUTURE PLAN

The frequency sensitivity of parameters of cooling water is studied for choosing practicable temperature and velocity of cooling water. The DB-DTL frequency sensitivity of cooling water temperature is shown in fig.6. The frequency tuning capacities of ridge and wall cooling water temperature are -1.56 kHz/^{0}C and 0.072 kHz/^{0}C, respectively. However, there are some constraints during adjustment of cooling water temperature. As illustrated in fig.6, the maximum deformation is varied with the variation of cooling water temperature. Furthermore, the maximum stress is also changed by the change of cooling water temperature. The simulation results indicate that the practical variation range of temperature is between 18 ^{0}C and 25 ^{0}C and the adjustment range should be as small as possible for frequency tubing. Otherwise, an everlasting inelastic deformation will occur with long time over-stressed operation and field distribution distortion will be enough big to affect the focusing and accelerating ability of DB-DTL.