CALCULATION OF THERMAL TRANSIENT CONDITION IN THE BIPERIODIC ACCELERATING STRUCTURE

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RF power distribution as well as deformation and resonance frequency of the structure after stepped changing of RF power or cooling water temperature were investigated. Transient process is not exponential. Effective time constant corresponding to 90% level of resonant frequency is equal to 16/19 sec at power/temperature changing. Effective time constant corresponding to derivative value in the control region is equal to 11/21 sec at power/temperature changing.

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1. INPUT DATA

On-axis coupled biperiodic accelerating structure is used in industry electron linac [1]. Main parameters of this linac are: electron energy 9 MeV; average beam power up to 11 kW (4.6 kW nominal); average RF loss in the structure up to 11 kW (3.1...8.3 kW nominal); operating frequency 2856 MHz; structure is cooled by the water flow through 16 longitudinal 10 mm diameter channels; water speed 2 m/sec; water flow 38 dm^3/min; outlet-inlet water temperature difference up to 0.2^0C; copper-water temperature difference up to 6.5^0C.

The calculation of thermal-frequency transient conditions in the structure is needed to design the regime of control of frequency, RF power and cooling water temperature.

2. BLOCK DIAGRAM OF CALCULATION

The block diagram of the calculation process is shown in Fig.1. All input data of the accelerating structure are introduced in Cavity Input Data module. The model of calculation is produced in Cavity Geometry module.

Cavity RF and Cavity Thermo modules prepare models for calculation of electrodynamics and thermal parameters using model, prepared in Cavity Geometry module. Cavity R[illegible] the field distribution in the model, namely the power loss distribution on the mod[illegible] frequency Stat modules calculate deformation and resonant frequ[illegible] specified RF power loss P and cooling water temperature T. Thermo[illegible] deformation and resonant frequency F(t) as a function of time t of the model in transient conditions after step changing of R[illegible] water temperature T.

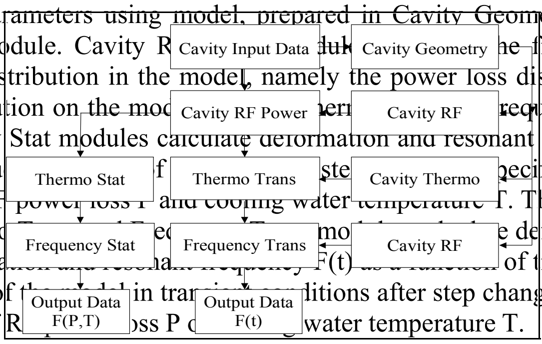


Fig.1. The block diagram of the calculation

3. MODEL OF CALCULATION

The model of calculation includes a quarter of two accelerating half-cells and coupling cell between them. It is shown in Fig.2.

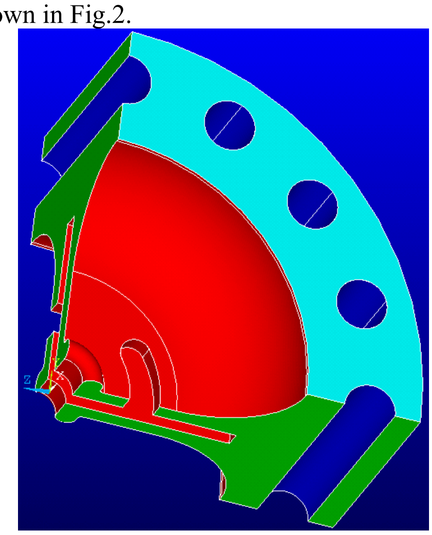


Fig.2. The model of calculation of accelerating structure

RF power can be lost on the inside surface of the accelerating cells and coupling cell. The cooling water flows in four cylindrical holes of the model.

Distribution of RF power loss on the model surface calculated in Cavity RF Power module is shown in Fig.3.

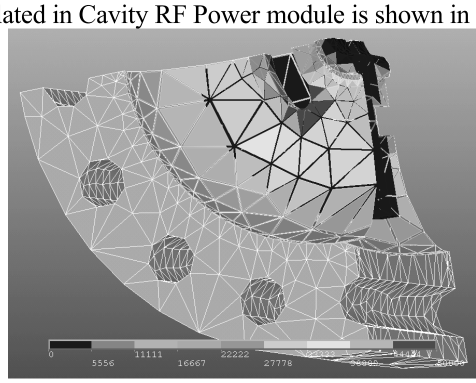
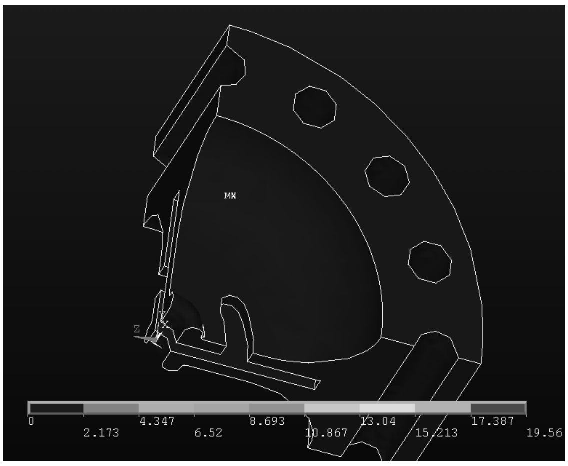


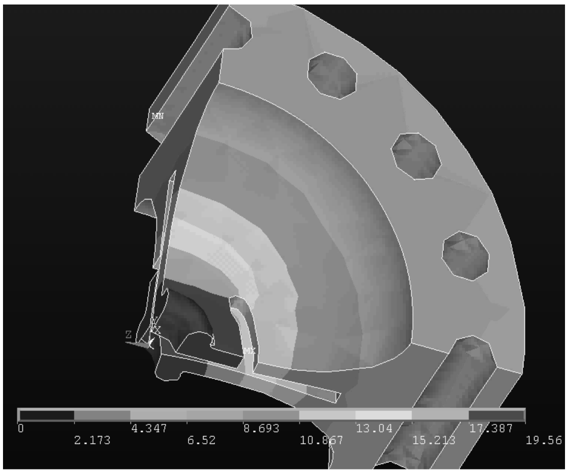
Fig.3. The distribution of RF power loss

4. STEADY STATE

Total RF power lost in the model is equal to P. Water speed is 2 m/sec. If water temperature is equal to T and RF power P=0, that temperature of the model is equal to T also, and resonant frequency is equal to F. Uniform temperature distribution and strainless model are shown in Fig.4,a.



a



b

Fig.4. Temperature gradient and deformation of the model increased 1000 times without RF power (a) and with RF power 600 W (b)

Thermo Trans and Frequency Trans modules calculate deformation and resonant frequency F(t) as a function of time t in the model in transient condition after stepped changing of RF power loss P or cooling water temperature T.

RF power loss leads to temperature gradient in the copper of the model and to its deformation. Temperature gradient and deformation of the model increased 1000 times at 600 W RF power lost in the model are shown in Fig.4,b. These results are got in Thermo Stat module. Temperature gradient on the surface is $\Delta T=13^0C$. Copper-water temperature difference is 6.5^0C.

The deformation leads in turn to the resonant frequency shift ΔF of the model. The frequency shift ΔF_0 in steady-state calculated in Frequency State module depends linearly on the power loss P as this is shown in Fig.5.

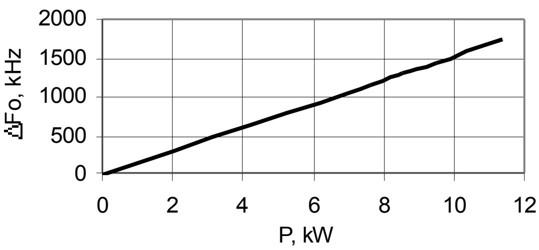


Fig.5. Frequency shift depending on RF power loss

Different science teams investigated the task of thermal calculation of accelerating structure.

The calculation of 2450 MHz disc-and-washer structure gives 16...20^{0}C temperature gradient at different types of disk cooling channels and – 450 kHz frequency shift at power 1 kW/cell [2].

As 2D calculation with 3D approximation shows, frequency shift in 2450 MHz on-axis coupled biperiodic structure with one coupling slot in the wall is – 455 kHz at I kW/cell [3]. 20...25 sec is needed to reach thermal equilibrium.

The temperature gradient in 1300 MHz Cut Disk Structure (a version of MHz on-axis coupled biperiodic structure) with circumferential cooling channels is 250^{0}C at 10 kW/m power loss [4].

The difference of the results is accounted by the difference of construction, power and cooling of structures.

5. TRANSIENT CONDITION

Thermo Trans module allow us to calculate the temperature gradient in the copper of the model and its deformation as a function of time during transient conditions after changes of RF power loss or cooling water temperature stepwise.

The frequency changing at stepped RF power changing is shown in Fig.6.

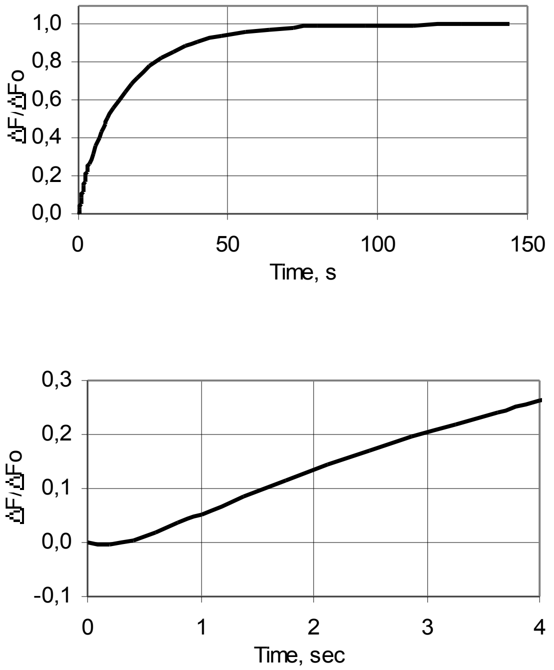
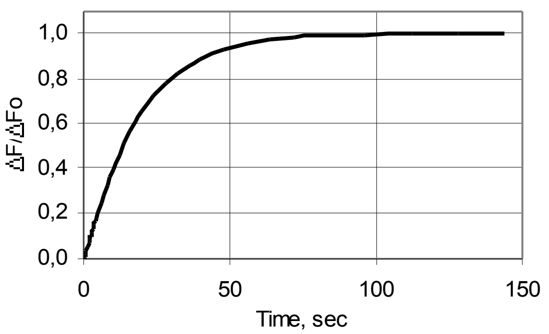


Fig.6. Frequency changing at stepped RF power changing

The frequency changing at stepped cooling water temperature changing is shown in Fig.7.



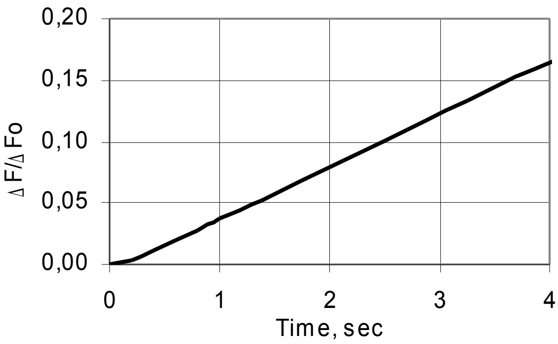


Fig.7. Frequency changing at stepped cooling water temperature changing

6. CONCLUSIONS

The main conclusions of the calculation are:

- The frequency stopway at RF power switching on stepwise is 1.7 MHz at maximum power 11 kW, and 0.5...1.25 MHz at 3.1...8.3 kW in different versions of nominal regime [1].
- The time dependence of resonant frequency during transient condition is not exponential.
- Effective time constant determined at 90% of steady state level of ΔF_0 is 16 sec at RF power changing.
- Effective time constant determined at 90% steady state level of ΔF_0 is 19 sec at water temperature changing.
- Effective time constant determined with respect to derivative in initial control region of time dependence of ΔF is 11 sec at RF power changing.
- Effective time constant determined with respect to derivative in the initial control region of time dependence of ΔF is 21 sec at water temperature changing.
- The RF power and water temperature do not change stepwise usually in accelerator. Therefore the control time can be faster at real smoothed changes.

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РАСЧЕТ ТЕПЛОВЫХ ПЕРЕХОДНЫХ РЕЖИМОВ В БИПЕРИОДИЧЕСКОЙ УСКОРЯЮЩЕЙ СТРУКТУРЕ

Д.А.Завадцев

Получены временные зависимости собственной частоты ускоряющей структуры при ступенчатом изменении мощности СВЧ потерь и изменении температуры и потока воды. Процессы – не экспоненциальные. Эффективная постоянная времени, оцененная по уровню частоты 0,9, равна 16 с при изменении СВЧ мощности потерь и 19 с при изменении температуры протекающей воды. Эффективная постоянная времени, оцененная по значению производной в области регулирования, равна 11 с при изменении СВЧ мощности потерь и 21 с при изменении температуры протекающей воды.

РОЗРАХУНОК ТЕПЛОВИХ ПЕРЕХІДНИХ РЕЖИМІВ У БІПЕРИОДИЧНІЙ ПРИСКОРЮЮЧИЙ СТРУКТУРІ

Д.А.Завадцев

Отримано часові залежності власної частоти прискорюючої структури при східчастій зміні потужності НВЧ втрат і зміні температури і потоку води. Процеси – не експонентні. Ефективна постійна часу, оцінена за рівнем частоти 0,9, дорівнює 16 с при зміні НВЧ потужності втрат і 19 с при зміні температури води, що протікає. Ефективна постійна часу, оцінена за значенням похідної в області регулювання, дорівнює 11 с при зміні НВЧ потужності втрат і 21 с при зміні температури води, що протікає.