HEATING ANALYSIS AND THE SOLUTIONS OF DCCT SYSTEM FOR BEPCII

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Abstract

The BEPCII e+ DCCT is damaged due to a high temperature heating. After 8 years operating, it is not working properly in 2014. As the BEPCII is trying to reach high luminosity, the CT will be a defective component with the high beam current, therefore a spare one has replaced it. In order to determine the heating source, some experiments and simulations have been done. A new vacuum chamber structure has been designed to solve the problem. The analysis and result can be also applied to CT designs in the future.

INTRODUCTION

There are two bergoz[1]in air DC current transformers fixed on BEPCII rings on both sides of the interact point(IP). One for positron and another for electron when the machine runs collider mode, both two DCCT can measure the electron current when the machine runs at synchrotron mode. Figure 1 shows the sensor's location. The two DCCT sensors have same parameter and identical mechanical design.

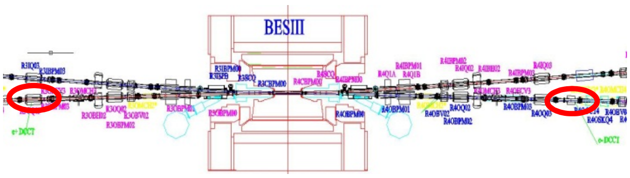

Figure1: Layout of BEPCII DCCT sensor.

Each DCCT has 2 sensors to pick up the temperature. One (e-/e+ T-SU1) is stuck on the DCCT sensor, another (e-/e+ T-SU2) is used to monitor the pipe's temperature. A problem has appeared in e+'s DCCT after once high current operation in 2012: In collider mode ,The e+ DCCT 's temperature is much higher than e- DCCT when the e+,e- beam current is the same. In synchrotron mode, the e+ DCCT's temperature is also slightly higher than e-'s. For the first e+ DCCT sensor was damaged by heating, a spared one with a identical new vacuum chamber made in 2010 has replaced it, but the temperature problem still exist.

The Fig. 2 shows the current and temperature curves when the machine runs at collider mode this year, the peak beam current is 720mA, bunch number is 92, bunch current is 7.9mA for both e+ and e- rings. The e+ T-SU1 is 33°C, 8°C higher than e-'s, the e+ T-SU2 is 50 °C, 10°Chigher than e-'s. The 2 DCCT vacuum chambers have the same water cooling system, they all work normal. The nearby BPMs show the beam position in X,Y direction, no . As the BEPCII will run over 910 mA for collision, and the high temperature will affect the magnetic characters of the DCCT cores [2], the e+ problem should be settled.

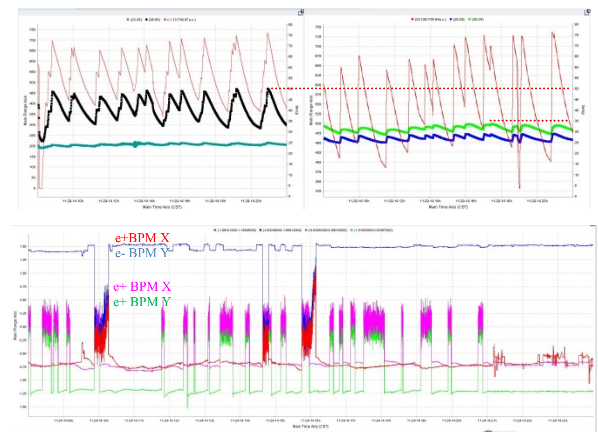

Figure 2: Current and temperature curve for e+ (up left) and e-(up right) DCCT, BPM nearby X,Y position(down).

ANALYSIS AND SIMULATION

For the measurement principle of current transformer, a break is needed in the vacuum chamber to cut off the mirror current. Figure 3 is the structure of DCCT with toroid, bakelite rack and metal shield. The vacuum chamber has a interlayer water cooling. The gap is 2 mm sealed with ceramic ring, kovar alloy is used to weld the ceramic ring to the Steel-316L vacuum pipe. This structure bring a micro vacuum part as a resonate cavity.

BEPCII Bunch length is about 15mm, it means the spectrum of bunch will cover the high frequency part of impedance, which will lead to an enormous heat deposition by the HOM. The HOM power will deposit at places where the wakefield trapped by small discontinuities of the beam duct, such as the ceramic gap. So when charged particles pass through the gap, it loses energy which would transfer into heat power[3].

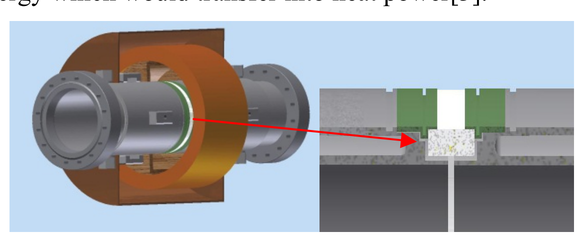

Figure 3: Structure of vacuum chamber.

ISBN 978-3-95450-176-2

The temperature curve also indicates the relevance between heat and bunch current. When the bunch current is above 7mA, the temperature is sharp rising. A large bunch over 10mA is injected into the synchrotron ring for experiment, it means the e+ and e- share the same beam current, the e+ T-SU2 is 69 °C, e- T-SU2 is 37°C, shows in Fig. 4.

Figure 4: Temperature and current curve with bunch current over 10mA.

In order to get the thermal power, a solid model of only vacuum part is built for wakefield simulation. Table 1 shows the BEPCII storage ring main parameters.

Table 1: BEPCII Parameters

Parameter(e+/e-)	**BEPCII**
Beam current (mA)	910
Bunch current(mA)	9.8
Beam energy (GeV)	1.89
Circumference (m)	237.5

In this case, the loss factor $K_{loss}$is 11.2V/nC when the gap is 2mm, bunch length is 15mm.

$$P_{loss}=I^2\ t\ K_{loss}/N[4]$$

I is the beam current 730mA,t is the revolution time 800ns, N is bunch number 92, so the P_{loss} is about 49.5W.

Eigenmode simulation is used to get the field distribution, the highest field amplitude near the gap is 2.48e+8V/m at 4.4GHz. Figure 5 shows the field distribution.

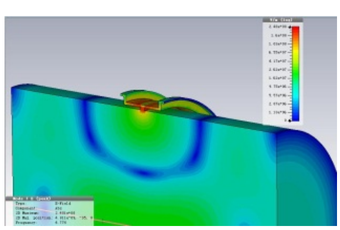

Figure 5: Field distribution of simulation.

A complete model of DCCT toroid, shield, rack and vacuum chamber with flange is established for temperature simulation. The loss power is all used for heat, the mode field distribution is imported to thermal losses [4] and no extra cooling, only the air flow is set on the surface. The temperature is from 20 to 83.8 Celsius degree as shown in Fig. 6.

Then the interlayer water cooling is add to the model by set the heat transfer coefficient in experience. The temperature is between 20 to 44°C, consistent with the e-'s situation. The e+ chamber most likely has other external heat source. As there are no other temperature sensors right now, it's difficult to confirm. We are plan to add a temperature sensor on the asylphon bellowsis connect to the chamber.

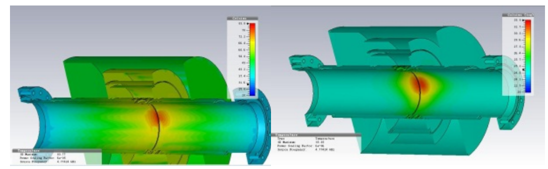

Figure 6: Thermal analysis without and with cooling.

SOLUTION

For not disturbing the machine's operation, a simple way that adding a fan to e+'s chamber for auxiliary cooling is used during last running period. It could lower the temperature for 2, 3°C. F

Examine and avoid the external heat power source is the next step to settle this problem. Meanwhile, for the 910mA or even higher running mode, the heat power will be higher, a new vacuum chamber is designed for spare.

The primary DCCT vacuum chamber has two section which separated by the gap. Both sections have interlayer water cooling. The water route is simple with several blocks to guide the flow, the water may not cover the whole inner surface, and will cause less effect of cooling.

The new vacuum chamber's micro structure will be shielded by improve the welding method, the loss factor may reduce to 6.5V/nC according to the simulation result, so the power will be down to 20W at the same condition above.

A new spiral water route will replace the old one, and the interlayer will increase from 2mm to 4mm as show in Fig. 7. As the water inlet's and outlet's diameter are 10mm, the distance between threads would not be too short or will slow down the water flow.

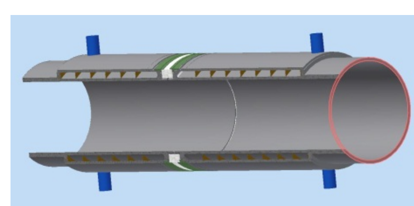

Figure 7: The interlayer of water cooling.

SUMMARY

Reduce the heat source and strengthen the external cooling are the main method to solve the heat problem. Through the simulation and experiment result, we can confirm that the primary mechanical structure and cooling system for DCCT is functional normal, and the analysis procedure could help to optimize the mechanical design for future current transformer. For e+'s special situation, more experiments should to be done for settling it.

ISBN 978-3-95450-176-2

ACKNOWLEDGMENT

The authors would like to thank to all members of the BI group in IHEP for their collaboration. The authors also would like to express their thanks to the colleague in IMPCAS for the assistance.

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ISBN 978-3-95450-176-2