Evaluation of the Beam Coupling Impedance of New Beam Screen Designs for the LHC Injection Kicker Magnets

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Abstract

During the 2011 run of the LHC there was a significant measured temperature increase in the LHC Injection Kicker Magnets (MKI) during operation with 50ns bunch spacing. This was due to increased beam-induced heating of the magnet due to beam impedance. Due to concerns about future heating with the increased total intensity to nominal and ultimate luminosities a review of the impedance reduction techniques within the MKI was required. A number of new beam screen designs are proposed and their impedance evaluated. Heating estimates are also given with particular attention paid to future intensity upgrades to ultimate parameters.

LHC-MKI and Beam Screen Designs

- The MKIs have recently been observed to undergo significant temperature rise during the increase of the stored intensity in the LHC [1]. This has been confirmed to be due to beam-induced heating via interaction between the circulating beam and the beam-coupling impedance of the MKIs
- The beam-coupling impedance of the MKIs is dominated by the beam screen (see Fig. 1); an alumina "carrier" tube into which are inserted a number of conductive strips.

figures/shortening_screen_conductors.pdf

Figure 1: Illustrating the layout of the beam screen, with the screen conductors electrically connected to the beam pipe at one end of the screen, and capacitively coupled to the beam pipe at the other by an overlapping external metallisation.

- Due to high voltage breakdown in the beam screen, most MKIs have had the 9 screen conductors closest to the HV plate removed. This causes an increase of the beam impedance, and thus increased heating.

figures/alternative_screen_design.pdf figures/enclosed_diagram.pdf

(a) (b)

Figure 2: Cross sections of LHC-MKI beam screen with either 2(a) an alternative screen layout, in which most conductors are capactively coupled at both ends, and 2(b) the beam screen in which the screen conductors are in enclosed slots rather than open slots.

- A number of different beam screen configurations are considered to reduce the beam impedance and avoid electrical breakdown in the beam screen (see Fig. 2).

Simulations Parameters

figures/mki-cross-section.png

Coaxial Wire Measurements

- We compare measurements to simulations to verify the validity of the simulation model. We take the example of 15 screen conductors, which has existing measurement data (see Fig. 4). We can see the agreement is very good over a substantial part of the frequency range considered.

figures/15_conductors_meas_sims_ipac.pdf

Figure 4: A comparison between the simulations and measurements of an LHC MKI with a beam screen with 15 screen conductors in open slots.

Beam Coupling Impedance of Beam Screen Designs

- Fig. 5(a) shows the impedance of the beam screen with different numbers of screen conductors. It can be seen that even a small amount of additional screening can contribute quite significantly to reducing the impedance of the MKI. The screening is especially effective at low frequencies where the beam current spectrum is high.

figures/15_24_conductors.pdf figures/24_plate_different_des

(a) (b)

Figure 5: The longitudinal beam coupling impedance of 5 different numbers of screen conductors in the beam screen of the MKI and 5(b) different screen layouts for the MKI.

- Fig. 5(b) shows the beam coupling impedance of a number of alternative screen designs compared to the present design with 24 screen conductors in place. We can see that all of these designs exhibit the same resonant structure, this being determined largely by the dimensions of the overlap between the screen conductors and the external metallisation. Work is underway to understand these resonances as a product of open-ended $\lambda/2$ resonators.

Heating Estimates

Table 1: Estimates of the total power loss (Watts) due to the beam coupling impedance of an entire MKI for a number of different beam screen configurations and layouts. Estimates are given with two different bunch lengths. The alternative layout is that shown in Fig. 2(a). Thick ceramic indicates using a thicker ceramic (5.5mm thick as opposed to 4mm for all other designs).

	Bunch Length $\sigma_z = 1.2$ns		Bunch Length $\sigma_z = 1.3$ns	
Beam Screen Layout	25ns	50ns	25ns	50ns
No Beam Screen	4933	2784	4320	2395
24 Screen Conductors, open	38	13	37	12
15 Screen Conductors, open	147	72	129	60
24 Screen Conductors, enclosed	76	23	73	22
24 Screen Conductors, open, thick ceramic	53	20	52	19
24 Screen Conductors, open, alternative layout	63	23	62	22
19 Screen Conductors, open	52	18	50	16
20 Screen Conductors, open	50	16	48	15

Summary

- We have demonstrated a number of alternative beam screen designs for the LHC MKIs, in particular designs optimised to reduce electrical breakdown have been demonstrated to provide comparable heat loads as the original.
- Using modern simulation tools it is possible to simulate very large and complex structures to produce results in good agreement with measurements.

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