CALCULATION OF LOSSES AND PROTECTION AGAINST IRRADIATION DURING BEAM ABORT AND LOSS LOCALIZATION IN THE UNK

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Abstract

This work presents the results on numeric simulation of particle loss and on the study of protection of superconducting magnets against irradiation during beam abort and localization of loss in the UNK. Using a system of local orbit distortions and movable collimators one may bring the radiation heating of superconducting dipoles down to ~ 0.1 mJ/g.pulse, when ~1% of the intensity is lost at the 1st septum of the magnetic deflector. This causes a raise in the coil temperature of not more than 0.2 K.

1. Introduction

A fraction of the beam lost in the UNK at various stages of the acceleration cycle may cause the superconducting magnets to operate in ionizing radiation fields. The most stringent situation related to the radiation heating of the superconducting magnets of the UNK is expected to occur in the region of matched straight sections (MSS) 1 and 4.

In our work we treat the radiation heating of the superconducting magnets caused by a beam loss in MSS1 of the UNK and protection against their irradiation.

The major sources of loss in MSS1 are the elements of the system localizing loss during injection and in the beginning of the acceleration cycle as well as the septa during beam dump onto the external absorber. The experience in exploiting accelerators showed that during injection and in the beginning of the beam acceleration a loss may reach up to 10 and more per cent of the intensity injected. In this case loss distribution over the machine azimuth is extremely non-uniform. Fairly simple estimates show that with the design parameters of the UNK beams a loss of even 1% of the total intensity may lead to a linear loss density in the ring of $3\cdot10^{8}$-10^{10} p/m, which causes the radiation heating of the magnet coils by tens of degrees. The parameters of the UNK magnets are such that the estimated value of heating leading to unacceptable stability violations of their operation is ~1 K during injection and ~0.1 K for the maximum beam energy.

The system of loss localization allows one to intercept protons left uncaptured into the bucket in the beginning of the acceleration cycle and also to form the transverse emittance and momentum spread of the beam.

2. Protection of Accelerator Magnets Against Irradiation

Figure 1 presents the layout of the elements of the system of loss localization in the 3d stage of the UNK. Figure 2 shows the amplitude and dispersion functions at this section. A loss is intercepted separately in the horizontal and vertical planes. Before the beam is injected from the 1st stage into the 3d one bump magnets B2-B7 producing a local orbit distortion in the vertical plane are switched on.

When the emittance is formed the beam edge is retained near the tungsten target T2 placed at the input port of absorber S2. Scattering in the target matter raises the amplitude of betatron oscillations of protons and they are intercepted onto the absorber. In the case of loss localization in the horizontal plane the beam edge is kept close to the scattering target

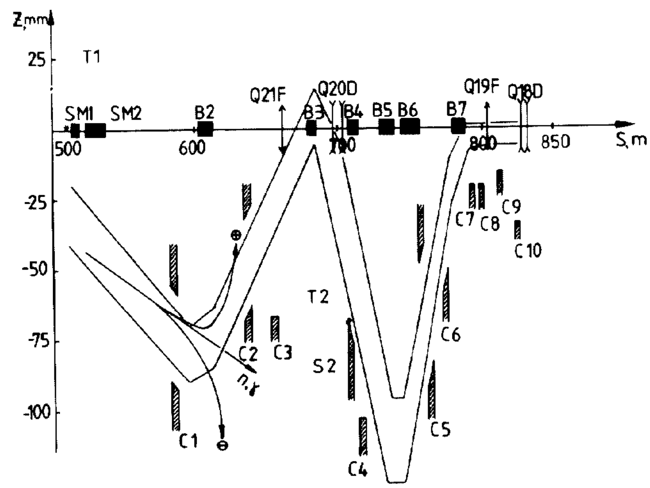

Fig. 1. The section of MSS1 for intercept and loss localization in the 3d stage of the UNK.

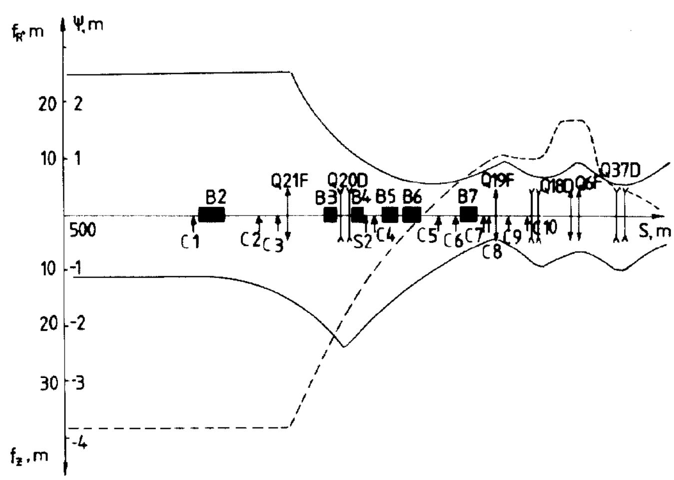

Fig. 2. The layout of optics in MSS1 of the 3d stage. The solid lines show the amplitude functions in the R and Z planes, the dashed lines show the dispersion function.

T1 placed at the input port of septum magnet SM1. In the process of an increase in the amplitude of betatron oscillations a fraction of the beam is intercepted into the aperture of SM1 and extracted onto the external absorber.

If a high dispersion, Ψ = -3.9 m, is produced where the septum is located, the protons having large momentum deviations at any amplitudes of betatron oscillations hit the target and are transferred further into the beam abort line.

The secondary particles emitting from the targets, electrostatic septa, from the absorber material as well as the protons acquiring a large increase of the amplitude of betatron oscillations as a result of interaction with the targets may be lost in the regu-

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lar part of the machine during the 1st revolution. These particles are localized by a system of collimators C1-C10 whose operational features are described in refs. [1,2,3].

Collimators C1-C3 and C5, C6, C8 localize all secondary particles whose energy differs essentially from that of equilibrium protons. Collimators C6 and C9 localize protons having an inadmissibly large amplitude of betatron oscillations which developed during interaction with the localization system elements in the process of intercepting the loss in the R and Z planes, respectively. Collimator C9 placed in MSS1 where the dispersion is Ψ = 1m, also intercepts the protons emitting from the elements of T1, SM1 and having a large momentum deviation.

As to their operational features, the collimators can conditionally be broken into 3 classes: constant-aperture collimators (C3, C4, C8, C10), those with an adjustable position of plates (C1, C2) and those with plates varying their position during the acceleration cycle (C5, C6, C7, C9).

Figure 3 presents the distribution of loss density in the ring part of the UNK which was computed using the code package MARTOR [4]. As was assumed, 1% of the total intensity of protons having an inadmissibly large amplitude of betatron oscillations was localized in the horizontal and vertical planes and 1% of the beam intensity having a momentum spread of $\Delta P/P = -6\cdot 10^{-3}$ was also localized. This situation is possible, for example, in the beginning of the acceleration cycle for protons not captured into the acceleration mode. As is seen from the figure, the maximum loss in the UNK lattice does not exceed 10^7 p/m leading to the radiation heating of the magnet coils by $\Delta T \sim 0.1$K. In the remaining part of the ring, the loss level does not exceed $10^4 - 10^5$ p/m coinciding approximately with that on a residual gas. With this loss, radiation heating is inessential.

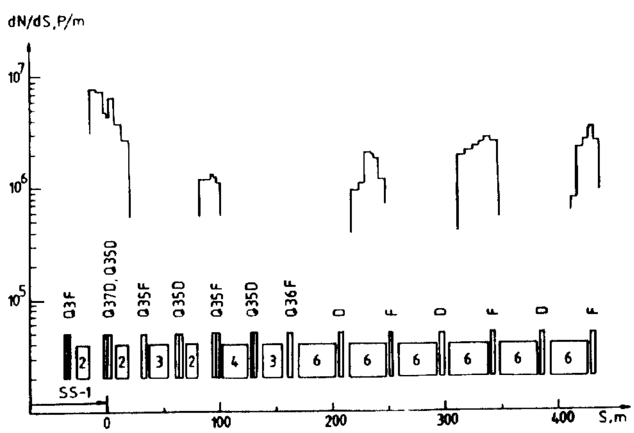

Fig. 3. The loss distribution in the UNK ring tunnel during interception of 3% of the total intensity on the elements of the loss localization system.

A similar situation is observed when localizing loss in the 2nd stage of the UNK. The scope of the protection measures (the number of collimators and bump magnets) is about the same as in the 3d stage.

Another source of loss in MSS1 is the elements of the beam abort from the UNK in the two directions. The mean frequency of triggering the beam abort system is supposed to be once per 10 acceleration cycles [5]. The most probable sources of loss are electrostatic extraction septa. The beam is transferred from the equilibrium orbit into the aperture of septum magnets with the help of kicker magnet to be further dumped onto the external absorber over the beam abort line. A fraction of the beam may in this case hit the septum. The nuclear electromagnetic cascade developing in the matter of the electrostatic septum is a source of secondary particles irradiating the superconducting magnets of the ring. This means that the situation is very similar to loss localization in the horizontal plane. Therefore it seems natural to assume that the protection measures against irradiation envisaged for operation of the loss localization system can also be applied for protection of the ring during beam abort.

To intercept low-energy and neutral secondary particles use is made of the local distortion of the closed orbit produced by the warm deflecting bump magnets placed directly behind the septum magnet and also of 3 collimators C1-C3 (see fig. 1). Since beam abort may be possible at any instant of the acceleration cycle, the local orbit distortion is maintained constantly up to 3000 GeV. As in the case of operation of the loss localization system, collimators C7, C9 (see fig. 1) make it possible to intercept high-energy protons leaving the electrostatic septa. The operational principle of these collimators is treated in detail in refs. [1-3]. According to the calculations, when the plates of the movable collimators C7 C9 are placed at a distance of 5-7 mm from the edge of the circulating beam the loss level in the UNK will not exceed 10^6 p/m if 1% of the total beam intensity interacts with the electrostatic septum. In this case, the heating of the ring dipoles will not exceed 0.1 K. Therefore the superconducting magnets of the ring are protected without introducing additional collimators into MSS1.

3. Protection of the Beam Abort Line Magnets

The beam abort line consists of superconducting quadrupoles and dipoles. Figure 4 shows the layout

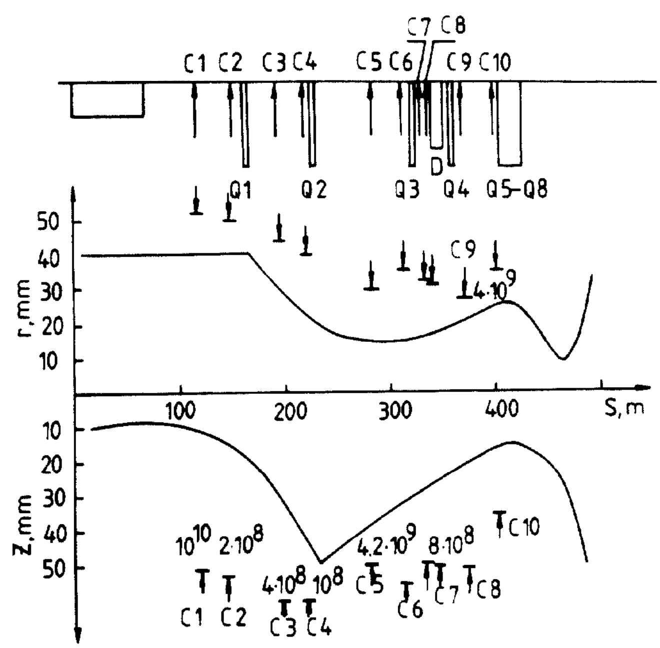

Fig. 4. The layout of the superconducting elements and protection collimators in the head part of the beam abort line from the 2nd stage of the UNK. The figures denote the loss on the collimators during interaction of 1% of the total intensity with the electrostatic septum SM1.

of the protection collimators in the head part of the beam abort line from the 2nd stage of the UNK. The meaning of the notations is as follows: Q1-Q8 - superconducting quadrupole lenses, D - superconducting dipoles, C1-C10 - collimators. This figure also shows the dimensions of the region occupied by the beam extracted onto the external absorber in the vertical and horizontal planes. The arrows show the transverse position of the collimator plates. The lower part of the figure presents the data on the proton loss on the collimators when $6 \cdot 10^{12}$ protons hit the electrostatic septum. As is seen from this figure, the superconducting elements are irradiated mainly by secondary radiation coming from the body of the collimators.

Septum magnets SM1, SM2 and collimators C1-C4 play the role of bump magnets for the local orbit distortion and system of collimators for interception of low-energy particles in the beam abort line. Collimators C5, C7, C8 are used to intercept high-energy protons emitting from the matter of electrostatic septa into the aperture of the beam line.

4. Conclusions

To conclude, it is worth noting that the elaborated measures of protecting the superconducting coils of the 2nd and 3d stages allow one to ensure the operational capability of the magnets and lenses during loss localization up to a few per cent of the design intensity at injection energy and also during beam dump onto the external absorber within the whole UNK cycle.

References

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