NEW MAGNET GIRDER DESIGN IN THE NSRRC

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Abstract

We have designed a new steel magnet girder using new schemes to achieve long-term mechanical stability, vibration suppression and a precision mover system. In the mechanical stability, we decoupled the thermal deformation of chamber from the girder and decreased thermal variation impact on the girder. For the vibration, composite material was adopted at some critical places to increase the horizontal stiffness. It has high eignfrequency and enough damping. The girder mover system used four compact stages with micron resolution over ±1mm region. A prototype of the new girder has been fabricated. The design consideration and test data are presented in the paper.

INTRODUCTION

For the installation of super conducting wiggler in NSRRC storage ring, the nearby magnet girder should be modified to accommodate this new device. There were three magnets and one straight vacuum chamber on the girder. The fixture of beam position monitor (BPM) was used as the support for the vacuum chamber and fixed to the girder. From our study in beam stability [1,2,3], mechanical stability of girder was influenced not only by direct thermal effects such as, the temperature gradient of the girder, thermal expansion of pedestal, but also by indirect effect such as thermal expansion of the chamber moving the girder via BPM support. When the position of BPM and magnet are perturbed it is difficult to get a stable beam. In the new design we proposed some method to eliminate the thermal problems.

In the vibration issue, both higher eignfrequency and high damping are preferred. But in the steel structure it is difficult to achieve both the goal. In some facilities [4,5], the eignfrequency of girder is usually below 10Hz. Passive damping methods have been proposed but eignfrequency was still same. We tried another approach, used polymer concrete to increase the stiffness of joint and keep enough high damping. For the girder adjusting, we used four compact stages to adjust in horizontal, vertical and three angles. The resolutions are about micron order. Sufficient damping and joint stiffness were specially considered.

In the paper we will discuss the details of the design consideration, key components design and some test results.

DESIGN CONSIDERATION

The space requirement of the new girder was kept nearly same as old one in the tunnel. Magnets were also same while vacuum chamber was shorter. The following design concepts were proposed to construct this new girder.

1. To keep the mechanical stability of girder the resistance of temperature variation should be increased by either thermal insulation or bigger heat capacity.
2. To avoid being perturbed by the thermal deformation of chamber it should be decoupled from the girder.
3. For the vibration suppression the eignfrequence and damping should be higher.
4. A fine adjusting mechanism was available with microns resolution for the installation.
5. Fine adjusting stages of sextrupole magnets were available for the coupling study.

To satisfy the above requirements the girder components were modified and described in the next section.

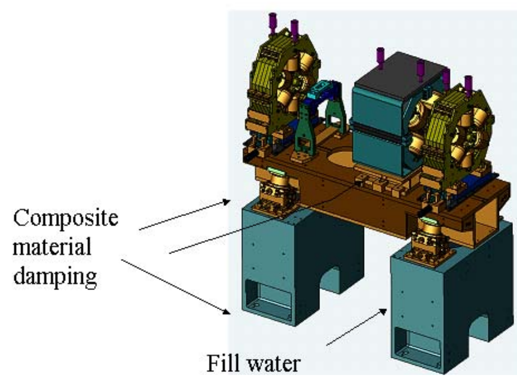

Figure 1: The whole structure of the girder system.

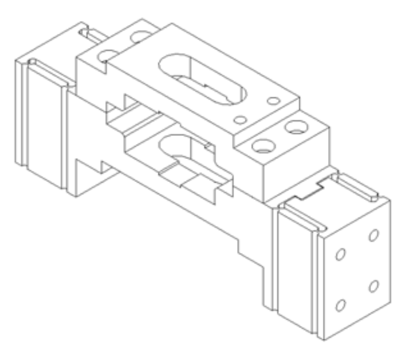

Figure 2: New BPM fixture with flexure.

KEY COMPONENTS DESIGN

Girder and Pedestal

One girder with two pedestals and magnets formed the whole structure system. We used welded steel structure after stress-relieved. Three magnets weighed about

800 Kg. To increase the eignfrequency the stiffness of the girder should be increased while the weight of the structure should keep reasonable low. A hollow boxed structure with ribs was adopted as the structure to increase the stiffness without add more weight. From the measurement of old girder the vibration in the transverse direction was about 15 Hz. It meant the horizontal stiffness was not big enough. To increase the transverse stiffness the span of the supports points of girder on the pedestals should widen somewhat within the space budget to reduce the rocking motion. The joint between the girder and pedestal was carefully designed to eliminate vibration. The surface of the girder for the location of the magnet stage was machined flat to remove local high spot and helped to increase the joint stiffness. The whole structure is shown in the Fig.1.To reduce the thermal deformation by the air temperature variation water was filled inside the pedestal to increase the time constant of temperature variation. Because water has specific heat 10 times higher than steel, then the height change of the girder by thermal environment variation could be expected to reduce to the least level. Thermal insulation on the girder surface is also an option to avoid the temperature gradient between the upper and lower surface of girder.

BPM supporting fixture

BPM mechanical position is important for electron orbit feedback, we hoped to keep it in 0.1μm position stability. BPMs were welded on the vacuum chamber of straight section. In the past concept, BPMs were rigidly fixed to the girder. As mentioned [1], thermal deformation of chamber would induce the movement of the girder. Vacuum bellows were designed to absorb the thermal expansion or shrinkage of chamber. But the stiffness of formed bellows was higher especially in the transverse direction. If the bending chamber was expanded in the transverse direction somewhat, then some transverse thermal stress would apply on the BPM fixture. This may be the reason why a strong correlation between the transverse BPM readings with chamber cooling than vertical BPM reading as reported in NSRRC [6]. In the new design we use a flexure type BPM supporting mechanism to allow the thermal expansion in longitudinal direction but keep vertical and horizontal nearly fixed. The support of bending chamber was also modified to eliminate the transverse expansion. Spear III also proposed similar concept but the mechanical design was different. We used a flexure type parallel mechanism. The picture of the new BPM support is shown in the Fig.2 It was designed that the stiffness in vertical and horizontal direction was more than 100 times in longitudinal direction. From Ansys simulation, apply 10 Kg force in longitudinal, horizontal, and vertical direction would induce 89 μm, 0.3 μm. 0.5 μm displacement. Tests in the laboratory also confirmed the above calculation. It is also easy to replace the old support without venting the vacuum.

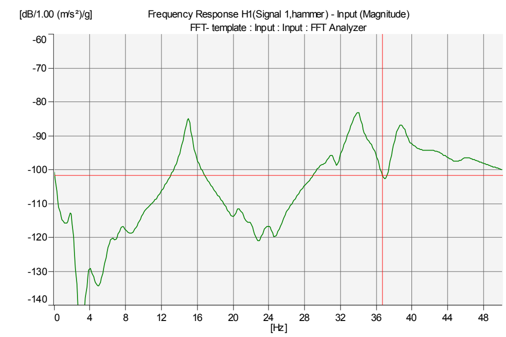

Figure 3: Frequency response function of quadrupole magnet on the old girder.

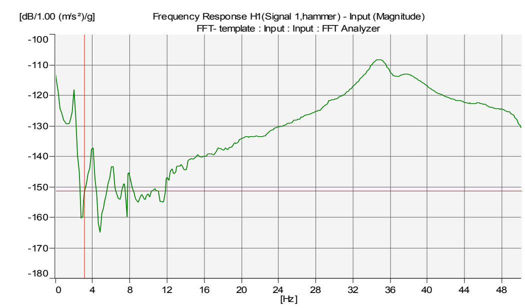

Figure 4: Frequency response function of quadrupole magnet on the new girder.

Vibration suppression

The basic vibration of the girder was the twist mode in transverse direction as mentioned. The eignfrequency was 7 Hz in ESRF [5], 10 Hz in APS [4] and 15 Hz in NSRRC. A typical frequency response function of quadrupole on old girder is shown in the Fig 3. To deal with this vibration, in APS they used damping pads to insert between the pedestal and girder jack [4], in ESRF they use the damping link. They had positive damping effect on major peak.

In the new girder we adopted the structure damping to push to higher eignfrequency and enough damping. It also provided the position stability. There were three places (the pedestal and ground, the pedestal and girder, girder and quadrupole magnet) adopting this structure damping technology. These interfaces were considered weakest points in the whole system. After anchor-lock the pedestal to ground by bolts, a polymer concrete with high damping and high stiffness [7] was used to fill the gap between the pedestal and ground. It would provide true contact between pedestal and ground and guarantee stability. The interface between pedestal and girder were carefully designed to prevent worsening the transverse stiffness. It was a joint for the adjusting mechanism. We adopted a slide rail rather than rolling rail to increase the stiffness of the adjusting stage. The joint between girder and quadrupole magnet also used this material. The frequency response function of the new girder is shown in the Fig.4. It shows the eignfrequency was shifted to 35 Hz. The loss factor was increased 2 times. The result seems encouraging because it is universal in any application of structure.

Girder adjusting mechanism

For the vibration consideration we used four points for adjusting the girder instead of three points. It had been used in SLS [8], but the mechanism is different. In our design, In each point there was one stage providing the vertical and transverse displacement adjusting. It consisted of a wedge jack and a commercial precision ball joint to assure the smooth motion of the adjusting. The schematic drawing is shown in Fig. 5. By adjusting two specified stages we could change the pitch, roll and yaw angle of girder. By adjusting four stages we could change vertical or transverse displacement. Resolution of adjusting was about 5μm. Manual or motor control versions were available for adjusting.

Magnet adjusting stage

There were three magnets on the girder. One quadrupole magnet was fixed to the girder; two sextrupole magnets were mounted on the adjusting stage of the girder. This offered the possibility to fine-tune the sextrupole magnet position for optimum coupling [9]. Drawing of the stage is shown in Fig.6. There were only three slides to offer vertical and transverse motion. Bottom slide was for the horizontal, upper two slides with wedge shape for vertical motion. Two DC motors and suitable algorithm could give the desired adjustment. Two limit switches and three potentional meters were attached for monitoring. It was remote-controlled. Adjusting range was about ±0.5mm, resolution was about 1μm in vertical and horizontal direction. Another feature of this stage was its low profile and high stiffness.

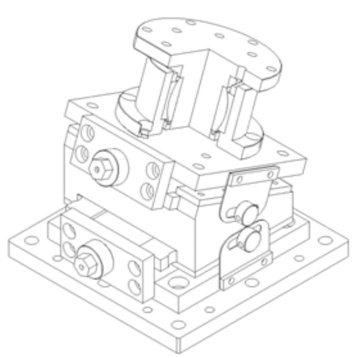

Figure 5: Drawing of the adjusting stage in two directions.

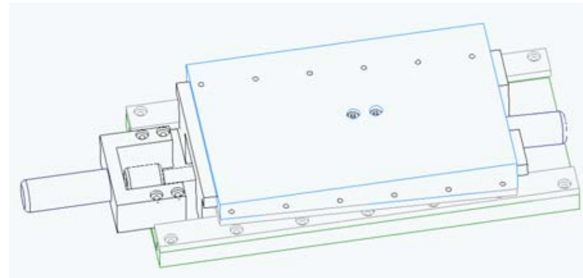

Figure 6: Low profile adjusting stage for magnet with micron resolution.

SUMMARY

We have designed a magnet girder with precision adjusting mechanism. It also utilizes several new schemes for dynamic thermal problems and vibration suppression. The result of the prototype was encouraging. The design consideration and test data are presented in the paper.

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