# INVESTIGATION OF MECHANICAL STABILITY FOR SSRF GIRDER

Wang Xiao, Yan Zhongbao, Du Hanwen, Yin Lixin
Shanghai National Synchrotron Radiation Center, Shanghai 201800, P.R.China

***Abstract***
Beam stability is a major concern for the construction of a 3rd generation light source. Mechanical vibration of the storage ring components is one of the contributing factors to electron beam instability. In order to improve the performance of the girder developed in the R&D period of Shanghai Synchrotron Radiation Facility project, an optimization for the girder design has been started recently. The number of the girders in a lattice cell is modified from 3 to 5 to increase the first eigenfrequency of the magnet-girder assembly. For improving the stiffness and the stability, the structure of the girder and support has been redesigned and studied. The FEA results show that the static and dynamic performance has been improved significantly.

## 1. Introduction

The Shanghai Synchrotron Radiation Facility (SSRF) project proposal was officially approved by the Chinese central government in beginning of 2004.

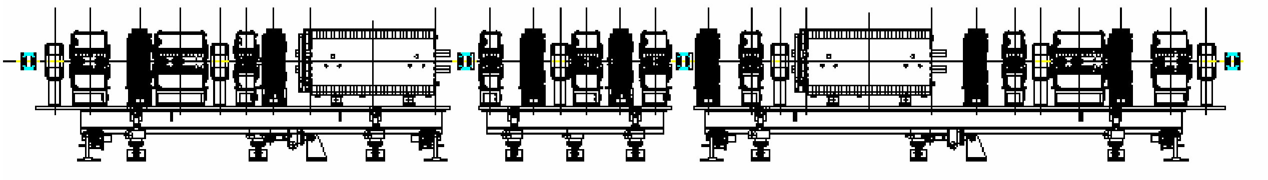

*Fig.1 Cell MGAs in R&D*

As a 3rd generation synchrotron light source, mechanical stability of the magnet-girder assemblies (MGAs) is essential for the beam stability of SSRF. A girder prototype was designed, fabricated and tested in the R&D period of the SSRF project three years ago. With the increase of beam stability requirements, an optimization for the girder design has been started recently.

## 2. Girder prototype in R&D

### 2.1 Girder prototype in R&D period[1]

*Fig.2 Girder prototype*

A long girder prototype was designed, fabricated and tested during the R&D period. It is a box structure welded from steel plates with thickness of 30~50 mm. Fig 2 shows the structure of the prototype. The "six-struts system" is adopted as the support and adjustment structure, and it can adjust in six degree of freedom (X, Y, Z, $\theta_X$, $\theta_Y$, $\theta_Z$) freely. The adjustment range is ±20mm in Y direction, ±10mm in X and Z respectively. The resolution is 0.025mm in X and Y, 0.05mm in Z.

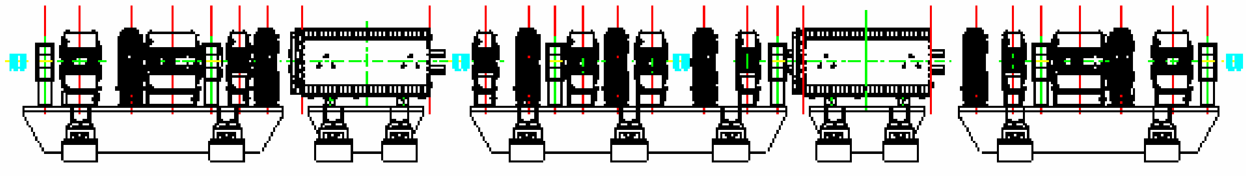

*Fig.3 Cell MGAs in optimization*

### 2.2 FEA calculation and experimental test

In order to realize the static and dynamic performances of the R&D girder, FEA calculation and experimental test for deformation and vibration modal were carried out. In the static test, laser tracker LTD500 was used to check the deformation of the girder with and without magnet load on it. In the dynamic test, a vibration was excited on the girder and the acceleration signal was picked up by accelerometer.

The maximum deformation of the girder under the magnet load is 0.2mm, which is located at the far corner to the vertical strut. It is the same with the calculation and test. The dynamic results from FEA calculation and experimental test are shown in Table 1. The first eigenfrequency of the girder is 5.875Hz with modal of translation along Z-axis. It is 5.368Hz in calculation. The relative difference is less than 10% between test result and FEA value.

*Tab. 1 Results from FEA calculation and test*

| Modal shape | FEA value (Hz) | Test value (Hz) | Relative difference |
|---|---|---|---|
| Translation along Z-axis | 5.363 | 5.875 | 8.7% |
| Translation along X-axis | 7.485 | 6.875 | 8.8% |
| Rotation around X-axis | 27.312 | 25.65 | 6.5% |

## 3. Girder optimization

In recent years, the requirement for the beam stability increased from several micrometer to sub-micrometer. Beam stability is sensitive to the vibration of Q magnet, especially for the response of MGA to ground vibration. In order to decrease the passive vibration of MGA, increase the first eigenfrequency of MGA is an effective method to decrease the amplification of ground amplitude.

For the R&D girder of SSRF, the frequency is relatively low compared with other new facility, such as SLS[2], Soleil[3] and Diamond[4]. Improve the girder's first eigenfrequency as high as possible is one of the most important goal in the SSRF girder optimization.

### 3.1 Theoretical analysis

In order to understand the optimization direction, simplify the model of the MGA by considering the vertical strut as beam loaded by 1/3 of the total weight. For the vibration along horizontal direction, a beam with radius R, length L, load mass M/3, the first eigenfrequency f is given as below[5]:

$$f = \frac{2*10^5*R[m]^2}{L[m]^{3/2}*M[kg]^{1/2}} \quad (1)$$

For the vibration of bend modal (rotation around X-axis), the first eigenfrequency f is[6]:

$$f = \frac{\pi}{2l_1^2}\sqrt{\frac{EI}{\overline{m}}} \quad (2)$$

Where E is the young's module. I is the inertia moment of the girder's body, $\overline{m}$ is the mass density, $l_1$ is the distance between two pivots.

From Eq.(1) and Eq.(2), the eigenfrequency of the MGA in horizontal and bend direction can be increased by decreasing the total mass of MGA M and the distance $l_1$ between two pivots, shortening the length of adjustment system $L$, increasing the radius $R$ and the inertia moment of girder body $I$. As we know, increasing in height of girder body can increase the inertia moment $I$ remarkably.

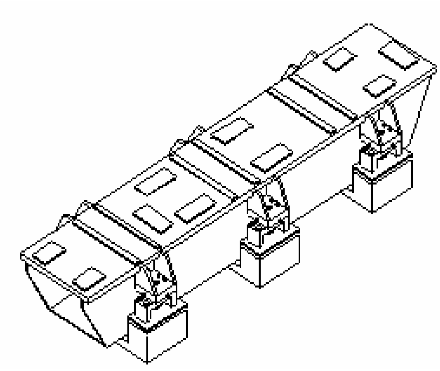

*Fig.4 New girder structure*

In order to improve the first eigenfrequency of the R&D girder, the MGA number of a lattice cell is modified from 3 to 5, with both dipole magnet having its own girder (See Fig.3). The structure of the girder and it's pedestal are also modified to increase the stiffness, shown as Fig.4. The largest girder is 4100mm in length 800 mm in width and 590 mm in height. The weight of the girder is about 2.5 tons and about 6 tons with the magnets on it is.

### *3.2 FEA analysis*

In order to check the performances of the new girder, FEA calculation for static and dynamic states for the largest girder were carried out. In order to investigate the effect of support structure, three kinds of structure are considered. Type A is a three points support with two of them near both ends along one side and the other at the middle of the other side. Type B is also a three points support with two of them near both ends along one side and the other at one end of the other side. Type C is a four points support, which is located near both ends of the two sides.

| | Max deformation(mm) | Max stress(MPa) |
|---|---|---|
| Original | 0.2 | |
| Type A | 0.068 | 19.138 |
| Type B | 0.183 | 25.338 |
| Type C | 0.034 | 10.723 |
| SLS[2] | <0.05 | <95 |
| SPring-8[7] | 0.095 | |

*Tab.2 Results of static calculation for new girder*

| | Frequency | Modal shape |
|---|---|---|
| *Type A* | 50.073 | Torsion |
| Type B | 35.769 | Torsion |
| Type C | 70.505 | Translation along X-axis |
| | | |
| | | |

*Tab.3 Results of dynamic calculation for new girder*

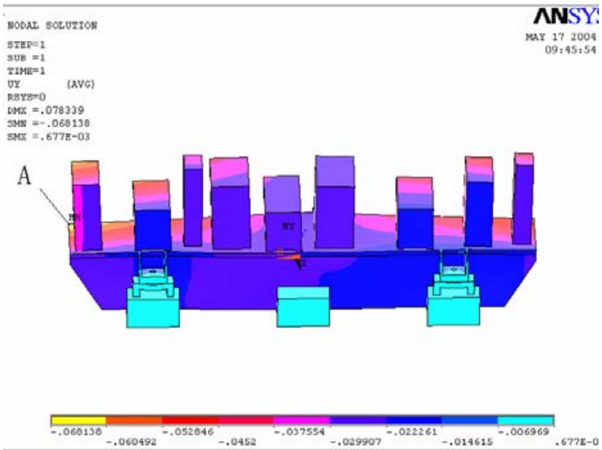


Figure 5: Deformation of Type A

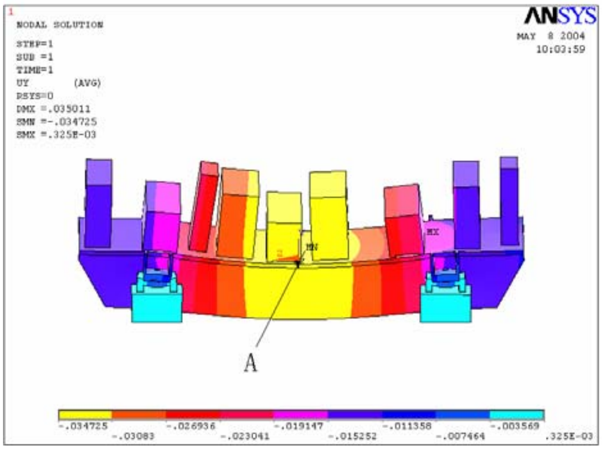


Fig.6 Deformation of Type C

Tab.2 and Tab.3 show the FEA results for static and dynamic calculation, respectively.

1. The deformation of the three girders is 0.068mm, 0.183mm, 0.034mm, respectively. Compared with 0.2mm deformation in the R&D girder, the static stiffness is improved in Type A and C. The maximum stress in the new girder is low.
2. The maximum deformation in Type A is at the corner without support (See Fig.5), while in Type C is at the center of the girder (See Fig.6). The distance between support point in longitudinal direction can be modified to decrease the deformation in Type C further.
3. The first eigenfrequency is 50.1 Hz, 35.8Hz and 70.5Hz in Type A, B and C, respectively. The first modal shape is torsion in Type A (See Fig.7) and B, while translation in X-direction in Type C (See Fig.8).
4. From the static and dynamic results, Type C is the best structure, which means that four points support is better than three points support to improve the static stiffness and the first eigenfrequency. It is important to make sure that four support points are fixed correctly. Type B shows the worst condition of Type C with one point in four is not touched effectively.

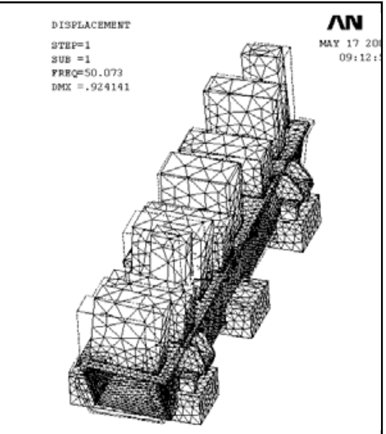


*Fig.7 First modal shape of Type A*

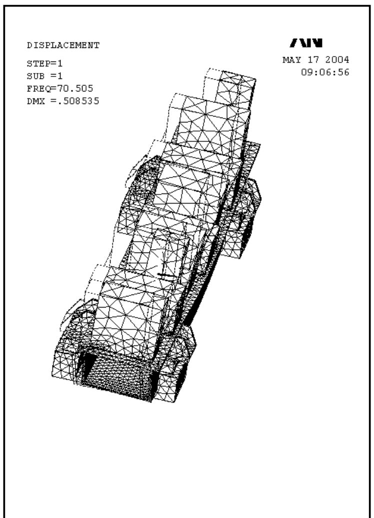


*Fig. 8 First modal shape of Type C*

## 4. Conclusion

In order to improve the performance of the R&D girder, the MGA number of a storage ring lattice cell is modified from 3 to 5. A new girder is designed and calculated by FEA. The results show that compare with the R&D girder, the static stiffness is enhanced and the first eigenfrequency is increased remarkably. Four point support structure is better than three point support. The detail design analysis for the new girder is in progress. The support structure for girder will be designed under the consideration of adjustment method, fixed method, precision requirement and the groundwork state.

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