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DESIGN OF MAGNET GIRDER SYSTEM FOR SIAM PHOTON SOURCE II

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Abstract

The new Siam Photon Source II (SPS-II) storage ring is designed with a circumference of 327.502 m. It consists of 14 DTBA cells, where each cell requires six magnet girders. For the storage ring of SPS-II we developed a magnet girder system which uses wedgemounts for the precision alignment. The girder alignment is based on a 3-2-1 alignment method and requires three wedgemounts to control Z direction, two wedgemounts to control Y-direction and one wedgemount for the X-direction. The magnet alignment is based on mechanical tolerances. Therefore, the girders top plate is designed with precision surfaces with a flatness tolerance of 30 µm. Regarding low girder deformation (from magnet load) and gaining a high mechanical natural frequency to reduce the amplitude of vibrations, FEM simulations were carried out. In this paper simulation results are presented as well as the design of the girder, pedestal and its wedgemount based alignment system.

INTRODUCTION

The existing storage ring of Siam Photon Source (SPS) has 1.2 GeV beam energy and ~41 nm·rad beam emittance. The new Siam Photon Source II (SPS-II) has to provide better parameters to stay competitive for the user community in the South-East Asian region. Therefore, a new machine is being designed with a storage ring circumference of 327.502 meters, a beam energy of 3 GeV and a beam current of 300 mA. The beam emittance should be lower than 1.0 nm·rad. For the lattice design a Double Triple Bend Achromat (DTBA) lattice was chosen. The storage ring consists of 14 DTBA cells where each cell requires six girders to provide a stable platform for the magnets of the storage ring.

Since the DTBA cell consists of two mirrored halves only three different girders have to be designed (Fig. 1). The girders are 2240 mm, 2750 mm and 2870 mm long. All of them have a width of 750 mm. The beam height was set to 1.2 meters. For all three girders a 3-2-1 alignment system was developed were wedgemounts are being used.

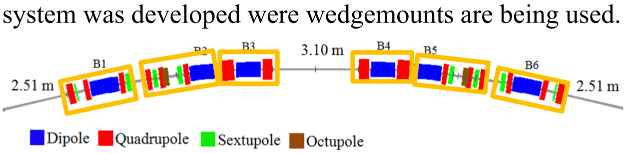

Figure 1: DTBA cell divided into girder sections.

The girder structure was developed focusing on low deformation and high vibration stability. Simulation software was used to design girders with less than 20 µm deformation under full magnet load. Also, modal simulation software was used to optimize the girder structure in terms of pushing the natural frequency as high as possible.

GIRDER DESIGN

The designed girder structure is a box-type structure with a thick top plate and seven internal enforcement ribs (Fig. 2). The steel plates thicknesses are between 30 to 70 mm. There are three 80 mm thick support beams welded transversal to the top plate and they provide a basis for three vertical girder support points.

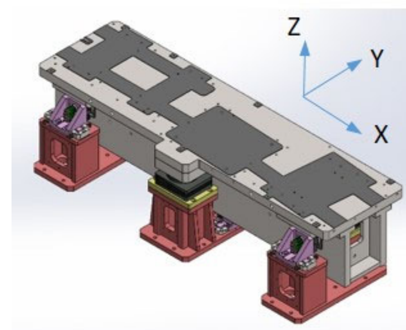

Figure 2: Girder system with three vertical support points.

The top plate of the girder requires high precision surfaces for the magnets. These surfaces as well as surfaces for fiducial marks will be machined with a flatness of 30 µm.

The pedestals are the connection between girder and the ground/concrete floor. The pedestals carry the weight of the girder and magnets. They transfer vibration into the girder which is caused by the ground itself (low frequencies) or from machines such as water-/vacuum pumps, air conditions, etc. installed nearby. Therefore, it is planned to install a damping layer (e.g. epoxy concrete) between concrete floor and pedestal base plate to improve the vibration stability.

The pedestals carry not only the weight of the girder and magnets but also they accommodate the adjustment components for horizontal girder alignment. The material for the pedestals is the same as for the girder structure which is a structural steel S355JR (or A572 Grade 50). This steel shows a good strength, durability and weld ability. The pedestals as well as the girder structure are put together by full penetration welding (wherever its possible). The pedestal deformation was decreased by increasing the steel plate thickness at high load areas. Also, an exchangeable "height compensation plate" was added between pedestal and each vertical wedgemount in case of large floor settlement.

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ADJUSTMENT SYSTEM

For the adjustment system six wedgemounts manufactured by AirLoc AG will be used (Fig. 3). It is planned to motorize the Y- and Z-direction for girder alignment in the future. For the Z-direction wedgemount model 414-KSKC was chosen since it was already successfully installed and used (with motorization) at ESRF [1]. For the Y-direction wedgemount 2130-KSKCV with modifications to allow motorization will be used. The X-direction will be adjusted manually with wedgemount model 2012-KSKCV. The horizontal (X and Y) fine adjustment range is +/- 6 mm while the vertical range is +/- 9 mm.

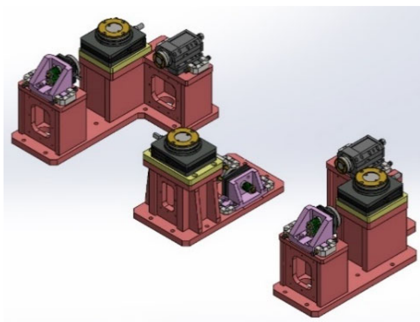

Figure 3: Wedgemounts for girder alignment on pedestals.

All adjustment components are equipped with oil-free sliding washers which contact the girder. The vertical Z-adjustment is realized by three large wedgemouts (414-KSKC) because having three support points is the easiest way to level a girder and no over-determination occurs. The center of mass of girder structure including magnet load stays within the triangle of the three support points.

All wedgemounts are equipped with spherical seat which follows the movement directions of the girder during the alignment process (Fig. 4).

On top of the spherical seat is a plate that houses an oil-free washer. Two long studs with coil springs at their end induce a preload between plate and seat. The coil springs are pushed onto a pair of spherical and conical seat as well which should allow the springs to follow the same movement as the girder respectively the oil-free washer.

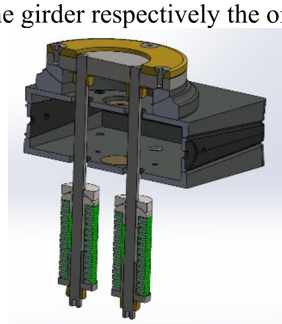

Figure 4: Section view of Z-align wedgemount.

For the horizontal adjustment the wedgemount had to be rotated by 90° so that the wedgemount position is vertical which it is not designed for. The wedgemount had to be modified to allow this installation position (Fig. 5). Two sets of coil springs with spherical/conical seat induce a pretension between the plate that accommodates the oil-free sliding washer and the wedgemount (same method as described before).

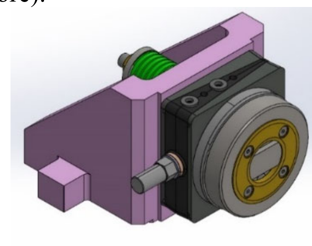

Figure 5: Vertically installed wedgemount for horizontal girder alignment.

Since a wedgemount can push the girder only in one direction a mechanism had to be designed which is installed opposing to each wedgemount and enables the girder to be moved back. In case of the Y-direction a push back spring assembly and for the X-direction a push-push screw is being used.

In Fig. 6 the push-back spring assembly is shown. Inside the push back spring assembly are two strong coil springs which have a maximal load of 18.4 kN each, which means a maximum push-back force of 3.75 t can be generated. The maximum deflection of the coil springs is 13 mm. The springs are pushing against a cylinder which is supported by an oil-free bushing. Inside the cylinder is a set of radial spherical and thrust spherical plain bearings. The bearings allow a shaft with attached oil-free washer to swivel and thereby follow the movement of the girder. A large screw at the end cover plate of the housing is used for adjusting the spring load respectively the deflection.

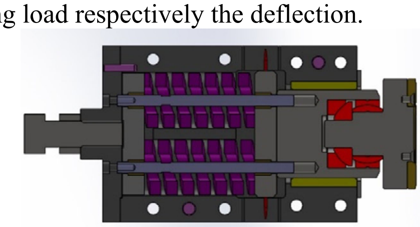

Figure 6: Push-back spring assembly.

The adjustment components for X-direction were placed on the base plate of the center pedestal and they contact the girder in its center (Fig. 7).

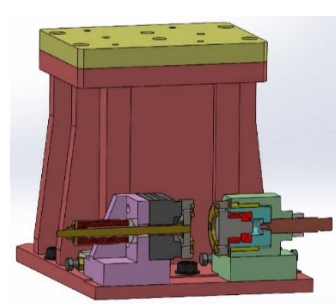

Figure 7: Section view of center pedestal and X-adjustment components.

All components for the horizontal (X and Y) adjustment can be pre-adjusted by push-push screws with a range of

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+/- 12.5 mm. For the girder fine alignment only the wedgemounts will be used. The sensitivity of the fine alignment is specified by the leveling distance per turn of the wedgemounts, e.g. for 2130-KSKCV (Y-direction) 0.3 mm distance is specified. When it is assumed that by manual adjustment with a key wrench a rotation of the leveling screw of 5° is easily possible, then the alignment precision can be given with approximately 4 µm.

STRUCTURAL FEM ANALYSIS

The simulation software ANSYS was used to optimize the girder geometry regarding an as low as possible girder deformation and a high first natural frequency. A simplified CAD model of girder with magnets was used for the simulations. The design goal was a total deformation of less than 20 µm and a frequency for the 1st mode of higher than 35Hz. The girder design was step by step improved by changing geometry parameters such as varying the thickness of all used steel plates as well as the length of the girder flanks. Also the width of the girder box and the number of internal ribs was varied. The arrangement and location of the three support points was also essential for the deformation and vibration behaviour. So, the location of all three support points was varied until a satisfying solution was found. Finally, three girder models were prepared each carrying a magnet load according to the half-DTBA cell design. All three girders (all with different length and load) were investigated separately to analyse the effect of the magnet load on each girder.

The results of the analysis (Table 1 and Fig. 8) were focused on "total deformation" and all "directional deformations" in X, Y and Z. The reaction forces at the three large wedgemounts and the spherical bearing forces were taken into account. These forces indicate the weight distribution on each girder.

Table 1: Girder Deformation Results

Deformation	Girder 1 (L2.75m)	Girder 2 (L2.87m)	Girder 3 (L2.24m)
at magnet top [mm]	0.013	0.017	0.014
at girder top plate [mm]	0.010	0.012	0.009

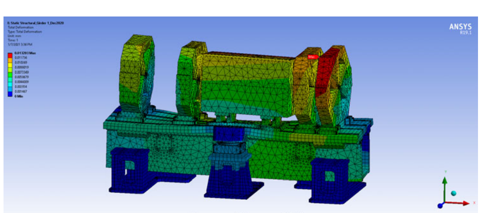

Figure 8: Girder 1 deformation simulation.

The results of the structural analysis were used further to perform the modal analysis. Enviroment vibrations for the exisiting machine SPS were measured between 20 to 30 Hz. We assume at this point the vibration level will be comparable for SPS-II as well which leads us to a first natural frequency that should be above the measured level. The simulation results for the modal analysis for all three girders are shown below in Table 2 and Fig. 9.

Table 2: Modal Analysis Results

Mode	Girder 1 Freq. [Hz]	Girder 2 Freq. [Hz]	Girder 3 Freq. [Hz]
1	72.7	54.9	69.4
2	86.4	63.8	83.6
3	94.8	67.3	100.4
4	107.7	70.6	116.9
5	110.4	72.3	136.7
6	112.7	83.4	146.6

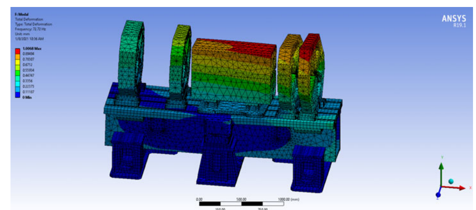

Figure 9: Girder 1, 1st mode modal analysis.

The frequencies for all three girders are above the design frequency of 35Hz. The high frequencies of more than 70 Hz can be explained by the strong structure of the girder but especially it is due to the short girder length of less than 3 meters. The frequencies for girder 2 (1st mode: 54 Hz) are lower due to a thin and tall structure of an octupole magnet.

CONCLUSION

A magnet girder system for the new SPS-II synchrotron with DTBA cell structure was developed. Three girders of different lengths were designed which share the same type of pedestals and adjustment components. It is explained how all components are designed and how the alignment system using wedgemount works. FEM simulation was used to investigate the deformation and vibration behavior of the girder system under full magnet load. The results of the simulations are presented.

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