GUIDEWAY BEARING TECHNOLOGY USED IN SHANGHAI MAGLEV DEMONSTRATION LINE

Wu Xiangming[*], Li Jinjun[**], Xu Bin[***]

[*]National Maglev Transportation Engineering R & D Center, Longyang Road 2520, Shanghai, 201204, P. R. China
[**]National Maglev Transportation Engineering R & D Center, Longyang Road 2520, Shanghai, 201204, P. R. China
+86 21 28907322(o) / 50331633(f), kingli99@263.net
[***]Shanghai Research Institute of Material, Handan Road 99, Shanghai, 200437, P. R. China
+86 21 65557050(o) / 65526185(f), hcqkt@online.sh.cn

Keywords
Adjustability, Friction Pair, Guideway Bearing, Maglev, Shanghai Demonstration Line

Abstract
Guideway bearings in Shanghai Maglev Demonstration Line (SMDL) are designed to realize precision control of guideway girders in both construction and operational maintenance. The technical requirements of guideway bearings for Maglev are therefore higher than those of the general elevated guideway. This article is to introduce the bearing technology used in SMDL, which includes the design technical requirements, friction pairs, two-way adjustability, fixing-sliding bearing. Those bearing technologies have provided a solution for precision control of Maglev guideway when it erected on soft soil ground.

1. GENERAL DESCRIPTION

Precision of guideway structures is very high in High-speed Maglev Transportation systems, which requires not only that guideway girders should be positioned and fixed exactly in construction, but also that the shift or dislocation of guideway girders caused by such random facts as settlements should be controlled within a very small range in operation. On the soft soil ground in Shanghai, however, it is unavoidable that settlements of the guideway substructure occur after long time of train operation. Settlements, especially nonuniform ones between the adjacent supporting columns can cause shift or dislocation of guideway girders and bring troubles to the guideway precision control.

For general elevated guideway structures, loads are transferred from guideway girders to substructures by bearings. The satisfactory performance of bearings in general elevated guideway structures can ensure reliable connections and deterministic forces transferred between guideway girders and substructures. For this purpose, bearings are designed to be able not only to transfer the vertical and horizontal forces resulting from loads (dead and live loads) of superstructure, but also to ensure free displacements (linear and angular displacements) of guideway girders in non-restrained directions under all possible environmental impacts and loading cases. For Maglev guideway structures, if bearings can be also applied to realize exact positioning of guideway girders and eliminate shift /

dislocation of guideway girders, it is technically economic and effective for positioning control in the construction and maintenance. This aim has been achieved in Shanghai Maglev Demonstration Line (SMDL). In addition to the performance for general elevated guideway bearings, special requirements such as low compression, two-way stepless-adjustment in vertical and lateral directions (Z- and Y-direction) have been met for guideway bearings in SMDL.

Two structure types, i.e. simple beams and simple-continuous beams, are applied in the guideway girders of SMDL. A new type of fixable single-way sliding bearing (fixing-sliding bearing) is invented for simple-continuous beam girders, other than fixing bearings, single-way (X-direction) and two-way (X- and Y-direction) sliding bearings for simple beam girders.

This article is to introduce the guideway bearing technology used in SMDL, which includes the design technical requirements, friction pairs, two-way adjustability, fixing-sliding bearing.

2. DESIGN TECHNICAL REQUIREMENTS

2.1 DESIGN SERVICE LIFE

Body of bearing: 40 years;
Coating of body for anti-corrosion: no less than 20 years.

2.2 ENVIRONMENTAL CONDITION

Temperature: -20℃ ~ +60℃
Relative humidity: 95%

2.3 LOAD CAPACITY AND DISPLACEMENT

For the requirements on load capacity and displacement of typical bearings, see Table 1.

2.4 THE TOLERANCE OF DIMENSIONS

Tolerance of dimension in X- and Y-direction: 0.05mm;
Tolerance of dimension in Z-direction: 0.5mm

2.5 ADJUSTMENT AND REPLACEMENT

For all the bearings, the maximum adjustable value in Z-direction is 20mm upwards, 10mm downwards. For the type of fixing and single-way sliding bearings, the adjustable range is ±20mm in Y-direction.

The body of bearings should be replaceable if necessary. The maximum lifting value of guideway girders is 5mm in replacement. The replace duration for each bearing should be less than half an hour.

Table 1. Load capacity and displacement requirements of the typical bearings

Type of bearing	Vertical load capacity (kN)	Lateral load capacity (kN)		Linear displacement (mm)		Angular displacement (tan)
		X-direction	Y-direction	X-direction	Y-direction	
Fixing	2500	450	800			±0.05
Single-way sliding	2500		350	±20		±0.05
Two-way sliding	2500			±20	±20	±0.05
Fixing-sliding	2500	450	820	±20		±0.05

3. FRICTION PAIRS

Friction pairs of bearings are designed to allow the free displacements of guideway girders in non-restrained directions, which include the rotational friction pair (to allow angular displacement) and planar friction pair (to allow linear displacements). The performance of friction pairs greatly depends on the coefficient of friction, elastic modulus and rate of wear of the friction material. To achieve the high precision of guideway, the friction material used for Maglev guideway should feature high compressive strength (to be large load capacity), small coefficient of friction (to ensure free displacements), large elastic modulus (to occur low compression), and low rate of wear (to be long service life).

3.1 ROTATIONAL FRICTION PAIR

In general, various bearings adopted in elevated guideway girders should be equipped with rotational friction pairs. According to design requirements, spherical rotational friction pairs made of new friction material have been invented. The major technical indice have been tested as following:

Permanent compression deformation: $D<0.06$mm
Allowable bearing stress: $[\sigma]=150$MPa
Coefficient of friction: $\mu \le 0.05$
Rate of sliding wear: $A \le 0.028$mm/km
Temperature rising during friction: <85℃

3.2 PLANAR FRICTION PAIR

The linear displacements of single-way and two-way sliding bearings are provided with planar friction pairs. A new type of plane friction material has been developed and the major technical indice of the plane friction pairs have been tested as following:

Permanent compression deformation: D<0.04mm
Allowable bearing stress: [σ] =40MPa
Coefficient of friction: μ=0.05-0.10
Rate of sliding wear: A ≤ 0.028mm/km
Temperature rising during friction: <10℃

Test results of the rotational and planar friction pairs have shown that the major technical indice such as coefficient of friction, compressive strength, compression deformation and rate of wear can meet the requirements of the Maglev guideway bearings. Additional, they have the features of self-lubrication, good anti-corrosion and free of maintenance.

4. TWO-WAY ADJUSTABILITY

The friction pairs of bearings can enable guideway girders' freely displacing in non-restrained directions. During the erection of the girders, or in case that the unallowable shift / dislocation of guideway girders occur, it is necessary to make the girders' positions be adjusted vertically and laterally and fall into the allowable scope by normal maintenance hours. Therefore, the good two-way adjustability of bearings should be required.

4.1 VERTICAL ADJUSTMENT

By inserted or drew out steel pads under the bottom plate, bearings can be adjusted vertically step by step. By this means, the adjustment precision can't meet the requirements of Maglev guideway, as well as much time and great effort will be took in adjustment.

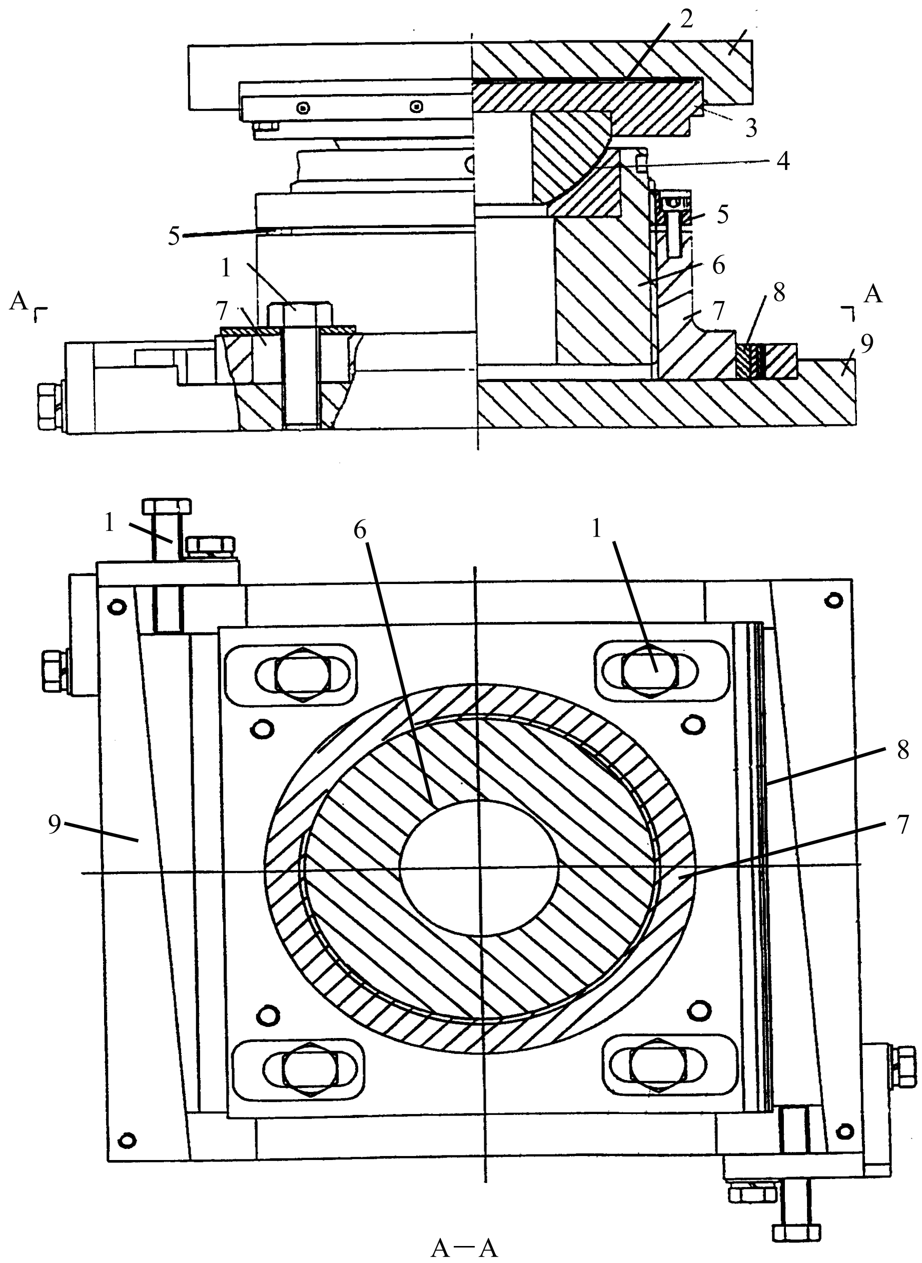
With reference on adjusting and fixing methods by trapezoidal screws in the bridge anchorage technology, the bearings in SMDL are designed to be adjusted steplessly in vertical direction by a trapezoidal screw. The operation of adjustment is convenient and the mechanical performance of trapezoidal screws is reliable. The adjustment range in vertical direction is 20mm upwards, and 10mm downwards (for compensation in case of occurring positive error of foundation height of bearings). The vertical adjustment of bearings is also designed to be equipped with the locking mechanism, to which only a small compressive force needs to apply to prevent the trapezoidal screws from loosening under the dynamic actions of trains.

4.2 LATERAL ADJUSTMENT

Generally, transfer of laterally horizontal forces as well as lateral adjustment of bearings is by using the high strength friction bolts connecting bearing base and bottom plate. It is difficult to measure the torque coefficient of the bolts in practice, so the actual horizontal resistance of the bearing by high strength friction bolts is ambiguous. Bearings may fail when the horizontal action force transferred is overloaded. Furthermore, it is inconvenient for the lateral adjustment by loosening and tightening the high strength bolts.

Shoulder ridges in the bottom plate plus wedges between the base and should ridges are designed in SMDL to transfer horizontal forces and adjust lateral position of bearings. The bolts attached in bottom plates are used only to position and not to load any lateral forces. This design is reliable since it waives the friction face to transfer forces. Because the total width between the bearing base and should ridges is constant, the wedges can be composed of a certain combination of rectangles and tapers with different width.

For the sectional view of a typical bearing, see Figure 1.



1—Top plate; 2—Plane friction pair; 3—Top seat; 4—Rotational friction pair; 5—Vertical adjustment locking nut; 6—Vertical adjustment screw; 7—Base; 8—Lateral adjustment wedge; 9—Bottom plate; 10—High-strength bolts on the bottom plate; 11—Fastening bolt of wedge.

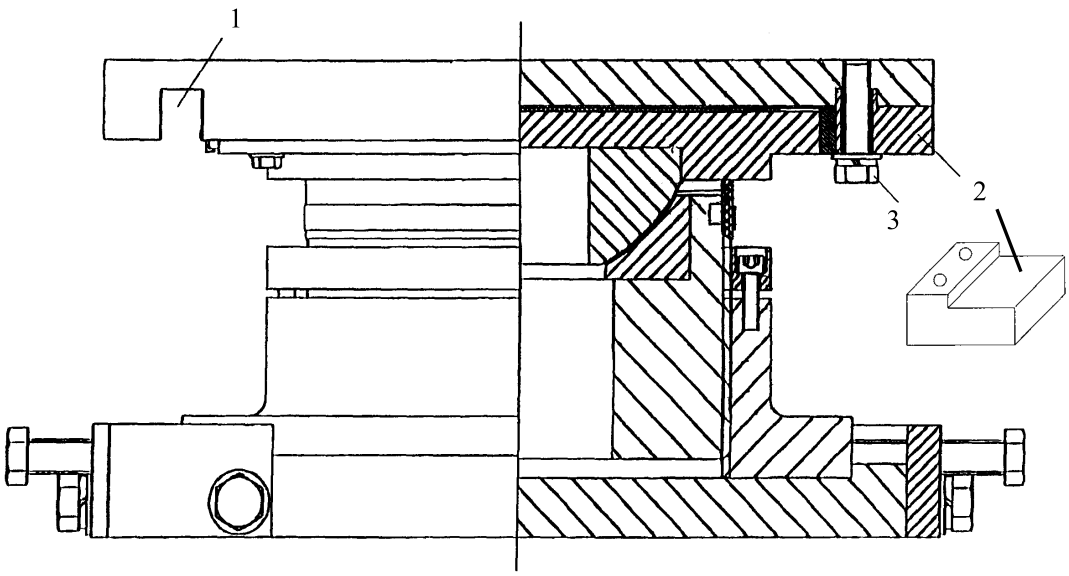
Figure 1. Sectional view of typical bearing

5. FIXING-SLIDING BEARING

With comparison of a two-spans continuous beam and two simple beams, the continuous beam has stiffness advantage to control deflections by temperature impacts and live loads. Presently since all girders of Maglev guideway are prefabricated, the design of continuous beam girders will bring considerable troubles in fabricating, processing, transportation, erection, and positioning due to the large size and heavy weight. Therefore, a simple-continuous beam design is proposed in SMDL, where the two simple beams are erected and positioned independently and then connected vertically into a two-span quasi-continuous beam. This design can fully utilize the stiffness advantages and overcome the size and weight disadvantage of continuous beams. In order to realize the simple-continuous beam, it is essential to invent a fixable single-way sliding bearing (fixing-sliding bearing) which can accommodate the loading change.

The single-way sliding bearing is re-constructed for this purpose where a recess cuts on the both sides near the top seat, perpendicularly to the ledges as shown in Figure 2. If necessary an "L" shaped lock key can be inserted in the recess to lock the bearing meanwhile a single-way sliding bearing is changed to be a fixing one.

Figure 3 illustrates the bearing layout of a two-span continuous beam connected by two simple beams. The simple beams use four pairs of bearings, among which item 1, 7 are single-way (X-direction)



1－Recess of top plate; 2－"L" shaped lock key; 3－fixing bolt.

Figure 2. Sectional view of fixing-sliding bearing

sliding bearings, item 2, 4, 6, 8 are two-way (X- and Y-direction) sliding bearings, item 5 is fixing bearing, item 3 is fixing-sliding bearing. When the two beams are simple, there is a fixing bearing under each beam; When they are connected to a simple-continuous beam, one fixing bearing should be changed to be acted as single-way (X-direction) sliding bearing. Otherwise the horizontal force resulting from the temperature impacts will damage the redundant fixing bearing in the simple-continuous beam. The fixing-sliding bearing enables the guideway girders to be interchanged between a simple beam system and a continuous beams system. In other word, simple beam girders can be changed to continuous beam girders when each simple beam is erected and exactly positioned (by unlocking the "L" key in the bearing) while continuous beam girders can be changed to simple beam girders when the positions of beams need to adjust (by locking the "L" key in the bearing).

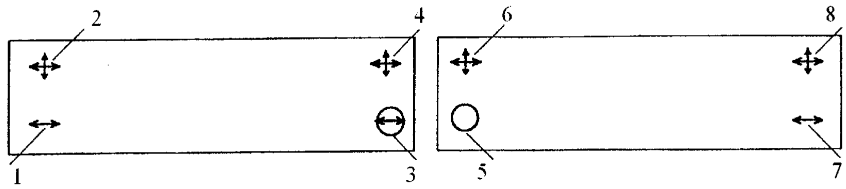


Figure 3. Bearing layout of simple-continuous beam girders

6. CONCLUSION

As a special type of facilities in Maglev Guideway, bearings are in application with large amounts and have high technical requirements in Maglev Transportation Engineering. The performance of bearings will affect directly the precision, difficulty and duration of the construction and maintenance work of Maglev guideway. The guideway bearing technology is successfully developed in Shanghai Maglev Demonstration Line, by which is realized the bearings with two-way adjustability, low compression, high precision, low cost, and free maintenance. Those technologies have provided a solution for precision control of Maglev guideway when it erected on soft soil ground.

References

1. Wu Xiangming, Xu Bing, Wang Xingfang, Fixable single-way sliding bearing and the usage method, Instruction about patent of invention (Patent No. 01126913.8)
2. Wu Xiangming, Zhang Zhongen, Weng Sirong, Lateral Adjustable bearing; Instruction about patent of invention (Patent No. 01126912.X)
3. Wu Xiangming, Zhou Hongwei, Huang Lingeng, Adjustable bearing; Instruction about patent of invention (Patent No. 01126627.9)
4. Project Managing Team of Shanghai Maglev Demonstration Line, Shanghai Maglev Transportation Development Co., Ltd., Research on key technology used for Shanghai Maglev Guideway System, April, 2003.