Primary Shaping of Smooth and Level Guideway Planes for High Precision Applications

Marius Berg[1], René Bernau[1], Torsten Erbe[1], Kay Bode[2], René Theska[1]
[1]*Ilmenau University of Technology, Institute of Design and Precision Engineering (IMGK), Department of Precision Engineering, Germany*
[2]*Bauhaus University Weimar, Germany*

marius.berg@tu-ilmenau.de; torsten.erbe@tu-ilmenau.de

Abstract

In high precision applications like coordinate measurement machines granite is the common material used for machine frames. Major drawbacks of granite are its high material- and machining costs caused by material hardness.

Today concrete can be produced with material properties similar to those of granite for a fraction of the costs. Therefore, concrete can be seen as an alternative material with the advantage of primary shaping technology like integration of components. The Ilmenau University of Technology, in cooperation with Bauhaus University Weimar, has developed a technology and a special concrete to mold smooth plane air bearing suitable guideway surfaces. This paper presents the technology and the results of the surface roughness and profile measurements of a concrete specimen.

1 Introduction

Granite is widely used for high precision guideways and functional surfaces for air bearing applications. These surfaces are frequently used in high precision positioning systems like coordinate measurement machines. The material properties of granite are superior to those of cast iron because of the good thermal and mechanical long-term stability and material damping. Concrete is a potential alternative material to granite because it can be produced with comparable material properties (cf. Table: 1). [1]

Along with several other profits the decisive advantage of concrete over granite are the low material (1 m³ concrete < 50 €) and production (molding) costs.

Table 1: Fundamental properties of granite, concrete and special concrete

Material property	Compressive strength	Transversal strength	Young's modulus	Thermal expansion	Spec.heat capacity
Unit	[N/mm²]	[N/mm²]	[kN/mm²]	[10-6/K]	[J/kg K]
Granite	250 - 360	10 - 35	60-95	5-7,5	0,850
Concrete	5 - 55	2 - 8	30-50	6-14	0,9-1,0
Special conc.	59	3,6	33	12	n/a

Caused by difficulties in attaining smooth and plane surfaces, in precision engineering, concrete at present only is used for machine fundaments – not for precision parts like aerostatic guideways.

2 Requirements to an aerostatic guideway surface

The guideway of an aerostatic guide system can be divided into two elements: The microscopic volume of the surface area (henceforth called surface) and the macroscopic volume (further on called support volume) behind it (cf. Figure 1).

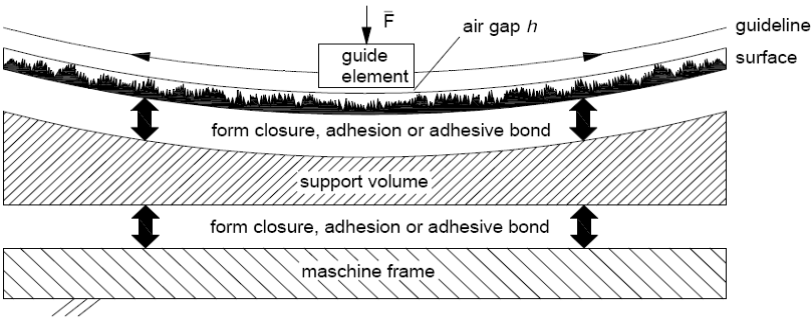

Figure 1: Elements of an aerostatic guideway and coupling to the machine frame

The surface has to ensure the movement of the aerostatic bearing and therefore fulfill the following requirements in order to prevent damages to the aerostatic bearing or surface. According to literature and the specifications given by the air bearing suppliers, the planarity of the surface under the air bearing has to be below 50% of the height of the air gap *h*. Commonly, an average surface roughness R_z better 1/3 of the air gap *h* is required [2]. Most air bearings are operated with an air gap of 5 µm, so that the planarity has to be better than 2.5µm and R_z better than

1.7 µm. Furthermore, NEW WAY AIR BEARING demands a roughness average R_a of 0.37 µm or better. [3]

The support volume defines the guideline – or guide level – of the aerostatic guideway. For this reason it has got a decisive influence on the positioning failure of the guiding system, especially in case of moving loads.

3 Molded special concrete surface

By molding of special concrete surfaces with a surface roughness R_z of 2.1 µm and a roughness average R_a of 0.21 µm were created without post processing. These values are better than those of common functional granite surfaces which are used for air bearings (R_z = 5.2 µm, R_a = 0.56 µm).

The sections in figure 2 and figure 3 show that the slightly too high roughness R_z of the special concrete surface is mainly caused by valleys in the surface (R_v). Contrary to peaks, valleys are uncritical in an aerostatic guide surface.

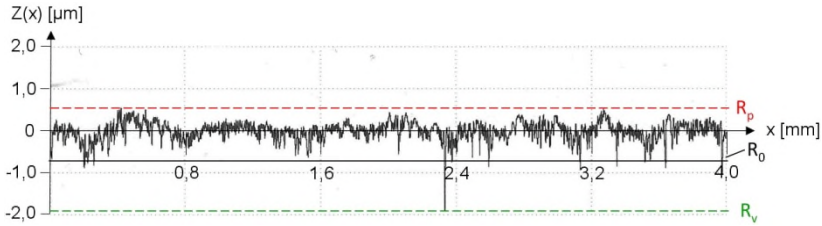

Figure 2: Section of a molded special concrete surface for air bearings

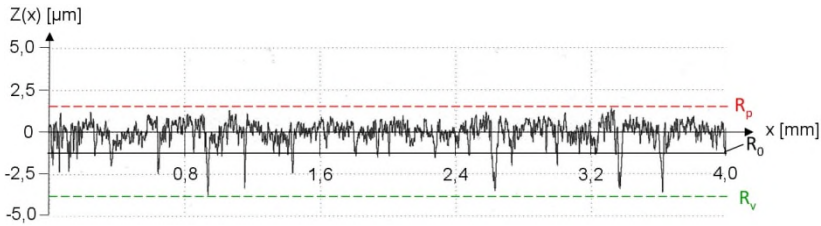

Figure 3: Section of a functional granite surface for air bearings

Because of the maximum peak height (R_p) of about 0.5 µm and the by factor 2 smaller roughness's than a functional granite surface the created special concrete surface can be considered functional for air bearings in terms of roughness.

4 Long term behavior of the special concrete surface

Special concrete also can be used as a support volume for the aerostatic guide surface because of its good long-term stability. Figure 4 shows the relative deformation of a molded 1.4 m special concrete guideway 56 days after the first measurement on day one (reference casting day).

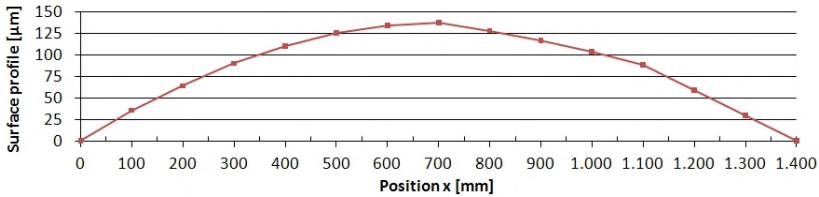

Figure 4: Surface profile of a special concrete guideway 56 days after casting

Over the length of 1.4 m the deformation is very small and even. The maximum deformation in the middle of the guideway is less than 140 µm and still decreasing because of drying shrinkage.

5 Conclusions

By molding of special concrete aerostatic guide surfaces with a lower roughness than functional granite surfaces can be created without post processing. Furthermore, special concrete shows good long term stability. With a first guideway specimen a straightness deviation (still decreasing) of less than 140 µm over 1.4 m was achieved. Therefore, special concrete can be considered as a potential alternative to granite for aerostatic guideways. The research now is focused on the influence of shrinkage on the straightness of molded special concrete guideways.

References:

[1] ERBE, T.; KRÓL, J.; THESKA, R: Mineral casting as material for machine base-frames of precision machines; Proceedings of the twenty-third annual meeting of the American Society for Precision Engineering and the Twelfth ICPE. October 2008

[2] DONAT, H.: Aerostatic guideways and bearings: Calculation, design and application of aerostatic bearings in precision engineering. Cuvillier Verlag, 2006

[3] NEW WAY AIR BEARINGS: Air bearing application and design guide. Version: Revision E, 2006.