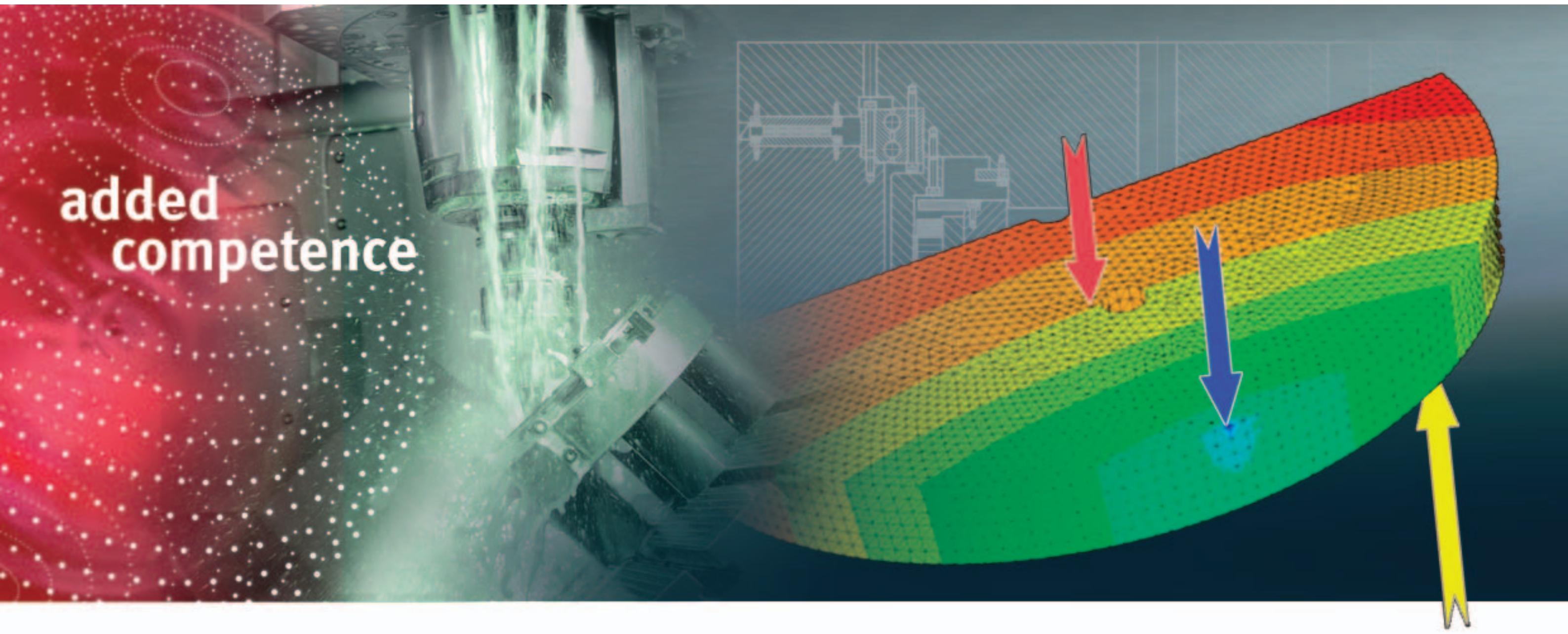

Rolling bearings and magnet bearings in rotary table axes

– a promising symbiosis

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Rolling bearings and magnet bearings in rotary table axes – a promising symbiosis

In practical application, a large number of different rotary table bearings are used. All the available variants have their specific performance limits and most rolling bearing manufacturers are working to increase these performance limits. In order to achieve this challenging goal, a completely new approach of combining rolling bearings with magnet bearings can lead to innovative, unexpected system characteristics and thus an increase in customer benefits.
As part of a development project, the Schaeffler Group has worked out the principles that are necessary in order to match a magnet bearing arrangement to a rolling bearing arrangement.

This paper explains the concept, the operating principle, investigation results and the achievable benefits.

Introduction

The leading rolling bearing manufacturers are continually making efforts to increase the performance data of rolling bearing arrangements, in particular the load carrying capacity and limiting speed. This is very important principally in machine tools since the cutting speed and output performance of these cost-intensive machines must be increased due to the pressure for rationalisation.
In relation to rolling bearings, these efforts are often subject to material and process limits.

The rotary table bearing arrangements have a considerable influence on the performance data of a machine tool, Figure 1. In addition to the normal development approaches, the Schaeffler Group is pursuing a completely new path. This involves the exploitation of the synergy effects arising from the combination of rolling bearings with passive magnet bearing arrangements. The combination of two different machine components can lead to completely new system characteristics and performance data.

Operating principle

The operating principle is as follows:
If a static force such as a weight acts on the rotary table from above, the rotary table bearing arrangement must provide the entire supporting force.
If an additional magnet bearing arrangement is integrated in the rotary table such that the rotating magnets in the rotary table and the static magnets in the machine bed repel each other, this can partially compensate for the weight acting on the bearing.
As a result, the rolling bearing must only provide a reduced supporting force.

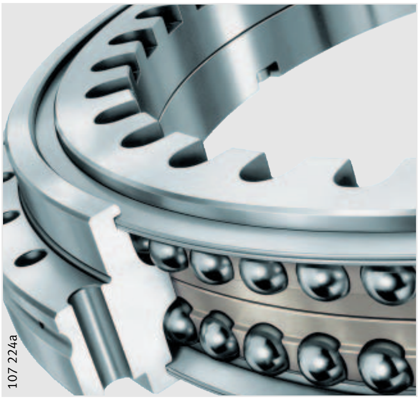

Figure 1: Rotary table bearing, series ZKLDF

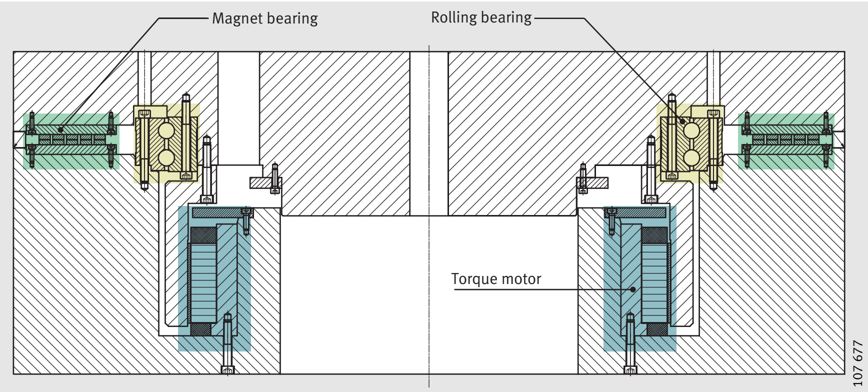

Figure 2: Concept for a rotary table with magnetic load compensation

This can give the following customer benefits: longer bearing life with the same bearing size and/or higher limiting speed with utilisation of a different bearing type or a smaller rolling bearing.

Concept

On the basis of a design brief matched to practical conditions, the concept of a rotary table with an integrated magnet bearing, henceforth also described as magnetic load compensation, was developed. As shown in Figure 2, a double row axial angular contact ball bearing of series ZKLDF was selected as a rotary table bearing arrangement. An IDAM torque motor with an external rotor was also incorporated in the mechanical concept in order to investigate the potential for integration with modern drive components.

In addition to the rotary table bearing arrangements, several concentric rings of permanent magnets are arranged on the machine bed and on the rotating table in such a way that the magnets repel each other. As a result a constant force irrespective of the rotation angle is induced that is vertically aligned and acts from bottom to top. This gives compensation to a certain extent of the weight and/or other constant force acting from top to bottom on the bearing.

Developing the design of the rotary table arrangement shown requires knowledge of two fields, namely rolling bearing technology and magnet bearing technology.

Simulation and investigation of the essential features of the bearing and rotary table

The simulations described below were aimed at developing system knowledge, especially in relation to bearing rigidity, rotary table rigidity and bearing life.

Rigidity and deflection of the rotary table

The rotary table bearing arrangement and the magnetic load compensation system were taken into consideration in the rigidity investigation. The loads selected were the weight of the rotary table and an eccentrically acting machining force. In addition, the rigidity of the rotary table bearing and the magnetic repulsive force, which acts concentrically distributed over a ring surface adjacent to the bearing, were taken into consideration.

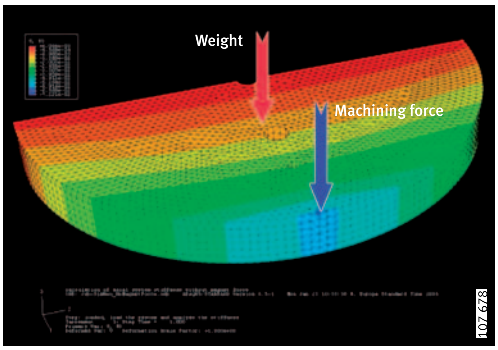

Figure 3: Simulation by FEM rigidity comparison without magnetic load compensation: deflection 72 µm

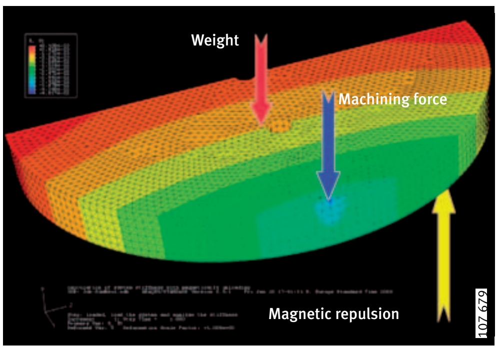

Figure 4: Simulation by FEM rigidity comparison with magnetic load compensation: deflection 48 µm

The comparison of Figure 3 and Figure 4, reflecting the results of the FEM-based simulation, shows that the magnetic repulsive force provides an additional supporting function on the rotary table bearing. This can be seen from the small deflection at the working point of the machining force, Figure 4.

Influence on the bearing life

Furthermore, simulation was carried out to determine what effect the magnetic compensation force F_m would have on the bearing basic rating life L_h, see Figure 5. A load spectrum was assumed that would lead to an unsatisfactory bearing life without magnetic compensation, namely significantly shorter than 5 000 h. The magnetic load compensation force was increased in the range from 0 kN to 65 kN.

As can be seen, a compensation force of 65 kN would achieve a satisfactory rating life range of more than 20 000 h.

Influence on the bearing life and rotary table limiting speed

Finally, the achievability of the originally formulated project goal “longer bearing life and/or higher speed with a modified bearing type” was checked in theoretical terms. The results are presented in Figure 6. A load spectrum was assumed that would lead, for a bearing ZKLDF725 with an inside diameter of 725 mm and a limiting speed of 400 min^{-1}, to an adequate bearing life of approx. 20 000 h, in this case an axial load of 90 kN and a speed of 400 min^{-1}. If the rotary table was to be run at a speed of 700 min^{-1}, however, a smaller bearing size could be selected. Through the change to the smaller bearing size, in this case ZKLDF460 with an inside diameter of 460 mm and a limiting speed of 700 min^{-1}, and by means of magnetic compensation, a bearing life of more than 20 000 h could also be achieved with the present load spectrum of 90 kN and 700 min^{-1}.

Trials

In order to allow confirmation of the simulation results previously described, a small test specimen was constructed, namely a rotary table without its own drive, Figure 7. This model is to be used to investigate the influence of magnetic load compensation on the bearing life. Once the trial results are available, these can be transferred to customer-specific rotary table applications.

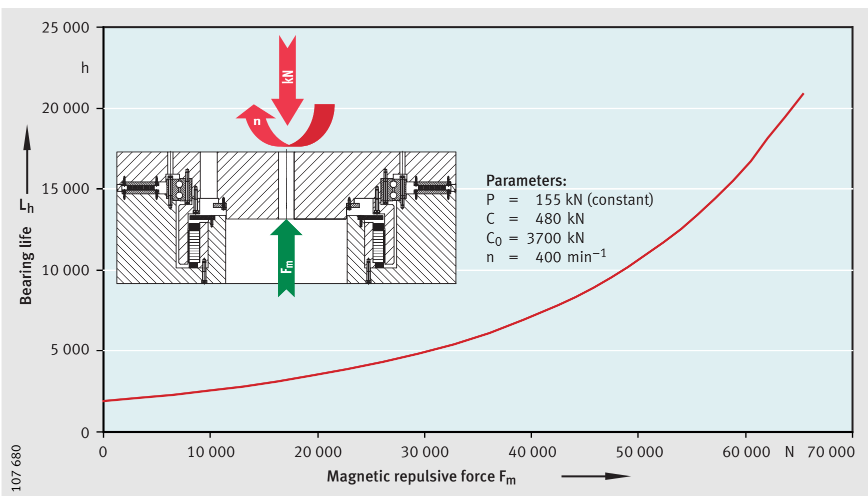

Figure 5: Influence of the magnetic repulsive force on the rolling bearing life L_h

Summary

The combination of a rolling bearing with a passive magnet bearing is highly complex. Matching these two different bearing arrangements concepts to each other is a demanding task and requires an interdisciplinary, mechatronics-based development approach.
The Schaeffler Group has developed the know-how required in order to provide customers with design and layout support in this field.

By means of selected examples, this paper has shown how magnetic weight compensation can be systematically matched to a defined rotary table bearing. This can make a significant contribution to achieving an increased bearing life and thus a high level of customer benefits.

Completely new system characteristics and new possibilities for increasing the performance capability and productivity of machine tools have been identified.

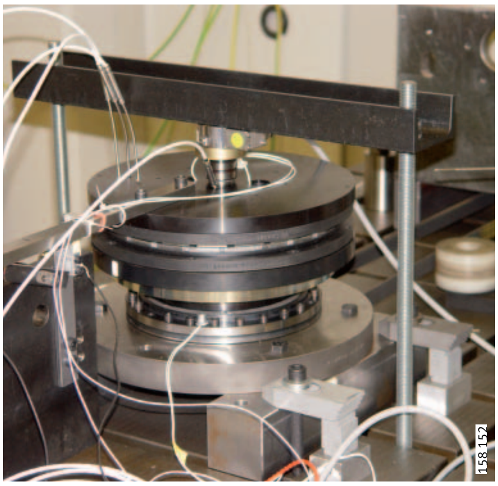

Figure 7: Incorporation of the test specimen in the test rig construction

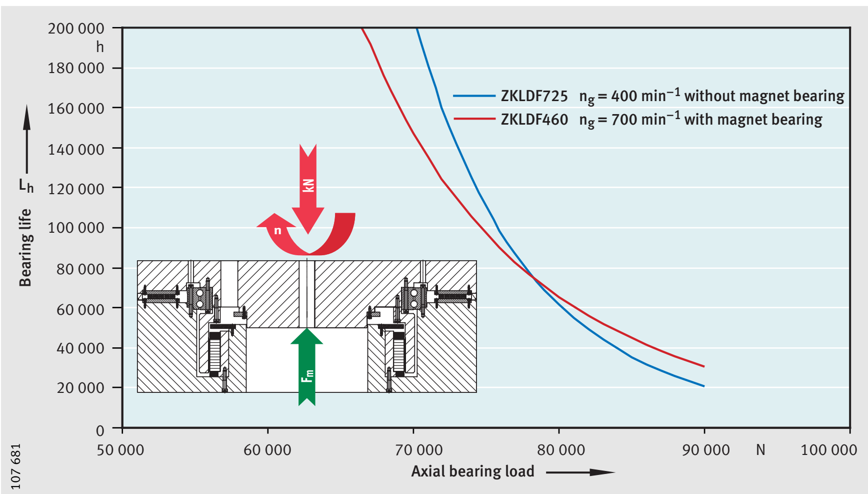

Figure 6: Longer life and/or higher speed

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