THE ENHANCEMENT OF OPERATIONAL CHARACTERISTICS OF CONTACTLESS SPINDLE BEARINGS BY SELF-ORGANIZATION OF A COMBINED DYNAMIC UNIT

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The study analyzes usage of different types of bearings in high speed spindle blocks. It indicates the advantage of gas-magnetic bearings in spindle blocks. It also shows the results of experimental and theoretical research.

Keywords: spindle block, bearing, dynamic unit, combined bearing

Modernization of any country requires implementing of innovative engineering solutions in industry. One of them is creation of highly productive precision equipment, including metal-working machines.

It is known that in the process of edge cutting machining spindle blocks (SBs) stand for 80% of accuracy in details production. Thus, the enhancement of this block construction is one of the main tasks in modern machine-tool industry.

Rotating accuracy and spindle speed, which are among major characteristics of SBs, are closely connected with the type of bearing applied. Here belongs the variety of bearings from rolling bearing to electromagnetic, hydro- and gas-static ones. It must be noticed that evolution of bearings application in SBs corresponds to the dynamism of technics development: one joint – many joints – flexible substance – liquid – gas – field. It should also be highlighted that all the bearings mentioned are not capable of meeting all the requirements to current SBs. It was scientifically proved in Work [7], where a detailed analysis of SB efficiency on different types of bearings was given.

All the bearings have a dynamic unit. For instance, a rolling bearing has a hydrodynamic layer of lubricant, a gas-static bearing – a gas film, and an electromagnetic bearing – a magnetic field.

In general, a scheme of force interaction between the elements of SB bearing can be shown as in Fig. 1.

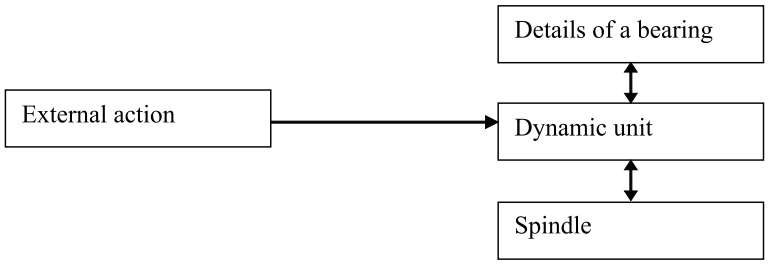

Fig. 1. A scheme of force interaction between the elements of a bearing

To stabilize the work of a bearing, its dynamic unit is regulated by external action, for example, by monitoring of quantity of the taken substance, its properties or by monitoring of magnetic field strength. The dynamic unit itself stands in the equilibrium position in some definite margins or, in other words, we may indicate self-organization of the dynamic unit.

In high speed SBs rolling, gas-static and electromagnetic bearings are applied. Hydrostatic bearings for high speeds of spindle rotation are not used because of big losses during friction in the layers of lubricating liquid.

Stable operation of rolling bearing is reached through persistent hydrodynamic lubricating layer, which is dynamic self-organizing unit. Thus, Work [2] has some methods of self-organizing hydrodynamic lubricating layer control. With the help of such approaches a parameter of speed dn = 1,2 million mm/min [8].

Recently the highest parameter of speed dn = 1,8 million mm/min has been achieved using hollow ceramic rolling element and high quality rolling paths. Though rolling bearings have a limited resource of operation due to a limited quantity of loading cycles.

The most perspective bearings for high speed SBs are gas-static and electromagnetic ones. As it was stated above, the dynamic unit of electromagnetic bearings is a magnetic field that gives an effect of attraction [1]. On decreasing of radial clearance in the bearing the

force of attraction increases with a quadratic dependence. Thus, a magnetic field without external action is not stable.

In comparison with electromagnetic bearings gas-static ones has the advantage, because with external action its gas lubricant layer is capable of stabilizing, that is self-organizing. Besides, gas-static bearings are characterized by almost absolute absence of wear and quite a high stiffness and they have a rather low load-carrying capability of lubricant layer especially with little spindle shift in bearing backing (in eccentricity) [3, 7]. On the whole it leads to undesirable decreasing of the load on to the cutting tool.

Taking into account the principal of superposition of fields, to the self-organizing dynamic unit of gas-static bearing we add a magnetic field which is not self-organizing. The summation influence of these two fields on the spindle leads to the noticeable increase of load-carrying capability of contactless bearing. At the same time an unstable magnetic dynamic unit, that has a little less potential and is situated in the self-organizing dynamic block of a gas field, becomes self-organizing. A bearing with such a combined dynamic unit can be called gas-magnetic. A mode of gas-magnetic bearing operation is described with details in Work [4].

The effect of self-organization of a combined dynamic unit of a gas field and magnetic forces allows to increase load-carrying capability of a bearing up to 50% in the range of working values of eccentricity and twice as much with little eccentricities. As theoretical and experimental research proves, this mode of bearing operation in SBs can be reasonably used in superprecision machining of articles.

Fig. 2 shows theoretical and experimental dependences of load-carrying capability ratio of gas-magnetic bearing $C_Q = Q/Q_{max}$ from eccentricity ratio $\varepsilon = e/c$, where Q is a current value of load-carrying capability of a bearing, Q_{max} is a maximal value of load-carrying capability, e is absolute eccentricity, c is an average radial clearance between a spindle and a spindle backing. The theoretical characteristics were estimated using bundled software [5]. The experimental data were obtained at the stand which was described with details in Work [6].

The graphs given demonstrate even higher values of load-carrying capability ratio of gas-magnetic bearing (lines 2) in comparison with a gas-static bearing (lines 1), especially with little values of eccentricity ratio.

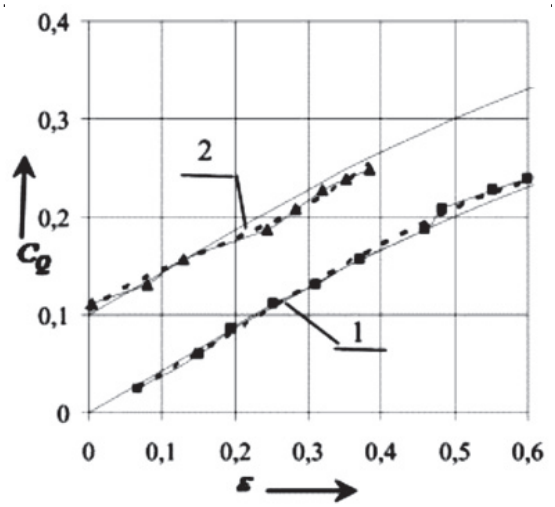

Fig. 2. Dependence of load-carrying capability ratio of gas-magnetic bearing CQ from eccentricity ratio ε:
1 – with the electromagnet off;
2 – with the electromagnet on; theory; experiment

In conclusion it should be underlined that one of the perspective resources of further enhancement of operational characteristics of SBs is external regulation of self-organizing dynamic unit of gas-magnetic bearing.

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