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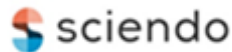
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OVERVIEW ON BEARING MANUFACTURERS RESEARCH AND DEVELOPMENT DIRECTIONS

BY

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Abstract. The paper presents an overview of development directions and market interest declared by the largest and relevant manufacturers of bearings worldwide. The general directions of improving the quality of and durability of bearings remained a current research field but also adding different products and services (such as remanufacturing of bearings and conditioning monitoring product and services) are in the manufacturers focus. Special considerations are on introducing AI technologies in the decision making process and process coordination in bearing manufacturing, also electrification is considered to be a large part of future sales in automotive and various electric drive units.

Keywords: development direction, bearing manufacture.

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1. Introduction

Roller bearing are commonly used components to enable the rotary motion in vast majority of machine tools, automobiles and in general in all industrial machinery. Although the reduced number of parts found in roller bearing (inner ring, outer ring, roller elements, cage) might induce the idea of a simple machine component, the geometry of each component is quite complicated, and the technical requirements imposed are very restrictive (Rabinovici, 1972; Harris, 2001; Harris T.A., 2006).

The processes of roller bearings manufacture are quite complex and lengthy and require a succession of stages that take place in different areas of a factory where highly specialized machine tools are used. The complexity of the manufacturing processes for roller bearings make this process inflexible in regard to production of different batches of bearings, the manufacturing process is designed especially for large batches (Mehmet, 2021; Mehmet, 2022).

This paper reviews several of the development directions and market interest declared by the largest and relevant manufacturers of bearings worldwide. The analysis is focused on manufacturers own report on activity published on their site.

2. Research and development direction for bearing manufacturers

The roller bearing market is divided between the following bearings six manufacturers SKF (Sweden), Timken (USA), Schaeffler Group (Germany), NTN (Japan), NSK (Japan), JTEKT (Japan), that occupy 55% of market of 120.98 billion in 2023 according to SKF Annual Report 2023 and Bearing Market Size, Share & Growth Analysis Report, 2030 made by Grand View Research Company. 25% of the bearing manufacturers are Chinese large and small producers, and remaining 20% consists of numerous smaller regional and specialized manufacturers. (*, SKF, Annual report 2023; *, Timken, Annual Report 2023; *, Schaeffler, Annual Report, 2023; *, NTN, Annual Report 2023; *, NSK, Annual Report 2023; *, JTEKT, Annual Report, 2023, *, Bearing Market Size, Share & Growth Analysis Report, 2023).

General research and development direction

The general directions of bearings optimization and implicitly of the components take into account increased L10 durability and reduced Pmax contact pressure (Harris, 2001; Harris T.A., 2006). Also, the development of accurate bearing design methodologies and the increased profitability of bearing production in small or medium series of manufacturing has led to the emergence on small batch manufacturing usually reserved for special bearings. This is a modern trend that is becoming more and more pronounced worldwide, to the detriment of the production of general purpose bearings (*, SKF, Annual report 2023).

The development of mathematical models for estimating and increasing bearing durability is performed by various software applications. Virtually every major bearing manufacturer has such software based on own test data, used to estimate bearing durability.

Development of profiles for active bearing surfaces (logarithmic profiles, etc.), lubricants for reduced friction especially in the automotive field, as well as identification of new materials, coatings, seals, etc.

Development of new heat treatments (bainitic treatment) for increased bearing durability (Fortini *et al.*, 2023; **, Heat treatment makes tougher bearings).

Specific research and development direction

The intense competition between bearing manufacturers has stimulated innovation and new product development. Also, in order to sustain market growth the bearing manufacturer are focused on the own manufacturing process in order to improve quality, reduce cost and environmental impact (**, SKF, Annual report 2023; **, Timken, Annual Report 2023; **, Schaeffler, Annual Report, 2023; **, NTN, Annual Report 2023; **, NSK, Annual Report 2023; **, JTEKT, Annual Report, 2023).

In terms of increasing bearing performance extensive research is focused on polymeric materials and ceramic coatings. Research results will lead to the realisation of products resistant to electrical erosion for electric vehicles (**, NSK, Annual Report 2023).

One research and development direction is that of ceramic bearings, in order to offer increased hardness, lower friction and superior corrosion-resistant to steel and typically reduced weight compared to steel bearings. Most ceramic rolling elements manufactured are electrical insulators such as silicon nitride. This is ideal for impeding eddy currents in electric motors. Hybrid ceramic bearings combine ceramic balls or roller with chrome steel or stainless steel inner and outer rings, combining the advantages of both ceramics and metals (**, Ceramic bearings ISK, 2023). When replacing steel balls with silicon nitride balls, the speed capabilities are increased between 20-50%.

Magnetic bearings are considered a key technology growth area for SKF, mainly in the field of hydrogen processing. By using a magnetic bearing system, the oil lubrication system, cooling system of some types of gearbox can be eliminated and the footprint of the machinery decreased.

Smart bearings or *sensor-based bearings*, are used to accurately monitor the status of rotating components usually for electric motor management, steering speed for automotive steering system and measurement of angular position for electric motors, electric vehicles, road rollers, tractors, forklifts and conveyors (**, SKF, Sensor bearing units, 2023).

Specialized bearings for energy efficient vehicles are found in many manufacturers portfolio for example SKF Rotor Positioning bearing consists of a high performance magnetic ring clamped to a high-speed, high-temperature

bearing thus a powerful, accurate, repeatable and durable magnetic field is generated (**, SKF, Sensor bearing units, 2023).

Remanufacturing of bearings is considered an important and growing sector of the bearings manufacturers' activity. Bearing remanufacturing or repairing of worn bearings to like-new geometric requirements is used for the increase of bearing service life and often can be performed in less time than required to manufacture new bearings. Usually the remanufactured bearings are large diameter or special application form heavy industrial field such as paper industry, metals mining, power generation and cement; railroad locomotives, special engines and gearboxes (**, Timken, Annual Report, 2023; **, SKF, Remanufacturing of bearings, 2023; **, NSK, Annual Report 2023).



Fig. 1 – Conceptual Diagram of Product Life Cycle from NSK-Japan
(**, NSK, Annual Report 2023).

Some smaller manufacturers that are focused on limited range of sectors and may be confronted with vulnerability and risks if the respective industries enter stagnation. For example RKB alongside general purpose bearing is focused, also, on marine industry composed on marine and offshore engineering and the shipyard sector (**, RKB, 2023).

Usually general information for experienced or novice users in the field of bearing handling, maintenance and troubleshooting is in the form of books, booklets, manuals. Various application are proposed to the clients covering a large spectrum from selection, installation and diagnose such as those produced by bearing manufacturer NSK-Japan called BEARING DOCTOR HANDLING, MAINTENANCE AND TROUBLESHOOTING, now this information is also available in the form of apps such as NSK Bearing Doctor App from the online app store Google Play (**, NSK Bearing Doctor, 2023).

Most manufacturers of bearing large or medium offer an application for bearing selection or various on-line catalogues (skfbearingsselect, NSK Online

Catalog app, Precision Bearings App - NSK Verify , Rexnord Bearing Mobile Pro App,), but the area covered by the apps offered by bearing manufacturer extend to mounting of the bearing (e.g. SKF Bearing Assist), to the grease degradation diagnosis and data regarding the spectral analyses performed with the supplied DAQ equipment. SKF Microlog Analyzer dBX is a vibration monitoring analyzer used for detection in condition monitoring rotating machinery (**, SKF, 2023. *SKF Microlog Analyzer dBX*). AI will also be used in data analysis regarding bearing faults (Yap *et al.*, 2024).

Environmental considerations

Koyo adopted Reduce, Reuse and Recycle (“3Rs”) methodology to manage the waste and the general aim is to reduce energy consumption 5% for a baseline set in 2022 (**, Koyo, Sustainability Report 2022).

The employees from the bearing manufacturing industry are encouraged to transfer environmental responsibility habits in their daily lives. Also by auditing subcontractors and suppliers accountability and sustainability is verified in the supply chain.

Bearing manufacture is an energy intensive business – directly using energy, mainly in the form of electricity and gas for this in order to reduce carbon foot print manufacturers are always investing in pollution control equipment and updated plant operational practices.

Business Model relation to Industry 4.0

In terms of business model, the approach of the Japanese manufacturer NSK when profitability is affected by inflation (steel and energy cost) and wages increases is to focuses on cost reductions and productivity increases also transferring production costs to customers through bearing selling price increases, adjustments through judicious use of equity and exchange rates (financial means).

JTEK being number one supplier in Japan is focused on smaller and lighter bearings as well as bearings compatible with lower torques is increasing in conjunction with electrification. NTN considers important the expansion of bearing refurbish business and also supplying the condition monitoring equipment to clients in form portable failure detection devices that will work with IoT system.

Manufacturers such as SKF, NSK and NTN are intensively developing bearings for wind turbines and are trying to get a bigger share of the Chinese wind turbines and machine tool market.

In order to achieve R&D and market objectives, manufacturers are looking to improve their manufacturing circuits, build new production units according to the principles of Industry 4.0 (green field) and apply digitization solutions for decision-making and manufacturing. NTN plans to optimize production by introducing IoT, AI into production process. AI techniques will be introduced in bearing behaviour analysis and in bearing performance prediction (Rossopoulos and Papadopoulos, 2024).

Implementing Cloud based platform allows for faster technology deployment, also from the management's point of view, data from ERP systems are now available in real time, allowing for precise and purposeful actions. Manufacturers are re-engineering processes before digitalization to ensure efficiency and effectiveness, and operations are being robotized and automated. SKF is equipping production machinery with proprietary software for data acquisition and processing process-related data and of the condition of the machine tool. Market risk analysis is large part of the report offered to investors and cover a large spectrum from Financial risk management (currency, interest rate liquidity risk) to energy price geopolitical risks, continued inflation lower production globally and the market environment,

3. Conclusions

Bearing manufacturers are always focusing on consolidating markets that are considered mature and increasing market share in the evolving market

A focus on development of automotive bearings compact lightweight, high-speed low-torque noise, and vibrations mainly found in electric vehicles can be remarked as a general trend for all major manufactures that target automotive OEM and aftermarket clients.

Another market trend is developing new business field in remanufacture bearing and maintenance (mainly condition monitoring, predictive maintenance market) of rotating machinery from paper, food and beverage and renewable energy domain, characterized by special large bearings that aren't usually on bearing dealer stock. Also, the trend of specialized bearing manufactured in low batches requires special attention on the maintenance of the machine tools where these types of bearings are used. This can be explained by the manufacturer's interest within the circular economy and the reducing environmental impact.

All bearing manufacturers actively exploring how AI can be used to increase operational efficiency and customer value, also electrification is considered to be a large part of future sales in automotive and various electric drive units.

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PREZENTARE GENERALĂ A DIRECȚIILOR DE CERCETARE-DEZVOLTARE A PRODUCĂTORILOR DE RULMENȚI

(Rezumat)

Lucrarea prezintă o privire de ansamblu asupra direcțiilor de dezvoltare și interesului pe piață declarat de cei mai mari și relevanți producători de rulmenți din întreaga lume. Direcțiile generale de îmbunătățire a calității și a durabilității rulmenților au rămas un domeniu de cercetare actual, dar și dezvoltarea și adăugarea de produse și servicii diferite (cum ar fi reparațiile rulmenților și produse și servicii de monitorizare a condițiilor de funcționare) sunt în centrul atenției producătorilor. Considerații speciale sunt acordate introducerii tehnologiilor AI în procesul de luare a deciziilor și coordonare a procesului de fabricație a rulmenților, de asemenea, electrificarea este considerată a fi o mare parte a vânzărilor viitoare în automobile și diverse unități de propulsie electrice.