Joint Research and Simulation Software for an Optimized Rolling Bearing Friction Model

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For individual companies, and especially SMEs, research is a cost-intensive undertaking that is often associated with high risks. For this reason, many gear manufacturers rely on joint research with other industrial enterprises. This allows companies across the industry to save costs, reduce personal risk, and collectively benefit from new discoveries. FVA (Forschungsvereinigung Antriebstechnik e.V.) has been conducting joint research in the field of drive technology for more than 50 years to promote cooperation between organizations. With a research volume of more than 14.9 million euros, as well as 224 projects and studies in 2018 alone (Ref. 1), the FVA represents a true success story for its members.

FVA-Workbench provides unlimited access to drive technology research findings.

The *FVA-Workbench* Bundles Hundreds of Research Findings in One Platform

Numerous calculation methods for the design and calculation of gearboxes, which have been valued by the industry for many years, have been developed and tested by leading research institutes within the framework of joint industrial research. It is impossible for a single engineer to possess this amount of research knowledge. Mastery of the contents of even a single research project can hardly be achieved in day-to-day business.

FVA GmbH develops the *FVA-Workbench* to provide unlimited access to these research findings. The software bundles the results and makes them available to the drive technology industry on a manufacturer-neutral and cross-sector basis, enabling companies to develop individual products at the highest level. This simple, high-performance software gives users access to research results in their daily business.

Increased Efficiency for Reduced CO_2 Emissions

Easy access to extensive research knowledge is important to be able to quickly respond to changing regulatory and market conditions. There is no time to study hundreds of research journals and findings. For example, current legislation requires the reduction of CO_2 emissions. Above all, power losses must be reduced to save energy.

Reliable information on expected losses is essential for system manufacturers and gearbox users. Losses occur in all contacts with relative motion — especially in bearings and gears within gear units.

Extensive Documentation for Calculation of Power Losses

An unmanageable amount of literature, studies, and experiments exist for the calculation of power losses. A tool such as the *FVA-Workbench* that provides access to experimentally validated methods is essential, especially when a reliable statement about losses is a purchasing factor.

Power loss in gearboxes has been thoroughly investigated and documented. Loss considerations for the load-dependent and independent shares of power losses are listed, experimentally proven, and precisely calculated in the research reports from FVA Research Projects 69 I through VIII, dating from 1989 to the present. For gears, a very good correlation can be observed to date, with real measurements from gear units. In the past, manufacturers' documented catalog methods were used for rolling bearings. In some cases, however, significant deviations from measurements have been observed (Ref. 2).

Estimation of Power Losses According to Palmgren

Palmgren is the most common method for estimating power losses. This often forms the theoretical basis for estimation of losses in a technical environment. For estimation according to Palmgren, power losses are divided into load-dependent and independent components. The two amounts are largely determined using bearing-specific coefficients. All relevant effects must be included in these coefficients. This makes the Palmgren model comparatively simple. However, additional effects which are particularly important in rolling bearing technology cannot be taken into account. Influences from

the type of lubrication or loads, for example from dominant tilting moments, cannot be represented. Therefore, an approach must be found in which the loss components are specifically listed for a design-dependent evaluation of bearing losses.

More Precise Calculations Thanks to IMKT, FZG, and FVA

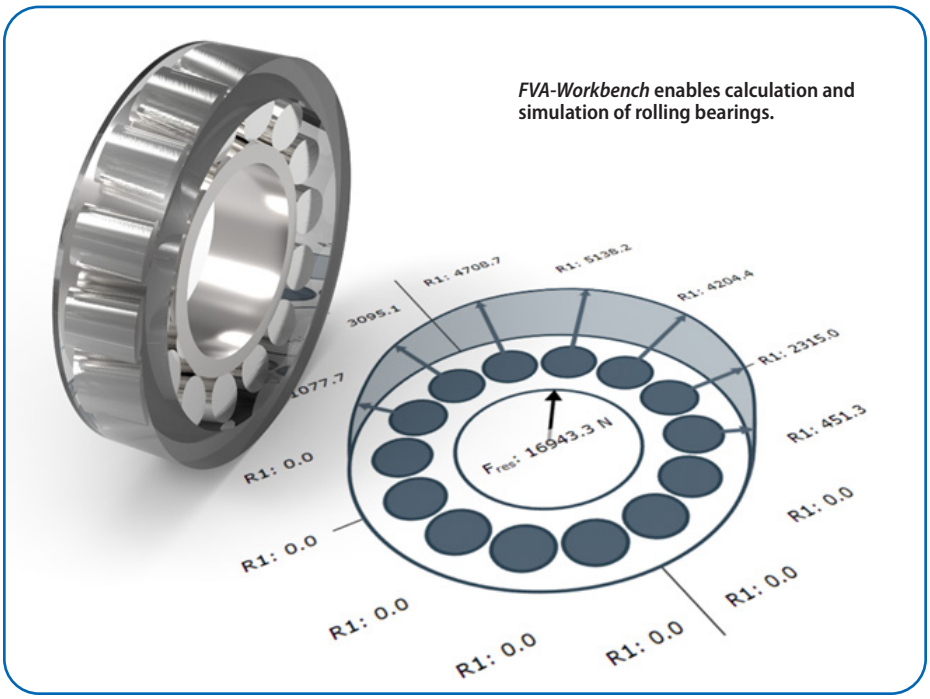
A new approach for the characterization of rolling bearing power losses based on seven FVA research projects and five dissertations was developed at the University of Hannover IMKT under Professor Poll. As part of the project, the newly developed approach was tested and validated on the test bench at the FZG of the TU Munich. The *FVA-Workbench* simulation software brings this theory into practice.

The foundation of the methodology is a precise resolution of the rolling contacts in the bearing, the tribological characterization, and the allocation of the loss components to the loss mechanisms. The total power loss is the sum of the individual losses in the bearing. The following individual friction components are considered: the hydrodynamic rolling friction M_{hydr}, hysteresis friction M_{irr}, splash losses $M_{Plansch}$, differential slip M_{Diff}, and the rib friction M_{Bord}. Friction from cage contact and seals is neglected. This results in the following general relationship:

$$M_{total} = M_{hyd} + M_{irr} + M_{Plansch} + M_{Diff} + M_{Bord} \quad (1)$$

The geometries of the rolling bearings are needed to calculate the contacts. The Breuer calculation approaches from FVA 184 are used to determine the internal load distribution on the rolling elements and the pressure distribution on the rollers. Thus, all influences from the gear system are fully considered (Ref. 4).

Different contacts and loss mechanisms occur in different rolling bearing designs. Formula (1) must be modified to take this into account. The ribs of deep groove ball bearings and angular contact ball bearings are ignored due to their design. For cylindrical roller bearings, on the other hand, the differential slip is ignored; however, if the bearing type has ribs, the rib friction is considered.



FVA-Workbench **enables calculation and simulation of rolling bearings.**

The calculation of the hydrodynamic rolling friction is based on the EHD theory. For this purpose, the bearing pressure across the contact length and contact width are resolved. The rolling element pressure can be derived from the stiffness calculation. All load components are considered in the stiffness calculation. The losses from irreversible deformation are determined by the material characteristics of the rolling bearings. The material damping influences the extent to which the irreversible deformation contributes to the total losses.

The splash losses in the rolling bearings are taken into account by many different influences. For a fast and powerful calculation, a CFD calculation is only of limited use. Therefore, the splash losses are determined based on the measurements from FVA 352. The losses can be derived from these measurements, depending on the oil level in the bearing and the bearing geometry.

With grease lubrication, splash losses are neglected. This is based on the assumption that the grease was completely pushed out of the contact during the first revolutions of the bearing. The contact is supplied with the base oil viscosity by a lubricant. Thus, splashing cannot occur.

For bearings with point contact, the differential slip must also be considered. In addition to the more obvious deep groove ball bearings and angular ball bearings, this also occurs in tapered roller bearings with rib contact. The Heathcote effect and the bore movement that results if a rolling element runs on a raceway with an operating pressure angle other than 0° are considered in this calculation.

The validation projects of FVA 364 IV and FVA 701 show an excellent accordance with the theory. Thus, significantly higher accuracy can be achieved compared to the factor-based catalog methods. These high-quality results are achieved by completely considering

the pressure distribution and the environmental boundary conditions, such as tilting and bearing clearances.

The *FVA-Workbench* Brings Theory into Practice

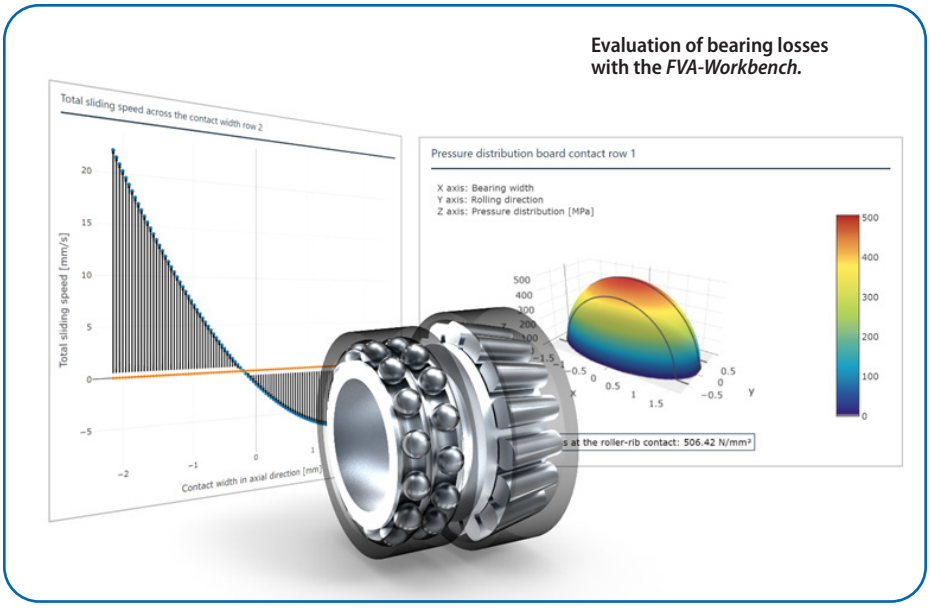
In practice, precise statements regarding losses in the drive are required as early as the project planning phase. Every bearing and every auxiliary drive counts. With the new statements from FVA 701 I and III, manufacturers can now provide these statements and prove them with investigations from joint research. The *FVA-Workbench* supports engineers with an easy-to-use calculation model, comprehensive input consistency checks, and easy-to-interpret results. With the results from FVA 701 II, gearbox manufacturers are now able to provide reliable statements regarding losses in the offer phase and better describe the loss mechanisms.

FVA-Workbench — The Simulation Tool for Efficient Gear Design

The *FVA-Workbench* is a manufacturer-neutral software solution for the modeling, parameterization, and calculation of transmission systems. It bundles 50 years of research and development from the FVA expert network into a single platform and makes this accumulated knowledge directly available for industrial application. The software includes an impressive scope of calculations for all phenomena relevant to the design of drive systems. Gearbox systems can be developed in shorter cycles and in leading quality.

Seminars on the Cutting Edge of Research

For detailed insight into damage mechanisms and how loss calculation plays a decisive role, FVA Software and Service GmbH regularly offers seminars with well-known experts on the subjects of gearbox calculation and rolling bearing damage. In these seminars, you will learn about what makes a good design, how damage occurs, and how it can be avoided. At the same time, you can also make contact with FVA experts and other participants with similar interests. **PTE**



Evaluation of bearing losses with the *FVA-Workbench*.

For more information.

www.fva-service.de

1. Forschungsvereinigung Antriebstechnik e.V. 2018 Annual Report
2. FVA 364 IV - Service Life - Industrial Gear Units - Rolling Bearings (Lager2 extensions)
3. FVA 382 - Influence of the Oil Level on the Friction Moment of Rolling Bearings with Line Contact
4. *www.fva-service.de/en/fva-workbench/features/overall-system-calculations/*