FAG

Take off to the future

SCHAEFFLER GROUP
AEROSPACE


more innovation
more performance

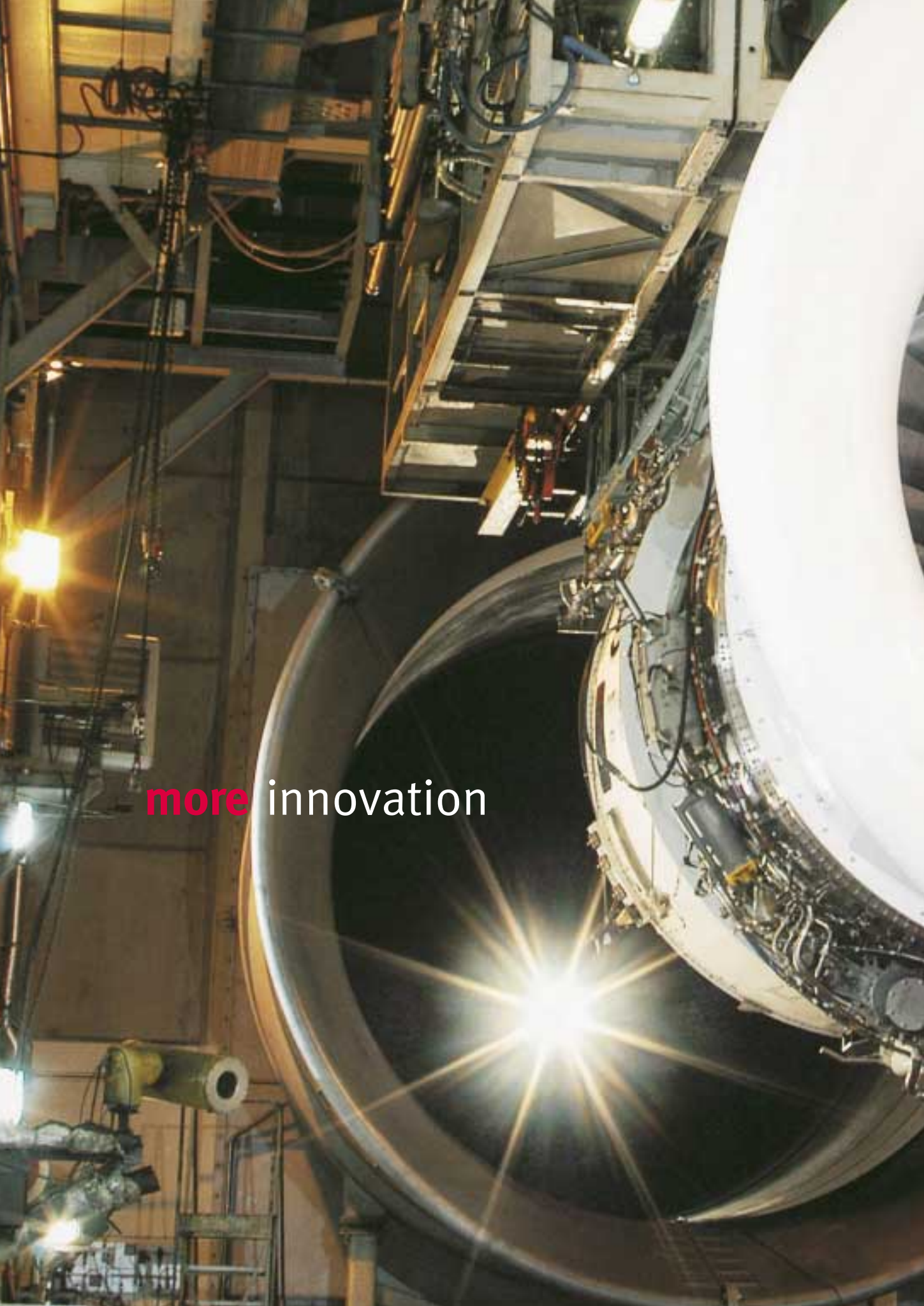
FAG Aerospace

FAG Aerospace develops and manufactures specialty bearings, integrated bearing systems as well as high-precision components for the aviation and aerospace industries. In addition, we offer specially designed bearings for use in related fields, such as CT scanners or turbochargers, where our technology and know-how is incorporated to provide additional benefits to our customers applications.

Bearings for aviation and aerospace applications have to withstand harsh conditions: extreme temperatures, demanding load profiles and high speeds. Each of our bearings is custom engineered and manufactured for a specific customer application. With the use of the most advanced manufacturing and material technologies, design methods, and comprehensive qualification tests, we achieve a quality and reliability standard that makes us one of the leading suppliers of aerospace bearings. More innovation, more performance, more reliability, more support and customer focus are our business principles.

We are committed to joint development partnerships with technology leaders in the aviation and aerospace industry. Our customers are world renowned manufacturers of airplanes, aircraft engines, helicopters, space launchers and satellites. International airlines and engine maintenance shops apply our competence in bearing diagnosis and repair.

Since 1969, the aerospace division has been an autonomous FAG business unit that serves the corporation as a nucleus of technology and a benchmark for rapid development. Production facilities are located in Stratford/Canada, Schweinfurt/Germany, Danbury/USA and Plymouth/United Kingdom.


more innovation

Never stand still. Discover new worlds. Advance into dimensions which are today unknown. The challenge: Realise new ideas and make the impossible possible. And what is still an idea in our minds today, can move the world tomorrow.


more performance

Lift-Off. After two minutes into flight, we are travelling at an altitude of 45 km and at a speed of over 4828 km/h. The main engines deliver thrust up to 8.5 minutes after start. They burn thereby 1.9 million litres of liquid oxygen and hydrogen. The temperature in the rocket motors now amounts to 3315 °C.


more reliability

The view of the clouds from the window. The wings glittering under the sun. A moment of endless freedom. And the feeling of being absolutely safe here and now. Knowing that in the future as well, one can rely on this level of reliability.


more support

Countless take-offs and landings. Countless hours spent in the air. Day after day. No end in sight. The aircraft is relied upon, because reliability results from those who do more for it. More support, means longer service life.


less system cost

Corrosion resistance

Corrosion is one of the main causes of bearing failure. We therefore utilise highly corrosion-resistant materials in our bearings, which significantly improves service life and reliability.

Component integration and weight reduction

Today‘s demands are reduced system and life-cycle cost, better performance, increased reliability, simplified installation at less weight. Therefore we develop integrated bearing systems where interfaces are eliminated and surrounding parts become an integral part of the design.

Temperature resistance

Extreme temperatures ranging from - 195 ¡C to + 600 ¡C demand extreme temperature resistant materials, from high temperature steels to case hardened materials and nickel superalloys to ceramics.

New records
are our challenge

Propulsion Systems for the Aerospace Industry

100 years of motorized aviation: for the FAG brand that means nearly 100 years of experience in the manufacture of aerospace bearings. Aircrafts with FAG bearings have always been record-breaking. ⇢ When Charles Lindbergh in 1927 completed the first non-stop transatlantic flight with the legendary "Spirit of St. Louis", the propeller shaft of the Wright-J5 "Whirlwind" engine was supported by a cylindrical roller bearing made by Norma Hoffmann, a former subsidiary of FAG. ⇢ Year 1995: "It gives me great pleasure to announce the selection of FAG as the recipient of the Pratt & Whitney Space Flight Awareness Award for your support in making the Space Shuttle Main Engine turbopump a success. FAG's commitment in advancing material processing, enhancing grinding techniques and development of a high-tech inspection system has been outstanding. The superior quality of the FAG bearing has been successfully demonstrated in the Space Shuttle mission STS-70." (John B.Olinger, Pratt & Whitney) ⇢ In 2004, a world record was set once again : Exactly 18 hours and 18 minutes took the hitherto longest non-stop commercial flight – stretching 16 600 km from New York to Singapore. The Airbus A340-500 powered by the Rolls-Royce "Trent 500" turbofan engines use main shaft and gearbox bearings developed by FAG in close cooperation with the customer. ⇢ 2005: the maiden flight of the new Airbus superjumbo A380 – the world's largest passenger airplane – has been a success. Bearings from FAG made a vital contribution to this success. All main shaft bearings and other engine components in the Rolls-Royce "Trent 900" engines were developed and manufactured by FAG. The second engine concept for the A380, the "GP7000" engine from General Electric and Pratt & Whitney is also using FAG bearings. ⇢ The concepts for future world records are already brewing in the minds of the FAG Aerospace engineers.

- ⇢ Simultaneous engineering – Joint Development with the customer
- ⇢ Weight and component optimisation as well as cost savings through system integration
- ⇢ Integrated bearings and components improve performance and reliability


Highest goals –
from the ground up

Engines and Engine Gearboxes for Civil and Military Aviation

Since the 1930's, when Sir Frank Whittle built his first jet engine, the aircraft gas turbine has been a continuous challenge for bearing engineers. High speed and temperature and the need of low weight components are combined with a demanding operating environment of corrosive exhaust products, contamination and high cyclic and vibratory stresses. Today's requirements in these application fields call for: higher power density, increased life, improved reliability with the ultimate goal of a "design for life". All renowned aero engine manufacturers worldwide rely on FAG to meet these requirements. ⇢ Almost all modern aircraft engines, which power passenger aircraft from the smallest to the largest, are fitted with aerospace bearings from FAG. Besides main shaft and gearbox bearings, FAG also supplies stub shafts, housings and various other parts as a kit, directly to the assembly line, as in the case of the A380 power plant. ⇢ Apart from civil aerospace applications, FAG is also an innovation partner and supplier in all major military engine projects, e.g. the Eurofighter program or the transport aircraft A400M from Airbus. In the Joint Strike Fighter program, FAG has been involved in the development of the engine mainshaft and gearbox bearings and the nozzle system which allows vertical take-off and landing of the Lockheed Martin aircraft. The large nozzle bearings, with a diameter of 1200 mm, are equipped with ceramic balls and bearing races made of heat and corrosion resistant steel for high temperature operation.

- ⇢ Continuous improvements in rolling bearing performance
- ⇢ Highest quality and reliability standards
- ⇢ Weight optimised and integrated designs for the most demanding applications
- ⇢ Application of advanced material technologies that allow expansion of the operating envelope, e.g. through-hardening and/or high temperature rolling bearing steels, case-hardening and nitriding steels or ceramic rolling elements

Responsibility means, offering
the best overall solution

Helicopter

In helicopter applications FAG accomplished pioneering work as well. Cylindrical roller and separable bearings in the motor of the first fully-operating helicopter, the Focke-Wulf FW 61 flown by Hanna Reitsch in 1938, came from the company FAG. Today, FAG is the development partner and supplier to all leading helicopter manufacturers. For the world's civil and military helicopters, FAG develops and delivers a large variety of helicopter bearings. Examples include swash plate bearings for the rotor head which are over 1000 mm in diameter and made of highly corrosion and wear resistant materials. For the helicopter main gearbox, FAG supplies the planetary bearings in all design configurations and other specially engineered bearings including cages made of lightweight and temperature resistant plastic materials such as glass fibre reinforced PEEK (Polyetheretherketone). Highly stressed ball and roller bearing arrangements as well as tapered roller bearing configurations are used to support the rotor mast. A wide array of bearing designs, ranging from needle roller bearings to innovative ball bearing designs, are equipped in the tail rotor and transmission shaft and many other moving parts of the helicopter. To protect against fretting corrosion, helicopter bearings are often given a special coating. Integrated design configurations allow distinct weight savings. To increase bearing service life, high alloyed, wear and corrosion resistant steels and other special materials are used, such as nitrogen alloyed steel in combination with ceramic balls and rollers. This material combination initially developed and introduced by FAG in the Space Shuttle main engines has meanwhile proven its superior performance characteristics in many customer applications.

- Design and manufacturing capabilities for all bearing configurations and sizes
- Use of high temperature, corrosion and wear resistant materials for extreme operating conditions
- Broad experience with coatings and in-house coating capabilities
- Integrated bearing designs for increased performance at significant weight reduction


Even the smallest detail
contributes to highest safety

Accessories

During take-off, cruise and landing, the engines and other systems of an aircraft are exposed to demanding operating conditions. These systems, like the wing flap and slat actuation and support systems and a multitude of accessories and instruments, are equipped with our specialty aerospace and superprecision bearings and our customers rely on them. FAG aerospace bearings stand for longer service life by means of improved seals, lighter weight and the use of wear and corrosion resistant materials. ⇢ To be highlighted in this regard are highly corrosion resistant track rollers, bearings for auxiliary power units (APU's), specialty bearings for aircraft and engine accessories such as cooling fans, oil and fuel pumps, starters and generators. ⇢ In the cockpit of an airplane are extremely precise instruments in use, which help determine the safety of the flight to a large extent. Thus highest performance demands are placed on the gyro-bearings in gyroscopic instruments in relation to drift rate, service life and size. FAG develops and manufactures bearings with carefully produced tolerances of less than a micrometer. This high precision, together with an exceedingly exact running accuracy and surface processing, cleanliness as well as an oil-lubricated cage, bring about numerous advantages such as reduced vibration level, less wear-related mass displacement and a greater uniformity of performance among all units. ⇢ In the development and production of high-precision instrument bearings, FAG places particularly high care into the inspection of materials, geometry and possible surface changes. Due to their unique design, the bearings can withstand fierce accelerations and high loads as well.

- ⇢ Low friction and minimum stick-slip effect
- ⇢ High efficiency thanks to low erosion
- ⇢ Optimised weight savings and high rigidity
- ⇢ Usage at high speeds made possible by optimum surface processing
- ⇢ Extended service life supported by special materials, lubricants and sealing concepts


On an innovation course
with creative solutions

Synergetic Applications

A substantial number of non-aerospace customers take advantage of our design, engineering and manufacturing capabilities for the development of specialty bearings for their demanding applications. Such application fields include turbocharger, stationary gas turbines, medical equipment and applications in the nuclear industry just to name a few. Just like in the aerospace industry, specially engineered bearings meeting the highest precision and reliability standards come into application in these demanding and sensitive environments. The special bearings developed and produced by FAG set themselves apart due to their long service life, corrosion resistance, special surface hardness, smooth and quiet operation as well as an enormous rotational speed capacity. ⇢ Our hybrid bearing systems used in medical computer tomography scanners are integrated units consisting of a large size thin section bearing with extremely low running noise, direct-drive motor and housing parts, and a high resolution position measuring system used for image reconstruction. Know-how and technology transfers from other application areas have contributed here. Thus, for example, large size thin section bearings used for the helicopter swash plate mechanism were further developed for application in computer tomographs offering highest operational reliability, high running accuracy and low noise even at high rotational speeds. ⇢ In the development of high performance bearings for turbo chargers as used in diesel motors for ships, railways, power stations, emergency power facilities, etc., we apply our design, materials and manufacturing technologies from the field of aerospace bearings to offer a superior performance and reliability.

- ⇢ Custom engineered design solutions for improved performance and reliability
- ⇢ High-precision bearings manufacturing capabilities up to 1500 mm in diameter
- ⇢ Engineering and manufacturing capabilities for integrated mechatronic systems, including direct drive motors and position measuring systems
- ⇢ In-house inspection and testing capabilities


Out of the old
emerges the new

Bearing Refurbishment and Remanufacturing Services

The demands on bearings in aero engines, gearboxes and helicopters with regards to speed, temperature and loads have continously increased over time, while at the same time the service life and reliability were also increased. These performance improvements are the result of advancements in bearing design, materials and manufacturing technologies. Nevertheless, bearings in these applications can operate in an environment that introduces surface imperfections which can ultimately reduce service life. Our bearing Refurbishment and Remanufacturing Service eliminates these life reducing imperfections from the functional bearing surfaces, thereby restoring bearings into an “as new” condition. ⇢ During engine overhaul, bearings are frequently replaced as a precautionary measure. In many cases, rather than being replaced, bearings can be re-entered into service with renewed performance expectations after completion of our comprehensive diagnosis and refurbishment methods. This substantially reduces maintenance costs with no sacrifice to reliablility. ⇢ Our diagnosis determines imperfections including wear and fatigue. Based on this assessment the adequate refurbishment and remanufacturing processes are defined. Such defined processes remove all life reducing effects on the functional surfaces and restore the full life capability. ⇢ But our service offers even more: in addition to bearings from our own production, we also diagnose and repair bearings manufactured by other companies. ⇢ As an added value to our customers, we also provide consulting services to OEM’s and overhaul facilities with regard to the set-up and required equipment for service shops. Personnel training courses for bearing handling, inspection and diagnosis are offered as well to our customers.

- ⇢ The diagnosis and refurbishment of used bearings is conducted by applying state of the art inspection and remanufacturing technologies of a worldwide leading bearing manufacturer
- ⇢ Inspection reports are provided for each assessed bearing
- ⇢ Short turn-around times
- ⇢ Reduced maintenance cost for our customers

Quality thinking –
the basis for every trust

Quality Management

Even minor damage or imperfections to an aerospace bearing can put people's lives in jeopardy and can cause substantial financial hardship. This imposes a critical responsibility for Total Quality. To assure the highest level of quality and reliability, we apply our Quality Management philosophy throughout the complete development and production process beginning at the conceptual design phase. ⇢ Our Joint Development and Co-Engineering activities conducted in close cooperation with our customers lay the foundation for the optimized design of our engineered bearing systems. ⇢ Our Computer Aided Design and Computer Integrated Manufacturing technologies ensure a high level of manufacturing efficiency and data accuracy. Statistical Process Control is pervasive in all plants providing predictive process information and ensuring the highest level of process control. ⇢ Our computer aided quality planning and inspection techniques are applied with the goal of "first time right". ⇢ Our advanced SAP MRP tool for computer aided capacity and production planning helps maintaining a world-class delivery performance standard. ⇢ Our state-of-the-art manufacturing facilities and technologies enable the highest quality standards and cost competitiveness. ⇢ Our continuous improvement activities ensure permanent progress in the quality and velocity of all business and manufacturing processes such that our customers can count on FAG being a long term contributor to their success. ⇢ Our highly skilled, motivated, and customer focussed employees guarantee a high level of service and responsiveness. ⇢ Our commitment to providing world-class Total Customer Service Excellence supports the future of all our partners. ⇢ We are a certified supplier to all major aerospace companies worldwide and hold the following official certifications: AS9100; ISO 14001; EASA Part 145; FAR 145; EASA Part 21 Section A – Subparts G and J.

⇢ Customer and AS9100 certified
⇢ Total Quality philosophy for Total Customer Service Excellence
⇢ Your partner for success


Expect the unexpected
means avoiding risks

Testing Services

Safety, reliability and cost effectiveness are indispensable characteristics of modern aviation and aerospace technology. Using innovative analysis tools and simulation techniques as well as advanced component and bearing rig testing methods we help to ensure the optimum bearing designs, materials and processes for each application. By rig testing of our aerospace bearings under real-life conditions, potential risks can be identified in an early stage and mitigated prior to introduction into the application. This helps to save development time and cost for our customers, and to achieve the goal of a “first time right” design going into an application. These benefits have been successfully proven in many joint rig testing programs conducted with our customers. Some of our major testing objectives. ⇢ Comprehensive material properties and element testing to assess new material technologies. ⇢ Bearing life testing programs to substantiate and statistically support the life capabilities of new materials, heat treating processes, lubricants, coatings and manufacturing technologies. ⇢ Pre-qualification rig testing programs to assure technology maturity. ⇢ Pre-qualification rig testing campaigns at typical operating or flight-cycles and at speed indices $d_m \cdot n$ exceeding 3 Mio. for design substantiation and risk mitigation. ⇢ Application specific performance testing such as heat generation, skidding, oil-off, damage propagation and many others. ⇢ Together with our customers, we cater for the safety, reliability and cost effectiveness of future aerospace projects and strive for continuous advancements in aerospace bearings technology.

- ⇢ Unique design and analysis tools for optimized bearing design
- ⇢ Full material and element testing capabilities
- ⇢ Comprehensive small-scale and full-scale bearing testing facilities to substantiate a reliable bearing design
- ⇢ Professional, experienced and committed employees
- ⇢ Saving development time and cost for our customers


Consistently high quality
means constant improvement

High-tech Production

Our production facilities for aerospace bearings, components, and systems employ specially developed machines, production techniques as well as specific measuring and inspection equipment. Every production step of every single bearing component is documented and “frozen” to assure process repeatability and consistent high quality of our aerospace bearings. By the use of new materials and constantly improving products, we have attained a level of quality in the aerospace field that is unmatched.

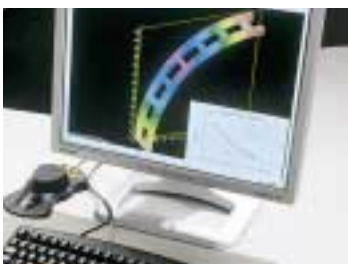
→ The high quality standard of our aerospace products is backed by the fact that all the critical production processes are carried out in-house – from forging, through heat treatment, to the finishing processes of the bearing parts. FAG also has in-house production of rolling elements and cages. FAG is the only aerospace bearing manufacturer that applies all these same resources to the Refurbishment Service. → Our production technology is always state-of-the-art. Nonetheless here, just as in the development of innovative products, we are constantly striving to find new techniques and make the existing techniques better for continuously improved product quality and reliability. In this continuous evolution of applied manufacturing technologies, our focus is not only on bearings but also on the vision of integrated bearing systems that will further reduce part counts, tolerances, weight, and of course total cost for our customers applications. Thanks to our modern high-tech production and our focus on technology advancement, we are able to meet the current and future demands of our customers for improved product quality and reliability, shorter development time and lower total cost.

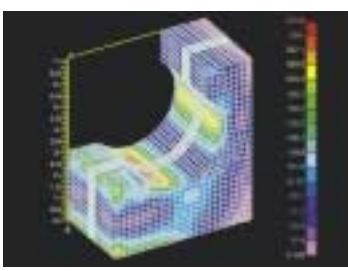
- → Specially developed production and inspection techniques
- → Documentation of all production steps for every single bearing component
- → Use of the most modern materials and production technologies
- → All critical production steps carried out in-house


Success factor for the future –
achieving more with less

Research & Development

Faster, higher, farther. But also safer, more reliable and cost-effective. These are the technology requirements of the future, especially in the aerospace industry. The current demands on aerospace applications challenge us to develop new materials, production processes, bearing designs and systems and to perfect the existing ones as well. "Design for life" is the utmost goal of our research and development activities. With success: Our research and development work has contributed and is contributing significantly to improve the service life of aerospace bearings and to attain enormous advancements with regards to reliability, efficiency and cost reductions. This profits our customers, business partners and even the entire aerospace industry. ⇢ FAG significantly contributed to the development of integrated bearing designs: less components and significant weight reduction for better performance and reliability at effectively lower system costs. ⇢ FAG is leading in the development of new bearing materials and material heat treatment as well. Besides using established materials, new corrosion resistant case hardened and through hardened bearing steels and ceramic rolling elements have been successfully introduced into various applications. ⇢ Our advancements in the surface engineering of the rolling contact areas have led to more robust aerospace bearings. ⇢ Continuous improvement and development of non-destructive testing methods for added reliability of our bearings. ⇢ Developing new analysis tools, the computer simulation of the dynamic behaviour of bearing systems and comprehensive bearing testing capabilities are essential steps for achieving better bearing designs at shorter development times. ⇢ We are committed to continuous advancements in aerospace bearings technology and view innovation as our ticket into the future.





- ⇢ "Design for life" is the utmost goal of our research and development activities
- ⇢ Material engineering, heat treatment and surface technology
- ⇢ Development of non-destructive inspection methods
- ⇢ Performance and prequalification testing of fullscale bearings under "real-life conditions"
- ⇢ Theoretical fundamentals and computation of dynamic behaviour of bearing systems

Imprint

Publisher

FAG Kugelfischer AG & Co. oHG

Business Unit
Aerospace/Superprecision

Contact Europe, Asia

Phone: +49 (0) 97 21/91-39 69

Fax: +49 (0) 97 21/91-34 96

Contact North America

Phone: 001 519 271 3231 Ext. 318
800 363 5574

Fax: 001 519 273 8512

www.fag.com

Photo credits

FAG, Klaus-Ulrich Köhler,
except pages
Title: NASA, Getty Images
2, 3: Rolls-Royce
4, 5: NASA
6, 7, 8, 9: Getty Images
12: Airbus
15: Lockheed Martin
16: Sikorsky
14, 18, 19, 20: Corbis

Printed on
chlorine-free paper

Design: Buena la Vista AG, Würzburg Germany

Innovation in Motion

FAG Kugelfischer AG & Co. oHG

Business Unit
Aerospace/Superprecision

Georg-Schäfer-Strasse 30
D-97421 Schweinfurt

Phone: +49 (0) 97 21/91-0
Fax: +49 (0) 97 21/91-34 35

www.fag.com

FL 09110 EA

97/06/05 Printed in Germany