APO-GEE TALK

SPECIAL EDITION:

How space bearing innovation meets new automotive challenges

APO-GEE
BALL BEARING ENGINEERING

March 2026

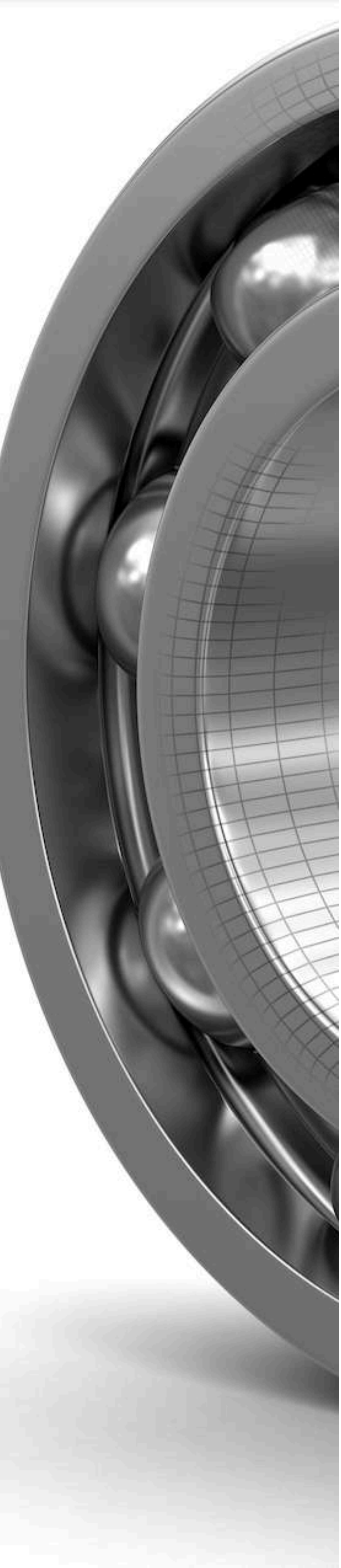


Table of content

From electrification demands to a new paradigm in bearing technology.. 3

Trends in the automotive industry: bearings under pressure.. 4

New challenges with electric vehicles.......................... 5

New automotive paradigms, but what about bearing technology?.. 7

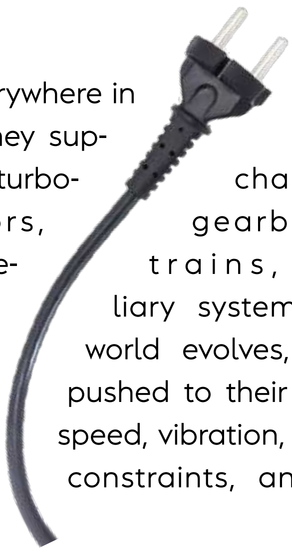
A bearing paradigm shift.. 8

Can we believe it?
From Tier 1 to Formula 1.. 9

How space bearing innovation meets new automotive challenges

1. From electrification demands to a new paradigm in bearing technology

The automotive industry is undergoing one of the most profound transformations in its history. Electrification, new mobility architectures, and increasingly demanding customer expectations are reshaping the way vehicles are designed, manufactured, and experienced. While much of the attention is focused on batteries, software, and electric motors, another essential component is quietly becoming a central challenge: the **ball bearing**.



Bearings are everywhere in modern vehicles. They support rotating shafts, turbochargers, electric motors, gearboxes, alternators, drivetrains, and countless auxiliary systems. As the automotive world evolves, bearings are being pushed to their limits in terms of speed, vibration, noise, thermal constraints, and reliability.

Interestingly, some of the most promising solutions to these challenges are not emerging from incremental automotive development alone, but from a field where constraints are even more extreme: space engineering. This APO-GEE TALK special edition explores how bearing innovations originally developed for space applications are now addressing the new demands of electrified vehicles, offering disruptive solutions where traditional approaches reach their limits.

2. Trends in the automotive industry: bearings under pressure

The automotive sector is currently shaped by several strong and converging trends.

First, electrification is accelerating rapidly. Electric vehicles are no longer a niche market; they are becoming the new standard. This transition affects not only propulsion systems, but also the entire mechanical ecosystem surrounding them. Second, demand for bearings has never been so strong. Electrification increases the number of high-speed rotating components in vehicles, while new architectures often require more compact and integrated solutions. The result is a growing need for bearings with higher performance, higher reliability, and greater efficiency. Third, performance expectations regarding noise and vibration have never been more important. In internal combustion vehicles, the engine noise masked many mechanical phenomena. In electric vehicles, the drivetrain is far quieter, meaning that even lower bearing-induced noises can become clearly audible and unacceptable. Finally, speed requirements have increased dramatically. Electrified powertrains and turbo-machinery in hybrid systems operate at rotational speeds that were previously uncommon in automotive environments. Bearings are now expected to perform reliably at speeds close to or even beyond traditional catalog limits.

These trends converge into one reality: bearings are no longer standard commodity components. They are becoming **key enablers**, and **potential bottlenecks**, of the next generation of vehicles.

3. New challenges with electric vehicles

The electrification of vehicles brings many benefits, but also introduces new technical challenges for bearing engineers. Two major challenges stand out: **noise and vibration** for one hand; and **speed** for the other.

<u>**Challenge 1: Noise and vibration - beyond comfort**</u>

Noise and vibration issues are not new in automotive engineering, but the electrified context amplifies them significantly. The first objective is straightforward: reducing vibration levels at all operating conditions. This is essential not only for driver comfort, but also for reliability. Vibrations accelerate fatigue, increase wear, and can cause premature degradation of components in the drivetrain. In EVs, where customer expectations of smoothness are extremely high, vibration control becomes a major differentiator.

The second objective is more subtle, and increasingly critical: eliminating the **cage instability phenomenon**. The bearing cage is the only component inside a ball bearing that is not mechanically constrained. Unlike the rings or the balls, it is free to move dynamically, and under certain operating conditions it can become unstable. This instability can generate unexpected high-frequency noise and vibrations, and even lead to cage breakage. Engineers often describe this phenomenon with terms such as « rattling noise », « hooting noise », « frog noise » or « intermittent squealing ». The most challenging aspect is that this noise is

not constant. It can appear and disappear unpredictably, making diagnosis extremely difficult.

Cage instability has already caused significant engineering challenges in several demanding automotive applications, including turbochargers, alternators, cardan shaft bearings, motor-generator units, or high-speed auxiliary systems. As EV architectures become demanding, the risk of cage instability increases further. This challenge remains poorly understood in the industry, and conventional cage designs have limited ability to fully eliminate the phenomenon.

Challenge 2: The speed challenge - no more compromise

The second major challenge is speed. However, speed in automotive does not simply mean higher maximum RPM. It also means optimized performance across the entire speed range, from low-speed heavy-load conditions to ultra-high-speed operation.

Until now, overcoming high-speed requirements has come at the cost of an unsatisfactory compromise. To cope with high speeds, bearings were typically designed with small balls and open curvature grooves. This configuration reduces centrifugal forces and allows high-speed rotation, but it performs poorly under heavy or combined loads. On the other hand, to support high loads, engineers traditionally needed larger balls and tighter groove curvature. This improves load capacity but makes high-speed operation extremely difficult due to increased friction or heat generation.

Thus, engineers have long been forced to choose between high speed capability or high load capacity. This creates a recurring problem in turbochargers for example, where extremely high rotational speeds must be achieved while also ensuring excellent robustness and reliability at intermediate operating regimes. This challenge is becoming even more critical today, as electrified vehicles increasingly require both high-speed capability and strong load performance simultaneously.

4. New automotive paradigms, but what about bearing technology?

Significant efforts have been made to improve bearing performance in response to these challenges.

These improvements are real and valuable. However, an important question remains: are these incremental improvements sufficient to follow the rapid evolution of electrified vehicle requirements? Despite progress, electrification has forced engineers to operate closer and closer to catalog limits. As a direct consequence, many situations arise where anomalies such as unexpected noise, vibration peaks, overheating or cage degradation, are not only difficult to diagnose precisely, but also difficult to solve without compromising expected performance.

Hybrid bearings, for instance, using ceramic balls, have become increasingly common in automotive. While the technology has existed for decades, it is now more widely adopted due notably to its electrical insulation properties, critical in EV motor environments. Major research is also underway in advanced materials, lubrication technologies, surface treatments, and manufacturing efficiency and precision.

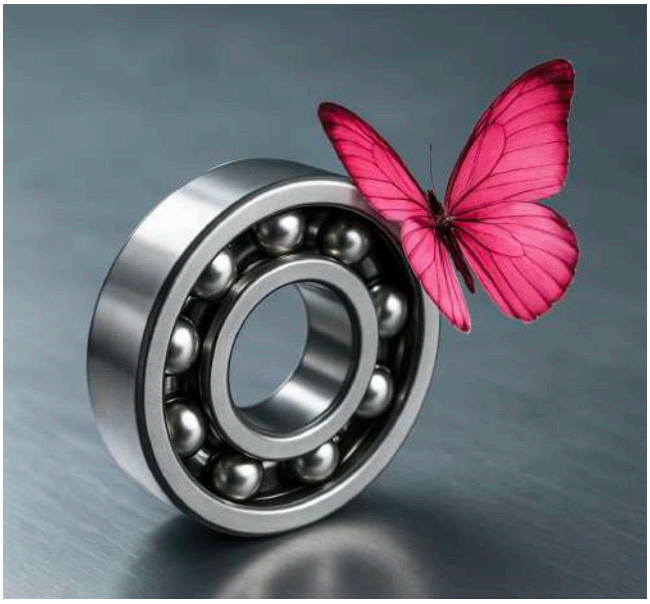
This suggests that incremental innovation alone may not be enough.

5. A bearing paradigm shift

The considerations above lead to an important conclusion: incremental bearing innovation, while concrete and valuable, may not be sufficient for the disruptive challenges of modern automotive electrification.

The key question becomes: are disruptive innovations with significant and immediate benefits possible and realistic?

The answer is **yes**. And the good news is that solutions already exist, originating from space engineering.



Solving cage instability: the Butterfly cage

For cage instability, a concrete solution has been developed: the **Butterfly cage**. Born from more than ten years of intensive research, this cage was initially created to solve instability problems in space applications, where vibration, reliability, and noise constraints are even more extreme than in automotive.

The Butterfly cage not only prevents cage instability, but also provides an overall background noise and vibrations level lower than any traditional cage design. It has been fully tested up to catalog limits and is already implemented in demanding applications, including space mechanisms, machine-tool spindles and other high-performance rotating systems.

In addition, the Butterfly cage has demonstrated improved thermal behavior compared to conventional designs, giving engineers greater flexibility in assembly design and operating margins.

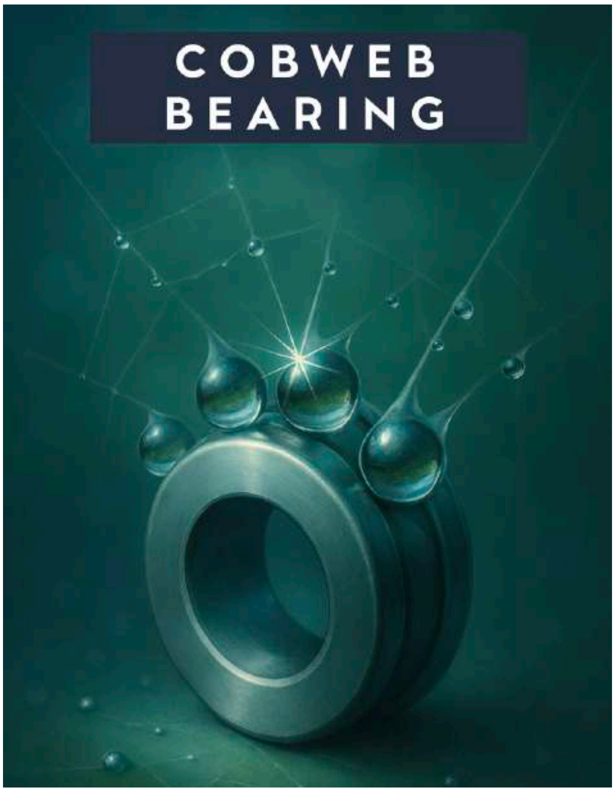
For automotive engineers facing unpredictable noise phenomena, this represents a breakthrough solution.

BUTTERFLY CAGE

Solving the speed challenge: the Cobweb bearing

A second disruptive innovation now exists to address the speed compromise: the **Cobweb bearing**. As mentioned here above, traditional bearing design forces an impossible trade-off between high-speed and high-load capacity. Now, the compromise is over.

The Cobweb bearing introduces an auto-adaptive groove profile that combines the best of both worlds: high-speed capability AND heavy and combined load support. This innovation was originally developed for a space challenge: the turbopumps of rocket launchers, where extreme rotational speeds and loads coexist. Today, it is directly applicable to turbochargers but also in high-demand automotive competition for instance.



The Cobweb bearing innovation is based on a fundamental question: why should the raceway groove profile always be circular? Non-circular optimized profiles can provide superior adaptive behavior, opening new possibilities in bearing design that were previously unexplored.

6. Can we believe it?

From Tier 1 to Formula 1

It is understandable that such innovations may initially sound difficult to believe. However, they are the result of more than a decade of continuous R&D driven by real operational problems in space applications. The performance of these solutions, as well as the original diagnostic and design tools developed alongside them, has been demonstrated in the aerospace sector.

Today, these innovations are being transferred into concrete industrial applications, offering direct answers to the new challenges of vehicle electrification.

The strongest proof lies in APO-GEE's collaborations with prestigious partners, including Tier 1 automotive suppliers and a Formula 1 racing team. This clearly demonstrates that APO-GEE is capable of delivering solutions where innovation, reliability, and performance are the key drivers.

The automotive industry is entering a new era where bearings play a strategic role in achieving performance, comfort, and reliability targets. Electrification pushes bearings toward unprecedented demands: lower noise, reduced vibration, higher speeds.

Incremental improvements alone may not be enough. Disruptive innovations, born in the extreme constraints of space, are now providing a new paradigm for automotive engineering. The Butterfly cage and Cobweb bearing represent concrete breakthroughs, offering engineers new tools to overcome the limitations of traditional bearing design.

The question is no longer whether disruptive bearing innovation is possible.

The question is: what will you do now? ◆

About APO-GEE

APO-GEE is the Belgian deep-tech start-up specialized in innovative ball bearing solutions.

APO-GEE helps aerospace and defense compagnies with innovative products and dedicated high-value services related to ball bearings used in harsh environments and severe conditions.

APO-GEE'S tools and methods have also proven highly effective in other demanding industries such as in machine-tools, medical techs, and automotive.

Driven by innovation and intellectual property development, APO-GEE has introduced major breakthroughs in the bearing industry, including the Butterfly cage (an unconditionally stable cage), the Cobweb bearing (the smoothest high-speed bearing) and APO-GEE's unique computational tools.

APO-GEE is located in the Liège Science Park, Belgium, in a premium environment dedicated to deep-tech start-ups.

www.apo-gee.tech