Morales Espejel

A real-world view of hybrid bearing life

A new modelling approach is helping engineers pick the right bearing for the right application

Hybrid bearings, which use ceramic rolling elements on steel raceways have some well-known advantages over their all steel counterparts. Those advantages include low weight, good electrical resistance and good performance under demanding lubrication and contamination conditions, characteristics that have earned hybrid bearings an important niche in specialist applications like high speed machine tool spindles for more than 50 years.

Over time, the range of possible uses for hybrid bearings has grown. In part this has been due to advances in manufacturing technology, which have brought down costs. But users have also found that in many circumstances ceramic rolling elements can outperform those in all-steel bearings. For example, they generally exhibit lower operating temperatures, are more resistant to surface damage from particulate matter, and do not suffer from the potential risk of steel-to-steel surface welding, which can occur in traditional bearings under extreme conditions. Additionally, hybrid bearings have a lower boundary-lubrication coefficient of friction, which allows them to function more efficiently in applications with poor lubrication.

Until now, however, it has been difficult for engineers to know in advance whether a hybrid bearing will outperform a steel one in their application, or whether the possible performance benefits are worth the extra cost. According to Guillermo Morales-Espejel, Principal Scientist as SKF Research and Technology Development, that's because the existing equations engineers normally use to calculate the rating life of a bearing don't reflect the real-world performance of hybrid designs.

"The conventional bearing life model is based on sub-surface fatigue," he explains. "As bearings rotate, their components are continually loaded and unloaded. Over millions of cycles, fatigue accumulates in the material, eventually leading to failure." Because fatigue behaviour is well-understood, engineers can plug information about the loads and speeds expected in their application into an equation to determine the rating life of a given bearing design. The dynamic load rating C, which can be found for any bearing in the SKF general catalogue or in the online product catalogue, is mainly used to quantify the sub-surface performance of the bearing."

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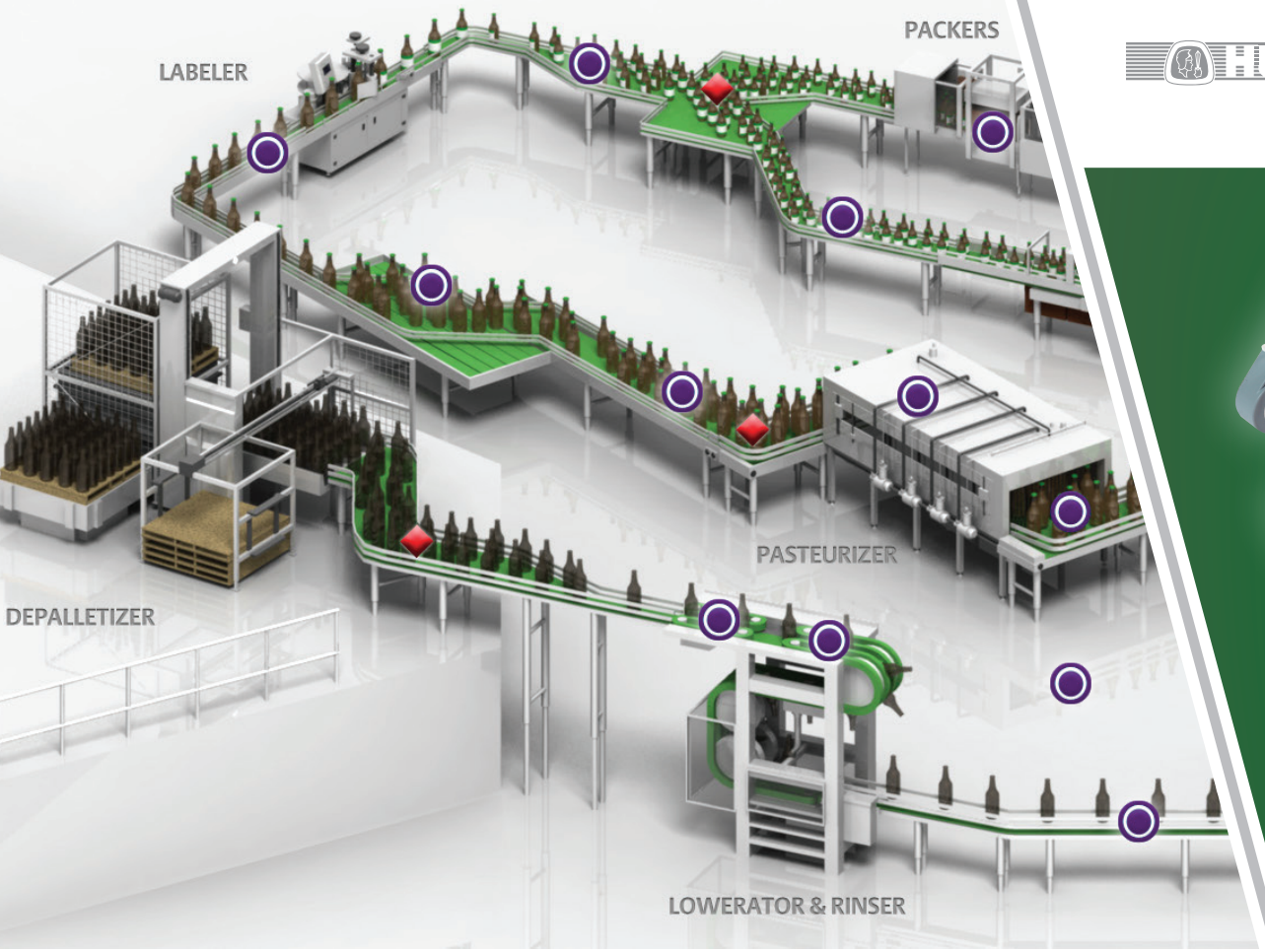

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This traditional model is widely used and incorporated into international standards, but Morales-Espejel notes that it doesn't show hybrid bearings in the best light. "Because the ceramic rolling elements are stiffer than steel, they deform less under load. That means loads are concentrated over a smaller area of material, increasing stress and accelerating sub-surface fatigue."

More significantly, however, real-world experience doesn't always align with the traditional model. "We know from experience in the field that the majority of bearings fail due to problems at the surface, not in the body of the material," explains Morales-Espejel. "The root cause is usually damage caused by poor lubrication or contamination." Nobody disputes that analysis, and modern standards such as ISO 281 include correction factors in an attempt to accommodate these effects.

A new model

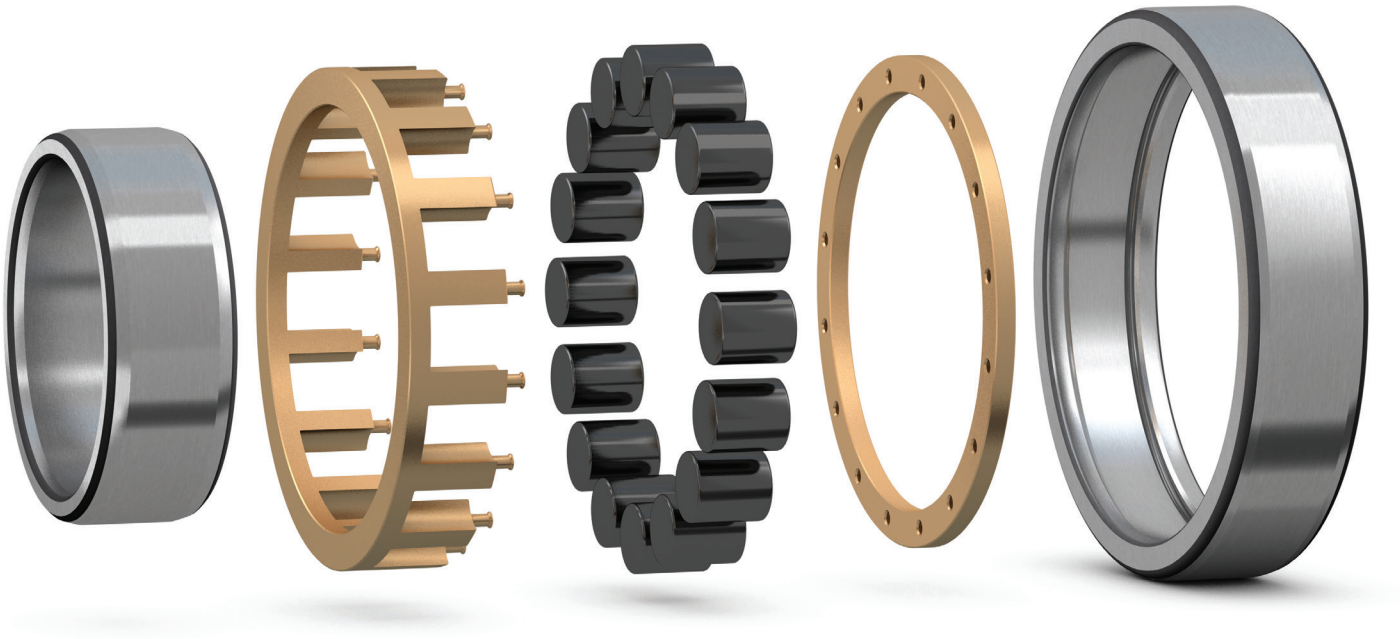
Those correction factors didn't attempt to represent the real behaviour of bearings in service, however, so in 2012, Morales-Espejel and colleagues at SKF set out to do better. To create a new bearing life model, he says, they needed three things. "The first was a model of sub-surface fatigue within the material, which we already had. The second was a model for failure at the surface. The third was data from endurance tests that we could use to calibrate and validate our model."

The SKF team worked on the new model over the next two years, drawing on decades of study in materials science and tribology. The approach required a detailed understanding of the behaviour of bearing surfaces, from their friction characteristics to the way dirt particles indent them under load.

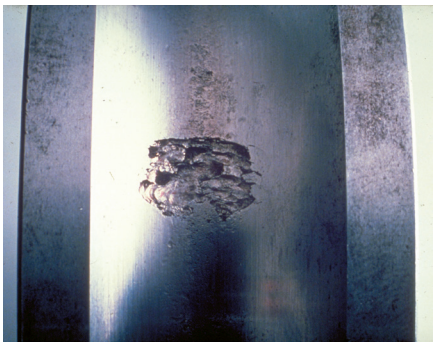
Although an initial concept model was presented as a Generalized Bearing Life Model (GBLM) in 2015 at the Hannover Messe, at that time it did not cover the modelling of hybrid bearings.

"One needs data to calibrate and then validate any bearing life model. To collect enough data for this, however, there is no substitute for hard craft. We needed data on the operating life of bearings over a wide range of loads and surface conditions," explains Morales-Espejel. "We were trying to build behaviour curves. For each point on the curves we needed to test around 30 bearings, with the expectation that several of them would fail." The SKF team also needed to compare bearings with steel and ceramic rolling elements, and bearings operating with poor lubrication and in contaminated environments.

All this added up to hundreds of tested bearings. In total, the test programme and the adaptation of the concept model required a further four years of effort by scientists and technicians at SKF's facilities in the Netherlands and Austria.



The SKF team completed its new Generalized Bearing Life Model for hybrid bearings in mid 2018. The approach has since been tested and approved by an important group of company's application engineers, who used prototype versions of the model alongside conventional



bearing life estimation techniques, and compared its outputs to their real-world experience on customer projects.

Real life insights

What does the new model mean for engineers and designers? "We already knew that hybrid bearings had advantages in many commonly experienced conditions," explains Morales-Espejel. "When a bearing is heavily loaded, but able to run in a clean, well-lubricated environment, sub-surface fatigue is likely to be the ultimate failure mode, and a steel bearing may perform better than a hybrid. But a lot of bearings operate under lighter loads, but with a greater likelihood of poor lubrication or contamination. Our model will show if a hybrid solution would offer a longer life on those applications and will quantify the difference."

In a scientific paper presented earlier this year, Morales and his colleagues have run those calculations for four representative real-world applications. In the case of a pump bearing running with oil-bath lubrication and diluted oil resulting in poor lubrication, the rating life of a hybrid bearing was eight times longer than a steel equivalent. For a screw compressor bearing running with contaminated lubricant, the hybrid offered a rating life time a hundred times greater than a conventional steel bearing.

In the other two cases, which looked at an electric motor operating in clean, well-lubricated conditions under two different load regimes, the rating life of the hybrid bearing was very similar to the conventional bearing. The paper's authors note, however, that in these cases other potential benefits of hybrid technology, such as electrical resistance or a longer grease life, might be the decisive factors in bearing selection.

Morales-Espejel and his team have developed two variants of their Generalized Bearing Life Model for hybrid bearings: One version is set to be incorporated into the webtool "SKF Bearing Select" that SKF offers to its customers on-line and through dedicated software applications. A second, more sophisticated and complex variant, will be used by the company's application engineers to support customer projects.