

SKF Contributes to Climate Change Mitigation with Friction Optimized Wheel Bearings

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ABSTRACT

Bearing friction is a direct contribution to vehicle CO₂ emissions. The friction is defined as the total resistance to rotation, resulting from the combination of rolling and sliding friction in the contact areas. First, friction reduction was approached from a theoretical standpoint by employing modeling and simulation techniques. Improvements identified in simulation were then used to: create a new set of design rules for the internal geometry of the bearing, introduce a new grease, develop new seals, also with the integration of labyrinth functions and an optimization of the preload range variation. In order to provide a reliable confirmation of the expected achievements, a new friction measurement methodology was also introduced.

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INTRODUCTION

In December 2015, 195 countries reached a universal and legally binding global climate agreement at the Paris climate conference (COP21). The target was to keep the global warming below two degrees Celsius by 2100, compared to the temperature in pre-industrial levels. Without global action, current previsions for global warming are above four degree Celsius. Two thirds of the greenhouse gases responsible for global warming, consist of carbon dioxide (CO₂) deriving from the combustion of fossil fuels. Transportation contributes to around 30% (reference U.S., [1], [2]) of CO₂ emissions. It is thus clear how important it is for original equipment manufacturers (OEMs) to reduce the emission of their vehicles.

Wheel bearings refer to the components connecting the wheel rim to the vehicle via driving, steering, suspension and braking systems when relevant. Wheel bearings are divided into three generations of Hub Bearing Units (HBU, [Figure 1](#)), based on angular contact bearings with either balls or tapered rollers. The first generation is the compact version, with a cylindrical outer diameter and a two-piece inner ring. The second generation has typically a rotating outer ring that integrates a flange with threaded holes or studs and a spigot to center and mount wheel and brake disc. The third generation integrates flange to both inner and outer rings for directly mounting the wheel and the brake drum or disk on the rotating ring and knuckle on the static ring.

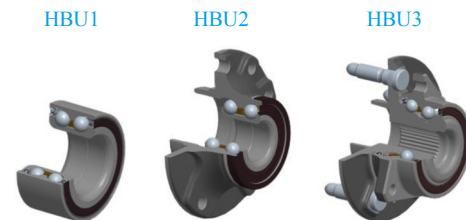


Figure 1. Three generations of HBU

For almost 10 years SKF has taken the challenge to positively contribute to reduce vehicle CO₂ emissions by reducing friction of the hub bearing units by 50%. This paper describes the main results reached, both in terms of product and process development. The use of Design for Six Sigma methodologies enables a structured statistical approach for the development. For Research and Development (R&D) projects, in order to make a robust assessment of the effect of the new features introduced, a minimum batch size of 12 bearings have to be validated, both in clockwise and counterclockwise directions.

The bearing components that contribute to a bearing's friction include the seals, the ball-set, the cage and the grease, split as indicated in [Figure 2](#). The chart has to be considered for general reference, it may vary according to the specific application.

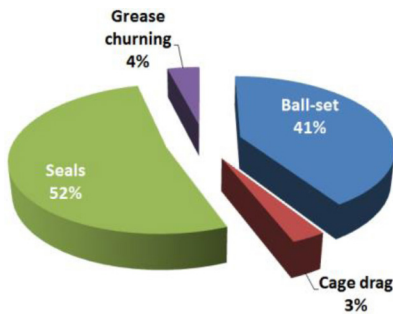


Figure 2. Bearing friction source

The drag reduction has been obtained with focus on the two main aspects: ball-set and seal. Considering the ball-set, the geometry has been optimized and a new grease has been developed. For a third generation wheel bearing, a new design has been developed together with an optimized manufacturing process that reduces the preload range, which is directly connected to the final friction of the bearing. Considering the seal a specific seal grease and a surface treatment of the sliding surface have been introduced and components have been shaped to create a labyrinth to limit the contaminant ingress. A new test methodology has been implemented on the friction measurement in order to have a more reliable procedure compared to existing one.

LOW FRICTION BEARING

Regarding the ball-set friction, two major activities have been run, on the geometry, [Figure 3](#) and on the grease, [Figure 4](#), both having the additional challenge of not affecting the reliability of the bearing. The target for the geometry improvement project, was to obtain an 8% friction reduction with a higher stiffness-friction ratio and an increased bearing life. The target for the low friction grease activity was to obtain a 9% friction reduction compared to baseline, without any change in the ball-set geometry.

Both concepts are applicable to all three generations of hub bearing units and are suitable both for new designs and retrofit on existing products.



Figure 3. Low Friction HBU



Figure 4. Low friction grease

Method

For the development, different simulation tools have been used. For the selection of the optimal ball-set and grease configuration, parametric calculations have been performed using SimPro Expert (SKF proprietary software). This considers the same sources for the ball-set friction as indicated in the SKF rolling bearing catalogue 10000: rolling and sliding resistance [3].

The estimation of the contribution of the bearing friction to the CO₂ emissions of a vehicle has been evaluated using the SKF proprietary software Vehicle Environmental Performance Simulation (VEPS). The assumption is to use four bearing units in a car, tested according to the New European Driving Cycle (NEDC, [4]), considering an annual mileage of 14,500 km and a car life of 245,000 km. The input data are based on a C segment vehicle class:

- Overall vehicle emission: 156 g/km
- Contribution of 4 Hub Bearing Units: 1.7 g/km

Benefits could vary according to the application as they are subjected to bearing size, type and testing conditions.

For the low friction hub bearing unit the focus was on changes in the ball-set geometry, therefore all of the prototypes were realized with the same manufacturing process and 100% of the significant parameters were measured. A statistical study was performed to verify the geometrical dimension distribution.

During the physical validation, the following tests have been performed for both projects:

- Endurance testing: up to failure, to get a proven statistical result.
- Friction Evaluation: a new specific procedure has been developed, as reported in the section "Friction measurements".

In addition to these, for the ball-set optimization, the stiffness measurement was also required, as the target is to increase the stiffness to friction ratio compared to the baseline.

For the low friction grease, the false brinelling test -20/+20 °C was required. The false brinelling is a wear phenomena, mainly due to absence of lubrication in ball-raceway contact caused by standstill

loads (no rotation). Two different procedures were used for test: Fafnir test, according to ASTM D 4170 that is the standard test method for fretting wear protection by lubricating greases, and the SKF Fretting Wear. After the fatigue test the following analyses were performed: residual grease life, X-Ray analysis, and chemical laboratory analysis.

Results

The Low Friction (LF) HBU obtains an average friction reduction of 8%. One of the targets was also to increase the stiffness to friction ratio. In Figure 5, a comparison of existing hub bearing units is shown. It is possible to see that moving from a standard HBU3 to a X-tracker solution, the stiffness significantly increases and there is a small increase in friction (around 3%). The low friction X-tracker is a solution that permits to have the same stiffness as the standard HBU3, but at significantly lower friction. On the other hand, moving from an HBU3 to a low friction HBU the resulting friction is lower than for the low friction X-tracker, while the resulting stiffness varies according to specific customer requirements.

The X-Tracker is an asymmetric hub unit design, presented at the 2006 Brake Colloquium [5], consisting of a double row bearing arrangement in which the outboard row is at a higher pitch diameter and contains more rolling elements than the inboard row. The terms outboard and inboard are referred to the mounted condition in the vehicle. Outboard refers to the wheel side, while inboard is opposite to the wheel side. The X-Tracker significantly increases the bearing stiffness compared to traditional symmetrical hub units and provides a higher carrying capacity and performance.

The Low Friction (LF) X-Tracker, presented at the 2010 Brake Colloquium, [6], combines the X-tracker geometry with an optimized raceway geometry and friction optimized seals.

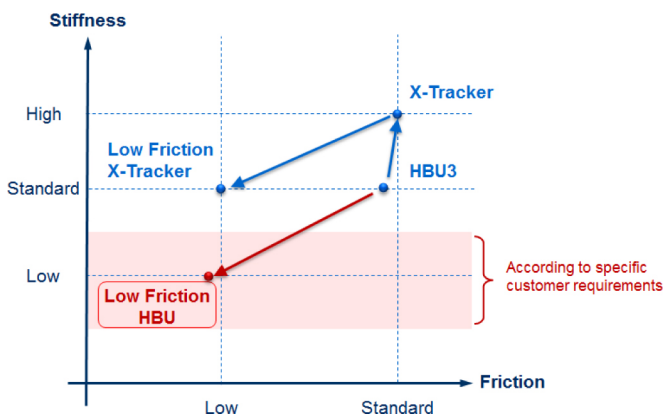


Figure 5. Comparison friction vs stiffness on different HBUs

Considering the low friction grease, Figure 6 shows the friction test results with the NEDC cycle, providing a comparison with the GHG baseline, that is the standard HBU grease, with the new low friction grease.

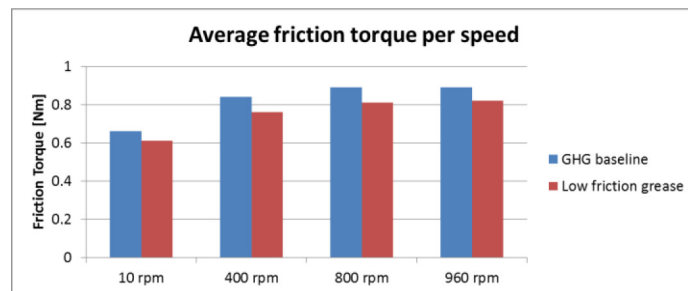


Figure 6. NEDC cycle - Low friction grease

Table 1 reports a split of the values obtained.

Table 1. Friction values - NEDC cycle - Low friction grease

Average friction per speed						
Speed	rpm	10	400	800	960	Complete cycle
GHG baseline	Nm	0.66	0.84	0.89	0.89	0.82
low friction grease	Nm	0.61	0.76	0.81	0.82	0.75
Δ from baseline	%	-8.5%	-9.3%	-9.7%	-7.4%	-8.8%

- Based on a reference Sedan application

In Table 2 the overall work absorbed during the cycle is indicated. The reduction of energy absorbed compared to standard grease is 9.5%.

Table 2. Work absorbed - NEDC cycle - low friction grease

Energy absorbed during NEDC cycle		
	Unit	NEDC cycle
GHG baseline	KJ	35.8
low friction grease	KJ	32.4
Δ from baseline	%	9.50%

Here only the low friction grease results are provided, but similar trend were obtained also for the low friction HBU.

The friction measurement has been evaluated with statistical methods taken from Design for Six Sigma toolbox, Figure 7.

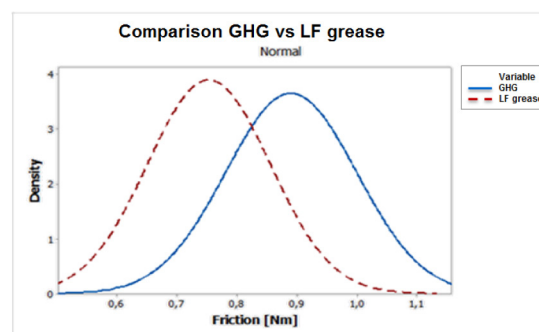


Figure 7. Statistical assessment of friction data