The evolution of railway axlebox technology

In the first of a two-part article on railway axlebox design, we look at the evolution of this key railway subsystem from an historical perspective. As a company with a long tradition of developing axlebox solutions, SKF has always addressed environmental issues such as energy conservation and lubrication saving for this market.
Through the application of tribology, the study of friction, lubrication and wear, engineers and scientists have learned much about the interaction of surfaces in relative motion. Examples of applied tribology can be found in transport. For railways, the humble beginnings of wheel and axlebox designs has evolved through early antifriction axlebox bearings to the latest development of highly sophisticated axlebox bearing units and complex solution packages covering bearings, seals, lubrication, mechatronics (e.g., sensors to detect operational parameters) and a comprehensive range of services.

**The first railways**

One of the early energy-saving examples is the Linz, Austria – Bratislava, Czech Republic horse railway, mainly built for the transport of salt, which was then very expensive. The 130-km-long line was opened in 1832. At that time it was by far the world’s longest railway connection. Fig. 1 shows that a rail system could carry eight to 10 times the load of a road transport.

**Axlebox bearings**

Some early patents exist but there is no evidence that they were all applied. Three-axle passenger cars, launched in 1903, were one of the first well-documented antifriction axlebox bearing applications. The cars were equipped with axleboxes, each of which incorporated two deep groove ball bearings (fig. 2a). The traction effort for a two-car set with a total weight of 33.15 tonnes was 4.4 kN with sliding bearings and only 0.62 kN with ball bearings, which is a reduction of 86% (fig. 2b). The bearings and axleboxes were manufactured by Deutsche Waffen- und Munitionsfabriken A.G. (DWF) in Berlin, Germany. This company later became part of the Vereinigte Kugellagerfabriken (VKF), which in turn was acquired by SKF.

A further test was carried out in 1905 in the United States by Professor Graham of the Syracuse University in New York. He conducted research into energy consumption in the form of a comparison field test of two trams, the first equipped with sliding bearings and the second with roller bearings (fig. 3a). Energy consumption over the route for the tram using sliding bearings was 6.45 kWh; compared to 3.10 kWh for the tram with roller bearings – an energy saving of 52% (fig. 3b). In 1907, the Syracuse Rapid Transit Cooperated told the Standard Roller Bearing (SRB) Co in Philadelphia that after 4.5 years of operation and some 400,000 kilometres, the roller bearings showed no wear. The annual saving in coal to generate the electrical power needed was 260 US dollars per year per vehicle, equal to 390 g of gold. The Standard Roller Bearing Co later became part of the Marlin Rockwell Corporation (MRC). SKF acquired MRC in 1986.

**Meeting the need for speed**

Speed has been the essence of railways since the first steam locomotive made its appearance in 1804. SKF remains at the forefront of high-speed train design, providing some of the most safety-critical components of railway vehicles – the wheelset axlebox assemblies, comprising the wheelset bearings or bearing units, the axlebox housing and integrated sensors. SKF has always been active in developing solutions to meet the challenging requirements of high-speed train builders and operators, for the
Axlebox bearings and bearing units

Ball bearings

**Deep groove ball bearings**
- One of the first axlebox applications by DWF, Germany (later acquired by SKF).
- Design: Arrangements with one or two bearings.
- Present status: Historical relevance only, replaced by roller bearings because of higher load-carrying capacity.

**Self-aligning ball bearings**
- Invented by Sven Wingquist, Sweden (later SKF). 1911 first SKF axlebox application.
- Design: Arrangements typically with two bearings.
- Present status: Historical relevance only, replaced by spherical roller bearings because of higher load-carrying capacity.

**Needle or long roller bearings**
- One of the first axlebox applications by SRB, USA, (later acquired by MRC, which was taken over by SKF).
- Design: Arrangements typically with one bearing, full complement bearing design (without a cage).
- Present status: Historical relevance only, replaced by other roller bearings with cages.

Roller bearings

**Spherical roller bearings**
- Invented by SKF
- Design: Arrangements with one or two bearings.
- Present status: Only bearing and sleeve replacements, alternatively replaced by tapered roller bearing units with integrated seals.

**Cylindrical roller bearings**
- Launched by SKF Norma (Germany), FAG and some other companies.
- Design: Arrangements typically with two bearings.
- Present status: Used for new vehicles based on existing designs, trend to be replaced by cylindrical roller bearing units with integrated seals.

**Tapered roller bearings**
- Launched for axlebox applications by Timken, USA and UK.
- Design: Arrangements typically with two bearings mounted face-to-face or back-to-back.
- Present status: Some bearing replacement, otherwise replaced by tapered roller bearing units with integrated seals.

**Cylindrical roller bearing units**
- Launched by SKF.
- Design: Arrangements incorporate two cylindrical roller bearings; the seals ride on the inner ring land.
- Present status: Design replaces arrangements with standard cylindrical roller bearings.

**Compact tapered roller bearing units**
- Launched by SKF.
- Design: Arrangements incorporate two tapered roller bearings with a common outer ring, the seals ride on the inner ring land.
- Present status: Preferred design for speeds up to 160 km/h.

Overview of the development of axlebox bearings and bearing units *1

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*1 SKF provides to its customers a comprehensive railway handbook containing very detailed information about axleboxes, bearings, sensors, condition monitoring and service solutions.
development, design and testing of wheelset bearings (figs 4a and 4b). By the 1930s, trains in Europe and North America had already reached travelling speeds of 130 km/h, with top speeds of 160 km/h. Today, high-speed rail transport is defined in some European standards as vehicles with a maximum speed of more than 200 km/h.

Lubricant saving
In addition to energy-saving capabilities, further contributions to the environment can be achieved by reducing the amount of lubricant consumption. Bearing lubricants such as oil and grease have to be refined from mineral oil. During maintenance, after many years of long service, the used lubricant has to be collected during axlebox dismounting and specially treated as waste disposal, like other used mineral oil-containing products. It is obvious that a minimizing lubricant quantity is a positive contribution to the environment.

At the beginning of rail transport oil-lubricated sliding bearings were used. The initial oil fill in the axlebox of a typical freight car was 1.3 kg, of which 500 g were used for the oil pad lubrication and 800 g for the oil reservoir. The oil level had to be checked frequently as the continuous oil loss during operation heavily contaminated the railway tracks and the environment. The oil consumption was around 200 g per 1,000 km.

A major step forward was the introduction of grease-lubricated roller bearings. The grease fill is applied during the mounting procedure, and for most applications no further relubrication is needed. In the 1930s, the grease quantity of a typical freight car axlebox fitted with cylindrical roller bearings was around 1.7 kg. Many investigations have been made over recent decades and confirmed that the quantity could be dramatically reduced without risking starvation lubrication conditions. Around 1950, the grease quantity was reduced to 1.2 kg. Later, it was reduced to 1 kg and then to the present level – 700 g for lubrication of open cylindrical roller bearings. A further major step in the reduction of grease consumption was the introduction of a sealed and pre-lubricated cylindrical roller bearing unit (CRU) where only 200 to 300 g grease is needed. The reduced grease quantity results in lower operating temperatures. This leads to longer grease and service life.

The second part of this article will focus on current axlebox developments.

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SUMMARY
Alongside the growth of the railways has been the overall ambition to reduce friction and wear as well as to save energy. Logically the development of axleboxes and bearings has been a key part of such efforts. SKF was one of the first exponents of the now well-established science of tribology that encompasses the study and application of the principles of friction, lubrication and wear, to create bearing solutions that delivered and still deliver benefits to railway operators.