Hybrid deep groove ball bearings in spreader rolls

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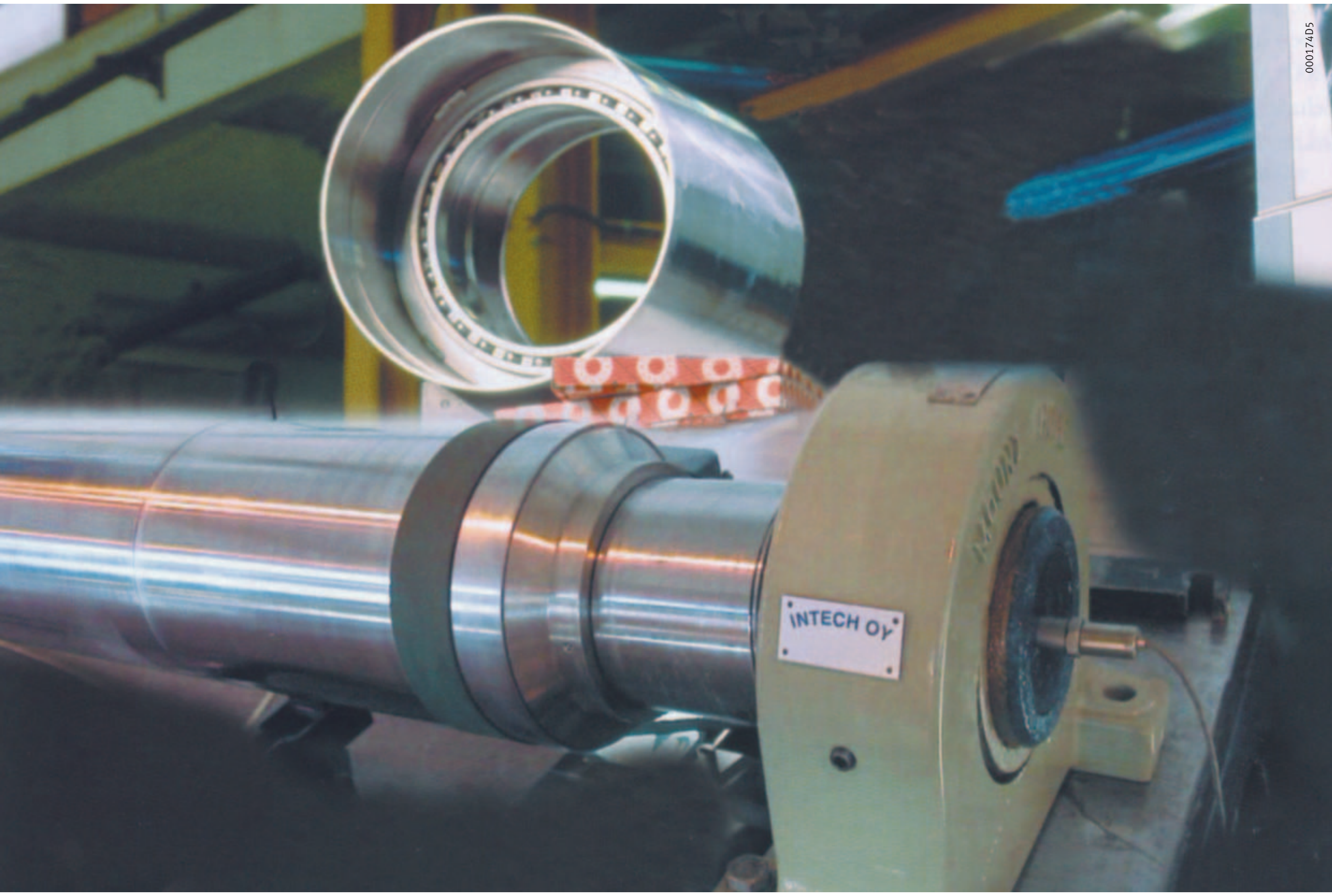

Figure 1 · Spreader roll with hybrid deep groove ball bearings

Plant photo: Metalspray-Intech

Spreader rolls are located in both the wet section and dryer section of paper machines. These subassemblies are also used in finishing and converting. In paper, textile and film production, their function is to guide the web product, keeping it smooth and flattening longitudinal creases.

The service life of the rolls is directly dependent on the operating life of the bearing arrangement. The difficult operating conditions require special bearing designs, seals and lubrication systems.

The Schaeffler Group supplies a solution incorporating hybrid deep groove ball bearings. These rolling bearings have rings made from rolling bearing steel and balls made from ceramic. With the appropriate seals and a suitable lubricant, the rolling bearings achieve a long operating life and thus allow a high level of cost-efficiency. In comparison with standard deep groove ball bearings, the operating life is increased by up to a factor of 3.

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Ambient conditions

Paper machines generally run 24 hours a day, more than 350 days a year.
If the machine experiences unplanned downtime, this incurs additional costs of the order of several thousand euros per hour. All the components must be highly reliable. A long operating life is also required. For conventional deep groove ball bearings in spreader rolls, a fatigue life of more than 100 000 hours has been calculated. In practice, however, the service life actually achieved is often significantly less than 20 000 hours.
The ambient temperatures of the rolls are approx. 40 °C in the wet section and up to 180 °C in the dryer section where infrared drying is used. The rolls are normally driven by the product web running over them at web speeds of up to 2 200 m/min, while the speeds in the finishing section are up to 3 600 m/min.

These web speeds lead, as a function of the roll diameter, to speed parameters ($n \cdot d_M$) of 200 000 $min^{-1} \cdot mm$ to 1 000 000 $min^{-1} \cdot mm$.

Design of spreader roll

Spreader rolls consist of a stationary axle that is bent symmetrically to the longitudinal axis of the paper machine. The roll shell rotates about this axis. The roll shell consists of tubular steel sections of the same diameter, *Figure 2*. As a result, it can track the curved axle. Each section is supported by a deep groove ball bearing such that it can rotate freely under slight misalignment.

The bearings are protected against moisture and contamination by special roll end seals.

Depending on the area of application, the sections have a shared rubber cover. This cover is light and flexible. The roll is subjected to only light load by the web tension at the wrap angle of max. 30°.

Technical data

- Roll diameter 285 mm
- Roll length 8 150 mm
- Section length 380 mm
- Section mass 15 kg
- Velocity 1 300 m/min
- Rotational speed 1 452 min^{-1}
- Web tension 2 000 N/m
- Wrap angle 30°
- Roll temperature +150 °C.

Load, speed

With wrap in the lower roll section, the web tension acts upwards, reducing the bearing load. This reduces the Hertzian pressure between the ball and bearing ring, such that the drive forces are no longer sufficient to start or maintain rotation of the ball and cage assembly. Sliding of the balls is the technical challenge in this bearing arrangement. This slippage exerts heavy loads on the lubricant film between the ball and rolling bearing ring.

In extreme cases, the lubricant film is broken and there is contact between the ball and rolling bearing ring.

In standard deep groove ball bearings with steel balls, the high adhesion tendency of the steel / steel material pair promotes wear and the life is significantly reduced as a result.

The bearing load is due to the load arising from:

- roll mass = 150 N
- web tension of
  $2 \cdot 2\,000$ N/m $\cdot$ sin 15° $\cdot$ 0,38 m.

The equivalent dynamic load on the bearing P is then 540 N.
If the bearings are used at speeds of v = 3 600 m/min, the speed parameter is $n \cdot d_M$ at 860 000 $min^{-1} \cdot mm$.

Bearing selection

The new bearing arrangement should be significantly more cost-effective.
The part demands on the bearings are:

- smooth running due to the smallest possible masses to be accelerated
- long life through prevention of slippage
- use of standardised bearing components.

In order to achieve satisfactory operating life under the difficult operating conditions, hybrid deep groove ball bearings are used. Each individual tube element of the spreader roll is supported by a special deep groove ball bearing F-HC804557.07.KL, *Figure 3*.
The bearing dimensions are (d×D×B) 190×260×33 mm.

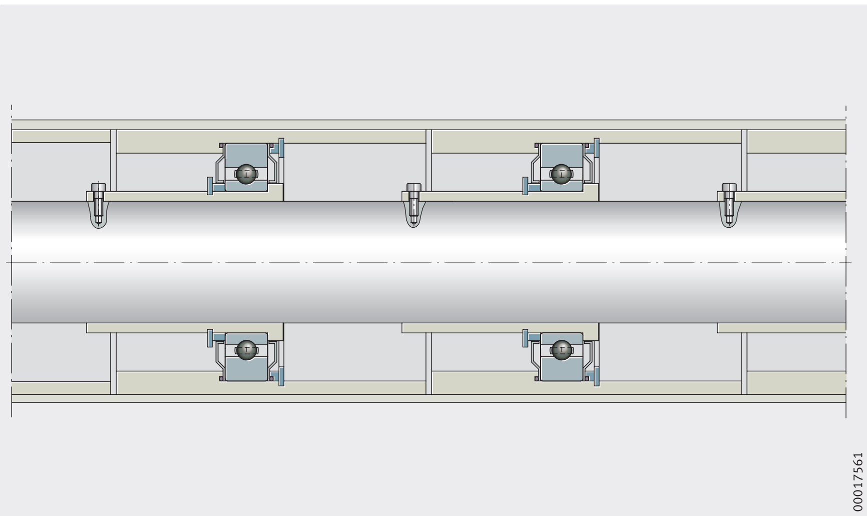

Figure 2 · Each individual tube segment is supported by a hybrid deep groove ball bearing

Figure 3 · Hybrid rolling bearing steel/silicon nitride deep groove ball bearings

In comparison with a standard bearing, this ball bearing has a thin inner ring, a rigid outer ring, small ceramic balls made from silicon nitride Si_3N_4 and a sheet steel cage. The solid-section outer ring has the advantage that it gives the thin roll shell additional rigidity and geometrical accuracy.

In order to reduce the rotating masses (the ball and cage assembly), only half the number of balls are fitted. This means that there is a higher load on the individual ceramic balls, which reduces the risk of slippage.

Internal clearance, mounting fits

Differences in the web tension can cause the individual tube elements to tilt relative to each other. The required radial internal clearance C3 permits sufficiently large tilting clearance even at high speeds.

The outer ring is seated firmly with a tolerance M6 in the roll shell. The inner ring has a loose fit with a tolerance h7 on the stationary axle and can thus be mounted easily.

Lubrication, sealing

The lubricant is subjected to only slight stress due to the small mass and the favourable contact geometry of the ceramic balls. As the outer ring rotates, there is a risk that the base oil will be centrifuged out of the grease, depending on the type of grease used. Proven sealing elements optimised specially for oil sealing integrity retain the separated base oil securely in the bearing.

Advantages of hybrid bearings

The use of hybrid bearings has several advantages:

- significantly less wear under slippage, since the tribological characteristics are better due to the favourable steel/ceramic material pair
- lower friction, so the drive power required is significantly lower, *Figure 4*
- higher accelerations and speeds possible due to lower inertia forces
- considerably less vibration
- longer grease life due to less friction and lower temperature.

Ceramic balls

Ceramic balls are more suitable under lubricant starvation and lubricant film breakdown since the material combination of steel and silicon nitride causes significantly less adhesive wear. Since the mass of the ceramic balls is lower by a factor of 2,5 and only half the number are fitted, the ball and cage assembly has considerably lower inertia forces, *Figure 5*.

The probability of acceleration free from slippage is thus significantly higher. In addition, the centrifugal force of a ceramic ball is approx. 90% lower than that of a steel ball of the original size. The modulus of elasticity of silicon nitride is approx. 50% higher than that of rolling bearing steel. As a result, ceramic balls have a smaller contact surface. Less friction thus occurs and less heat is generated.

Due to the smaller contact surface, in combination with special machining of the raceways, the sliding contact area is reduced. Furthermore, better lubricant supply is achieved. Overall, this gives a longer grease operating life.

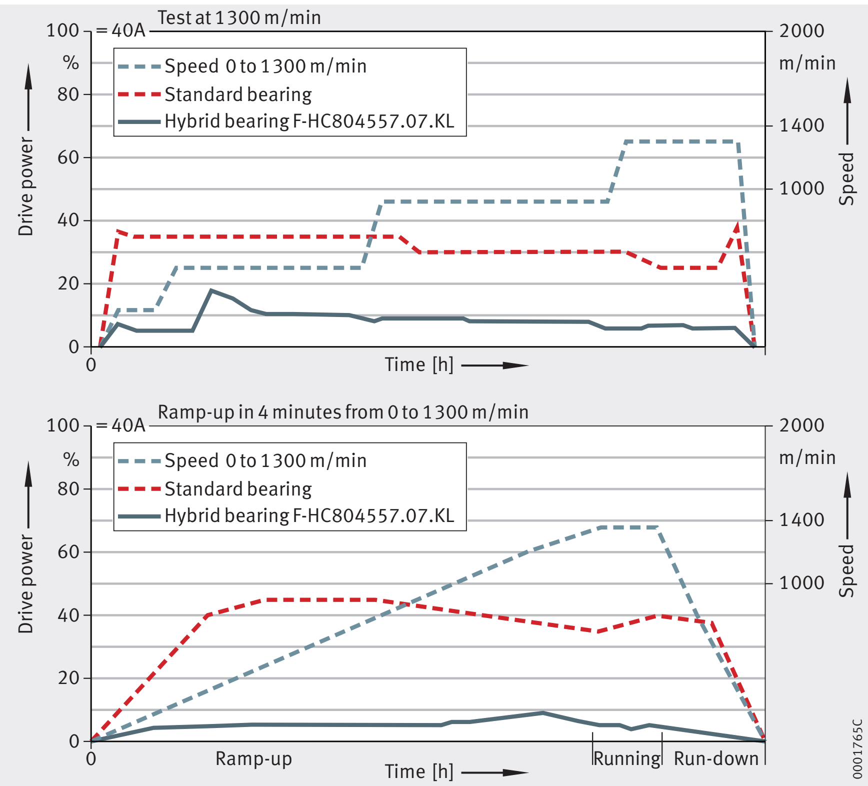

Figure 4 · Drive power and speed in stepwise and uniform ramp-up of the paper machine

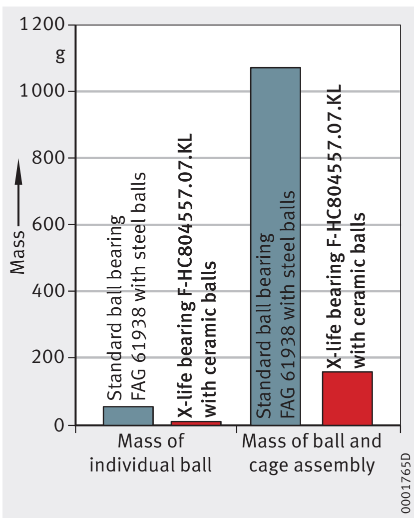

Figure 5 · Comparison: mass of individual balls and ball and cage assemblies

Cost-efficiency

The system costs are determined only partially by the purchasing costs for the rolling bearings and the outlay required on the adjacent construction. Other significant factors include operating costs, repair costs and the costs incurred for downtime.

Operating costs are low if power consumption is low and maintenance costs are reduced.

The operating life of spreader rolls is considerably longer with the use of hybrid deep groove ball bearings. Replacement of the bearings is required much less often, *Figure 6*.

The maintenance intervals are extended and the costs incurred by machine downtime, roll replacement and roll repair are reduced.

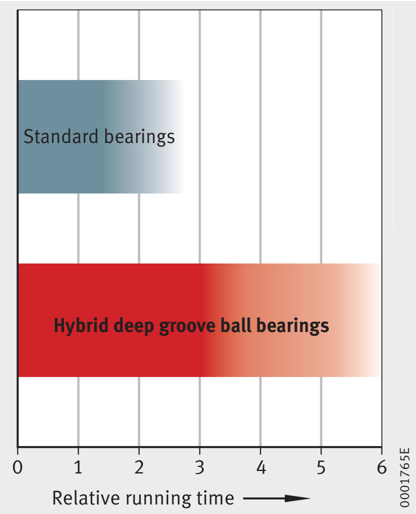

Figure 6 · Operating life of hybrid deep groove ball bearings, compared with standard bearings

Customer benefits

The improved cost-efficiency is the result of several factors:

- less friction, leading to lower operating temperature
- longer bearing life.

Due to the use of the new rolling bearings, the previous operating life of three years is increased from three years to more than six years. When calculated on the basis of six years, the saving on three rolls is more than 30 000 euros. The saving is actually even greater since this figure does not take account of the costs associated with downtime for roll replacement after three years.

The advantages arising from the use of hybrid bearings in spreader rolls will have an even greater impact in future with increasing web speed or web tension.

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