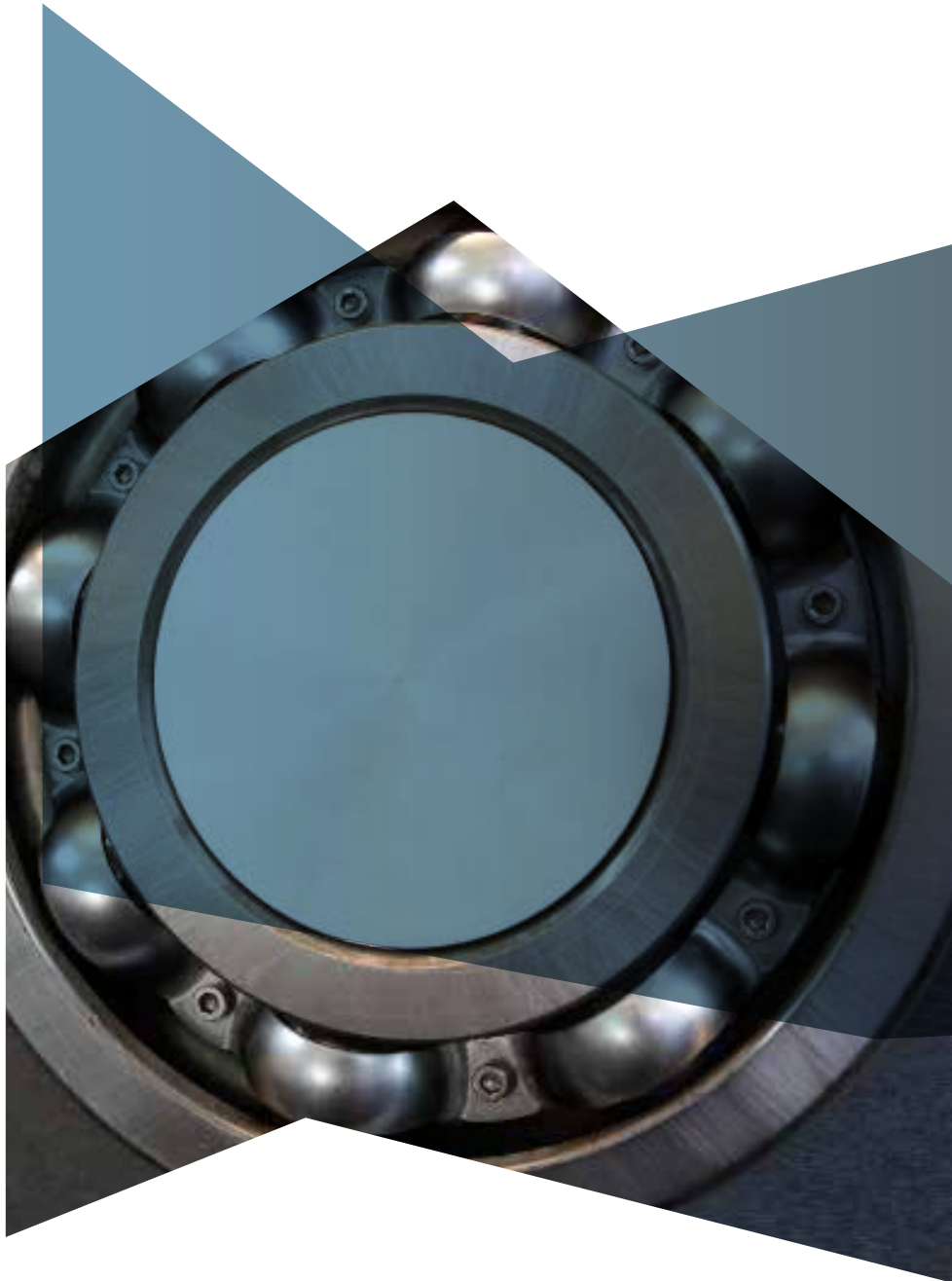


PROJECT NO. 342-032

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# ENERGY SAVING BEARINGS

WINNER OF THE ELFORSK AWARD 2013



NEW ENERGY  
EFFICIENT AND  
LONG LASTING  
HYBRID BEARINGS  
FOR THE INDUSTRY



**ELFORSK**

– RESEARCH AND DEVELOPMENT IN EFFECTIVE ENERGY USE

**CERAMICSPEED**  
bearings

# IT ALL STARTED ON SKATES



*Jacob Csizmadia (right) and Bøje Schauman Kjær are now well equipped to follow up on their success in the sports world in the much larger industrial market.*

CeramicSpeed was established by Jacob Csizmadia in 2004, following his 1998 world record for 24 hour in line skating. A major factor in achieving the new record of 505 km was that he had, in cooperation with bearing manufacturers SKF, replaced the traditional steel balls in the skates' bearings with ceramic balls.

Ceramic balls manufactured from Silicon Nitride were invented in the 1970's, and were first utilised on a large scale by NASA in the early 1990's. Several years later ceramic ball bearings also entered usage in Formula 1 motorsport, and a small number of bearing manufacturers began producing hybrid bearings with ceramic balls for use in electrical motors.

## FROM ROLLER SKATES TO THE TOUR DE FRANCE

In 2001 Jacob Csizmadia applied his positive experience with hybrid bearings to Bjarne Riis' new-started Team CSC in the Tour de France. The results were so convincing that Jacob Csizmadia started producing his own hybrid bearings in Holstebro in 2004. It quickly became clear that serious cycling enthusiasts, who were willing to spend over 50,000 DKK on a bike, would also pay extra for efficient and long lasting bearings. Today roughly half of the Pro Tour teams use CeramicSpeed hybrid bearings.

ARLA FOODS SPENT AROUND 750,000 DKK PER YEAR ON SCHEDULED MAINTENANCE OF A DECANter. INSTALLING CERAMICSPEED LONGLIFE XTREME BEARINGS AND IMPLEMENTING CONDITION BASED MAINTENANCE HAS REDUCED COSTS TO LESS THAN 175,000 DKK PER YEAR.

TABLE 1: RESULTS FROM THE 6318 TEST BENCH APRIL 2012

Date	6318-bearings	Speed	Measured loss/bearing
26.04.12	SKF 2Z.C3	2997 RPM	175 W
27.04.12	CS 2RZ/HC5	2998 RPM	100 W
30.04.12	SKF 2RS1.C3	2348 RPM	355 W
25.04.12	CS 2RS1-HC5	2349 RPM	325 W

*Table 1: Measurements taken on the optimised 6318 test bench show that CeramicSpeed hybrid bearings with ceramic balls have a loss which is 75 W less than SKF's standard bearings, equating to a saving of over 40%. The last 2 measurements are from bearings with friction generating seals, where the difference is lower.*

Contact with animal food manufacturers Arovit in Esbjerg led to CeramicSpeed's first experiment with hybrid bearings for industrial uses in 2005. At the time Arovit had to replace the bearings in a bag closing machine every third month, whereas the CeramicSpeed hybrid bearings from 2005 are still in operation today. Grundfos and Arla Foods Hoco have had similar positive experiences with long lasting hybrid bearings.

## ANNUAL GROWTH: 50-150%

In order to build on these results Bøje Schaumann Kjær became co-owner and head of the industrial sales department in 2009. The department has since grown to five employees, making up a third of the entire staff, and in 2012 CeramicSpeed supplied hybrid bearings to approximately 150 companies.

Turnover has increased by 50 to 150% annually over recent years. In order to consolidate this growth CeramicSpeed is now focusing on expanding their sales from professional and amateur sport to the much larger industrial market. In cooperation with the local business development centre Jacob Csizmadia has set a goal of a total of 50 employees in 2015.

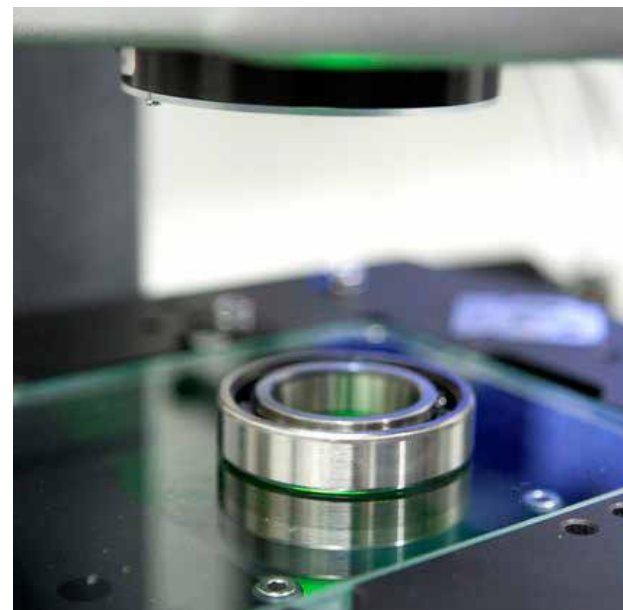
On the sports market CeramicSpeed already exports to more than 20 countries, selling products to road cyclists, mountain bikers and triathletes, who are willing to pay for higher speeds and greater durability.

The company has conquered these niche markets with high quality products, based on the innovative application of tried and tested components. The company's strategy is based on on-demand production, which makes it possible to customise individual products to meet the customer's specific needs, and reduces stock costs. Close collaboration with other actors in the innovative environment around the local business development centre (NU Park) has provided support for this strategy.

*Jacob Csizmadia made his first foray into the industrial market in 2005. Today CeramicSpeed supply a wide range of custom-made hybrid bearings to companies who wish to improve their energy efficiency.*



*The production of hybrid bearings requires enormous precision. CeramicSpeed has the equipment necessary to meet the high quality demands.*



# SIGNIFICANT SAVINGS IN INDUSTRY

The global market for industrial bearings has an annual turnover of several hundred million dollars. Most of this is generated by standard bearings with steel balls, which are produced by large American, Japanese, German and Swedish companies. However over the last 20 years the positive experience with effective and long lasting hybrid bearings with ceramic balls in aerospace and sports has gradually spread to industry.

## 10% OF BEARINGS ARE CRITICAL

Replacement of bearings in the moving parts of production equipment is generally considered to be an unavoidable part of regular maintenance. However some bearings operate in such harsh conditions, that they break down after only a few years or even months in operation, the associated costs in terms of maintenance and lost production can be felt economically. This applies, for example, in the food industry, the chemical industry and in agriculture, just as bearings in vehicles can be subject to rough treatment. In electrical motors with frequency converters current leakage increases the risk of damage to steel bearings. This problem can partly be reduced with an insulating coating, but CeramicSpeed hybrid bearings are the only bearings that are guaranteed to solve this problem.

In these niches, which make up 5-10% of industrial bearings, the use of hybrid bearings with ceramic balls would lead to such a large reduction in operating costs that the investment would quickly be repaid. CeramicSpeed have calculated that Danish industry spends approximately 750 million DKK per year on the purchase of standard bearings, with an installation cost of 3,800 million DKK. For an extra cost of approximately 500 million DKK per year, hybrid bearings could be purchased instead, this would save approximately 3,300 million DKK in installation costs, and avoid the much higher costs associated with production downtime. A report from The Danish Maintenance Society, which in 2006 calculated that there is a potential to optimise maintenance in Danish industry of approximately 50 billion kroner per year, supports these findings.

## 4-8 TIMES LONGER LIFETIME

These calculations have been confirmed in an analysis of 1,000 bearings with a lifetime of less than 2 years. Replacement with hybrid bearings increased the lifetime of 99.6% of these by 4-8 times, this applied to bearings used in a wide variety of applications. Furthermore, ceramic balls are harder, weigh less, and have a polishing effect; this reduces lubrication requirements as well as increasing stiffness and reducing vibration – all properties which contribute to more efficient production.

Hybrid bearings with ceramic balls have lower friction than steel ball bearings and therefore have a correspondingly lower energy loss. The low friction in hybrid bearings also means that hybrid bearings can be used in larger electric motors and for other applications where it is otherwise necessary to use bearings with friction generating seals, which result in a much higher energy loss.

*The Silicon Nitride ceramic balls are superior to steel balls in many ways; this makes a vital difference to the stability of industrial production.*



## EXTRA COST SAVED MANY TIMES OVER

The analysis supports the practical experience of companies which have used CeramicSpeed hybrid bearings over several years. Animal feed producers Arovit invested 40,000 DKK in hybrid bearings for a bag sealing machine in 2005, but have since saved over 300,000 DKK in operating costs, because the CeramicSpeed bearings still work.

Danish Crown had a similar experience, when they replaced steel bearings with hybrid bearings in a splitting saw. An increased annual bearing purchase cost of 1,886 DKK has generated annual savings of approximately 20,000 DKK in replacement costs, as well as increasing production stability, which is vital to ensuring the productivity of the slaughter house. At Arla Foods Hoco dairy in Holstebro a grinding mill which operated at 5,000 RPM presented a challenge, as the bearings quickly reached the critical limit of 80°C, and therefore needed to be permanently monitored. The bearings were replaced every 1,000 operating hours. After the bearings were replaced with hybrid bearings in 2009, the lifetime has increased fivefold, and the operating temperature is stable at 45°C.



*Following the ELFORSK project Bøje Shauman Kjær is ready to increase marketing of the energy efficient bearings to industrial customers.*

Generally it is CeramicSpeed's experience that new customers start by introducing hybrid bearings in the most critical areas, installing them in the entire production line when they have realised the full benefits.

## NEEDED DOCUMENTATION

Bøje Kjær was convinced that companies could reduce their electricity consumption in motors by using hybrid bearings, but he didn't have any documentation to support this. He was therefore extremely motivated when he heard of the possibility to receive grants for research and development in electricity saving technology, at an ELFORSK information meeting in 2009.

Through his network at the North-West Jutland Business Advice Centre, Bøje was introduced to the experienced project leader, Mogens Johansson from Danish Energy Analysis, who could assist with the application process and calculations of the total potential for electricity savings in Denmark. This resulted in a grant from Danish Energy of 895,080 DKK, towards a total budget of 1,446,000 DKK. This meant that the small entrepreneurial company could start the demanding development and documentation project in early 2010.

FIGURE 1: DANISH INDUSTRY'S ANNUAL BEARING MAINTENANCE COSTS

	STANDARD BEARINGS	CERAMICSPEED BEARINGS
Bearing purchase	750 mio. DKK./year	DKK 1,250 mio. DKK/year
Labour and material costs of replacing	3,800 mio. DKK/year	No replacement
Cost of lost production from downtime	Several billion DKK/year	Savings in billions

*Figure 1: The purchase price of hybrid bearings from CeramicSpeed may well be higher, but experience from Danish industrial companies shows that the extra investment is usually repaid after the first saved replacement interval. The reduction in production downtime results in an additional, and much larger, saving. Replacing critical standard bearings with hybrid bearings has the potential to provide a net saving of approximately 3.3 billion DKK within the first year.*

HALDOR TOPSOE A/S USED TO REPLACE THE STANDARD BEARINGS IN A GRINDING MACHINE EVERY 3-4 WEEKS. THE COMPANY INVESTED AN ADDITIONAL 6,000 DKK IN CERAMICSPEED BEARINGS, WHICH LASTED 13 MONTHS. THE FIRST YEARS SAVING: 40,000 DKK.

# HYBRID BEARINGS FOR ELECTRIC MOTORS



*PRONOR and Grundfos have assisted with the demanding measurements. Pictured: Dennis Soerensen from PRONOR with the 6205 test stand.*

ELFORSK project 342-032 on energy saving bearings is one of the latest examples to demonstrate that even a relatively small helping hand from Danish Energy can give an innovative entrepreneurial company a vital push, leading to a development which in the long term can create growth, new jobs and increased export. In this way the project supports Danish Energy's strategy of assisting Danish industry to use energy more efficiently and thereby increase their competitiveness.

## DOCUMENTING REDUCTION IN ENERGY LOSS

The main aim of the project has been to document that hybrid bearings with ceramic balls significantly reduce bearing energy loss, thereby reducing the energy loss in electric motors and motorised machines by 3-10 %, equating to 0.2-0.3 % of the electricity they consume. This has been documented by measuring various types of CeramicSpeed hybrid bearings against standard bearings with steel balls and some of the major manufacturers' most energy-efficient ball bearings (E2). The know-how gained concerning the energy loss in hybrid bearings and their other properties will be utilised in CeramicSpeed's continual product development, with the aim of increasing the suitability of hybrid bearings for widespread use in industry.

CERAMICSPEED HYBRID BEARINGS HAVE A HIGHER PURCHASE PRICE THAN STANDARD BEARINGS, BUT QUICKLY PAY FOR THEMSELVES, AS IN 99.6% OF CASES THEY ARE PROVEN TO LAST 4-8 TIMES LONGER.

FIGURE 2: TEMPERATURE DEVELOPMENT FOR 6318 BEARINGS, MEASURED IN THE TEST STAND. SOLID LINES: BEARINGS WITHOUT FRICTION GENERATING SEALS. DASHED LINES: BEARINGS WITH FRICTION GENERATING SEALS.

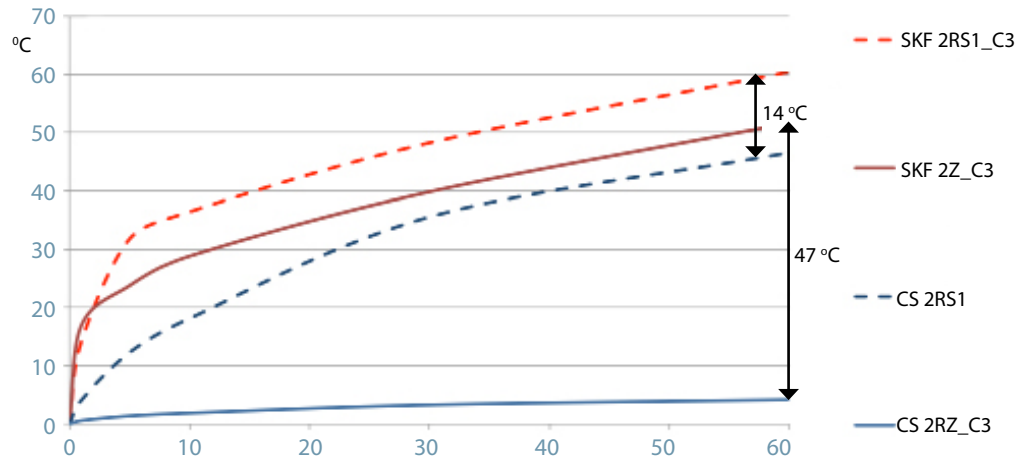


Figure 2: The difference is clearly visible, both with and without friction generating seals. The temperature of the CS bearings (CeramicSpeed) is lower. This is a result of the lower friction, which saves energy.

The results will first and foremost be used for technological development and marketing by CeramicSpeed. However, the project group has an important task in informing energy advisers and other consultants of the high energy efficiency of hybrid bearings. Energy advisers can also refer to the significant Non Energy Benefits (NEB) of longer lifetime and optimised production which can be achieved by utilising hybrid bearings.

ROLD SKOV SAWMILL REPLACED THE BEARINGS ON A SAW EVERY 3RD MONTH. EACH REPLACEMENT COST 20,000 DKK IN PRODUCTION DOWNTIME. EVEN THOUGH CERAMICSPEED LONGLIFE XTREME BEARINGS WERE MORE EXPENSIVE, THE COMPANY SAVED 20,000 DKK ON BEARINGS ALONE IN THE FIRST YEAR. INCLUDING INDIRECT COSTS THE SAWMILL HAS SAVED APPROXIMATELY 250,000 DKK OVER 3 YEARS.

An especially attractive branch is the food industry, whose ability to compete internationally is of significant importance for growth, export and jobs in Denmark. The food industry places especially high demands in hygiene, which CeramicSpeed hybrid bearings, with their minimal lubrication requirements and use of food industry approved grease are specially suited to meet.

### MADE THEIR OWN TEST BENCH

The project has been carried out by CeramicSpeed, who have carried out the actual testing in cooperation with PRONOR (previously Grene). Danish Energy Analysis acted as the administrative project leader, identifying the market potential for energy efficient bearings in industry and carrying out the analyses, which have been used to calculate bearing energy loss and energy efficiency based on the results of measurements taken on the test benches. CeramicSpeed have implemented the results of the project in their product development. The measurements should have been carried out by the Danish Technical University's Wind Energy department at their Risø campus, but it turned out to be more appropriate that this demanding task be carried out by CeramicSpeed themselves, who have therefore invested more resources in the project than planned.

With the assistance of PRONOR and Grundfos two test stands were constructed, for the large (size 6318) and the smaller (size 6205) bearings. In 2010-2011 measurements were carried out on the large bearings, both with and without friction generating seals. Six sets of bearings with ceramic balls from CeramicSpeed were tested against bearings with steel balls from three foreign manufacturers.

AARHUS KARLSHAMN FREQUENTLY REPLACED THE BEARINGS IN A 400 KW FREQUENCY CONTROLLED MOTOR. COATED BEARINGS WERE NOT ABLE TO SOLVE THE PROBLEMS OF ELECTRICAL DAMAGE. REPLACING THE BEARINGS WITH CERAMICSPEED LONGLIFE INSULATE HAS EXTENDED THE LIFETIME BY 6-8 TIMES. INSTALLING CERAMICSPEED BEARINGS COST AROUND 50,000 DKK. THIS HAS LED TO A SAVING OVER THE FIRST 2 YEARS OF OVER 400,000 DKK.



The measurements included bearing temperature and run-down time, which are significant in calculating bearing energy loss. After improvements were made to the test stand new measurements were carried out in April 2012 of the energy loss from CeramicSpeed bearings and bearings from SKF.

The experience gained was used to construct a test stand for smaller 6205 bearings, and in spring 2013 friction loss measurements were carried out on five sets of bearings: Energy efficient E2-bearings with steel balls (SKF) and ceramic balls (CS), standard bearings with steel balls and ceramic balls and standard bearings with friction generating seals. At the same time tests of bearing energy loss based on run-down time were carried out on two identical Grundfos 3 kW motors with E2-bearings using steel balls (SKF) and ceramic balls (CS). To complete the project tests were carried out on 6205 standard bearings produced by NSK and SKF, which were compared to equivalent hybrid bearings produced by CeramicSpeed.

The project was carried out in close cooperation with industrial customers. The project has been followed by an advisory group including representatives from Danish Crown, Arla Foods Hoco, Cheminova, Grundfos, PRONOR, DONG Energy Maabjerg Plant, North-West Jutland Business Advice Centre and NOE Energy.

## LOWER LOSS IN CERAMICSPEED BEARINGS

Measurements taken on the larger 6318 bearing show that CeramicSpeed bearings with ceramic balls maintain a significantly lower operating temperature (see figure 2). This applies both to bearings with and without friction generating seals. The operating temperature of CeramicSpeed bearings is 20-45 degrees lower, at both high and low temperatures.

The run-down time was 2-4 times longer for CeramicSpeed bearings (158-424 seconds) than for standard bearings (69-134 seconds). This clearly demonstrates that CeramicSpeed bearings have a lower energy loss than equivalent bearings with steel balls (see figure 3).

FIGURE 3: RUN-DOWN TIME FOR A GRUNDFOS MG100LC2 MOTOR WITH STANDARD BEARINGS FROM NSK (GREEN), SKF (RED), AND CERAMICSPEED (BLUE).

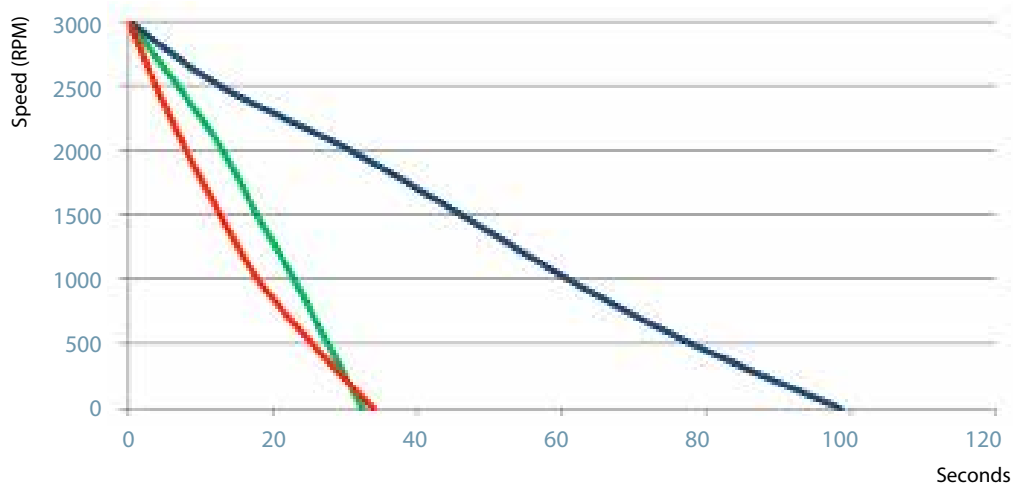


Figure 3: The run-down speeds measured for NSK and SKF standard bearings and CeramicSpeed hybrid bearings documented that the hybrid bearings, as a result of lower friction, had a run-down time which was almost 3 times longer.



FIGURE 4: PAYBACK TIME VIA ENERGY SAVING IN YEARS -  
ABB MOTORS WITH CERAMICSPEED BEARINGS, CONTINUAL OPERATION

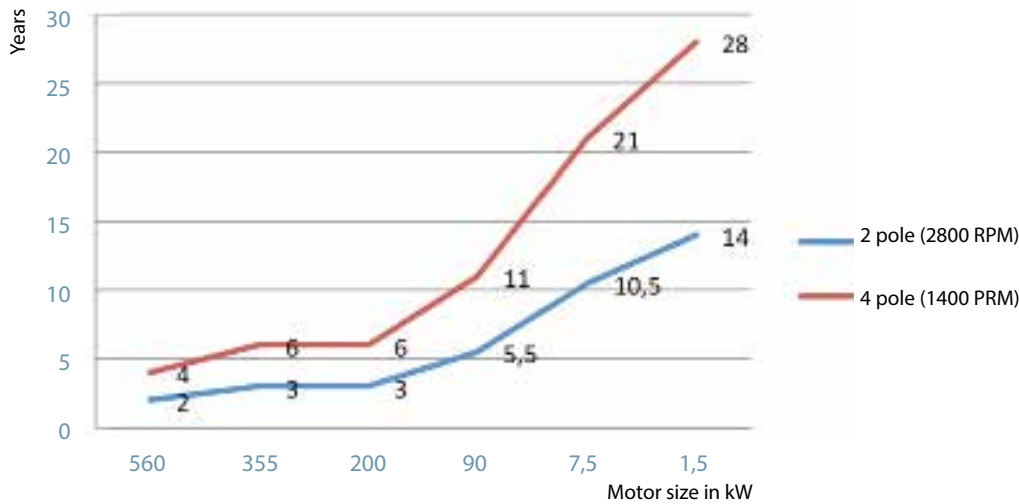


Figure 4: Documentation for the energy saving properties of CeramicSpeed LongLife Insulate bearings provides an additional benefit, as they already pay for themselves several times over as a result of their longer lifetime. The results were better than expected, in that an investment in optimised bearings can be repaid in as little as 2 years, based purely on energy savings.

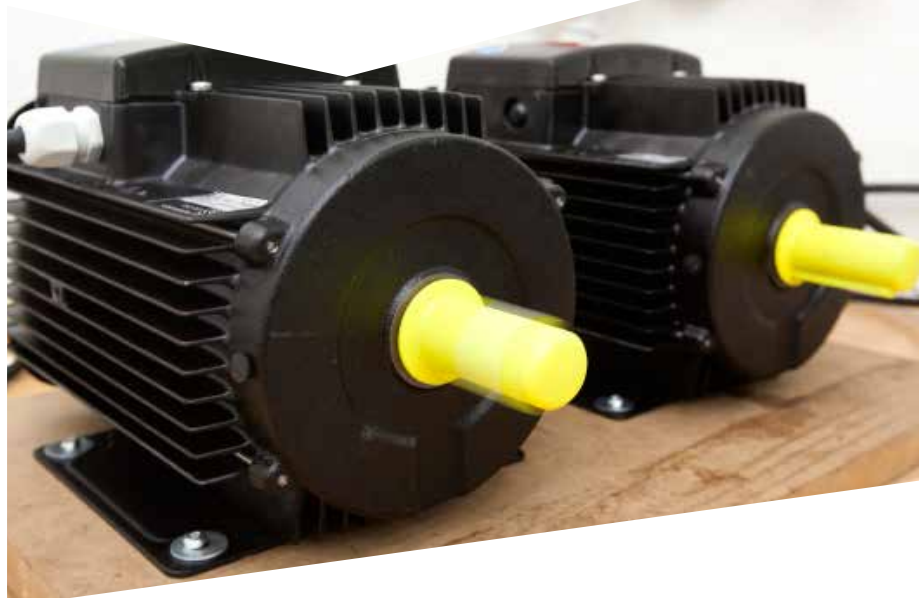
The measurements showed that bearings with friction generating seals generally experienced a higher energy loss, however as in the other cases, CeramicSpeed bearings had lower temperature increases, longer run-down times and a lower energy loss than standard bearings with steel balls. All in all the tests documented that the amount of energy lost in a 6318 bearings was reduced by at least 50%.

The measurements carried out on the smaller 6205 bearings in spring 2013 also showed that bearings with ceramic balls have a lower energy loss than steel balls. This applied both for energy-efficient E2-bearings and standard bearings. The lower energy loss in CeramicSpeed bearings was further confirmed through measurements of the run-down time carried out on Grundfos motors. All in all it can be concluded that energy loss in bearings can be reduced by at least 60-70% by using CeramicSpeed bearings instead of standard bearings. Translated to energy conversion efficiency this means that installing CeramicSpeed bearings increases energy efficiency by 0.7 – 1.3 percent in smaller motors and 0.2 – 0.4 percent in motors of 90 kW and above. A calculation of the payback period based purely on energy savings on a selection of electric motor sizes is shown in figure 4.

The ELFORSK project has thereby documented that CeramicSpeed LongLife Insulate bearings, which are designed specifically for use in electric motors, provide the energy savings which the company advertises. The more advanced knowledge regarding the consequences of varying the operating temperature, run-down time, RPM and ambient temperature, which has been accumulated during the course of the measurements, has made it possible for CeramicSpeed to optimise their standard products.

DALOON HAD TO REPLACE THE STANDARD BEARINGS IN A VEGETABLE SAW EVERY 3-5 WEEKS DUE TO THE EFFECT OF THE VEGETABLE JUICE. CERAMICSPEED CORROTEC BEARINGS HAVE SO FAR INCREASED THE LIFETIME BY 5-8 TIMES.

Tests on two identical 3 kW Grundfos motors showed that the motor on the left with CeramicSpeed bearings kept running long after the motor with SKF bearings had stopped.



## PROFIT MAXIMISATION

CeramicSpeed's hybrid bearings are especially advantageous when used to replace standard bearings which, as a result of their specific operating environment, have a very short lifetime. Experts calculate that approximately 90% of all bearings in industry last several years, while the remaining 10% are the critical bearings which in many cases have a lifetime of only a few weeks. Causes of this can be aggressively corrosive environments, high RPM operation or motor operation with frequency converters.

Within these niches it has proved extremely profitable for companies to work with CeramicSpeed and PRONOR. The ELFORSK project's economic calculations have demonstrated that it is only possible to achieve a level of profitability which is acceptable for industry in exceptional circumstances, if the only factor taken into account is the energy saving from the lower energy loss of hybrid bearings. This applies, for example, where CeramicSpeed hybrid bearings replace standard bearings with friction generating seals, which have an especially high level of energy loss.

It is therefore important that energy advisers and other consultants, who assist industrial companies in increasing energy efficiency, look at all the economic factors of the two alternatives: standard bearings with steel balls and CeramicSpeed bearings with ceramic balls. In order to calculate the complete effect on the company's bottom line it's necessary to take into account the purchase price of the bearings, costs of materials and labour involved in installation, and – not least - the significant loss of production, which companies experience when important machinery is stopped for maintenance.

CeramicSpeed has, in cooperation with PRONOR, developed a method to integrate these Non Energy Benefits (NEBs) in the calculations which companies use to form the basis for their decisions.

FIGURE 5: BEARING ENERGY LOSS FOR CS 6318-2RZ (BLUE) AND SKF 6318-2Z (RED), BOTH MEASURED AT 56°C

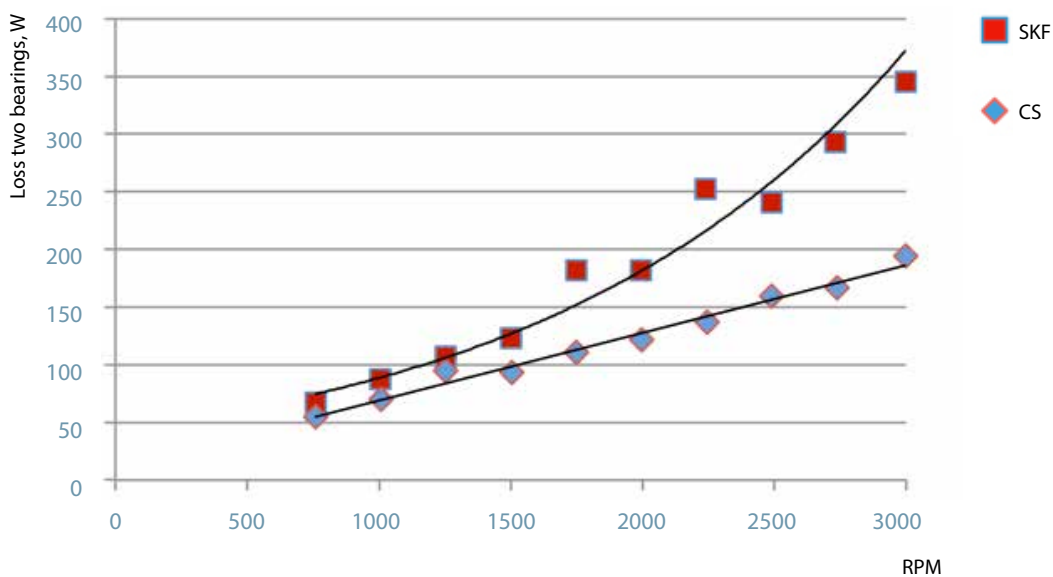


Figure 5: Bearing energy loss measured in watts for standard bearings (SKF) compared to CeramicSpeed bearings (CS) with ceramic balls. The graph clearly shows how the difference increases as the RPM increases. The final measurements show that CeramicSpeed bearings reduce energy loss by a minimum of 50 %.

*Mark Cavendish (in the yellow jersey) with his colleagues from team Omega Pharma - Quick-Step, who is one of the Pro Tour Teams using CeramicSpeed hybrid bearings to maximise their speed.  
Photo: Tim De Waele*



# CYCLISTS INSPIRE THE INDUSTRY

Omega Pharma - Quick-Step is one of the most winning Pro Tour Teams . In recent years they have taken over 40 victories in the three major stage races: the Giro d'Italia, Tour de France, Vuelta de España and World Championships.

Just as Omega Pharma - Quick-Step leave the competition standing in the final meters of a race, Danish industrial companies can boost their competitiveness using hybrid bearings in electric motors and motorised machines to improve energy efficiency. It's possible to reduce the energy consumption of a motor by 1% by replacing standard bearings which use steel balls with CeramicSpeed bearings which use ceramic balls, and this can have a significant impact. If Danish industry utilises the full potential of hybrid bearings, then electricity consumption can be reduced by approximately 150 GW-h per year, the equivalent to the annual electricity consumption of 35,000 households.

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