

## Electrical and Fire-safe Bearings for Ventilator Motors

Bearing must resist electrical erosion under normal operating conditions and high temperatures in case of fire. To provide flexible, reliable and energy efficient ventilation in many buildings, tunnels, offshore and marine applications, new or upgraded variable-air-volume (VAV) systems are being installed. They replace constant-air-volume systems that have been the standard for many years...



- Lars Kahlmn  
- Linus Svensson and  
- Fredrik Frånding

Electrical motors for fan arrangements are increasingly used with power frequency converters for variable-air-volume ventilation systems or in fire-safe fan designs. This means bearing must resist electrical erosion under normal operating conditions and high temperatures in case of fire.

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Each zone to be ventilated at a controlled level often has its own inlet and outlet fans. On both fans the fan blades are directly connected on the electrical motor shaft and speed control is through a frequency converter. This arrangement enables VAV systems to provide precise airflow control to a specific zone; as is required for hospitals, modern manufacturing plants etc. They also provide economical and effective ventilation of large building structures with complex layouts, such as airports, commercial shopping centres and office buildings, as well as ferries and naval ships.

Some types of structure or zone can make additional demands on a system. For example, hospital operating theatres demand very high functional reliability. In other instances there might be need to duplicate, as in powered smoke and heat exhaust ventilation system (SHEVS). These are typically found in large building works and tunnels where fire is a hazard. With such applications, it is also necessary to be in line with the fire-safety, requirements of new EN 12101-3 standard for powered SHAVES, whilst offering long service life during normal use. To fulfill these requirements of low life-cycle cost and reliable function on VAV systems and SHAVES, the use of hybrid bearings and other specific bearings will be of growing importance.

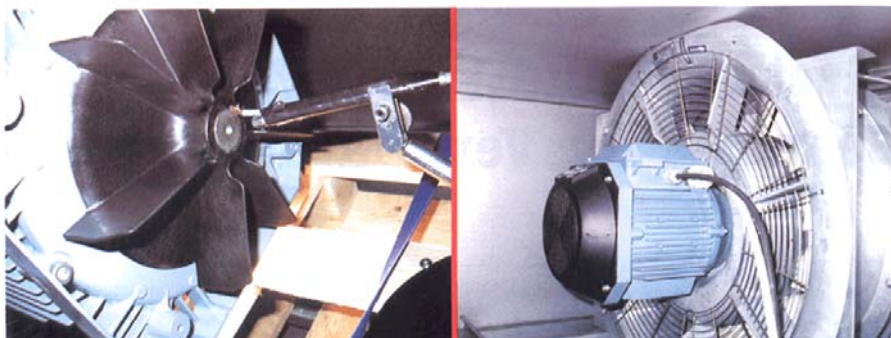


Fig 1: Shaft to earth measurement to detect common mode faults and edge spikes (non-drive end)

Variable-air-volume fan motor

Electrically safe bearings new VAV systems typically incorporate several hundred electrical motors with high demand on reliability. In fans, the motor bearings are the only highly loaded moving components with possible metal-to-metal contact. The bearing, therefore, the most critical parts when

it comes to high reliability and low service costs. Today, around 50 % of electrical motor failures are related directly to bearing damage. This rate of failure is expected to increase significantly for smaller, continuously used motors in the 0.15-15 kW range, due to the steady increase of incorporating frequency converters.

Usually, smaller motors are prone to damage because they are equipped with standard bearings that do not have protection against electrical discharges in the race-way rolling element contact. By contrast, larger motors normally use electrically insulated bearings, SKF INSOCOAT<sup>®</sup>, or polymeric insulation layers that provide such protection. Hybrid bearings are the most viable solution to give smaller motors the same kind of electrical protection.

### Damage signs

The discharges arise because the common mode voltage differs from zero and edge spikes occur, due to the very short switching times of the frequency converters. This can be measured using shaft-to-earth couplings and appropriate oscilloscope on electrical motor installation (*Fig 1*). Typical damage signs are micro-cratering and pitting of raceways, graying of rolling elements and raceways, washboard patterns and blackening of the grease. This results in poor lubrication, high vibration levels and, in the end, seizure of the bearings.

Electrical erosion of bearings in VAV systems reduces the bearing service life. This can be recognized as an increase in early failures and a faster rate of failures. A recent example comes from a four-year-old Swedish hospital with a new VAV system, using PWM frequency converters. By statistical analysis of maintenance data, it appeared that the basic rating life L10h (90 % reliability) was reduced to only 30 % of the expected value (*Fig. 3*). The bearings were greased-for-life, and the statistical analysis showed an even sharper decrease in operating hours for the L50h life (50 % reliability), due to a faster failure rate. The presence of electrical current on the bearings was established directly by diagnostic measurements (shaft-to-earth) on motors and by analysis of damaged bearings (blackening of grease and smelling of ozone).

**Table 1: Comparison between different solutions**

<b>Needs</b>	<b>Standard motor Bearing<sup>1</sup></b>	<b>Electric Grease solution<sup>2</sup></b>	<b>High-temperature Grease solution<sup>2</sup></b>	<b>Fire-safe bearing Solution<sup>3</sup></b>
Suitable for emergency class	≤ F300		F400	≤ F600
Grease life	> 3 years <sup>4</sup>		< 2 years <sup>4</sup>	> 3 years <sup>5</sup>
Relubrication of open bearings	Possible		No	Possible
Reliability of the emergency function over time	Unsure		Unsure	Very good
Quiet Operation	Good		Poor	Good
Low temperature operation	Satisfactory		Poor	Satisfactory
Bearing free of: silicon, PTFE and FKM	Yes		No	Yes
Resistance to vibrations (false brinelling)	Normal		Unsure	Very Good
Good speed behaviour	Yes		No	Yes
1,500 rpm (normal use)	Yes		No	Yes
3,000 rpm (normal use)				

1. Equipped with SKF selected grease for electrical motors
2. Equipped with high-temperature silicon or PTFE based grease or paste
3. Needs to be specially ordered and should be implemented in cooperation with SKF
4. Electrical erosion and other factors may shorten grease life
5. Insensitive to grease-life shortening due to electrical erosion

An analysis, similar to the one shown, can be done on a limited number of damaged bearings in larger VAV systems, as the statistical outcome is better with a few system failures on a large population than with many failures in a small one. The failure intensity of the system, i.e., the likelihood of early bearing damage, in the case of the hospital, will increase rapidly with time after four failure of equipment serving critical zones such as operating theatres is not acceptable. To avoid such risk increase, it is highly recommended to equip this type of fan motor with two hybrid bearings. Being electrically insensitive, they provide protection against common mode voltage differences, edge spikes and other causes of electrical damages to bearings.

It should be noted that one hybrid bearing, typically on the non-drive-end side, could provide protection. However, the application of electrically insulating bearing such as hybrid bearings should be done in cooperation with experts on motor currents and bearings, and verified by field measurements. It should be stressed that the original equipment manufacturer should always be consulted about any design changes to electrical equipment.

### **Insulating solution**

In response to this solution and ensure rapid deliveries, SKF has expanded its range of stocked hybrid bearings for the electrical machinery market. Stock will consist mainly of deep groove ball bearing in the 60, 62 and 63 series with bore sizes ranging from 5 to 70 mm. Larger ones will also be available, either from stock or made to order at short notice. Hybrid deep groove ball bearings for VAV motors are typically equipped with low-friction seals (2RTZ or 2RSL), an injection moulded cage glass fibre-reinforced polyamide, roller centered (TN9), ceramic balls (HC5), clearance greater than normal (C3) and a wide temperature grease (WT) with high-performance characteristics for electrical motors. Typically SKF bearing designations are 6004-2RSLTN9/HC5C3WT or 6208-2RTZ/HC5C3WT.

### **Fire-safe bearings**

Good fire-protection is essential for large scale building works such as tunnels (for rail and roadways), airports, warehouses and large public buildings. Many of these structures are equipped with powered smoke and heat exhaust ventilation systems to provide formation of cooler and cleaner air below hot gases in case of fire. These potentially life-critical, dual purpose systems (normal ventilation and smoke exhaust ventilation) need to provide reliable emergency function over time.

The recent European standard EN 12101 – 3 specifies that ventilators for SHEVS and the associated direct – driven fan motors should be classified for use at emergency temperatures in case of fire. Today the F400 class (400 °C) is the most important applied level, and many European SHAVES for tunnels and buildings are being built to or upgraded to this standard. New motor design developments, however, can be expected to enable fulfillment of the requirements for the F600 class (600°C). Additionally, SHEVS installations should also give users low operating costs, as these systems are in continuous daily use for comfort ventilation. In many installations reliable comfort ventilation is of critical importance for removal of toxic combustion gases from cars and trucks and to limit disturbances of traffic flows.

It should be noted that the EN standard leaves it up to manufacturers, owners and operators to provide low life-cycle costs for daily comfort operation of dual-purpose ventilators. Also, the ability for emergency running after prolonged daily use is not specified. For further technical developments and large market acceptance, SKF has identified the requirements for bearings to be used in F400 and higher-class equipment, as stated by the EN standard, and also for additional user needs:

- Emergency running capability at 400 °C (two hours) or 600 °C (one hour) according to the standard;
- Shutdown and restart capability, at emergency temperature, according to the standard;
- Reliable emergency function over time;
- Very long service life (grease life) at normal motor temperatures (+ 70 to 120 °C);
- Satisfactory performance in cold climates;
- Quiet operation of the motor; and
- Re-lubrication possibility for open bearings.

Based on these requirements, SKF has selected and pre-tested bearing variants to support the development of electrical motors to meet the fire class F400 and beyond.

## **New test rig**

For screening and emergency testing of bearing concepts to withstand heat up to 600 °C. HEAT1, SKF has designed and commissioned a new HEAT1 test rig (heat emergency approval test). This new rig allows testing under load and running conditions as specified in EN 12101-3 for electrical motors. As a first classification step, a screen test was made on various potential bearing variants with different materials, grease and cage combinations, including bearings with high temperature greases.

In the screen test, three variants with SKF-selected electrical motor grease (A, B and C) did show superior emergency performance compared with variants with-temperature silicone or PTFE greases (D, E, F and G), or with polymeric cage (H). This was due to better material combinations in rings and rolling elements. Subsequent function tests (copying the specific EN 12101-3 schedule for motors regarding time, speed and temperature) went well for the two prime candidates. These two bearings types can be used in motors that need to fulfil the F400 and F600 requirements (Table). The function tests showed that the F600 class is achievable for bearings without the need for a bifurcated design. The fire resistance of the electrical windings, however, is the limiting factor, and it is in the range of 400 °C.

SKF bearings used within fire safe designs will normally be supplied and certified with the electrical motor. Retrofitting of existing fan motors using high temperature greases is also desirable to reduce operating costs and noise levels, and to allow an increase in safety over time. To assist such work, SKF can offer testing and engineering knowledge within this field to enable re-certification without need for retesting of complete ventilator and motor ranges.

## **Reference Book:**

Electrical India  
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