tech.mag

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NEW IDEAS AT A GLANCE

ebmpapst

Editorial

Dear ebm-papst friends, partners and customers,

welcome to the new ebm-papst tech.mag. You surely wonder what this new medium is all about and what sort of information you can find in here.

First of all, our tech.mag is the technical magazine jointly published by ebm-papst Mulfingen, ebm-papst St. Georgen and ebm-papst Landshut. The main criteria in selecting the contributions for the tech.mag was to offer you innovative, interesting and new technical solutions and food for thought. One or the other publication included in this selection may have caught your eye in trade magazines. For your convenience, our tech.mag brings you these innovative technical articles in one omnibus edition at last.

Published twice a year, our tech.mag will be posted to ebm-papst friends and partners. You will also be able to find it at all the fairs and trade shows ebm-papst takes part in throughout the world. Just ask for it. Also, if you would like to keep the tech.mag for further reference, there is a special collector's file available which you can also simply order from our PR department in Mulfingen.

In the editorial, our technical directors will keep you informed of what is going on in our R & D departments and share with you their ideas and thoughts concerning innovative solutions and approaches. Thus, the tech.mag can doubtlessly serve as impetus for our friends, partners and customers and may hopefully trigger off new ideas and solutions.

We are looking forward to your feedback and hope you find some interesting aspects for your daily work by reading your way through this first edition of our "tech.mag – new ideas at a glance".

„We are looking forward to your feedback!“

Enjoy!

Thomas Borst
Managing Director
ebm-papst

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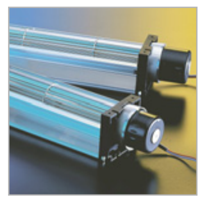
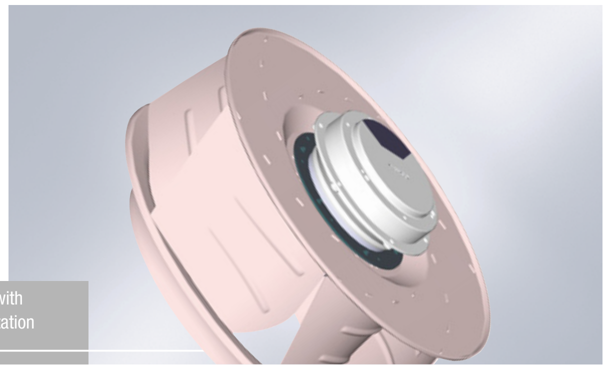



From mere dwarf to a giant of a fan

1. Introduction

By now, it has become almost second nature for most people to go soft on and save natural resources. This is why companies, too, should face up to their obligation to make their products contribute actively to environmental care. As huge numbers of fans are to be found in the most varied of applications, there is an enormous potential for saving energy here. Unfortunately, this potential is still not being tapped fully, despite the fact that the simple use of electronics offers this possibility. Nevertheless, the solutions known so far are flawed by three disadvantages: significantly higher costs than conventional solutions, electronics that appear to be complicated and have to be connected separately, plus rather an unsatisfactory noise behaviour.



modern DC motor with electronic commutation

Against this background, ebm-papst as market leader in motors and fans has taken up the challenge and now supplies the market with a complete line of innovative fans that can be connected directly to the mains and which substantially and positively differs from current solutions both in technical and economic terms.

2. Advantages of EC technology for fan applications

Using a classic asynchronous motor is still justified in many applications. However, when used as fan drive, there are quite a few shortcomings to consider, among them:

- Maximal efficiency of less than 75%, which can, moreover, only be achieved within a narrowly defined speed range.
- In order to realise different speeds, designs with different numbers of pairs of poles are required, and thus there is an ever bigger variance.
- Different motors or motor designs are needed for operations at 50 Hz or 60 Hz.
- In order to change speeds, additional components (star-delta transformer, triac control, frequency converter) are needed that result in higher costs, require more space, cause additional losses and lead to higher noise emission.
- A fan is suited for only one optimal operating point for which it has to be designed precisely – and so the number of variants goes up once more!

These disadvantages can be avoided with motors in EC technology in the power range of up to 3 kW, which shall be dealt with here.

EC motors are synchronous motors excited by permanent magnets and with phase currents being converted by an electronics in dependence from the rotor

„Installing the EC fans is absolutely simple ... "

position. This principle allows to reach efficiencies of up to 90% across a very wide speed range – and this with the losses caused by the electronics already being taken into account! As the electronics makes it possible to operate the motors at different speeds, there is no longer any need to supply variants with different numbers of pole pairs. This reduces the number of variants for both manufacturer and customers. Their controllability also makes sure that optimal operating points can be set exactly; moreover, the comfortable open and closed loop control possibilities do in no way have a negative impact on acoustics, efficiency or system costs!

3. New fan lines

During the past three years, ebm-papst Mulfingen has consistently developed an entire line of EC motors. This line consists of motors in four sizes, from 100 W to 3 KW. Each size is available in two or three face-to-face dimensions and is thus graded fine enough. These motor variants suffice to realise the line of axial fans with diameters between 250 mm and 1,000 mm (see **fig. 1**), as well as the line of centrifugal fans with backward curved blades and diameters from 250 mm to 630 mm (**see fig.2**).

Throughout the development, special attention was paid to the design objective of getting groups of components properly separated. This then made it possible to manufacture the groups of components at different locations, and it also ensured safe and economical assembly. The new motor design also comes in protection type IP54 without requiring any additional efforts. These EC fans are simple to install: they are fully compatible with and can be used like 3-phase fans – there is no need for additional components. However, the EC fans can also be controlled via linear or BUS interfaces.

4. Potential for saving energy and costs

The power input of an axial fan in EC technology is compared to that of an axial 3-phase fan in figure 3, with three different control modes used. In the maximum air flow range, the EC motor requires 15% less power input than the 3-phase motor, which is due to its better efficiency. When it comes to lower air flow values, especially in the partial load range, then the advantage of the EC technology get even more pronounced. This is simply due to the fact that the EC motor has a high efficiency across a wide speed range, whereas the efficiency of the 3-phase motor quickly drops with decreasing speed.

Power input in the partial load range is more than 50% lower than what the 3-phase motor requires. Based on an average annual operation time of 4,000 h/a and the power saving according to **fig. 3**, the annual saving in costs by simply using an EC fan can be calculated easily by relying on **fig. 4**.

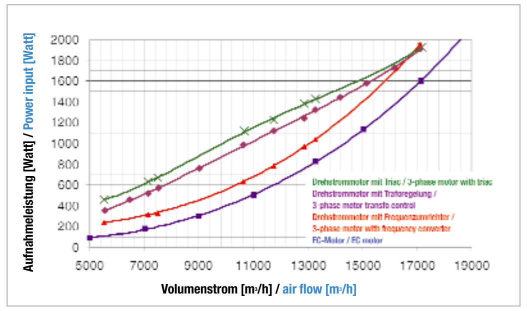
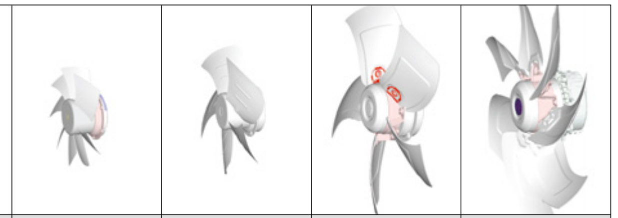
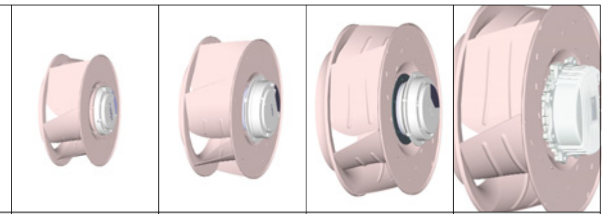


Fig. 3: Comparison in power input between axial fan in EC technology and axial fan in 3-phase technology in the partial load range.



Motor type	M3G074	M3G084	M3G112	M3G150
Impeller Ø [mm]	300 250	450 400 350	630 560 500 450	1000 910 800 710

Fig. 1: New line of energy-saving EC axial fans



Motor type	M3G074	M3G084	M3G112	M3G150
Impeller Ø [mm]	310 280 250	400 355 310	500 450	630 560

Fig. 2: New line of energy-saving EC centrifugal fans

These enormous savings in operating costs as offered by EC technology have, so far, not been adequately taken into account. Regarding the entire service life, the savings thus gained are substantially higher than the purchasing cost of the EC fan! For operators of plants, the consequence is simple and straightforward: only energy- and cost-saving EC fans should be exclusively used in future. Yet those responsible for setting up a plant were forced, for competitive reasons, to go for speed-variable fans in 3-phase design as EC solutions available up to now have been more expensive than the conventional types. The new ebm-papst line marks the beginning of a new era: suddenly, purchasing costs of EC solutions are at the same level as the purchasing costs of technically comparable 3-phase solutions.

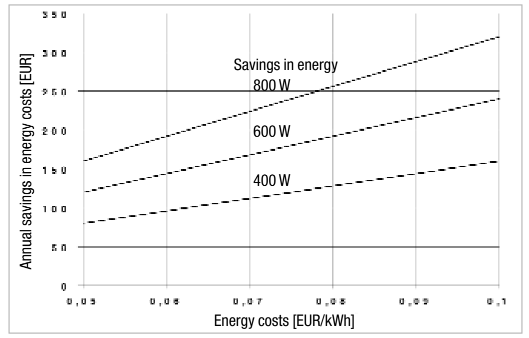


Fig. 4: Saving in operating costs by using EC fans, at an operating time of 4,000 h/a.

Cost savings that normally do not get considered are to be found on the logistic side of things: EC fans can be operated without any need for modifications on power supplies with different frequency, and the operating point can be set via variable speed. For this reason, it is possible to replace a large variety of 3-phase fans with just one EC fan.

5. Noise behaviour of the new fan lines

Whenever a 3-phase fan is operated with triac control or frequency converter, the noise behaviour in the partial load range gets negatively influenced. This is illustrated in **fig. 5**, and comes as a result of the oscillations in the electro-magnetic fields and deviations in electric conductance which form electro-magnetic harmonics with their resulting power and torque excitations. The fan emits them in the form of air-borne or structure-borne noise.

So far, and from an acoustic point of view, the most harmless case has been operating a 3-phase fan with a transformer. The same positive noise behaviour can now be achieved with EC fans, with phases and their time sequence being impressed in a suitable way.

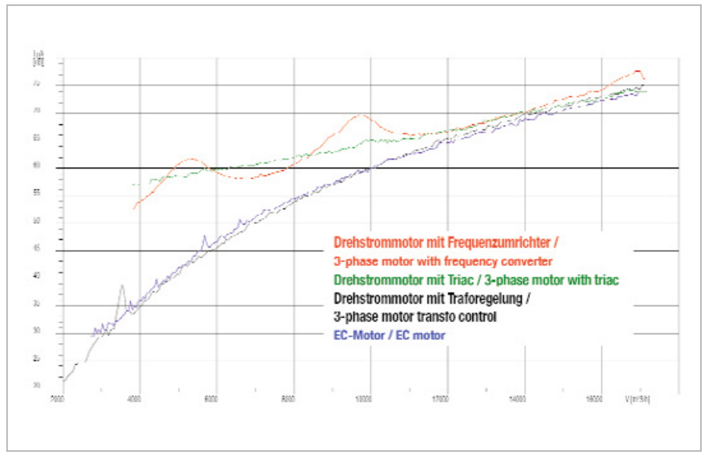


Fig. 5: Comparison of noise behaviour between axial fans in 3-phase technology and an axial fan in EC technology.

6. Summary

With this newly developed and complete line of ebm-papst external-rotor motors in EC technology with integrated electronics, there is an intelligent and compact alternative for speed-variable fans a wide market can make use of. The new lines offer a substantial potential for saving energy, with the purchasing costs paying off quickly, as operating costs can be reduced significantly. Compared to axial fans with speed-variable 3-phase motors, the new EC fans do not generate higher motor noise in controlled operation.

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The right fan design: axial, centrifugal, mixed flow?

„Operations as softly as a whisper require know-how“

As varied and different as the operating condition, as varied and different are the designs of fans and blowers. "Air suppliers" mainly differ in the physical principle of transmitting energy to the medium gas. Depending on the design, a fan is suited for different operating conditions. This text focuses on the various fan types, their corresponding physics, and the effect their design has in practical terms. (Part 2 in this series then examines further distinguishing characteristics, also dealing with the drive chosen, the material used, and the question whether and what control electrics are integrated in the fan.)

„Axial fans: lots of wind, little pressure“

Air in motion possesses kinetic energy. This energy has to be fed into the stagnant ambient air in order to generate any sort of airflow. The most commonly known example for this principle is the propeller of a plane: a profiled rotating wing transmits the shaft output into the air and a directed airflow is generated. Impellers with centrifugal blades and drums with longitudinal lamellas as well as types in between these designs are suitable designs for the conveyance of gas.

Axial fans: lots of wind, little pressure

The propeller principle is used in axial fans. The flow of air through the impeller with the (propeller) blades is

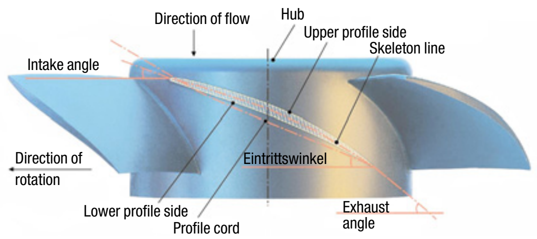

Fig. 1: Section: impeller profile

almost entirely parallel to the rotor axis, which is why we call it an axial fan. The rotating fans are complexly formed in order to guarantee a high efficiency. Not only the curve of the entire blade (**fig.1**), but also the profile of the blade changes with the diameter, and so does efficiency. This is because of the increasing circumferential speed of the individual blades the further away they are from the driving axle. Essentially, the working principle can be explained like this:

The air sucked in always flows toward the air inlet from all sides of any room. The outer housing assumes the role of suction head. For this reason, the air intake edges are rounded off. On the air discharge side, the air is expelled in axial direction. This is done by the fan blades, which press the air through the fan, so to speak. As homogenous a flow of air as possible without any vortex being generated is what is striven for. A fan designed this way operates very quietly. Outside the optimum operating point, i.e. with pressure constantly increasing, this changes drastically: The „conveyance by positive displacement“ is increasingly superseded by conveyance via centrifugal acceleration of the gas molecules. This is because additional energy can only be supplied by increasing the speed. And then the blade geometry, optimised to one speed, is simply overtaxed. However, with an increase in back pressure, conveyance by centrifugal acceleration of the gas molecules gets increasingly stronger. In consequence, the airflow is increasingly at risk of being severed from the inner part of the impeller, close to the axle, and starts to push outward. In places where the airflow is severed, i.e. close to the fan axle, separation vortexes (**fig. 2**) appear. These in turn generate turbulences and noise. Besides, this vortex zone is not available for further energy supply. And so the efficiency of the fan drops with increasing back pressure while the noise level goes up.

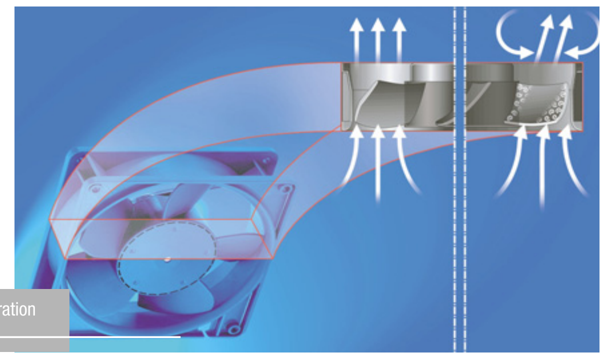

Fig. 2: Vortex separation at the hub

Operations as softly as a whisper require know-how

For the cooling of electronics, axial fans with a complete outer housing are mainly used. This compact design with drilled mounting holes in the flanges makes for space-saving installation possibilities. One disadvantage of this compact solution, though, are the indispensable struts going from motor housing to outer housing. During operation, when the blade edges of the rotor pass the struts, then, perforce, pressure jolts occur which can increase the running noise of a fan substantially. This effect is widely known in traffic, too: your traffic light on red, you sit in your car to turn right or left, and any truck driving past you straight on generates pressure jolts making your whole car vibrate and which your ear perceives as bumps.

The problem can be resolved by optimising the design of the geometry of the blade end edge and by the ratio number of blades to number of struts. Principally, a smooth transition from blade to strut is of advantage. This is why spirally curved struts, spread non-symmetrically along the housing circumference, are to be preferred because of less noise being generated this way. The less a vortex is generated, the better the acoustic behaviour of the fan is. The human ear perceives the noise generated by an odd number of blades and struts as more agreeable than that generated by an even number. Optimal results can be attained by continuously improving this via special software simulations.

Handling air at higher pressure

For applications where maximal pressure build-up is required at minimal airflow, a centrifugal fan is the better option, as the entire airflow leaves the impeller at the outer diameter. The higher kinetic energy of the air molecules thus possible generates higher pressure than an axial fan, the circumferential speed of which at the impeller hub is limited. If, for instance, the airflow has to be deflected by 90° or if components, filters, etc. obstruct free airflow, then centrifugal fans are more effective. Here, too, a centrifugal fan design complete with housing is available. The product range offered by ebm-papst St. Georgen also contains various and different motor/impeller combinations for applications making it possible to integrate the conveyance of air to build up pressure in the housing.

A distinction must be made between two different impeller types. There are impellers with – in direction of rotation - forward curved blades, and there are impellers with backward curved blades (**fig. 3**). Forward curved blades allow for a stronger deflection of the airflow and thus a higher energy conversion. Their disadvantage lies in the

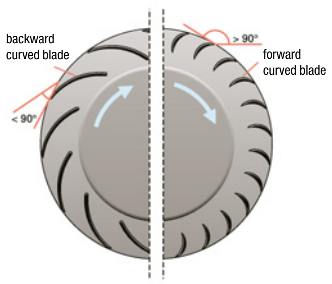

Fig. 3: Impeller of a centrifugal fan, forward/backward curved

higher angular momentum of the exhaust air, which then has to be converted into pressure in a subsequent diffuser. The simplest form this takes is a spiral diffuser that can be integrated in the fan housing (**fig. 4**). But one can also use baffle plates respectively diffusers inside the unit. In contrast to this, backward curved blades do not have such a high energy-conversion rate, again in respect to the mounting space. The advantage of this configuration, however, is that pressure builds up mostly in the impeller itself. And so, in most cases, the scroll housing can be done without. Especially when it comes to cooling the electronics, one needs a free and unrestricted airflow, and thus the principle of the backward curved blades without diffuser is most welcome.

To get higher air performance, so-called dual inlet centrifugal blowers can also be used, with the air allowed to flow into the impeller from both sides. The drive is placed between the two impellers. A special design of centrifugal fan is the so-called drum rotor (**fig. 5**). This fan with forward curved blades is mostly chosen for applications requiring small radial dimensions.

Hybrid solution: the mixed flow fan

Placed between these two extremes in fan design discussed so far, there is the so-called mixed flow fan. Its principle makes use of both the „blade effect“ of the fan impeller and the centrifugal acceleration. The advantage of such a design is that the airflow almost comparable to that of the widely used axial fan with the possibility to build up far higher pressure. Thus, without having to make modifications to the unit design (as normally the case when using a centrifugal fan) it is possible to overcome higher back pressures. Units that are refitted with additional components obstructing the airflow can thus be quickly equipped with a suitable and quiet fan. The main characteristic of a mixed flow fan is the conical rotor hub. The air intake with the mixed flow fan is almost axially, too., but the conical, ninepin-like hub has a small diameter at the intake zone. Towards the pressure side, the diameter increases. The resulting higher circumferential speed of the blade tips at the air exhaust also makes for a higher centrifugal acceleration of the air (**fig. 6**). The flow path is thus adapted to the aerodynamic process. Compared to axial fans of identical size, more energy is transmitted to the air and the pressure that can be achieved also increases. Due to the conical form of the impeller hub, the vortex generation can be minimised. This makes sure the fan operates very quietly even at high speed or high pressure build-up.

Fig. 4: Centrifugal fan with integrated spiral diffuser

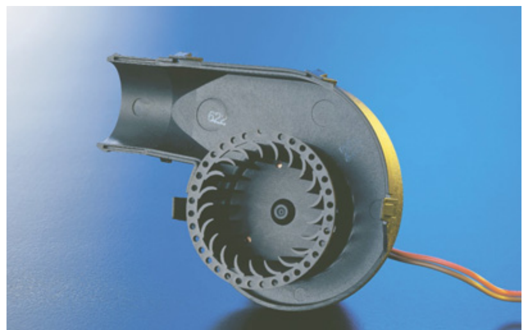

Fig. 5: Drum rotor for extremely small dimensions

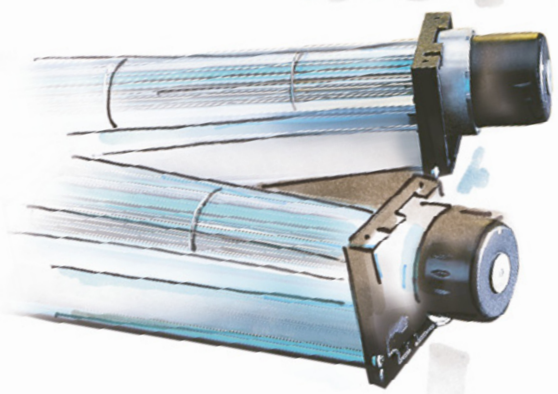

Fig. 7: Tangential blowers

For applications requiring a high air volume at low pressure build-up, the tangential blower principle is ideal. The air flows twice through a drum-shaped impeller with numerous small blades in axial direction (**fig. 7**). This happens outside-in at the intake zone, and inside-out at the exhaust zone. Diffusers placed inside or outside the impeller drum generate vortexes that guarantee consistent and stable flow through the impeller. The main field of application for tangential blowers are units requiring air to be supplied across a wide surface.

Fan and blower designs adapted to the application make it possible to achieve optimal air handling by making the best use of the physically existing flow conditions. Minimal running noise and minimal power input are then guaranteed. A second paper will deal with the drives, material and control possibilities for the practical realisation of the principles discussed in this paper.

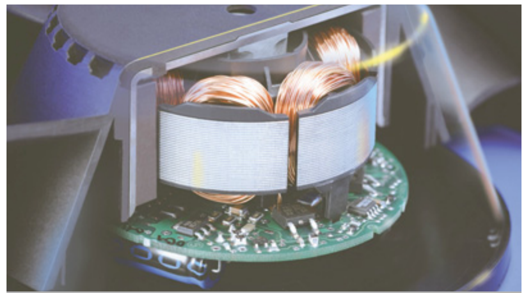

Fig. 6: Sectional view of a mixed flow fan

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Blowers for refrigerator applications with improved performance

Freezers with automatic de-icing and zero degree compartments in refrigerators depend on the use of air moving devices. In modern convection-based systems, the reliability of the frost-free blower has become very important because a failure of the blower will also cause the entire appliance to fail.
This paper describes blowers for cold storage appliances that have been developed with the focus on high reliability and the lowest possible energy consumption. The sleeve bearing system is based on new materials and special humidity protection is applied to the electronics. These features have been introduced in order to achieve reliable products that fulfill the stringent specifications of cold storage appliances. Today brushless DC motors are an interesting solution for these applications.
The noise properties of these motors have been optimised to resemble those of an AC motor making it a hassle-free direct replacement in existing appliances.
In todays cold storage appliances ease of use and comfort features are the main innovations that are obvious to the customer. In the background new standards for energy consumption put pressure on the efficiency of every single detail solution.

Introduction

Motors for blower applications inside a freezer or refrigerator are exposed to a harsh environment including very low temperatures, high humidity, and rapid temperature changes.
Modern designs of variable capacity compressors lead to longer duty cycles for the blower.
This results in extreme demands on a life expectancy exceeding 100,000 operating hours. The increased duty cycles and new standards for energy consumption in the EU and the USA require improvements to the motor efficiency.
However, the most demanding development target is the fulfillment of the continuously increasing expectations of the consumer concerning the reduction of audible noise emitted by technical products. Refrigerator blowers are typically mounted on the internal cabinet of the appliance which, for cost reasons, normally consists of a thermoplastic material. Its acoustic properties include rather poor damping. Therefore, a great deal of attention must be paid to the composition of the blower-induced vibrations.
This paper describes new approaches to the improvements of energy efficiency as well as reliability in the unfriendly condition inside an appliance. The properties of standard AC motors are compared to competing designs of brushless DC (BL-DC) motors.

Application and Ambient Conditions

In freezer and refrigerators, the typical mounting location of the blower is inside the cold cabinet. This increases the compressor load by the radiated energy loss of the motor, which further reduces the overall efficiency of the appliance.

Frost-free blower

Typically the frost-free blower is mounted in the circulation path of the airflow between evaporator and cabinet. In cooling mode the blower maintains the flow of cold, dry air from the evaporator to the cabinet. During the de-icing operation of the evaporator, the ambient temperature is increased above the freezing-point for a short time resulting in saturated humidity due to the melting ice. During this phase, the motor is switched off and there is no airflow.

Some of the humidity will then condense on the cold surface of the motor. Later, the motor is restarted when the evaporator has reached the normal operating temperature. The flow of dry air will then remove the condensate from the surface of the motor.

Refrigerator circulation blower

Refrigerator circulation blowers are, for instance, used to produce layers of different temperature inside the cabinet. There, the ambient temperature is just above freezing-point. Exposure to humidity depends mainly on the mounting position and how often the door is opened.

Operation point

The typical axial impeller of the blower has a diameter of 100 mm. The known operating point is about 2400 rpm. This is a compromise between the efficiency of an AC shaded pole motor and the noise composition. The output power demand is about 0.7 W. As can be seen in Table 1, a standard C-frame shaded pole motor of 2.5 inch size consumes 7 W which yields only 10% in motor efficiency. The following new designs are discussed and compared to this set-up.

Shaded pole motor with improved efficiency

A new shaded pole motor (EM2513LN, **Fig. 1**) has been developed targeting the general market. This includes some unique design features for optimising the power consumption, reliability, and ambient temperature range.

Compared to the market standard for frost-free motors, the geometry of the C-frame has been redesigned to a smaller rotor diameter with increased active length. The benefit is a reduction of losses caused by end effects. These are a combination of nonlinear contributions to slip losses in the rotor and of stray losses in the stator.


Fig. 1: Shaded pole motor EM2513LN

The improvements were achieved by reducing the cross sectional area of the iron path, both inside the coil and on the sides. Naturally, the flux density was kept at a reasonable, reduced level. The major benefit of these modifications was the reduction in the average turn length of the coil resulting in a reduction of copper losses.

The axial length of the motor is fixed by the position of the rubber grommets of the resilient mounting. Hence the increase in stack size by 3 mm had to be compensated by smaller bearing brackets. In particular the length could be reduced by omitting inner covers on the cavity of the bearing bracket.

In former designs, these covers were needed to prevent the lubricant from dropping out of the motor. This occurred when the felts or other fibre material of the reservoir could not retain the oil, e. g. due to rapid temperature changes or excessive saturation.


Fig. 2: BL-DC frost free blower BG2012

In the new bearing bracket design the felt has been replaced by a slow release material that proved to lubricate the bearing more reliably under all conditions.

The method of transporting the lubricant to the sleeve bearings is based on capillary action. Any lack of lubricant will therefore only drag the required amount of oil from the reservoir, but never an excess amount, which could happen with a felt system.

Extensive tests proved a life expectancy of more than 100,000 operating hours. Furthermore, comparative tests in real applications showed the absence of any lubricant whizzed from the shaft or leaking from the bearing system.

The lubricant used is a silicon oil with very low viscosity index. In cold conditions, it has a significantly lower viscosity than other, more commonly used, synthetic oils.

The low viscosity index allows the same motor to be used from the lowest temperatures (-40°C) up to about 60°C, as can be found in compressor cooling applications.

The coil is protected by encapsulating it in a polyamide resin. A special patented fixation method also allows the connection between the coil and the supply leads to be sealed within this enclosure. Even connectors and other additions can be moulded directly to the coil.

PM BL-DC motor for direct mains connection

The mechanical design principles of an asymmetric shaded pole motor have been applied to a permanent magnet brushless DC (BL-DC) motor (BG2012, **Fig. 2**) in conjunction with the objective of achieving a direct replacement, but with higher efficiency. However, the addition of an electronic circuit board demands renewed discussions on humidity protection. The printed circuit board (PCB) is covered by an enamel as a protection against corrosion. Hence small amount of condensate will not affect the electric function of the circuit.

However, additional protection of the electronics is necessary. This could be achieved by enclosing the whole motor. To protect the electronic components from mechanical stress caused by the enclosing resin, it was decided to use a simple plastic cover. This separates the PCB from the moisture-carrying airflow. During the defrost phase, the ambient temperature rises and the expanding air inside the cover prevents any humidity from entering the enclosure. Consequently, condensation of humidity on cold motor surfaces is avoided. In order to reduce the long term exposure of the PCB to humidity, special care should be taken that the blower is switched on only after the ambient temperature has dropped below the actual motor temperature. This procedure minimises the exposure to moisture with the least effort.

The motor is supplied by a low voltage circuit , which uses a capacitive current limiter to feed the low voltage directly from the mains. A series resistor provides short circuit and voltage surge protection.

The shape and mounting arrangement of the BL-DC motor are identical to AC motors making it a perfect replacement for appliancies with energy efficiency class A.

„No-Frost blowers under test“

Energy efficiency

The energy efficiencies of both the new motor designs have been compared to the market standard.

Fig. 3 shows the input power of a typical C-frame AC motor in comparison to the new designs. The power consumption of the AC motor lies at the known level of 6.9 W. Its operating point is 2400 rpm with a 100mm axial impeller.

The energy-optimised EM 2513LN consumes only 4.8 W, corresponding to a reduction of 30%. In order to achieve further improvements, a commercially effective solution could be the reduction of the shaft diameter to less than 1/8 inch.

A diameter of 2 mm would be sufficient as regards the bearing. However, the motor would have to be handled very delicately with a shaft this fragile. By combining better steel for the laminations and a higher copper content, the power consumption could reach targets below 4 W, but at considerably higher cost.

The brushless DC motor BG2012 achieves a better efficiency level easily with a measured power consumption of 2.4 W, which is 1/3 of the standard. A large part of this power is dissipated by the protective resistor. With external devices as a substitute for the resistor, the power consumption could be further reduced to approximately 1.8 W.

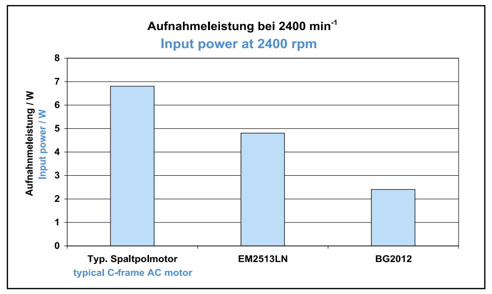

Fig. 3: Input power of frost-free blowers

Noise

The increasing number of motors and blowers in electric devices has led to more demand for noise reduction, in particular for blowers in household appliances. Consequently, an investigation was carried out to compare the different frost-free blower solutions with respect to their noise emission.

Three different designs were investigated: a 4-pole and a 2-pole version of BL-DC motors and a 2-pole version of a shaded pole motor. Although the 4-pole BL-DC motor utilises the materials to a higher degree, the final decision was taken for a 2-pole design. As will be shown below, the noise properties of 2-pole shaded pole motor and BL-DC motor versions are superior to those of 4-pole BL-DC motors.

Measurement set-up

Each motor was fitted with the standard 100 mm impeller and mounted under normal conditions in a commercial upright freezer with a height of 1.84 m. The blowers were mounted using rubber grommets, which is usual in customised appliances. For these tests, the blowers were supplied from the mains, while the compressor remained inactive. Thus only the noise emitted by the built-in motors was measured.

This allowed an excellent comparison between the tested motors because all other influences were eliminated. Before each measurement, the speed was adjusted to 2400 rpm with the 100 mm impeller fitted.

Sound pressure was measured using a microphone placed one meter from the front of the closed cabinet door at half the height of the freezer. Alternatively, a stereophonic microphone (artificial head) with recording facility was used for off-line evaluation of the sound impression. Sound measurements were carried out in our special anechoic room (**Fig. 4**). The acoustic levels were represented in an autospectrum with 1/24 octave filter in a frequency range from 16 Hz to 10 kHz.

Spectral composition

The essential results of the noise measurements are shown in **figure 5**. The fundamental frequency, i.e. the motor speed, is reflected in the dominant 40Hz component. However, the lower order harmonics (80, 120, 160, 200 Hz) have been found to be of major significance, too. In addition, the line frequency caused a 100Hz contribution, especially in the case of the shaded pole motor. Analysing only the fundamental levels, it appears as if the shaded pole motor causes more noise than either of the BL-DC motor designs. However, experience has shown that the shaded pole solution is a preferable choice with respect to acoustic noise emission.

Fig. 4: Test setup in the anechoic room

Looking at the harmonics, it becomes evident that the AC motor solution has advantages in the higher frequency range where the susceptibility of the human ear increases significantly.

In this range, a striking difference occurs between the 2-pole and the 4-pole BL-DC motor blowers. The noise emission of the latter was considerably higher resulting in a significant increase of annoyance.

On the other hand, the line frequency induced 100Hz component is only relevant for the shaded pole AC motor. Naturally, voltage rectification minimizes this noise contribution of the BL-DC designs.

When the acoustic noise was evaluated using the common A-type filter, the result displayed in **Figure 6** was found. This shows that the 4-pole BL-DC design has remarkable disadvantages concerning noise emission. On the other hand, the 2-pole BL-DC motor produces a noise level that is approximately equal to that of the shaded pole AC motor. These results coincide with the subjective impression.

Consequently, considering both noise emission and energy efficiency, the preferable solution is the 2-pole BL-DC motor blower. Fortunately, this coincides with mechanical dimensions that allow a simple replacement of existing AC motors by the new BL-DC design without any other modification.

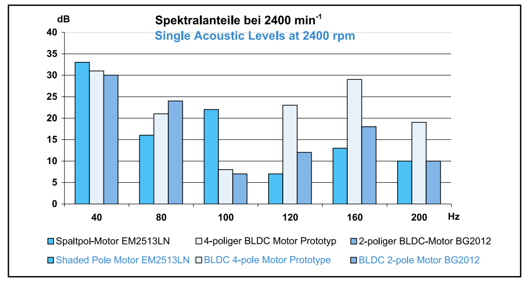

Fig. 5: Single acoustic levels at 2400 rpm

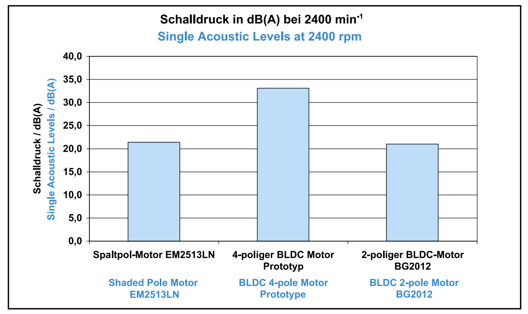

Fig. 6: Single Acoustic Levels at 2400 rpm

Conclusion

New technical approaches have been put forward for the important features of air moving devices in cold storage

Twin-centrifugal blower units for air-conditioning

appliances. A sleeve bearing system lubricated by a slow-release, silicon based material allows a wide operating range of the blowers including reduced friction at freezer temperature.

A humidity-protected brushless DC motor is proposed featuring very low power cosumption and thus providing an easy way to achieve higher energy classification. It has been shown that the noise emitted by the BL-DC motor does not require a resiliant mounting solution different from the method used for similar AC motors.

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Sales Director
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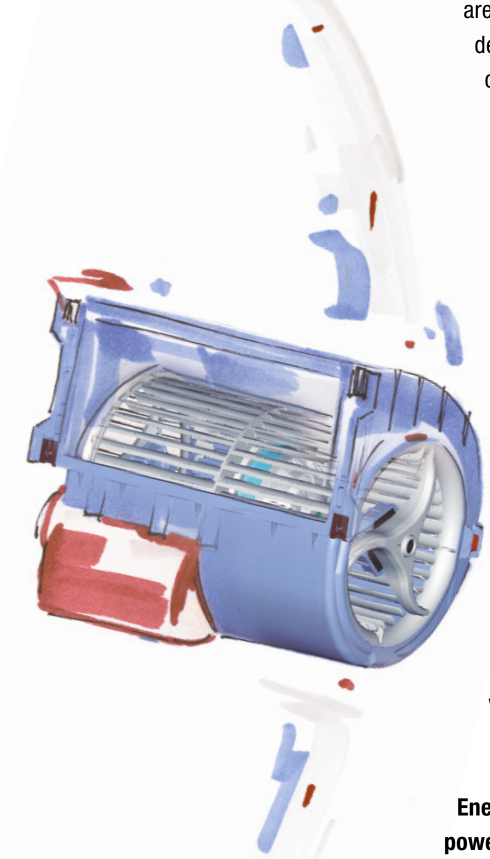


For applications in air-conditioning, high-quality twin-centrifugal blower units, also termed „Fan Coils" by ebm-papst, are in ever increasing market demand. Due to their attractive pricing and their high power range, these blowers can be used wherever conventional centrifugal blowers have been in operation so far. Typical fields of application of these units are, among others, air-conditioning units, heat convectors or hot/cold air curtains.

In this field, ebm-papst have developed a highly innovative product for an important reference customer: a unit in size 146 mm, available both as Fan Coil and as conventional, dual inlet centrifugal blower.
This unit achieves maximum air volumes of up to 1180 m³/h.

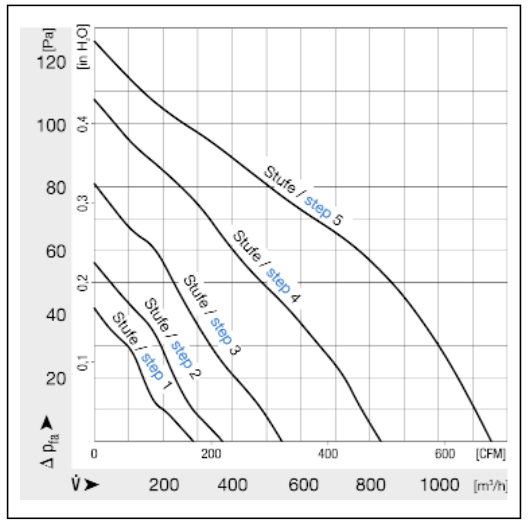
Energy-efficient: two blowers powered by one motor
What makes the Fan Coils or twin-centrifugal blower units so special is the fact that both blowers are driven by one motor via one shaft. This helps to save one additional motor and translates into substantially lower investment and energy costs.
Due to the proven ebm-papst experience in motor engineering and fan technology, both long service life and minimal noise generation are guaranteed.
This long service life is based on the ball bearing system as used in the 68-motor, our proven standard for decades. Blower housing and impeller are aero-dynamically optimised and, together with the motor suspension with integrated anti-vibration mount and the balancing of the motor as complete unit, are responsible for the minimised acoustics.
The 1-phase AC external-rotor motor features 5 speeds that can be defined to fit specific customer applications.

Designed with customer-specific mounting conditions in mind

With standard Fan Coils, the forward curved blowers have to be mounted onto a mounting sheet (drip pan) as supporting element. This can cause problems in customer-specific applications. By contrast, the ebm-papst solution with its self-supporting design makes the unit suitable for the most diverse mounting configurations, thus offering new flexibility in customer-specific applications. And so, various flange and nozzle solutions for all types of drip pans are available, making the unit compatible with existing systems. A robust mechanical design, optimised by FEM calculations, provides stability that is required.

The compact build of the Fan Coil unit also offers another obvious advantage: though providing the same air volume, it needs substantially less fitting space than a conventional system.
As the unit is already completely wired up and ready to use, potential installation mistakes are simply avoided. Moreover, the required capacitor is already integrated in the terminal box. Post-assembly contacting of the Fan Coil unit is also possible via an adequate plug connection. Connection leads can therefore be installed well before the unit itself is mounted. And the modular design also makes it far easier to dismount the unit should there ever be a reason to do so.

The Fan Coil unit not only comes in designs corresponding to VDE respectively EN standard; it can also still be manufactured in UL-approved plastic materials of inflammability class VO and UL-approved motor system.



Modular design for optimal cost-performance ratio
Developing the Fan Coil unit also resulted in the development of a matching conventional centrifugal blower. This blower has the same build with identical mounting dimensions and an external-rotor motor with integrated anti-vibration mount. This modular system allows the customer to enjoy an optimal cost-performance ratio.

Fan Coil unit Dual inlet		**Centrifugal blower** Dual inlet	
Part number:	K4E 146-AB57-01	Part number:	D4E 146-LV55-01
Voltage	230 VAC	Voltage:	230 VAC
Frequency:	50 Hz	Frequency:	50 Hz
Air volume:	1180 m³/h	Air volume:	565 m³/h
Speed:	750 min^{-1}	Speed:	780 min^{-1}
Power input:	85 W	Power input:	65 W
Current draw:	0.38 A	Current draw:	0.29 A
Noise level:	47 dBA	Noise level:	44 dBA
Protection type:	IP44	Protection type:	IP44
Insulation class:	F	Insulation class:	F

Brief overview of performance data

Dipl.-Wirt.-Ing. Hauke Hannig (left)
Marketing Support

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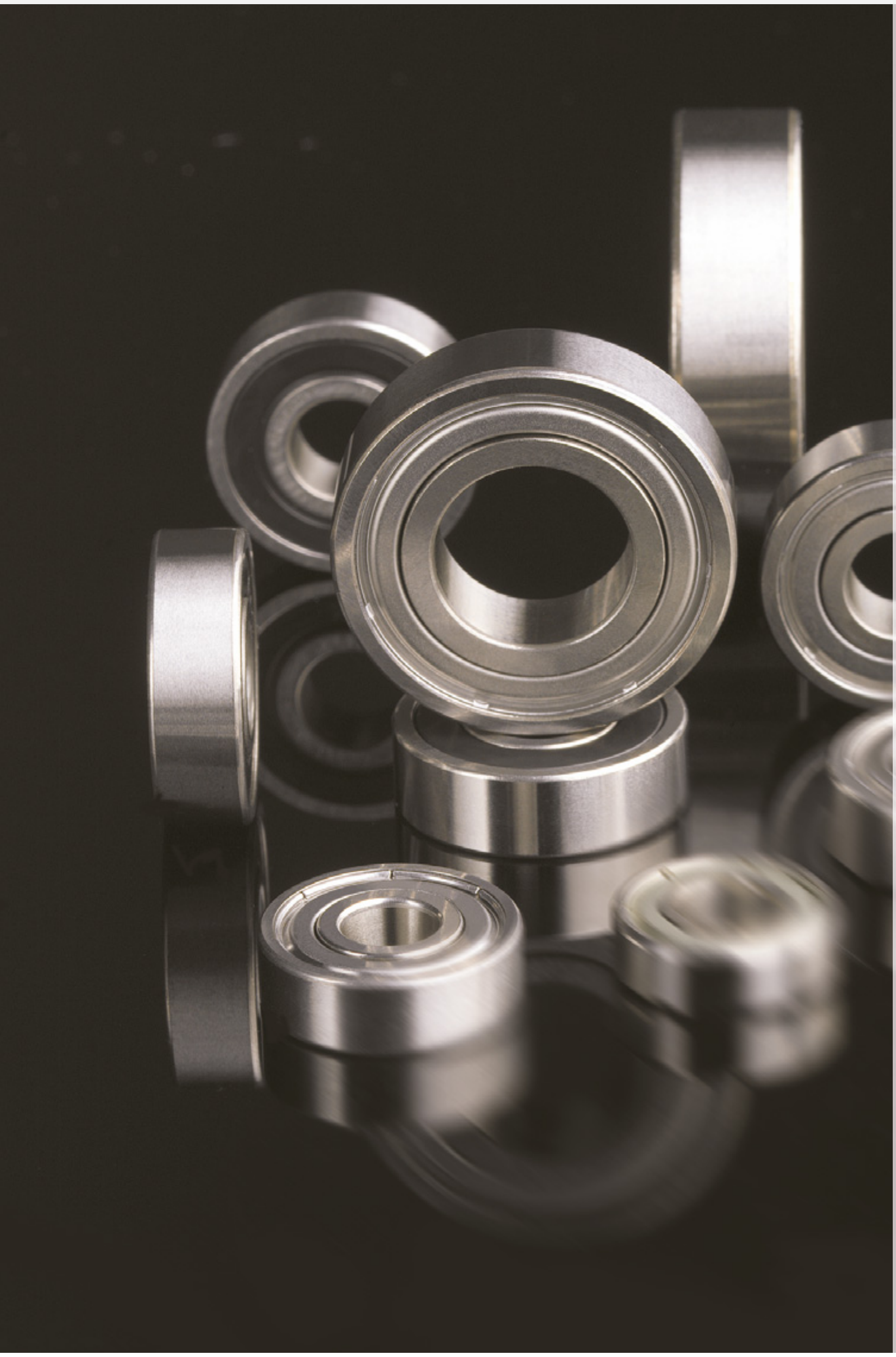
Requirements as to durability of fans



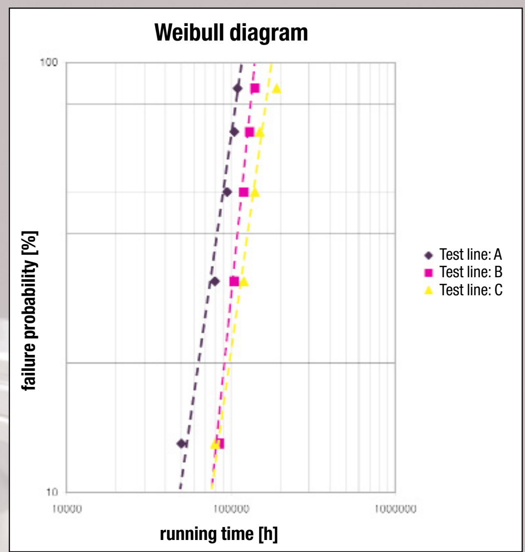


Fig. 1: Evaluation of the test results in the Weibull diagram

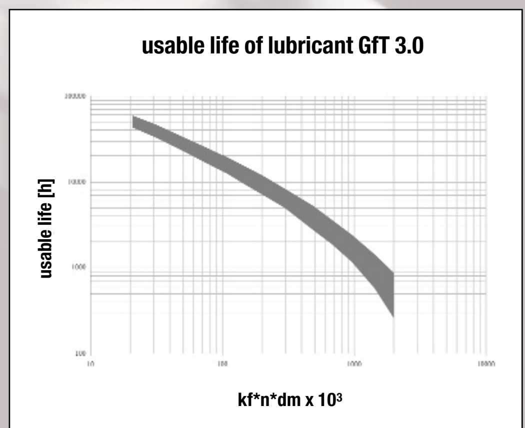


Fig. 2: Usable life of a lubricant as per Gft 3.0.

This was the go-signal for the „Life Time Extension Project“ (LTE).

Demands on the durability of fans are getting higher all the time. In 1995, a manufacturer in telecommunications requested a durability of 10 years, and this was only the first step. As a second step, 20 years should become possible. The objective was to make sure no fan needed replacing throughout the entire lifetime of a so-called radio base station.

These demands triggered the **„Life Time Extension Project“ (LTE)**. This project was a co-operation of all the people involved: lubricant manufacturer, bearing supplier, fan manufacturers ebm-papst Mulfingen and Landshut and users. This was important, as the necessary basics and influencing quantities on the bearing lifetime and their interdependence could be worked out together and the results were thus available to all participants (**fig. 1**).

Factors affecting lifetime

When calculating the bearing durability, the purely mechanical side has to be looked at first before checking the tribological aspects. Mechanical calculations are based on the method as defined in DIN ISO 281. The proper bearing dimension has to be established. But it is not only the type of bearing and the size that have to be exactly defined; equally important is the proper environment (bearing alignment, bearing adaptations, bearing preload, as well as amount of lubricant, dosing, ball or cage material).

As the ball bearings used by ebm-papst are not meant to be re-lubricated, the usable life of the lubricant has to be established very carefully. Bearing size and the bearing temperature, but also by speed and, last but not least, the lubricant itself influence the usable life of a lubricant. A worksheet supplied by the GfT (Gesellschaft für Tribologie / Tribological Society) only serves as rough orientation (**fig. 2**). Further insights into the usable life of a lubricant are gained in extensive stress and short-term tests (a few thousand hours) run by lubricant manufacturers, for instance on the FE9 test station, or in extensive long-term tests under almost realistic operating conditions, as in the fatigue test of the fan manufacturer. The lubricants used in this LTE project have thus been under test since the beginning of 1990 and have been lubricating the ball bearings of the test fan for more than 14 years. In 2000, with no failures having occurred till then, and with the test samples still in excellent condition, the 140,000 h in lifetime as demanded by the customer could be granted.

Evaluation of the tests

These actually attained test results are more convincing and safer than many other ones often quoting even higher durability figures. But those higher figures are usually based only on short-term tests (max. 20,000 h) at significantly higher ambient temperatures. Those results are then translated to normal room temperature by reducing the ambient temperature by 10 to 15°C and doubling the attained lifetime. Thus, one often sees theoretical lifetime figures of more than 300,000h that cannot be verified in practice and are utterly unrealistic. Any statement as to actual lifetime can only be made and evaluated if one has precise and empirical data to support such an endeavour.

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Product Development / Motor Bearings
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Development of solid backward curved centrifugal impellers made of plastic

Increasing demands by the markets to get compact fan units with high efficiencies and easy-to-realise motor control lead to an ever increasing number of electronically commutated DC motors in EC technology. For this reason, ebm-papst Mulfingen as world market leader in external-rotor motors and fans have redesigned their

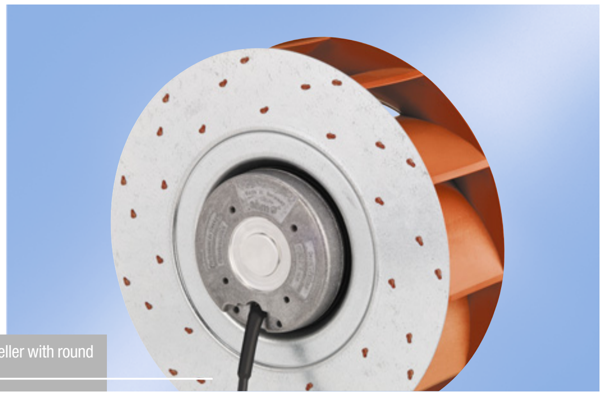


Fig. 1: Centrifugal impeller with round sheet-metal plate

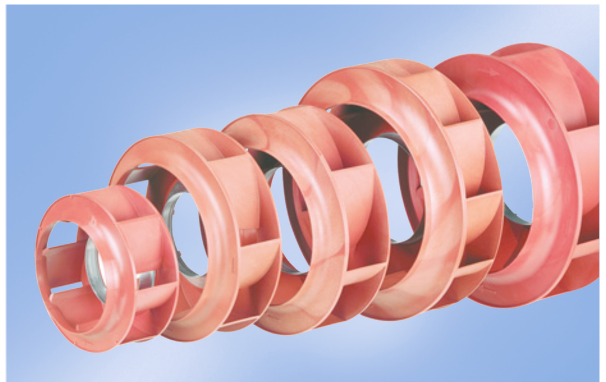
impeller lines. One of the main development objectives was to improve the stability of the impellers.
With backward curved centrifugal impellers, the air enters axially via the intake, gets deflected in the impeller and is emitted in centrifugal direction.
This impeller type is mainly used in range hoods, computer trays, duct fans, roof fans etc. The impellers are press-fitted directly onto the rotor of the external-rotor motor via the round sheet-metal plate.

Conventional design principle
The conventional design principle consists of a large round sheet-metal plate used as base plate and a plastic impeller enclosing the blades and the cover plate. This plastic impeller is fitted with pegs that fit through matching drilled holes in the round sheet-metal plate. Once the round sheet-metal plate has been joined, the pegs are thermally staked.
New technical demands cannot be met with the conven-tional design principle. Especially when it comes to applications with DC motors, increasingly higher operating speeds are required that conventional impellers cannot support. The insufficient strength of the pegged joint between plastic impeller and round sheet-metal plate has been established as major weak spot.

New design principle
With the new design principle, the impeller is a solid plastic impeller. The base plate is also made of plastic. The impeller blades are therefore attached on both sides, which makes for better stability. The round sheet-metal plate to be press-fitted is put into the injection-moulding tool and gets enclosed in plastic. It takes a sophisticated slide mould with drag slides to get the distance between the blades right.
The new design has the advantage of higher speed resistance and improved process safety. Further

advantages such as better concentricity and less initial imbalance facilitate simpler production processes.

Fig. 2: Solid centrifugal impeller



Our complete line – diameters ranging from 133 to 255 mm

Development process

Redesigning the impeller called for an adjustment in the blade geometry in order to be able to remove the impeller from the mould with the slide tool. Changing the blade geometry resulted in a new aerodynamic design.
After the impeller design, the geometry was then translated into a 3-D CAD model. Via FEM calculations, the impeller geometry was then optimised as regards stability.
This done, the impeller model was realised as Rapid Prototyping sample. This sample was used to carry out the trial runs to establish air performance and acoustics.
Unsatisfactory results of the trial runs may cause new impeller geometries to be designed, but successful trial runs here resulted in the generation of tools.

Result

The design principle of the solid centrifugal impellers as described was applied to a completely new ebm-papst line with diameters ranging from 133 to 225 mm.

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R & D / Aerodynamics

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Active driving fun through newly developed steering support motor

„Pure and undiluted drivin fun – the new active steering“

What optimises safety at high speed comes as a disadvantage in serpentines, narrow bends and parking. Whereas steering movements made while driving at 200km/h on the motorway must only be minimally transmitted to the wheels, it is quite a job to steer properly at low speed: safety on the one hand, extra steering wheel turns and hand acrobatics on the other. One solution for safe and yet agile driving dynamics could be fully electronic steering („Steer by Wire“) as already used in planes. If only this didn't have this decisive drawback: there is no road – steering wheel feedback, which is ever so important when driving a car. Other than planes, cars move across rather different road surfaces that are also

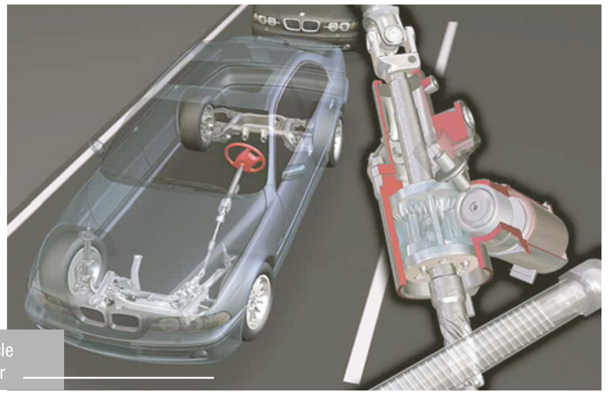

Fig. 1a: BMW vehicle with steering motor

more exposed to different weather conditions – here, individual driving feel and sensory instinct are indispensable.

Now, BMW presents a revolutionary new technology: thanks to the unique „active steering“, their new BMW 5 is the first car you can actually enjoy the advantages of electronic steering control in without having to sacrifice authentic driving feel. This intelligent and speed-dependent active steering allows optimal steering transmission in every driving situation. And this means: safety when driving straight on and fast, and dynamic driving on winding panoramic roads – resulting in more driving enjoyment throughout the whole driving distance.

Pure driving experience – the new active steering

At the core of the latest BMW revolution in cars is the innovative steering support integrating a planetary gear and an electronically commutated EC motor. With this design, a modulating gear with two inputs is added to the conventional servo-aided steering: one input is for the manual steering via steering wheel, the second for the electric motor. The two independent input speeds are translated into one output speed (**Fig. 1a, b**). In practical terms, this means that, on the one hand, the central gear input still retains the mechanical connection between wheels and steering wheel – and thus there is full "road contact" for the authentic steering feedback; on the other hand, a sophisticated electronic control feeds a certain speed and direction of rotation into the gear via the electric motor – depending on the manual input from the driver and also on each vehicle status.

In the slow driving range, the electric motor is driven in such a way as to have its speed added parallel to that of

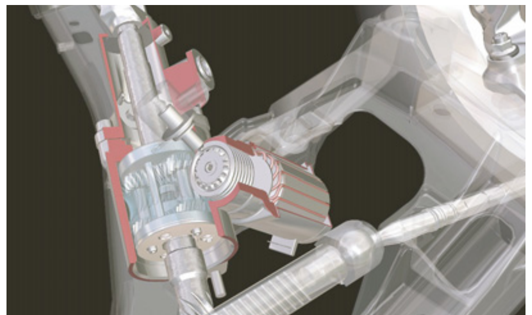

Fig. 1b: Servo-aided steering with servomotor and modulation gear (section)

„For superior demands and extra class!“

the steering wheel. The steering mechanism reaches maximum angle, and the steering movements are drastically reduced up to speeds of 120 km/h. In contrast to this, the electric motor works against the driver's direction of rotation in the high-speed range. Thus, the speed output and, in consequence, the steering angle, gets smaller at the gear output and driving straight becomes safer. The electronic control also allows for counter-steering in certain driving situations (**Fig.2**). Sensors for angular acceleration about the vertical axis measure the driving reactions of the vehicle and deduce stabilising interventions. This results in better cushioning and a relief of the DSC driving stabilisation systems working via the brakes. Even if the motor-assisted steering support fails in an extreme situation, the unit is simply locked mechanically and the steering operates safely like a conventional mechanical steering.

Top class requirements in comfort

Car-specific „taking qualities“ are looked for in all components of the steering support motor. Reliable top performance at different ways of driving is simply a must - especially in an environment putting maximum strain on all components: the bottom part of the vehicle where they are mounted.

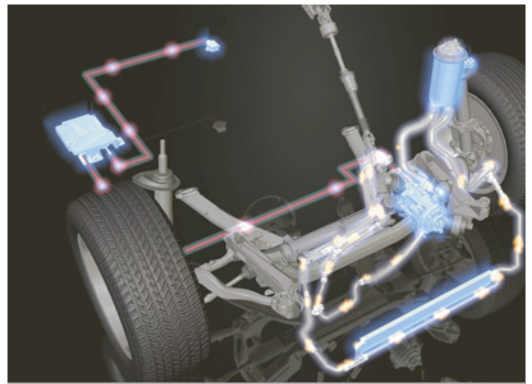

Fig. 2: Safe steering due to electronically aided steering support

For ebm-papst St. Georgen, this meant developing an electric motor (**Fig. 3**) that is powerful, effective and efficient, reliable, with only a minimum of torque pulsation, and generating only an absolute minimum of noise - and one that could also resist the unfavourable conditions under the bonnet. Solutions had to be found offering both outstanding quality and a good chance of economic implementation.

Powerful drive in every situation

Throughout the entire service life, speeds ranging from 0 to 6,000 U/min must be withstood. For the discreet steering support, both the very sensitive, almost pulse motor operation and, in quick alternation, the dynamic run-up in typical parking situations, or when supporting dynamic driving situations. In the vehicle itself, the motor is continuously exposed to four-quadrant operation. Despite the forces in effect here, reliability across the entire service life of the vehicle has to be absolutely guaranteed. The innovative solution is based on the principle of a 3-phase, permanently magnet-excited synchronous motor with internal rotor and sinusoidal current, i.e. the motor is made up of a six-slot stator and a 4-pole rotor. A compact

„A particular challenge for our motor development team“

Fig. 3: Newly developed and robust ECI steering-support motor

stator winding offers all the advantages of minimal copper losses and robust structure, as coils do not cross. The purposeful expansion of the air gap (**fig. 4**) in the rotor surface modulates the sinus-shape of the voltage. Significant technological advantages are also achieved by avoiding any sort of slant in the stator and the rotor. The rotor configuration used has been known among experts for some time, but applying it to the field of steering support is a complete first attempt. The cuboid permanent magnets made of high-quality neodymium-iron-boron material are inserted into the rotor stack. This makes the design especially robust. Rotor and stator have punched laminations made of low-vortex cold rolled electric sheets.

The special challenge the motor developers were faced with was to keep lowest possible torque pulsation in on and off mode as well as a very low level in running noise. Their solution can best be termed a synthesis of electro-mechanical and thermal motor development, using suitable optimisation algorithms based on analytical and numeric calculation programmes. Calculations according to the finite element method helped to optimise torque pulsation to an absolute minimum. Optimal torque quality was achieved by the original rotor topology.

Unsusceptible to changes in temperature

The components under the bonnet have to always work properly and safely, even with extreme changes in temperature. Specifications state a temperature range from -40 to +125 °C. Despite temperature-dependent material expansion, a gear used in the steering zone has to work without any play whatsoever. Here, a conventional solution incorporating expansion gaps is not sufficient. This is why the electric motor has a coil-loaded rotor shaft that can also be swivelled by a few degrees. The worm shaft (**fig. 5**) of the motor is thus constantly in play-free contact with the worm wheel of the modulation gear. The construction and design of such a motor is, of course, tricky, as the electrical ratings have to be kept to with different rotor positions. An integrated shaft encoder (**fig. 6**) with a swing angle accuracy of 1 % makes sure that motor and control are supplied with the data they require. Motor commutation and monitoring of the steering are both effected via external control. Sealed permanent magnets in the rotor and a special sealing safeguard a service life of at least 15,000h, as requested.

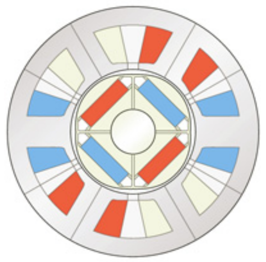

Fig. 4: Simple, but effective design: air gap modulates the sine form of the voltage.

Endurance test for safety

The EC motor passed the most sophisticated, demanding and high-quality tests. Naturally, the motor resists water jets coming from a high-pressure cleaner. Further approval tests included temperature shock tests with gushes of water, cooling down the motor (120 °C hot, cooled down by 4 °C water within 3 seconds and 4 l water/sec), spray tests with salt fog, immersion test and dynamic strength test. In addition to this, it the motor was tested for resistance to a whole range of fluids, not just engine oil, petrol, diesel, bio-diesel (RME), but also even to radiator liquid, battery acid and windscreen cleanser. Moreover, the motor excelled at the EMC test – an aspect that is extremely important in the complex system of a car.

Fig. 5: Preloaded by coils, the worm shaft makes for steering support without play.

Electronic assisting systems not only provide more safety, they also bring more driving fun – this is exactly what BMW proves with their innovative active steering, which is by far the best assisting system apart from DSC and Servotronic. This technological revolution was made possible by the unique steering support motor designed to perfectly meet the requirements of automotive specifications.

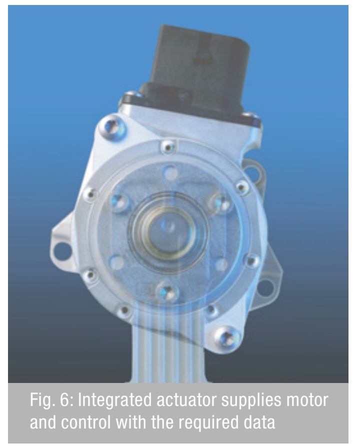

Fig. 6: Integrated actuator supplies motor and control with the required data

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