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NEW IDEAS AT A GLANCE

ebmpapst

Editorial

Dear ebm-papst customers, partners and friends,

The first edition of our tech.mag was well received and you gave us very positive feedback. This, of course, motivates us to continue in our way and with this magazine. As announced in the last edition, we want to use this forum to report on innovative approaches and solutions. But what, then, is innovation? It is certainly not restricted to mere product innovation, i.e. completely new product design. Visible proof of this our innovative competence can be found by simply attending the various trade shows and fairs where we exhibit, and, of course, in our catalogues. To me, however, it is of far greater interest to cast light on what the processes are behind these innovative products. In our case, we are talking of a skilfully masterminded innovative process. Experience shows that a development requires only 5% genius, and the remaining 95% are made up of tough professional work. For this, quite a number of development and simulation tools are needed, as is a powerful CAD system. These tools have to be employed effectively and efficiently at the same time in order to meet your requests and specifications: to provide you with innovative products of best-in-class quality at competitive prices. To this effect, however, the development process has to be expertly mastered, i.e. the various existing tools have to be used properly so as to make it possible to meet both the demand for speedy development and a careful eye for details.

For some time now, we have been working on networking all the development tools we use via data system technology. In doing so, we avoid redundant data and save precious transfer time. The consequences of this our approach are outlined in a special feature in this edition. Should you have come up with similar ideas in your R&D, feel free to contact us und let us share our experience – after all, it is in our mutual interest to use the synergy effect for optimal and competitive results!

Our secret of success: "Skilfully masterminding the development process"

Enjoy!

Dr.-Ing. Thomas Bertolini
Executive Technical Director
ebm-papst Mulfingen GmbH & Co. KG

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Fans with constant airflow and pressure control

Abstract
Numerous practical examples are living proof: Conveying too much air results in a squandering of energy and acoustic nuisance, conveying too little air usually reduces the proper function and thus the benefit of a unit. Both effects can be avoided by using fans with constant pressure or airflow characteristics. This paper presents industrial solutions based on two different control concepts. The first concept only uses information from the electric fan motor, the second requires information supplied by a flow sensor.

1. Introduction
Many applications require the fitted fan to precisely provide the specified air performance – independent of changing external and internal influences across the entire service life of the unit. There are numerous examples for this: with mechanical home ventilation units, the heat exchange only works optimally if the air supply and discharge flows correspond to the set value. Fan units for clean-rooms guarantee a defined flow condition in the room only if the airflow is controlled to its specified value. And the overpressure for a laboratory cabinet has, for safety reasons, to be kept constant regardless of any leakage flows. The list can be extended indefinitely.

In practical terms, there are two relevant effects. For one thing, the operating point can change with and for a certain time, e.g. when filters get clogged, with changing exposure to wind or changing thermal lifting forces at high-rise buildings. For another thing, external resistances in varying sizes, depending on the mounting situation, result from, for instance, the connection pipe duct systems in different designs or from obstructions in the air intake and discharge zone of the unit.

2. Control concepts
This problematic state of affairs can be solved by control readjustments in the speed of the fan in such a way as to make sure that either pressure or airflow of the fan is kept constant. The solutions presented below are based on two different control concepts.

The first approach without additional sensors rests exclusively on information as to motor load, either already present or established at only little time expense. There is absolutely no need for any information provided by a flow sensor here. In order to realise this concept, there has to be a direct and unambiguous correlation between motor load and air performance of the blower ("monotone characteristic"). This precondition is not met by all fan types, yet it applies to blowers with forward curved centrifugal impellers. In their case, the present operating point can be determined via speed and motor current. To this end, approximation

„The control accuracy mainly depends on the quality of the sensor signal ...“

functions are employed, the coefficients of which have been established in air performance and motor measurements and stored in a micro-controller beforehand. The controller implemented on the commutation electronics of the fan compares the calculated actual values with the preset values and adjusts its function accordingly.

The second approach with sensors also works with impeller types such as the freewheeling backward curved centrifugal impellers, which do not allow the precise determination of the operating point by simply drawing results from the measured motor data. In such cases, additional aerodynamic information is required, which is provided by a sensor. Via speed and sensor signal, the operating point of the fan can now be determined and readjusted according to the specifications. Compared to the control without sensors, the algorithms employed here are substantially less complex. This results in less memory and computing capacity required in the micro-controller.

3. Realisation

Below, various products are presented that have been developed on the basis of the control concepts as discussed.

3.1 Control without sensor

Figure 1 shows a blower controlled without sensor and developed especially for home ventilation units. As already mentioned, it is of special importance in this field of application to keep the preset airflow constant irrespective of the filter contamination and the pipe duct connections used. Via step switch on the home ventilation unit, the end user can select various airflows in operative mode; the overall level can be preset via DIP-switch on the blower in advance. **Figure 1** (bottom part) shows the results of the air performance measurements. The measured characteristics correspond quite well with the preset values. Using the existing possibilities, a constant pressure control could be as easily realised as the constant airflow control as demonstrated here.

3.2 Control with pressure sensor

The control concept with sensor is based on the evaluation of additional aerodynamic information. A typical application is schematically shown in **figure 2**. The pressure sensor is accommodated by the motor electronics and, via circuit pressure line, measures the static negative pressure in the inlet nozzle of the centrifugal fan before transmitting the voltage signal to the fan motor electronics. As the measured negative pressure in the inlet nozzle represents a definite measure for the required airflow, and as the correlation p_{Sensor}=f(V) is only dependent on the nozzle geometry, airflow control can be realised. The closed-loop control algorithm is entirely integrated in the micro-controller of the motor electronics. Apart from the sensor signal, the fan motor has to be provided externally with a set value. With the motor as shown here, the set value can be given via PWM signal, via 0-10V linear input, or via BUS interface.

This control concept guarantees good results. The control accuracy, however, mainly depends on the quality of the sensor signal. **Figure 2** (bottom part) shows the measured air performance characteristics at different set values. In order to demonstrate the capability and capacity of the control, the measurements focused on both the constant airflow control as discussed above and the constant pressure control. As input signal, the static differential pressure of the fan unit was established. Here, too, the actual result and the preset values correspond closely; any of the deviations result from the individual errors of the entire control chain pressure drop – pressure sensor – speed control. The black fan characteristic as given in **figure 2** was measured with constant speed (1420 rpm). As this speed is below the maximally permissible operating speed, the constant pressure and airflow characteristics in this example exceed the fan characteristics.

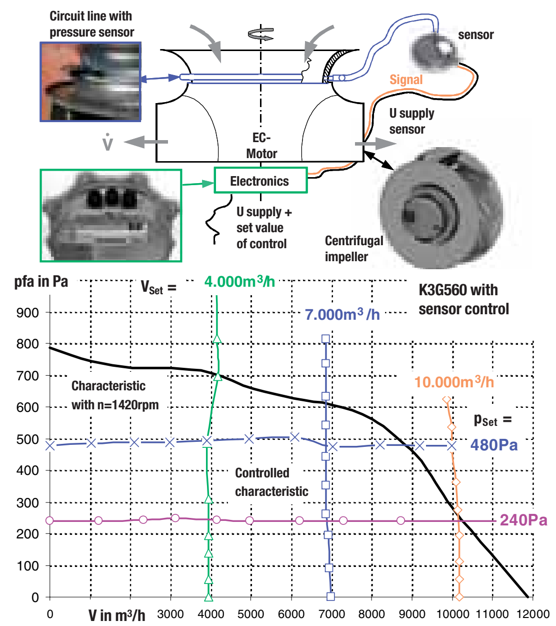


Figure 2: Air performance curves of centrifugal impeller R3G560 with motor M3G150.

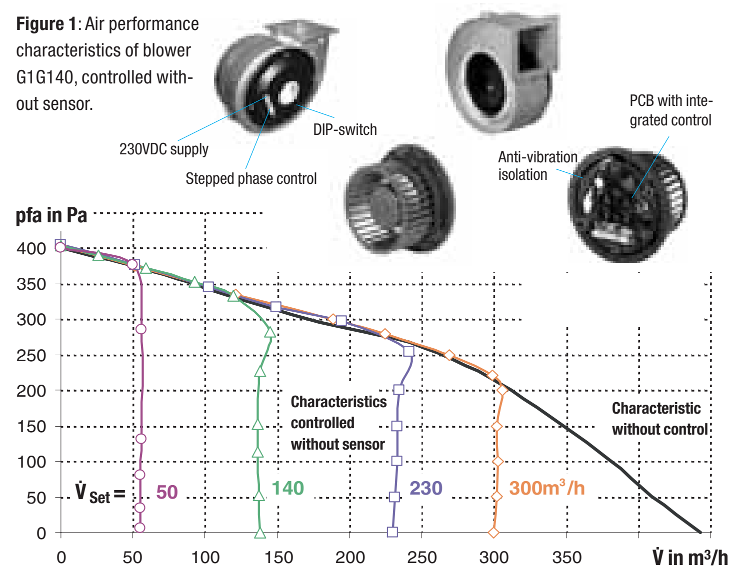
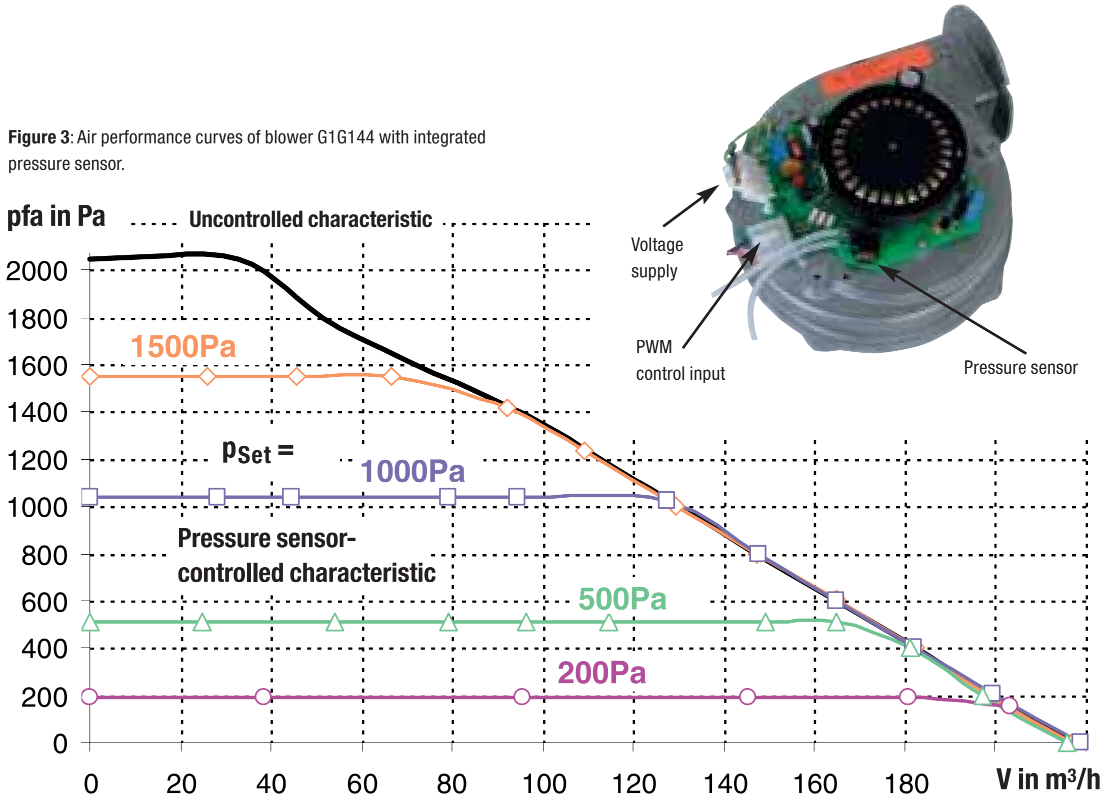


Figure 1: Air performance characteristics of blower G1G140, controlled without sensor.

In customer applications, the sensor can be mounted in advance, onto the blower housing or as SMD component even directly onto the PCB of the commutation electronics (see **figure 3**). Apart from the electrical supply, the customer then just has to connect the blower with flexible pressure tubing. **Figure 3** shows the constant pressure air performance characteristics of a blower equipped like this.

Figure 3: Air performance curves of blower G1G144 with integrated pressure sensor.



4. Summary

This paper presents fans with pressure constant or airflow constant air performance characteristics. The realised control concepts are based on two different approaches. The control without sensors only uses internal motor data, but it is limited to impeller types with an unambiguous correlation between motor data and fan operating point. The more generally applicable solution with pressure sensor uses additional and external aerodynamic data. When employed, though, both these innovative concepts allow good control precision to be achieved.

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Small blowers for gas-condensing units

„ebm-papst provides innovative solutions for every conceivable system design ...“

Gas-condensing heaters allow a more efficient energy utilisation than conventional gas heaters. This improvement of gas-condensing units is due to the fact that the condensation heat of the water vapour contained in the exhaust gases is made use of by cooling these gases down in a heat exchanger to the point where the water vapour condensates and gives off its inherent heat. Blowers are generally employed to get a combustion result that does not depend on the ambient air.

1.1. High efficiency at maximal comfort

The basic demand on modern gas-condensing units, namely to supply maximal heating comfort at minimal power consumption, substantially influences the demands placed on the blowers.

However, optimising the combustion process and maximising the total efficiency make sure this basic demand is met.

Modern gas-condensing units are not only able to provide the necessary permanent heating capacities in the low performance range, but also to muster the required sudden high performance peaks, e.g. for heating the water for domestic use. The width in variation between lowest and highest performance is known as modulation factor. Currently used standard units have a modulation factor of as high as 5.

Blower line RG100. Centrifugal blower with asymmetric EC motor. Smallest basic design for heating capacities of up to 18 kW.

The airflow $\dot{V}_{A.min}$ required for the stoichiometric combustion results from the oxygen demanded for total combustion. When combustion takes place with air ration λ and boiler efficiency η_B, the resulting total airflow follows the equation

$$\dot{V} = \frac{P}{3.6 C_i \eta \kappa} (1 + 8.43\lambda)$$

(C_i = net calorific value of the fuel [kWh/m3].

In order to meet the demand for as high a total efficiency as possible, the power input of the blower has to be minimised, too. This can be achieved via two parameters: the efficiency of the blower as such and the minimisation of the system resistance.

Another demand having an important influence on the design of a blower for gas-condensing units is a long service life. With the market expecting units to run for 12 – 15 years, and an average operation time of about 2,000 hrs/year, the blower has to have a guaranteed service life of 25,000 – 30,000 operating hours.

The maximally permissible noise emission of the entire unit is an aspect of paramount importance nowadays, which is why the blower has to be assessed and optimised as potential noise source within the overall system.

Finally, the hydraulic design has to be complemented by the optimal drive. The specifications as to speed, performance, acoustics, controllability and service life make brushless DC motors (EC motors) the ideal choice.

Blower line RG128.
Centrifugal blower with EC motor for heating capacities of up to 40 kW.

1.2 The "pneumatic compound"

With the majority of gas-condensing units on the market, the gas is added to the air before it reaches the blower, resulting in a very good gas/air mix. Regulating the desired mix ratio at different performance levels is realised via pressure-controlled gas valve. This gas valves often takes the form of a constant-pressure valve, which adds a defined amount of gas depending on the control pressure applied.

The differential pressure needed for controlling the valve is generated via a so-called differential pressure transmitter, which – in its simplest form - can take the form of screens or nozzles. To minimise the losses incurred by this, venturi nozzles are the proven choice. Due to pressure losses in the armatures leading up to the blower (e.g. sound-absorbing pipe etc.), the air enters the venturi nozzle with reduced pressure. Immediately afterwards, the flow is accelerated because of the diminished cross-section, which also reduces static pressure. The pressure intensification describes the ratio between static pressure at the venturi nozzle inlet and the static pressure at the narrowest point of the nozzle at which the gas is added. The pressure loss of the venturi nozzle has also to be mustered by the blower, and so it is best to use venturi nozzles with the highest possible pressure intensification at minimal pressure loss.

1.3 The electronic compound

With the pneumatic compound, the blower has to be designed in such a way as to make sure that the minimal pressure needed to pneumatically control the gas valve can still be supplied even with the entire unit set to lowest power stage. Therefore, the minimal pressure needed in this operating point determines the design for the blower capacity, even though far lower capacities would suffice to generate the actual heater output.

With the so-called electronic compound, the exhaust gas quality is measured as controller output, e.g. via lambda probe, ionisation electrode or CO_2 probe, and gas supply is then adjusted via an electrically controlled gas valve. This way, the blower design can be ideally matched to the pressure and airflow requested by the unit.

The future lies with this control technology, as it makes it possible to employ smaller blowers with lower power input

1.4 System characteristic

The specified maximal performance of the blower is calculated as the intersection of blower characteristic and system characteristic of the heating unit at maximal heating capacity. The system characteristic takes the form of a parabola, as pressure depends in square from speed. The form of the parabola is determined by the minimum pressure needed by the differential pressure transmitter at minimal load and the additional pressure losses caused by armatures such as deflectors, nozzles, diffusers, the air-exhaust gas system and the pressure losses caused by the burner and the heat exchanger.

Development of a streamer to increase the thrust range of axial fans

1.5 Summary

A modern blower for use in innovative gas-condensing heaters has to meet the following, at times even contradictory demands:

- **Power input**
  Minimising the electric power input via maximal overall efficiency of the gas-condensing unit is supported by a top efficiency of blower and motor. The optimal design of the differential pressure transmitter serves the same purpose.

- **Noise**
  Taking into account the latest findings on electro-acoustics and monolithic acoustics, the sound radiations caused by flow noises as well as excitation of the structure and, subsequently, structure-borne noise, are minimised.

- **Service life**
  The tough specifications as to long service life can be met by using proven and innovative bearing systems.

- **Emissions**
  Due to its ideal design and optimised use in the unit, the blower can contribute substantially to reducing the amount of pollutants emitted by the entire unit.

From the start, ebm-papst has been playing an active role in developing our modern gas-condensing technology, and it has the necessary know-how and expertise to optimally meet these specifications.
Relying on more than 10 basic designs, suitable EC blowers for heater outputs ranging from 3kW to 1,000kW are available. Customised electronics interfaces for all combustion controls and superb adaptability to special electrical and mechanical conditions help provide innovative solutions for every conceivable system design.

Dr. Roland Keber (right), Design engineer Fluid mechanics
Dipl.-Ing. Rudolf Tungl (left), Head of R & D
ebm-papst Landshut GmbH

„Axial fans: a cost-efficient, robust and technically quite better solution!“

For their efficient cooling, enclosed spaces need to be evenly permeated with flowing air. To this effect, cooling modules nowadays carry elaborate accessories that, however, also result in higher electrical power input and higher noise levels. This paper presents a cost-efficient, robust and technically quite better solution.

1. Objective

Nowadays, the performance of air coolers in enclosed spaces is often limited because the cold air streaming from the fan does not permeate this space sufficiently enough and thus gets sucked back into the short circuit without having any significant cooling effect. The corner of the room in which the evaporator is usually positioned gets sufficiently cooled, but the required temperatures in other places are not reached as the controller of the cooling module simply controls down or even shuts down as soon as the cold "short-circuit" air is sucked back in. This problematic situation is illustrated in **figure 1**.

In order to avoid having to install bigger or even more of these cooling units in this space, the practice so far has been to mount honeycomb grilles on the fans. In some cases, textile hoses have been used to spread the air around. Apart from higher installation costs, these accessories also cause higher power consumption and more noise, as the fan has to overcome the additional difference in pressure. To counter this, new approaches focus on a direct improvement of the fan discharge (see **figure 1**). An effective way of reducing the angle of the jet divergence is to deviate the circumferential and radial components of the discharge in axial direction. This effect can be realised not only by adjusting the blade geometry, but also by providing fixed guide blades. Translating this approach into the development of a streamer is presented below.

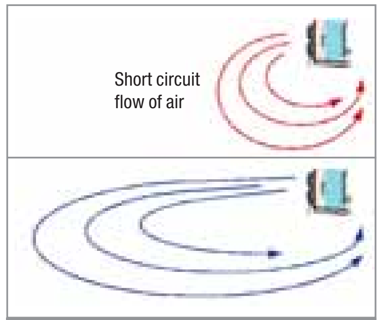

Figure 1: Bad (top) and good (bottom) permeation of cold storage rooms with cold air.

2. Prototype measuring data

The first phase saw the design of various variants that were mounted to the axial fan on the discharge side. After a preliminary analysis, the following 4 basic designs with axial streamer elements were examined in more detail:

- Prototype 1: Honeycomb insert
- Prototype 2: Strut ring with 6 radial and 5 circumferential struts
- Prototype 3A: Streamer with 16 radial struts
- Prototype 3B: Streamer with 16 radial struts and pipe nozzle

To assess these prototypes, they are compared to the basic variant of the cooling module without any additional streaming devices. The main assessment criterion is the thrust range as defined by CECOMAF standard GT6-001 or ENV 328 and giving the distance to the fan at which maximum speed has sunk to the limit of 0.25m/s. It also has to be made sure that the solution is a substantial improvement of the basic variant with respect to air performance, efficiency, and acoustic performance.

Figures 2 and **3** illustrate the results of the first series of measurements. **Figure 2** shows the maximal flow rates as measured on the rotational axis. The farther away from the cooling module, the lower the flow rates. As opposed to the initial state (blue line), all prototypes show substantial increases in velocity close to and around the air cooler. Whereas this effect quickly vanishes with increasing distance with the honeycomb insert and the strut ring, the two streamer prototypes showed marked improvements even in the long distance. In this connection, the measurements showed an increase in thrust range from 12m to 18m and even 22m.

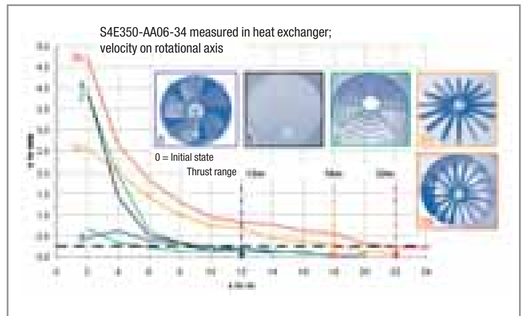

Figure 2: Maximal velocity of flow on rotational axis.

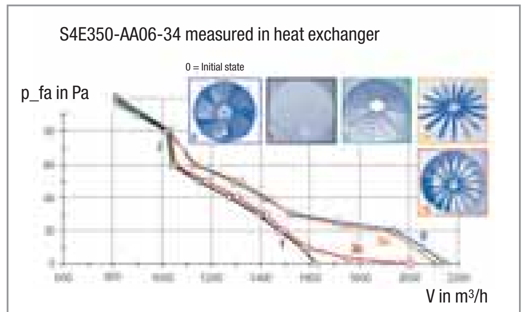

Figure 3: Air performance curves of examined prototypes.

Figure 3 shows the air performance curves of the various variants. Compared to the initial state, the flow resistances of the honeycomb insert and the strut ring result in a significant drop in air performance. Without external backpressures, the air performance of the cooling module goes down from 2,150m³/h to approx. 1,600m³/h with these fittings. The reduction in air performance explains why the flow deflection with these two designs results in an increase in velocity only in the proximity of the cooling module. The streamer with pipe nozzle reduces the air performance in free blow mode by only 150m³/h. However, additional pressure losses, for instance with formation of ice on the heat exchanger or in case the air cooler is set up in a corner, cause severe losses in air performance. This means that this design only achieves high thrust ranges under ideal conditions. The best results from among the examined prototypes were achieved with the streamer without pipe nozzle. This design not only shows a substantially increased thrust range, it also results in only a minimal reduction of air performance across the entire characteristic range.

The results of the acoustic measurements carried out and the analysis of efficiencies also demonstrate that the prototypes "honeycomb insert" and "strut ring" cause marked losses. Whereas higher sound pressure levels were measured with these designs, the designs with streamer (variants 3a and 3b) result in no aggravation of the acoustic performance (see also **figure 4**). Varying the axial length of the struts, the distance to the fan and the number of struts showed no further potential for improvement.

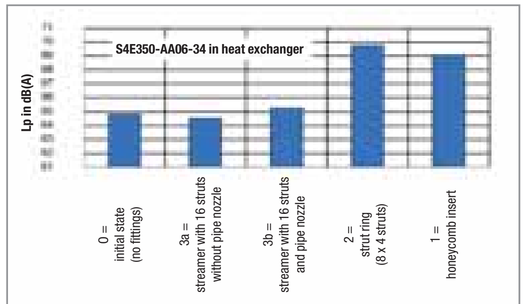

Figure 4: Sound pressure measurements of examined prototypes.

3. End product

In order to be able to design the optimum contour of the streamer blades, the velocity components in the flow field of the reviewed fans are determined via LDA measurements and this then used to calculate the angle of deflection. For size 450mm, the results of the LDA measurements are exemplary shown in **figure 5**. In order to minimise losses, the angle of incidence of the streamer blades is adjusted to the angle of deflection as measured. **Figure 6** shows the streamer developed on this basis. This streamer is mounted to the guard grille of the axial fan via a clip connection. The robustness of this connection was subjected to and passed rigorous temperature, vibration and shock tests. **Figure 7** to **9** show some exemplary validation results. **Figure 7** shows that the thrust range can be increased from 10m to more than 22m by using a streamer with diameter 350mm (the exact value could not be determined as it surpassed the length of the measuring floor). **Figure 8** shows that mounting a streamer with diameter 400mm onto 2 different heat exchangers causes neither a reduction in air performance nor a drop in efficiency. **Figure 9** shows the measured flow rates in the discharge cross-section (left) and the improved flow performance with streamer in the mist test (right).

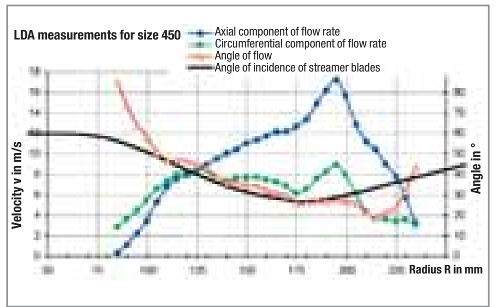

Figure 5: Result of LDA measurements for size 450mm.

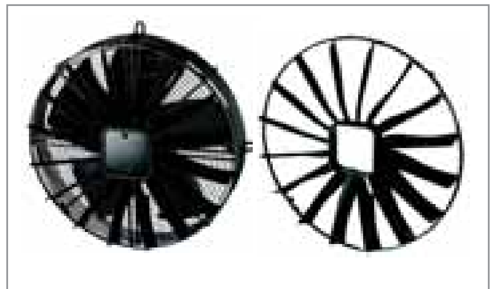
Figure 6: Streamer mounted onto axial fan ø = 450mm with guard grille.

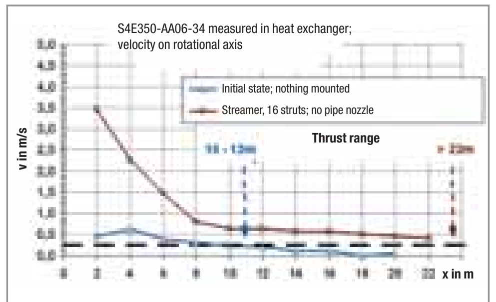

Figure 7: Result of thrust range measurements with streamer in size 350mm.

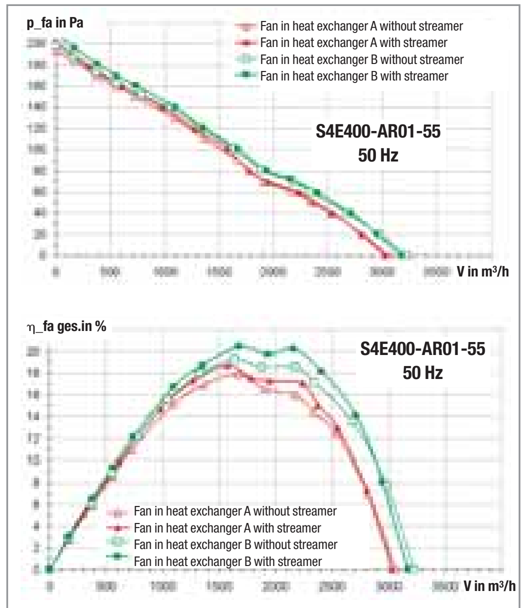

Figure 8a: Streamer Ø 400mm mounted onto fan in heat exchanger: Air performance.

4. Conclusion

Depending on the fan size, using the streamer can actually result in double or even triple the thrust range. This finally allows an even permeation of cold storage rooms with the cooling airflow – without the need to expand the exchanger surface or to increase the air volume to be cooled. In contrast with other rectifier solutions, such as the honeycomb inserts used so far, this improvement is achieved with almost no losses, thus avoiding any negative influence of the technical data of the axial fan (air performance, efficiency, acoustic performance) when using this mounted streamer.

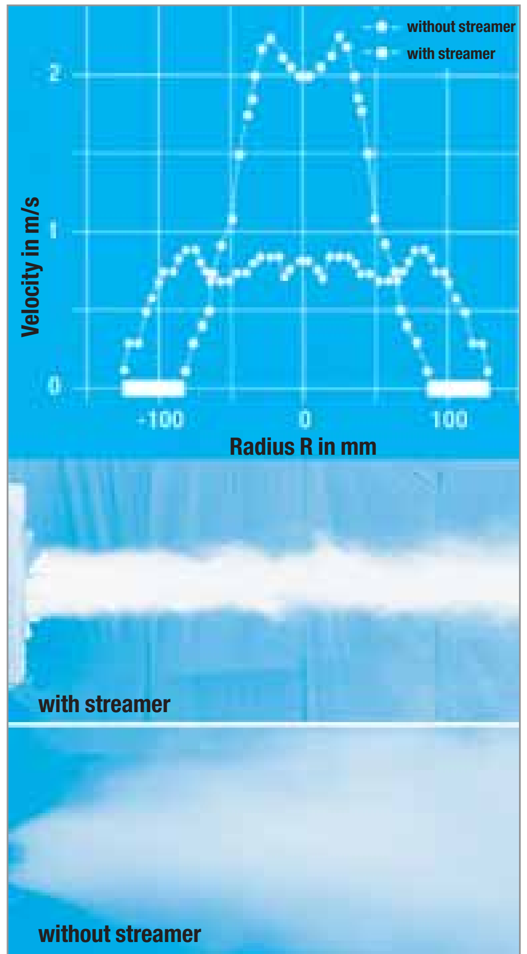

Figure 9: Flow performance without respectively with streamer (Source: ILK Dresden).


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Blower range for commercial vehicles with long service life due to brushless motors

Introduction

In motor vehicles today, blowers driven by mechanically commutated motors are used in most cases. However, their commutator and their brush system are subject to wear-and-tear and do not last. Still, as the service life of such motors in passenger cars corresponds to that of the vehicle, it can be considered adequate. This, however, is not the case in commercial vehicles. In order to reduce the maintenance and down times (and costs!), ebm-papst Mulfingen GmbH & Co. KG developed two lines of blowers for commercial vehicles offering higher service life, improved technical characteristics and more functions than the blowers used in the past. This development helps a lot in meeting the ever-increasing demand for more comfort even in commercial vehicles!

Electronically commutated small motors

In order to generate the torque in electric machines, it is necessary to have the load independent currents in the individual windings rotate synchronously along with the rotating magnetic field, regardless of the winding being part of the motor stator or rotor. With mechanically commutated motors, where the permanent magnetic excitation comes from the stator, the commutator makes sure that the currents in the rotor windings are switched over in time when alternately entering unto the static magnets. The exact switchover time is determined by the spatial position of the brushes alongside the circumference of the commutator. With increasing speed, there is also an increase in the voltage induced in the winding, generally resulting in a current decrease; at the same time, the AC resistances increase, resulting in a slow current rise, together with a spatial displacement of the maximum value of the specific current density on the circumference. The torque decreases. However, if the currents are switched over via electronic switches, then it is possible to set the switching-on time and thus the position of the maximum value of the specific current density on the circumference variably. The torque behaviour of the motor can thus be influenced within a wider range. Moreover, the maximum value of the current is set with the same electronic components, with the high current at make being limited to a tolerable size. Using electronics in such small motors thus makes for a far wider range of applications with additional functions and is free from wear-and-tear as well. With speed-controllable small motors, the mechanical commutator becomes less and less important.

Platform development

For these reasons, ebm-papst Mulfingen has come up with two blower lines for use in commercial vehicles, with

electronically commutated synchronous machines (EC motors, also known as brushless DC motors). The motors serve as platform for the blower development and complement an existing modular system. As for costs, the components profit from the huge quantities gained by individual parts being used in other motor lines, too. The electronics is integrated in the motor housing and is thus protected from external environmental conditions, can be efficiently cooled in the airflow and makes for good electromagnetic compatibility. Additional components for a second housing are thus not required. The motors are designed as external-rotor motors. This facilitates a short build in axial direction and a better use of the radial fitting space, e.g. between the impellers of the centrifugal blowers shown in **figure 1**. With the external-rotor motor, the stator can be wound simply and easily, the winding is non-rotating, and the electrical connection of winding and electronics is no problem at all. The rotor carries the magnets on its inside. External-rotor motors have proven their worth in ventilation and air-conditioning. Their big moment of inertia guarantees even running characteristics. Blowers and fans are required to speed up slowly and without much noise, and so high dynamics are anything but needed.

Technical characteristics

The shafts are fitted with ball bearings, and the electronic components have a life expectancy of 25,000 hours. This service life can be attained if the imbalance of the impellers is not changed by external influences.

In contrast to conventional blowers with mechanically commutated motors, these new blowers have increased electromagnetic compatibility. The wiring-bound interference emission meets the highest interference suppression class 5 in all frequency ranges in accordance with EN 50025. As for the emitted electromagnetic interference, it remains under the limit as set by EG 94/95 by 20 dB. Therefore, the German Federal Automobile Office (Kraftfahrtechnisches Bundesamt) approved our units, rating them e1 units.

Due to the special winding technique, the efficiency exceeds 80%, thereby requiring less the power input than conventional blowers. With an average of 10 blowers in a rooftop unit for bus air-conditioning, this has a positive effect, especially on the on-board supply system.

The short axial face-to-face dimension of the motor reduces the obstruction of the air inlet of the centrifugal blowers. This is an improvement in air conduction and noise.

The electronics allows speed control with a variety of input signals commonly used in commercial vehicles. Analogue signals from 0 to10 V, 24 to 0 V and digital PWM signals from 10 to 30 kHz can be processed. Moreover, there is a digital input to reduce speed to half the maximum speed, and so all control signals commonly available in busses today can be handled. One output signal emits two digital impulses per rotor rotation. It also indicates any abnormal operating status such as locked rotor, the supply voltage being below a minimal value, or the permissible operating temperature being exceeded by emitting a PWM signal with different pulse-duty factor.

„External-rotor motors have proven their worth in ventilation and air-conditioning“

Thus, the electronics also offers comprehensive diagnosis possibilities, too.

This electronics features reverse-polarity protection as well as protection against over-voltage in case of any load dump. When the operating voltage margin (19 to 31 V) is left, the motor is switched off and restarted automatically. The run-up always takes place slowly and within a period of 5 s. This not only significantly reduces the current at make, it also prevents noise pollution generated by the sudden start of all blowers.

Application development

These motors formed the basis for the development and design of two new lines of blowers: centrifugal blowers with forward curved impellers (**fig. 1**) and axial fans (**fig. 2** and **3**). Thus, there is a wide range of applications. The centrifugal blowers are available with different flange designs, the axial fans come in two sizes, with 300mm and 280mm in impeller diameter. Both lines of blowers are available in 24 V design. Typical air performance in the 24 V design is 200 Pa and 1,000 m³/h for the centrifugal blowers, and 100 Pa and 2,000 m³/h for the axial fans in size 300. There is an option of either integrated plug or a connecting lead for the centrifugal blowers.

Fig. 1: Centrifugal blower with electronically commutated motor and different connection flanges

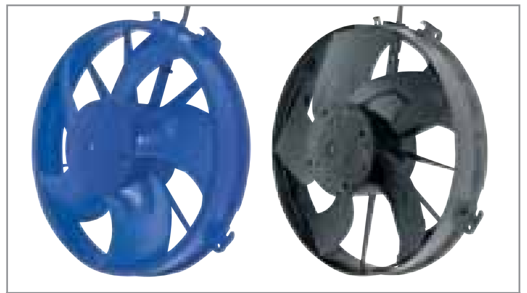


Fig. 2: Axial fans in size 300 with electrnically commutated motor and different air flow direction

Fan blades with winglets for quiet fans

Summary
Based on the development of two motors, the so-called platform development, two lines of blowers were designed for use in commercial vehicles. Compared to conventional blowers for commercial vehicles, these new ebm-papst blowers have improved technical features and have a significantly longer service life, thereby substantially reducing the service, maintenance and down costs of the vehicles. For more information, contact ebm-papst Mulfingen.

Dr. Michael Schier
Platform development
ebm-papst Mulfingen GmbH & Co. KG

Fig. 3: Axial fans in size 280 with electronically commutated DC motors

„Winglets – innovative approach to noise minimization of small fans“

Also, the special noise of blade rotation audible to the human ear is considerably reduced by the winglets.

Innovative approach to noise minimization of small fans

Modern fans operate reliably and usually behind the scenes. They are required to fulfil their job of cooling electronic components as unobtrusively and quietly as possible. At the same time, the mass production of small fans must be cost-effective. To produce a device that meets all these requirements is not easy. Innovative solutions therefore, are required that achieve improvements in service life and performance without additional costs. A completely new approach to the reduction of noise is the aerodynamic design of the annular gap between the fan blades and the inside of the housing.

As far as the mechanical structure is concerned, today's small fans are designed to operate with the minimum of noise. Only completely new paths in the further development of small fans can create new chances for significant improvement and for this purpose, all possible noise emitters must undergo rigorous testing on the test bench. In addition to continuous improvement and noise minimization of the drive and its components, aerodynamics, present a special reduction potential for acoustical diffusion.

Gap, turbulence, costs

To separate the suction side from the pressure side, small fans usually have an external housing panel. The size of the gap between the panel and the impeller depends mainly on the following factors and is required for tolerance reasons:

- Tolerances of the components
- Linear expansion of the blades due to the effects of centrifugal force
- Linear expansion of the blades due to thermal effects
- Environmental influence, e.g. linear expansion due to the absorption of humidity by plastics.

For this reason, a relatively large gap must be allowed for fans and in particular, mass produced small fans where reworking of components to reduce the tolerance cannot be given consideration for reasons of cost. (**Fig. 1**). To avoid or minimize aerodynamic interference in this sector, ebm-papst is treading new paths and is applying for the first time a solution that is well tried in other sectors and which has high noise reduction potential.

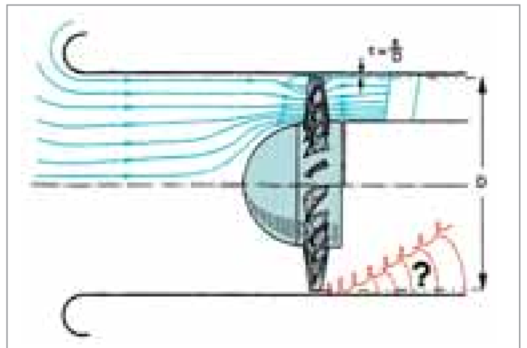


Fig. 1: Schematic flow diagram with generation of turbulence at the annular gap by difference in pressure

Not only small but different

In large-scale technology as in nature, vortices at the at the tips of the blades are minimized by so-called winglets. Birds spread the feathers at the edge of the wing and on aeroplanes the differently designed ends of the wings causes a vortex to form around the wing tips. The objective is to minimize turbulence and in turn the loss of energy.

However, this principle of action cannot be applied in this form to small fans. A further reduction of noise is not based on the separation of large vortices into smaller ones, the idea rather more is to create a type of labyrinth seal (**Fig. 2**) by thickening the extreme wing tips. This winglet-type of end plate should increase the fluid resistance rather than reducing the required gap. This can be achieved by the wider end of the winglet that reduces the transportation of the air mass in the gap. At the same time, the force of the blade tip vortex that induces the noise is reduced. Examinations of different types of winglet shapes showed a considerable noise reduction in all operating points. Reduction in the most practical area of application at the right of the saddle point in the fan diagram (**Fig. 3**) is 2 to 4 db(A). Also, the special noise of blade rotation of approx. 500 Hz audible to the human ear and the noise percentage of over 6 kHz is considerably reduced by the winglets.

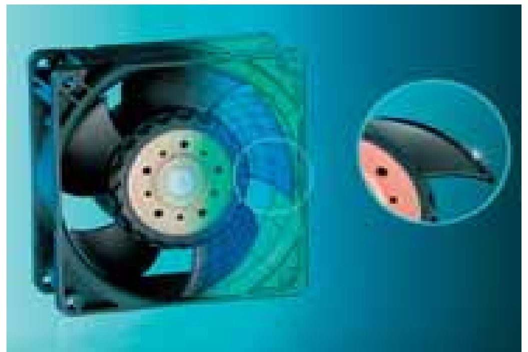


Fig. 2: The new blade design, winglets at the blade tips reduce the generation of turbulence

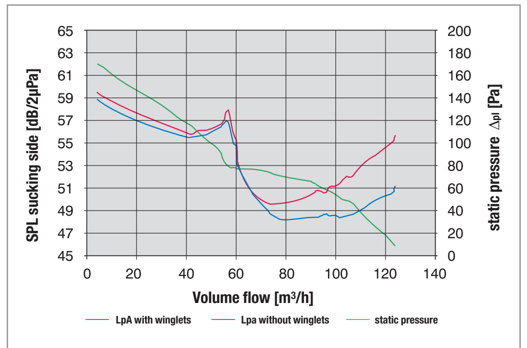


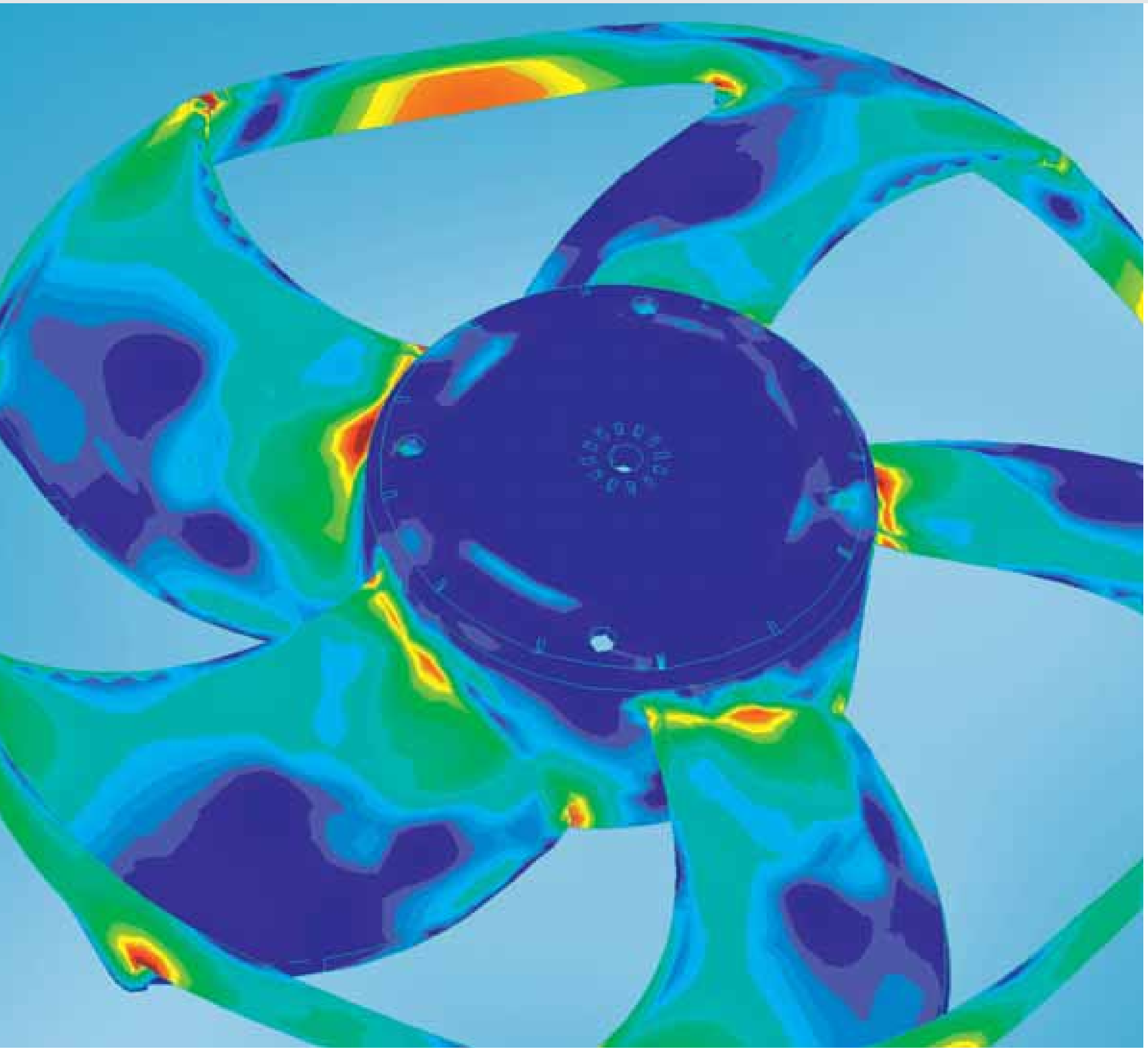
Fig. 3: Evidence that the winglets reduce the suction noise by up to 4 db(A)

Thus use of winglets at the blade tips of small fans thus results in a distinct reduction in noise. The advantage of this ingenious solution: The fans can continue to be produced by injection moulding and the air gap between the impeller and the housing which is necessary for cost favourable mass production no longer needs reducing.

This is an extremely cost-efficient way of reducing the operating noise of small fans without having to make major alterations to the existing production.

Dr.-Ing. Walter Angelis (middle), Manager Fan Development ebm-papst St. Georgen GmbH & Co.KG

Determining the operating performance of fans in advance – No problem for ebm-papst



„The fan – a complex system!“

1. Introduction

For some time now, engineers have been hoping to be able to determine in advance, in full and comprehensively the operating performance of the aggregates they develop. So far, this hope was held to be an unrealistic dream. However, ebm-papst in Mulfingen is about to make part of this dream come true: by systematically integrating the simulation and calculation tools, the road is clear to have the entire operating performance established with sufficient precision for practical purposes.

2. Objective

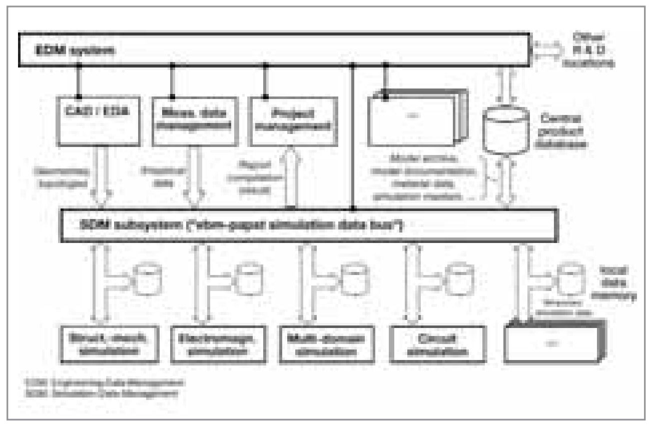
There are three major reasons why a sufficiently precise calculation in advance is hard to realise. For one thing, the data processors have not been powerful enough so far, and undefined conditions in the mechanics or insufficiently known material properties do not, in principle, permit the exact generation of a desired model. Moreover, certain problems that need to be solved require specifically developed simulation tools - which, on their own, can then only be reasonably made use of for solving singular tasks taken from a single discipline: interrelation and interplay of all the individual components of a fan are only insufficiently taken care of and into account. What is missing is the interconnection of all the different tools.

Taking into account the present market demands for extremely short development periods, ebm-papst wants to shorten the design process for fans significantly. To this effect, a development environment is being worked out that enables ebm-papst to determine the entire operating performance of a fan step by step and as precisely as needed. The individual simulation tools shall be integrated in this environment concurrently and shall all access one single product database.

3.The fan – a complex system

Fans with electronically commutated motors represent complex mechatronic systems (**figure 1**). The operating performance is determined by the combined effects of the various fan components based in electronics, electro-mechanics and aerodynamics, and their interaction with the customer's system. The calculation draws on different disciplines, beginning with aerodynamics, through to structural mechanics and on to microprocessor technology, and makes also use of different calculation methods, from simple analytical

Figure 1: Systematic scheme of a fan



„Simulators allows to shorten the develop and design process!"

calculation to transient three-dimensional FEM calculation.

4. Situation with simulation and CAD tools frequently used today

ebm-papst uses CAD tools that are, to a large extent, integrated in the development process and the Engineering-Data-Management (EDM) (see **figure 2**). These tools also cover simulations taken from construction, design and product engineering. Both the CAD system and the simulators access the same data model. Various individual simulation tools used for analysing the performance of system components of the fan, however, are only minimally integrated.

5. The integration of simulation and CAD tools

A simultaneous look at all system components of the fan in the form of a comprehensive virtual prototype in a single general simulator is desirable and would even be technically possible for the most part. The interplay of the components would even be fully taken into account. However, the advantages of specialised tools, especially their high accuracy and quick calculation due to fine-tuned modelling and analysing options remain unutilised. At the same time, the improved consideration of the interplay also leads to a less accurate consideration of the components. Therefore, the precision of the overall result depends on the attributes of the system to be calculated. For fans, this general approach does not get us very far.

Between the system components of the fan, there are connections influencing each other to varying degrees (confer **figure 1**). With very strong influences, as possible in the case of motor and electronics, it is not advisable to examine the separate parts of this system. Here, interconnecting the specialised simulators in the form of a parallel simulation (co-simulation) or making use of a multi-domain simulator is indispensable. With lesser mutual influences, dividing into subsystems and separate simulations is possible. Interconnecting the simulators involved is then limited to an automatic data exchange (e.g. distribution of power being transferred from the electromagnetic FEM calculation to the structure mechanical calculation).

Adding this (company-specific) knowledge of the system structure to the calculation makes it possible to arrive at an advantageous breakdown in subsystems by defining interfaces in such a way as to make sense and to carry out separate, specific simulations. The advantages of specialised and commonly used tools can thus be retained. At the same time, the interplay can be taken into account in a sufficiently exact way as long as a suitable connection (integration) of the individual tools is provided for.

Figure 3 shows some of the simulation tools used and how they are integrated in the existing CAD/EDA environment. Many quantities that are important in order to evaluate the operating performance cannot be established via individual simulators, but require an interconnection of the individual tools (connections represented by the red lines). Individual results have to be further processed via additional calculation and analysis programmes in order to gain the required information. Both the co-ordination of the process and the data management have to be taken care of by a higher order system.

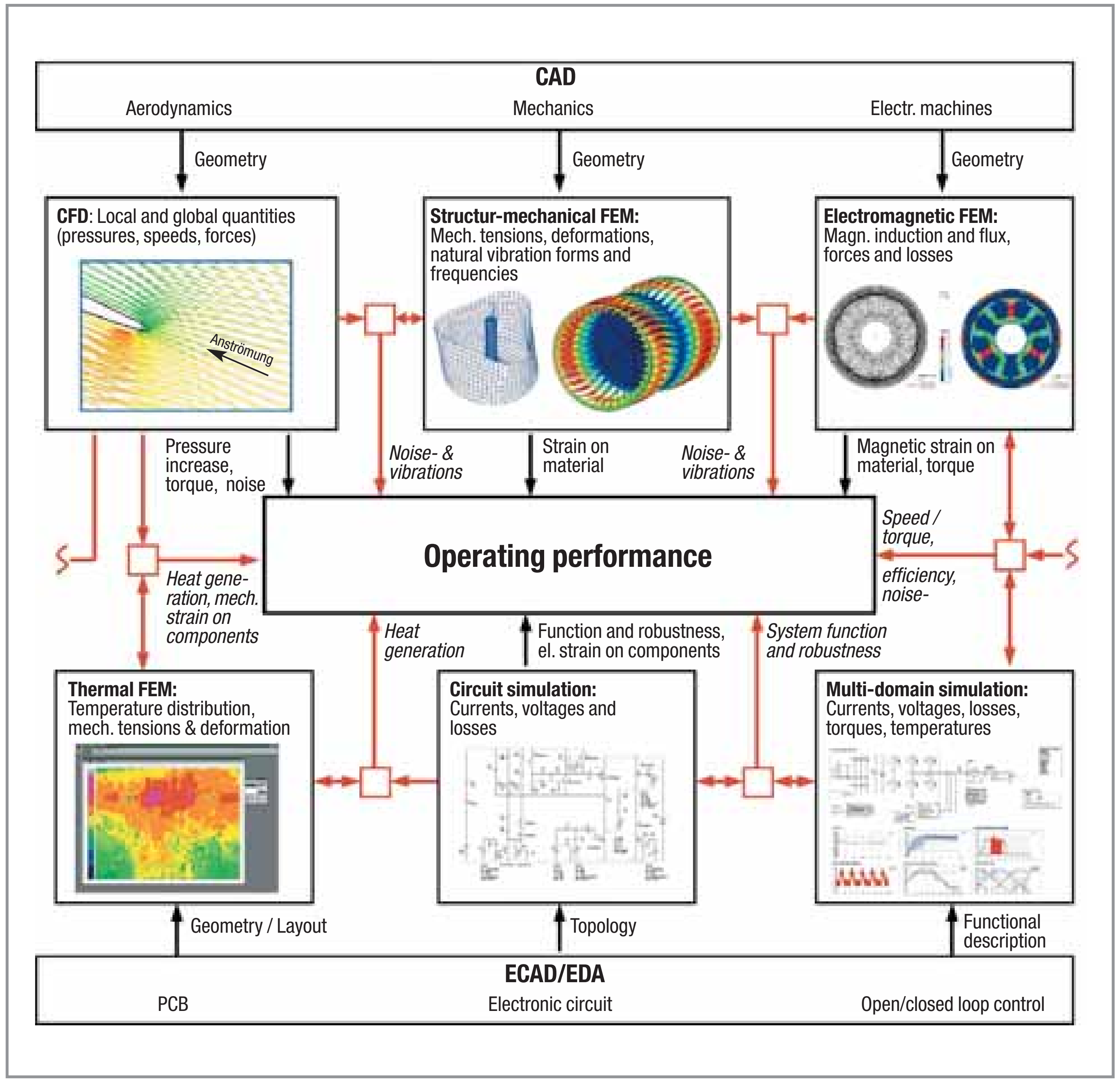


Figure 2: Integrated CAD

ebm-papst is currently developing its own simulation data management system (SDM system) that takes on this job and that is integrated in the already existing EDM system without leaving any gaps (**figure 4**).

Apart from the data processing interconnection of simulators and calculation programmes, the SDM system also manages the simulation-related data. Among those are libraries, models, model parameters, material indexes, as well as programme-specific simulation files. Being interconnected with the central database, all data is archived and documented according to product. The SDM system is also designed to co-ordinate an efficient utilisation of the existing computing capacities by distributing it among the available workstations. At a later point in time, the standardised data structures and models shall be exchanged with other R&D locations to be accessed and used there.

„ebm-papst is currently developing its own simulation data management system“

Additionally, prototypes and serial parts are also measured. The results gained from these measurements are useful in matching measurements and calculations in order to arrive at a continuous improvement of the calculation precision based on empiric data.

6. Conclusion

Methods and tools taken from the different disciplines to be taken into account when designing a fan nowadays are described. For practical purposes, stringent specialised systems cannot always be optimally employed. For this reason, widely available and known tools are used to solve specific problems and are interconnected as to data processing, and complemented by particular calculation programmes.

All this results in a company-specific toolbox that allows ebm-papst to substantially shorten the design process and to develop a technically better solution in less time than before.

Dr. Thomas Bertolini (left), Executive Technical Director
Jens Krotsch (right), Team manager Basic Development
ebm-papst Mulfingen GmbH & Co. KG

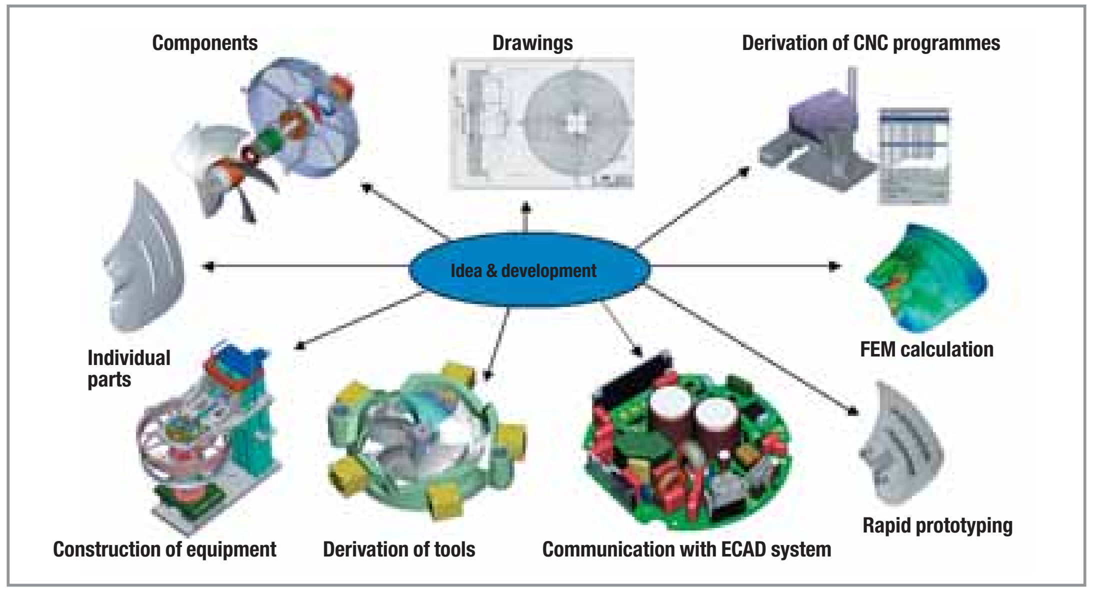


Figure 3: Interconnection of simulation tools

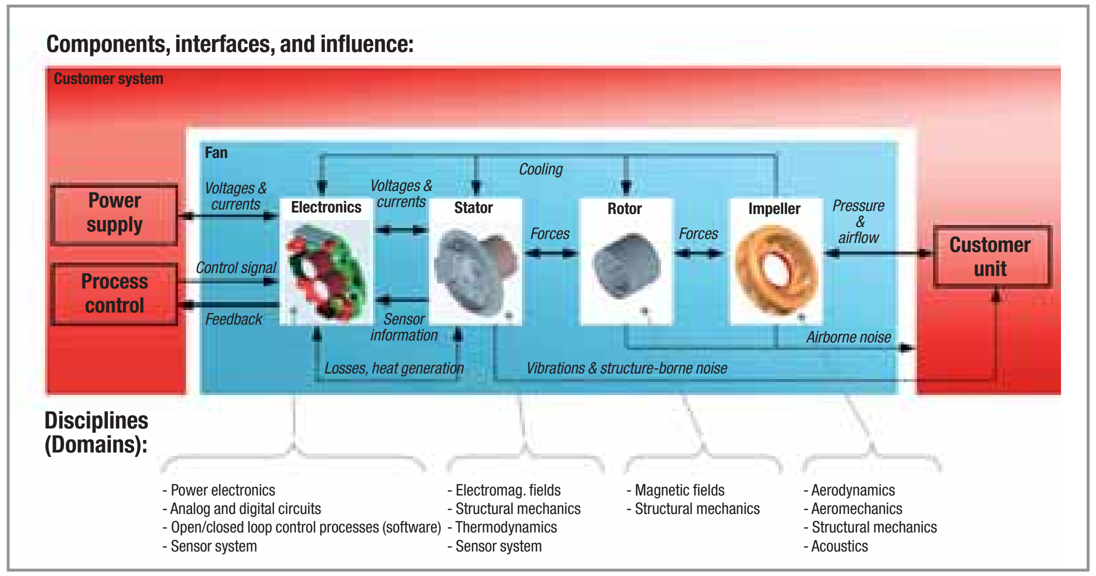


Figure 4: Integration of the SDM system into the EDM system

Customised speed programming of energy-saving motors for refrigeration

„Energy-saving axial fan – a profitable investment!“

Introduction

Reducing energy consumption through improved efficiencies has become one of the most important demands of our time. When it comes to refrigeration plants, especially to cooling cabinets, refrigerated shelves and freezer chests, there is rising demand for energy-efficient components. However, the fans used inside to cool these units are still mainly powered by shaded pole motors, which are not very efficient. Obviously, going for an energy-saving axial fan in such applications is a profitable investment.

Economic and efficient

Non-stop operation (24 h/day) and the far-too-frequent use of uneconomic and outdated motor systems cause very high energy costs in refrigeration plants. Using the ebm-papst energy-saving motors - optimised for these applications – instead results in a substantial saving potential for the end user.

Though their primary costs are higher for technical reasons, these energy-saving motors pay for themselves within one to two years.

Another advantage lies in the fact that the electronically commutated external-rotor motors have a very long service life. This just emphasis how economic these motors are.

The second speed step for night operation at lower refrigeration capacity, easily realised electronically, helps to take advantage of still more energy-saving potential.

The solution with EC motors (EC = electronically commutated) has the great advantage of freely programmable speeds that can be adapted to any customer application. Using ebm-papst EC fans, the customer can therefore individually adjust and adapt his air performance in the design and development phase of his refrigeration plant already.

Once there are serial deliveries, the customer can then either use a standard fan and program it himself, or he can get large quantities of the fan adapted to his specifications. Based on one basic electronic design, customised variants are then programmed in production (end of line), thus making it possible to take specific customer demands into account at very little expense.

Moreover, the option of setting the speed himself gives the service technician in the field a far better chance of adapting the plant to changes in application and ambient conditions.

Programming function

Either a PC or a laptop with USB interface is needed. ebm-papst supplies its customers with a PC monitor programme, the programming adapter with the relevant connecting cables and a wall power supply as accessory (**figure 1**).

The programming adapter facilitates communication between PC and motor/fan interface via a USB port. As soon as a software driver is installed, all standard USB-connectable Microsoft operation systems are supported. Downward compatibility to USB standard 1.1 and 2.0 is given.

„Programming adapter – customer-friendly and cost-saving!“

The USB-RS232 converter used transcribes the rather complicated USB protocol as RS23 protocol and transmits the data to an 8-bit micro-controller. This micro-controller monitors the connection set-up with the connected motor and, via I^2C bus, transmits data to the EEPROM found on the motor electronics.

The housing of the programming adapter contains three integrated LEDs for visual display and indication of applied operating voltage, data transmission and alarm (**figure 2**).

Software

The user-friendly surface and the operating manual as part of the delivery scope enable the user to do his own programming within a short period of time.

The operating software designed by ebm-papst monitors the entire writing and reading process. This software can be operated under all conventional USB-supported Microsoft operating systems.

When the software is started, 1000 rpm are loaded for both speeds.

The user now has the choice to either press the "read" button and read out the speeds as saved in the motor, or to enter new speed values and to transmit them to the motor by pressing the "write" button.

Figure 1: Energy-saving motor as axial fan design being programmed

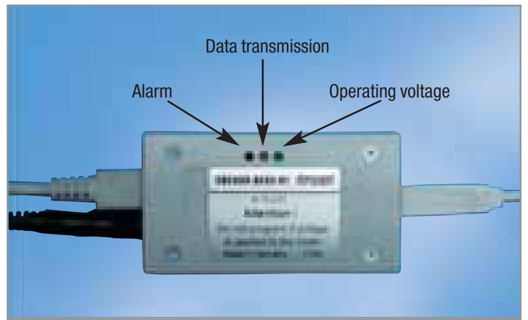


Figure 2: Displays of programming adapter

The transmission time elapsed is indicated optically (see **figure 3**). The customer can also switch to various interface ports via PC surface.

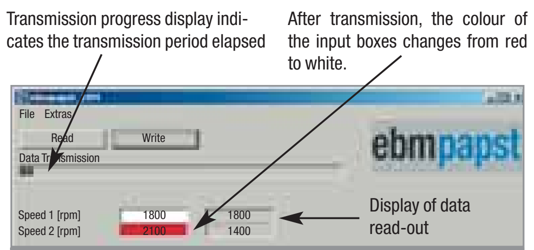


Figure 3: Data transmission

The software also allows the user to select one of the languages provided (German, English, French, or Italian) in the menu and to gain information on the software version supplied.

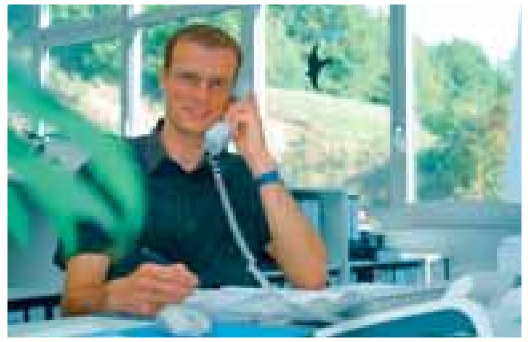
Moreover, individual speed profiles can be generated and saved and, whenever needed, these can be reloaded and retransmitted. This enables the customer to save and use frequently recurring setting profiles.

The software features various alarm windows to warn the user of transmission failures and to inform him of the cause of alarm.

Perspective

In future, ebm-papst EC motors will come equipped with a programming interface as a standard. This new feature will make it far easier to adapt the motors to specific application demands and to also carry out post-assembly software updates.

This makes it possible to restrict the diversity of types to a few basic designs, with the manifold customer applications to be realised - in terms of software – shortly before these customised designs are to be shipped or once they have reached the customer (on site). This new standard reduces the logistic expenditure and the variant management for both ebm-papst and the customer enormously, thus allowing all parties to save costs.



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