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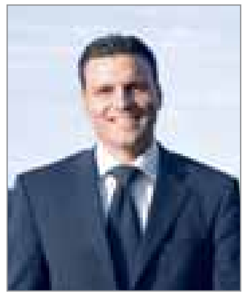
NEW IDEAS AT A GLANCE

ebmpapst

Editorial



"ebm-papst offers its customers expert advice and co-operation!"

Dear ebm-papst customers, partners and friends,

This is the fourth issue of our tech.mag, the magazine on ebm-papst technology. Again, we invite you to take a virtual tour of our R&D facilities as you read your way through the research papers originally written by our engineers for publication in specialist magazines and compiled in this edition for easy reference. As usual, colleagues from ebm-papst Mulfingen, ebm-papst St. Georgen and ebm-papst Landshut have contributed their specialist knowledge to provide detailed technical information on products "made by ebm-papst".

As Sales Director of ebm-papst Landshut, I gladly seize my chance to give you some information on the history and development of our company. When ebm-papst Mulfingen acquired mvl in 1997 and we became part of the ebm Group, there was a great deal of anxiety as to the future of our company. However, a clear strategy and, most of all, the opportunity we were given to develop the company on an independent basis turned this initial anxiety into enormous motivation and ambition. And so we succeeded in developing new products, managed to invest in state-of-the-art production equipment and facilities and accomplished to set up an efficient sales and distribution structure tailored to ebm-papst needs. Since the takeover, our number of staff increased from 540 to 900 in Landshut, and our turnover has steadily gone up since, from 50 million per 1993 to more than 140 million Euros per last year.

This new brand name ebm-papst, launched on the market in 2003 together with our colleagues from St. Georgen and Mulfingen, was yet another important milestone on our joint way towards a successful future. Our comprehensive range of ebm-papst motors and fans in both AC and innovative EC technology enables us to provide our customers with solutions tailored to their needs. Being part of the strong ebm-papst team, we here at ebm-papst Landshut focus on household appliances and heating technology. Our latest development, the gas blower 2006, is set to become a new standard which we are going to present to you in the coming weeks and months. You will find this gas blower a lot smaller, substantially quieter and more economical. In short: just another proof of the innovative strength and the pioneering perspectives ebm-papst offers its customers whenever they need expert advice and co-operation.

So let me wish you an interesting and informative time as you read your way through our ebm-papst magazine, the tech.mag. Enjoy!

Best regards,

ppa. Stefan Brandl
Sales Director
ebm-papst Landshut GmbH

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Drive for blowers used in gas condensing units

Introduction:
At the end of the 80ies, manufacturers of heating units were faced with increasing demands to reduce emissions in order to protect the environment and finally came up with a totally new system design to generate heat for room and water heating. This new system design, by now known as “gas condensing unit”, makes use of the heat released during the condensation of waste gases. These gas-condensing units have a blower placed in front of the burner, and this blower blows the gas-air mix into the burner. As pioneering company, ebm-papst developed suitable blowers for the manufacturers of heating units to boost this new technology. This blower development also included developing a motor tailored to this application. The result was the BG36-01 as dynamic, single-core, brushless DC motor in internal-rotor design. This motor was supplied for the heating unit market in its initial design up to the mid-90ies. The mid-90ies then saw the development of the second design, the BG36-02, characterised mainly by having the PCB assembled in the final stage of assembly. By the end of the 90ies, the market had grown to an annual demand of more than 1 million pieces. A further increase in demand was obvious, and so it became necessary to develop yet another design, the BG36-03. This paper presents the predominant development stages of this third design, the BG36-03.

Development objective
The development scope for the BG36-03 was clearly defined:
- Lower in height than BG36-01 and BG36-02
- Improved possibility to balance rotating mass
- Allowing for automated production

Bearing cap
The design was based on the idea of developing a motor with only one bearing cap. The resulting bearing cap combines various functions, being a highly integrated and central component of the BG36-03:

Receptacle for
- The ball bearings
- The spring for preloading the ball bearings
- The electrically conductive sealing for the shaft duct
- The stator
- The motor screws
- The noise decoupling
- The motor support (in horizontal shaft position)

As for bearing cap material, the engineers at ebm-papst decided to use plastic. Classified as technical plastic, a PA 6.6 with 25% glass fibre meets the tough specifications for such a component. Due to the different vibratory behaviour, however, glass-fibre reinforced components tend to distortions along and across the glass fibre. In order to minimise such distortions, the bearing cap was consistently designed symmetrically with a 120°pitch and it was also decided to go for

“Heating units in living spaces require a low noise generation ...”

Bearing cap – outside view

injection moulding directly in the centre and with three injection points staggered by 120° in the injection moulding tool. The injection-moulding tool is manufactured in a special process, thus making sure that the two ball bearings are optimally aligned. The first prototypes proved that the idea behind this design works. The bearing cap is almost free of distortions and the bearings are optimally aligned. Even the extreme temperature change test between 20º C and 130º C showed no subsequent distortion. Mechanical stability was established in a shock test with a shock load of 30g (acceleration due to gravity) in different load directions.

One ball bearing, the fixed bearing, can now be pressed directly into the bore-like receptacle of the bearing cap, a process that, with aluminium die cast parts, would only be possible with extensive subsequent machining. The design of this bore-like receptacle is patented by ebm-papst and geared toward a firm and secure hold of the ball bearings, making sure the outer race of the ball bearing is not crushed. The second ball bearing is placed in a conductive elastomer ring that connects the rotating impeller via the motor shaft and the ball bearing with the housing and is electrically conductive. This helps to prevent sparking discharge - due to electrostatic charging – from impeller to housing. This would be extremely critical as, after all, this blower handles an ignitable gas-air mix. The design of the bearing system reflects the findings and experience from various ebm-papst motor lines, thus making sure the market specification as to a service life of 25,000 hours is complied with. There are two main factors limiting the service life of ball bearings in small electric motors: For one thing, material fatigue of the ball bearing races or balls, and the lubrication becoming destroyed. Calculating nominal lifetime according to DIN ISO 281shows that it is mainly the length of lubrication service that plays the major role. In this calculation, service life is taken as lasting until the ball bearings fail, yet this service life is substantially longer than the length of lubrication service. In general, ebm-papst relies more on their own endurance tests than on the statements made by the lubrication manufacturers when it comes to establishing the length of lubrication service. The grease used in the BG36-03 has been tested in endurance tests at ebm-papst for years and is already used in serial blowers for the gas heating industry. The quality of the bearing system is evident in the fact that there has been any ball bearing failure in the endurance tests so far. In developing the BG36-03, these endurance tests were set up after each milestone, to some part even under excessive loads. In total, ebm-papst has 34 blowers with BG36-03 motors running in endurance tests. Meanwhile, the A-prototypes have already run for 30,000 without any failures having occurred.

Dimension

Two measures helped to reduce the axial dimension. For one thing, a part of the bearing system emerges into the blower, and the cooling blade is integrated in the space

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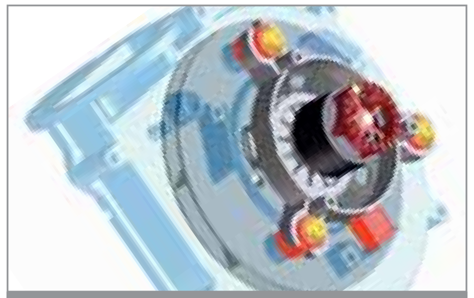

Fig. 1: Pre-mounted bearing system with all rotating masses

available for the stator and the PCB. An active cooling of the motor is necessary with many motor designs, as their power density is so high as to make winding, bearing and electronic components overheat in the required operating points. Often, it is necessary to press a cooling blade onto an extended motor shaft. This additional demand for space plays no role in many applications. In gas-condensing units, however, the past years have shown an increasing demand for a more compact build, as installations in living areas, e.g. inside kitchen furniture, are striven for, making it vital to find an integrated solution for the motor cooling. Here, the unilateral positioning of the bearing of the BG36-03 offers an excellent opportunity. The heat generating stator is only covered by the bearing cap on one side, and is open on the other side. In order to attain a good cooling effect, it is often not important to guide a big airflow to the stator; instead, it is often sufficient to generate some small convection at the hot components. As the cooling blade blows directly onto the stator windings with the BG36-03, it was possible to reduce the cooling blade diameter from 65 mm to 33 mm. The configuration to the same height as the PCB and the exact adjustment to the rotor generate a second airflow that cools the PCB components. This open design and the engineered handling of cooling air through the motor results in the classification “not protected against contamination” according to DIN EN 60335-1:2001-08. The VDE Offenbach examined the BG36-03 extensively and certified that it complies with the specifications as set out in this standard.

Balancing

As already mentioned, heating units are increasingly installed in living spaces, which is why low noise generation is a requirement. Among other factors, a decisive role is played by the imbalance of the blower. According to VDI 2060, rotors for fans and blowers are classified into quality level Q 6.3 As for acoustic specifications, it used suffice to produce the rotating components impeller, rotor and cooling blade in a certain imbalance quality and to mount them without correcting the imbalance quality in the assembled state. In many cases, this procedure is indeed sufficient to comply with the noise specifications. The disadvantage of this procedure lies, however, in the fact that the inevitable deviation in the axial run of the impeller creates an additional imbalance that is not corrected. Deviations in the axial run lead to an angular deviation of the main axis of inertia in relation to the rotational axis, and thus to changing forces on the bearing positions. The position of the main axis of inertia can be corrected if the rotating system is balanced in two planes in assembled state. Here, there is a conflict between the demand for short axial dimension and low-noise running in the motors with two bearing caps, as a second balancing plane is only available in the form of a component taking up precious space. With the BG36-03,

Fig. 2: Bearing cap – outside view (left), Bearing cap – inside view (right)

EC motors, the ideal vehicle actuators

however, the integrated cooling blade also serves as receptacle for the balancing weights, thus providing one of the planes for the balancing process. Together with the blower impeller as second balancing plane, there are now two balancing planes without the required space being increased. More recent demands as to running smoothness also show that a quality level of 6.3 is no longer sufficient in modern units to meet the enhanced customer demands. Normally, lowers are balanced by way of placing them in a measuring device and having them driven by the blower motor. Due to their design, there is a periodic driving torque with single-core DC motors that interferes in the balancing process and affects the measuring result. To make sure the specified imbalance is kept to, the blowers are balanced to values far below the critical limit. The BG36-03 has the advantage that all rotating masses can be mounted without the stator. This makes it very simple to use an external drive for the balancing process of the complete rotating system. This eliminates the falsifying influence on the measuring result with single-core DC motors.

Automation
There is one vital difference between the previous models and the BG36-03 motor: it is suitable for automated production. Providing suitable receptacles and guiding slants for the components made this possible.

Summary
Based on the demand for smaller dimensions and improved balancing possibility, the single-phase, brushless DC motor BG36-03 was developed. The highly integrated bearing cap is a central motor component combining numerous functions. Due to the innovative balancing concept, toughest noise specifications can be kept to despite the small dimensions.

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“EC motors: durable, sturdy, reliable!”

In modern vehicles more and more processes are being controlled by electronics. This sector accounts for approx. 30 % of the development expenditure. As in automation, the trend in the automobile industry is towards on-site intelligence that is underlined today by decentralized control devices for brake assistants, motor management, air conditioning, chassis stabilization etc. However, this concept can only be implemented when the actuator is located directly on site. V-belt transmission and hydraulic control are antiquated means, modern electronically commutated (EC) DC motors offer completely new possibilities as actuators in vehicles.

The car is an extremely demanding workplace for mechanical and electronic equipment. All components must function smoothly under constantly changing conditions e.g. heat, vibration, water etc.

Demanding assignment in vehicles

Both the interior and periphery of vehicles place varying demands on the EC motors. In the passenger compartment, what counts is “inaudible, invisible”, in other words: A motor should neither be seen nor heard. The demands on a quiet-running motor are particularly high and the extremely strict specifications of the automobile industry as regards resistance to vibration and shock (minimum 4 g load) do not exactly facilitate the design of a „quiet rotor”.

As far as the exterior is concerned, e.g. under the bonnet matters are even more difficult. The drives have to permanently withstand shock and vibration loads of over 10g and other environmental influences such as a wide temperature range (-40 to +120 °C) or temperature shock (120 °C warm, and cooling down in 4 s with cold water of 4 °C). The chemical and mechanical resistance is also of major importance. Salt spray test, impermeability to the influence of vapour jets or fuels are basic requisites for use in a car. Just how complex this topic is, can be seen from the brief list of fluids that car components are tested for: Motor oil, diesel, RME and petrol play just as important a role in these tests as cooler fluids, windscreen cleaners or battery acids. If an electric motor has successfully passed these tests, the final hurdle is still to come – the EMC test. The highly complex interaction of many components in the automobile is only successful when based on “mutual consideration”. Low noise radiation and tolerance towards interference from external sources are just as important as mechanical and chemical resistance and in this respect the brushless EC motors are at advantage; brush sparking and noise radiation are unknown to them. Incoming disturbing pulses can be easily extracted by filtering thanks to the integrated electronics.

EC motors, external rotors

With external rotor motors, the rotating rotor is on the outside above the field winding. The advantage of this location is a high torque and simultaneously excellent constant velocity (**Fig. 1**). The freely accessibly rotor is ideally suitable e.g. as a fluid drive for carrying different blades. With this in mind, the motor and fan specialist ebm-papst produces a wide range of fans specially for the

“The internal rotor motor is the right choice for dynamic requirements...”

Fig. 1: Compact external rotor motor. A fixed stator and integrated electronics ensure high motoring refinement.

automobile sector. However, it is important to make a distinction between versions for the consumer or PC sector and products for the automobile industry. The wide operating temperature alone means that the storage and service life lubrication as well as the control electronics have to be specially adapted. In addition to the strict EMC requirements in the vehicle, anti-blocking protection of the electronics is required to prevent blowing. The control of motors via integrated interfaces has already become standard. For the passenger compartment an extremely low, virtually inaudible running noise is equally state of the art as excellent speed control.

If one compares these motor requirements with those for PCs or consumer devices, one soon comes to the conclusion that both types of drive are not comparable. A PC stays put. A navigation device with radio and CD changer in the vehicle also requires cooling air and constant drive as does the PC but a simple PC fan or drive motor would soon fail. Although external rotor motors are also ideally suitable for other drive requirements with comparably high torque and low demands on dynamic, the internal rotor motor is the right choice for dynamic requirements.

Dynamic EC internal rotors

Function drives require dynamic motors so that control commands can be realized quickly and in this respect internal rotor motors fare considerably better than external rotor motors. The lower moment of inertia of the smaller internal rotor enables speed and direction to be changed quickly. Thanks to the use of choice materials and miniaturized electronics, an extremely high power density is possible (**Fig. 2**). These motors offer a wide range of applications for booster and auxiliary generating sets. The most well known example is the ECI motor (**Fig. 3**) for the steering aid in the car. The characteristics of this motor demonstrate the requirements that need fulfilling in the automobile:

Speeds between 0 and 6,000 r.p.m. are achieved during the entire service life. The discreet steering aid requires not only the same delicate activation as is virtually required

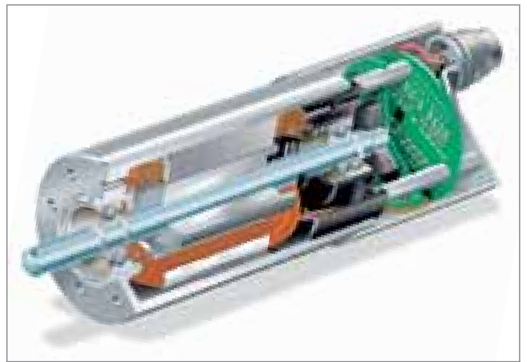

Fig. 2: Internal rotor motor, a dynamic power pack with integrated electronics

by a stepping motor but also the quick change of direction and dynamic run-up. The motor is continuously loaded in the vehicle in 4-quadrant operation. The ebm-papst solution therefore, is based on the principle of the three-

Fig. 3: The ECI steering aid defies all environmental influences under the bonnet

phase, excitated permanent magnet, synchronous internal rotor motor with sinusoidal current. A specific air gap extension in the rotor surface modulates the sine-wave form of the voltage. This means that a very low idle click point of the motor is achieved and a high uniform torque when under current.

Modern EC DC motors open up new possibilities for vehicle designers. Preset positions for drive units as is the case with V-belts or toothed belts are no longer necessary. Reliability increases drastically. High power density in minimum space enables unlimited aerodynamic shapes – the actuators fit the chassis and not vice-versa. The maintenance-free motors enhance the comfort and lower the maintenance costs for the vehicle owner. Inspection intervals can be prolonged and normal driving becomes safer and more reliable.

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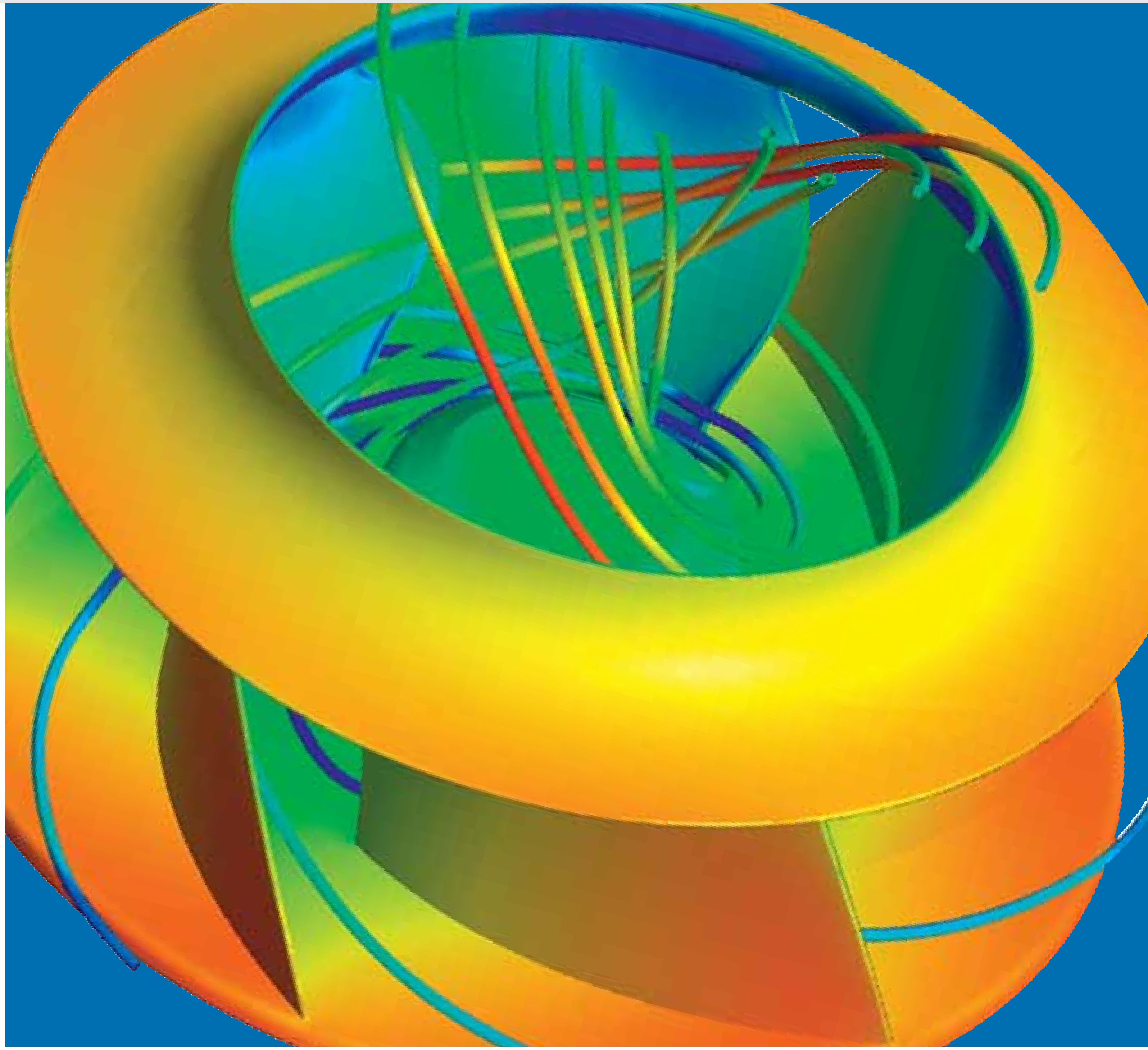
Optimising fan impeller geometries by using CFD



"CFD facilitates impeller optimisation on the PC!"

Synopsis
As leading manufacturer of motors and fans, ebm-papst Mulfingen employs the CFD tool in developing impellers. The first part of this article focuses on the objectives and the necessary steps in getting the simulation tool integrated in the ongoing development process. The second part then uses the first results gained from selected projects to demonstrate what new possibilities this tool offers and where its limits are.

1. Introduction
The numerical flow simulation (CFD = Computational Fluid Dynamics) is getting more and more important as efficient tool in the field of fluidic developments. The gained results can serve as basis for a precise, PC-supported optimisation, thus reducing the prototyping loops substantially. As it is far quicker to carry out flow simulations on the PC than to do an actual prototyping and measuring, using CFD makes it easier to analyse and assess a far greater number of variants. Moreover, the detailed information on the flow field helps to detect the sources of losses and to avoid them by using a suitable modification of the geometry.

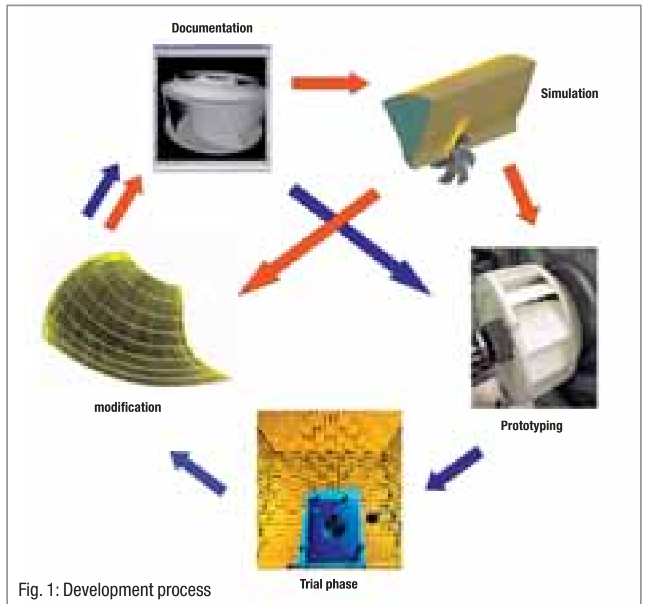


Fig. 1: Development process

2. Integration in the development process
The design tools mentioned in the books can only approximately describe the flow conditions in impellers. When developing and optimising without CFD, it is necessary to rely on cost- and time-intensive experimental loops. In the course of these processes, prototypes are generated, measured in the air-performance test bed and then evaluated. If the set targets are not met, modifications have to sought by way of trial and error, then the modified impellers have to made, set up and measured (blue arrows in **fig. 1**). In order to shorten the development time, CFD can be used as intermediate loop between design and prototyping (red arrows in **fig. 1**).

The design data is put into a suitable format and fed into the CFD tool for recalculation. The evaluation of the simulation results indicates sources of losses (e.g. separation), making it clear for the design engineer in which areas of the impeller he/she needs to make modifications. However, the complexity of the 3D flow through the impeller allows only a rough estimate of the effects of a planned impeller modification. This is why there has to be a new recalculation once the geometry has been changed in order to check whether the desired improvement has been actually achieved. This makes impeller optimisation with CFD also an iterative process, yet the duration of a loop is substantially reduced when compared to measuring and prototyping. Once an impeller has reached a satisfactory level in simulation, a prototype is generated and measured. The CFD software facilitates the transmission of the geometry by offering an export function into CAD format taking the form of standard interfaces (e.g. IGES).

In order for the CFD to work smoothly in the process chain as described, all the individual modules have to work and must be connected with each other via defined interfaces. Validating the simulation guarantees the generated CFD results to be consistent with the measuring result. For the comparison, measuring the flow field is more suitable than measuring on the air performance test bed, as the latter only provide integral values. Their random conformity with the measuring values can be caused by a number of erroneous influences being compensated; a correct flow-off filed, however, is a reliable validation. Speed distributions for rotating machines are possible by using an LDA system, for instance. LDA (Laser-Doubler-Anemometry) is a non-contact measuring approach using a laser to determine the speed components. Detailed information on this can be found in [1]. **Figure 2** shows an example of a comparison between CFD simulation and LDA measuring, referring to the speed field of an axial fan with an impeller diameter of 350 mm. The distribution of the axial component was measured 40 mm after the impeller discharge, correlating the angle of rotation, and then compared to the section of the control space of the simulation with identical constant axial coordinates. This comparison between measured and calculated speed field proves to be a good correspondence.

3. Possible applications
As the physical interrelationships on which CFD is based are generally applicable, there is a great variety in possible fields of application. In order to carry out the simulations in the requested time period of only a few days, certain

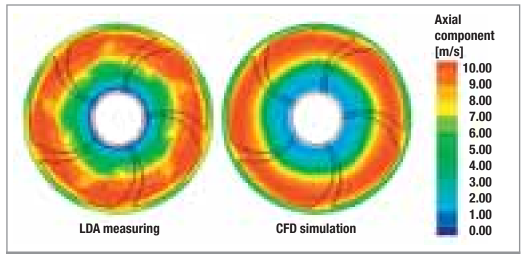


Fig. 2: Comparing LDA measuring and CFD simulation

allowances have to be made as to accuracy of the models or field of application. With a mere impeller optimisation, the impeller is at first modelled without any unit inserts (heat exchanger, fit-in boxes, etc.). The rotation symmetry permits the blade pitch to be calculated on its own. In addition to this, a stationary flow can be assumed, thus rendering the expenditure for a simulation following the progression of time obsolete. As one impeller type can be mounted in the most varied of units, the optimisation for one particular application does not make much sense at first. The development aims at arriving at an impeller with as minimal a loss as possible at free running, which generally also improves the characteristics once mounted.

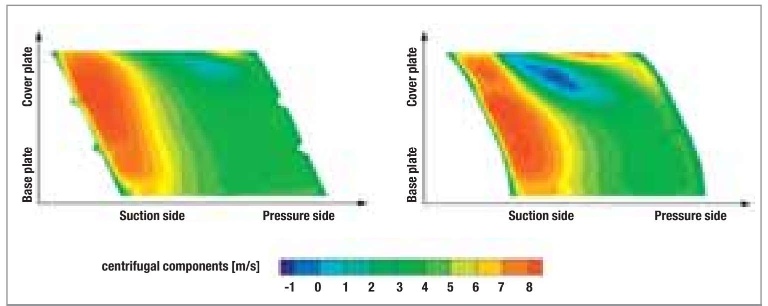


Fig. 3: Distribution of centrifugal components; left: impeller with good efficiency, right: impeller with bad efficiency

4. Exemplary application

The efficiency and noise behaviour of centrifugal fans depends largely on an even feeding of the blade channels without the speed getting too high. In order to check for a uniform flow, a section is made with a constant radius of 200 mm through a centrifugal impeller with an outer diameter of 450 mm. This section, developed, is illustrated in **figure 3** and coloured in according to the value of the radial component of the speed as calculated via CFD. The impeller with good efficiency is given on the left; the one with bad efficiency is shown on the right. This impeller with bad efficiency shows backflow close to the cover plate, the flow pattern is rather irregular. The better efficiency of the impeller shown above can be explained by the fact that the centrifugal speed within the channel is more evenly distributed. There is no backflow, and large areas are permeated at an average speed of ca. 4 m/s. The reason for the backflow with the right impeller was found to be the incorrect flow towards the front edge of the blade, as the separated flow drifts off and causes substantial losses.

5. Summary

Due to the detailed information on the flow pattern within the impeller as well as the relatively short time a recalculation takes compared to actual measuring, CFD is a practical tool for developing impellers and optimising geometries. As flow physics are very complex, there are some inaccuracies when generating the model, and so the CFD solution has to be critically checked as to consistency and accordance with existing measuring data. Still, integrating CFD in the development process facilitates the precise optimisation of impellers, as the number of prototypes to be measured and the development time can be reduced.

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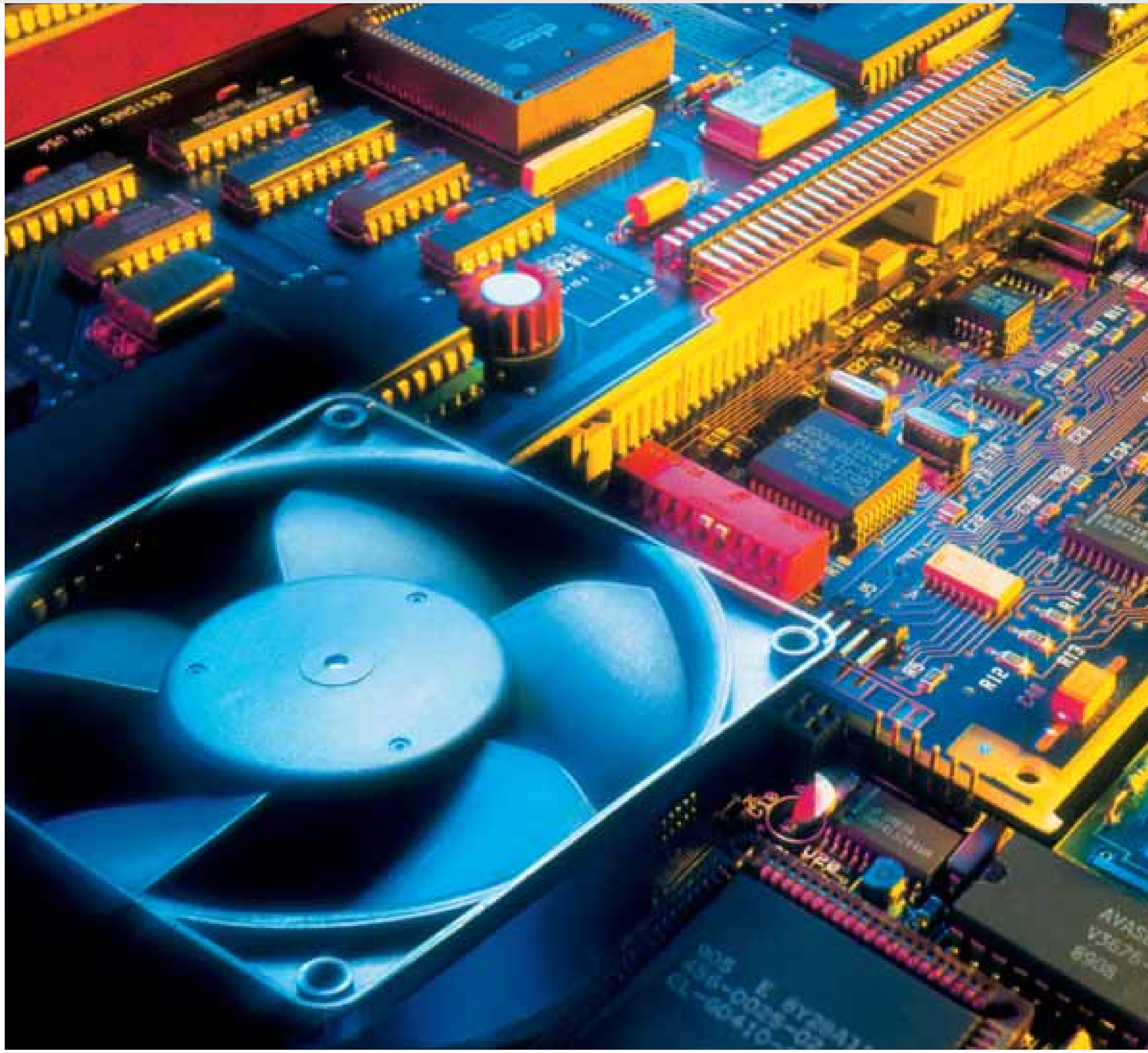
The basics of electronic cooling



"The perfect conversion of energy is the dream of many inventors and developers ..."

In order for electronic appliances to function reliably, they must be adequately cooled. However, this is not always easy to define in concrete terms. Does the housing require venting slits? Is an additional fan required? And if so, what are its dimensions and where is it located? These are the vital questions that have to be clarified giving consideration to the application conditions in question. Even those who are not specialists may find it worthwhile to familiarize themselves with the basics of electronic cooling.

The perfect conversion of energy is the dream of many inventors and developers yet in reality it will always remain impossible. In electronic components energy loss will always occur. Electrical power dissipation is converted into the equivalent volume of thermal efficiency. This thermal energy is absorbed by the thermal capacity of the components. Thus, the components heat up and radiate heat both to adjacent assemblies and to the surrounding air. **Illustration 1** shows how the mean atmospheric temperature in a device slowly increases until a condition of thermal equilibrium is reached. In this state, all assemblies reach their maximum temperature level and no longer absorb thermal energy. The heat flow is then discharged solely by heat transfer as a result of the temperature gradient. (**Fig. 2**).

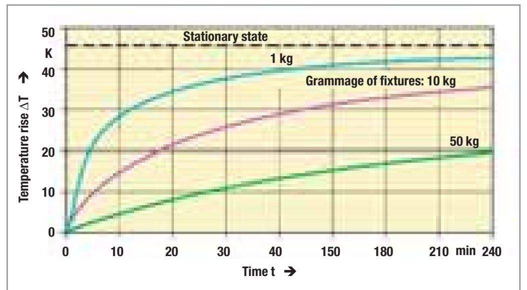


Fig. 1: Time history of the rise in temperature of a closed housing and constant power dissipation of 150 W. The greater the mounting dimensions, the slower the increase in temperature

Free and induced convection

By arranging the components accordingly, this temperature gradient can be reduced, i.e. the increase in temperature of individual components is reduced compared to the cooler surroundings. The quality of the housing has an immense influence on how heat can be successfully discharged from the appliance. Closed housings have the advantage that the interior is protected against dirt but on the other hand, the airflow cannot contribute to the discharge of heat. The heat can only be discharged via the housing panels. This takes place in three stages: The heated air inside the unit transfers the energy to the cooler housing panel. In the housing panel, the heat from the warmer interior side is transferred to the cooler exterior side and finally to the ambient air.

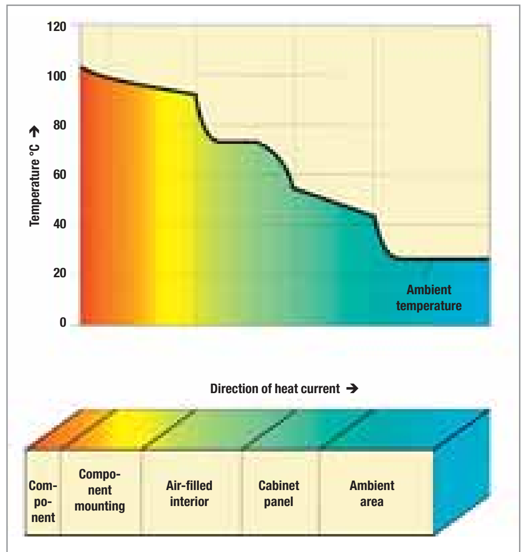


Fig. 2: Temperature gradient of a device

Due to the heat transfer between the panel and the fresh air, the air density is changed resulting in a so-called free flow that discharges the heat. This process if known as free convection. (Convection = discharge or transfer of heat by gas or liquid currents.) The transmission of heat can be improved by an induced flow, e.g. created by a fan. This is then called induced convection.

Figure 3 illustrates the mean increase in temperature of the air in the device depending on the dissipated heat for the different applications. Example A illustrates what happens in a closed housing with free convection, i.e. without active ventilation: Dissipated heat of a mere 100 W causes the temperature in the appliance to increase by 40 K, which is not acceptable in most applications. In Example B a fan is in installed in the closed housing. At a mean flow velocity of 2m/s in the device with the same dissipated heat, the temperature rises by 40 K, this means that there is only a moderate drop in temperature compared with Example A, although a relatively powerful fan is required. If one assumes housing dimensions of 500 mm x 500 mm x 250 mm, the fan would have to generate the relatively high airflow rate of approx. 150 l/s.

The conduction of heat can be considerably improved by an additional flow on the outside of the housing. If the flow velocity is 2 m/s both on the inside and outside, a temperature rise of only 26 K (curve C) is realized with the same power dissipation. In order to achieve the same velocity when circulating the air, an additional external chassis must be provided to channel the outside flow and provide space for the second fan. Further ways of improving the conduction of heat are possible by increasing the surface, e.g. panels and intermediate ribbed panels.

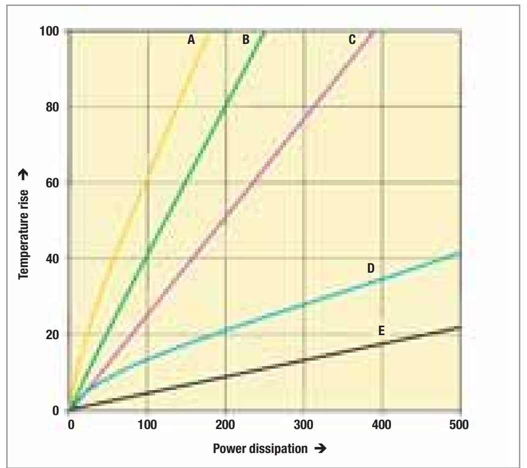


Fig. 3: Temperature rise in the device depending on the cooling conditions

This results in heat exchange systems, however, that require additional constructional expenditure and naturally greater volumetric densities.

"Chip coolers are extremely compact and are easy to integrate in the devices!"

Heat transfer in open housings: Venting slits
Open housings provide considerably better possibilities for discharging heat through openings or slits that permit the passage of air. In open cabinets the heat may be transported directly from within the unit on currents of air. The mean temperature rise ΔT can be calculated with the following equation:

$$\dot{V} = \frac{P_v}{(c_p \varrho \Delta T)}$$

P_V = power dissipation, c_p, specific heat capacity of the air, ϱ air density and $\dot{V}$ the airflow rate.

An air current arises from the difference in density between the air warmed in the unit and the cooler environment. The curve D in **Figure 3** illustrates that the temperature rise is only 14 K for a power dissipation of 100 W, even when only 5 % of the upper and lower cabinet panels are perforated with slits – thus lying significantly lower than the various cases with enclosed cabinets. This simply but very effective cooling technique with slits in the upper and lower cabinet panels is thus widely employed when high power dissipation is not to be expected.

Fig. 4: Fans provide high reliability and effectiveness at moderate cost

Active ventilation with equipment fans: The correct dimensioning
A more significant reduction of temperature increases can be achieved when convection is induced by fans (**Figure 4**). Curve E (**Figure 3**) illustrates what happens with a relatively modest flow rate of 20 l/s. With a power dissipation of 100 W, the rise in temperature would only be 5 K. In electronic equipment, this cooling method is therefore, the most widely employed today, since it provides particularly effective performance and high reliability at relatively modest cost. Suitable filters may be employed to prevent environmental contaminants from being "blown" into the unit.

For dimensioning the airflow rate and selecting a suitable fan, the equation for the rise in temperature can be used by rewriting the formula accordingly:

$$\Delta T = \frac{P_v}{(c_p \varrho \dot{V})}$$

If the power dissipation Pv is already known, the required flow rate results by specifying the permissible average temperature rise ΔT. **Figure 5** illustrates this relationship.

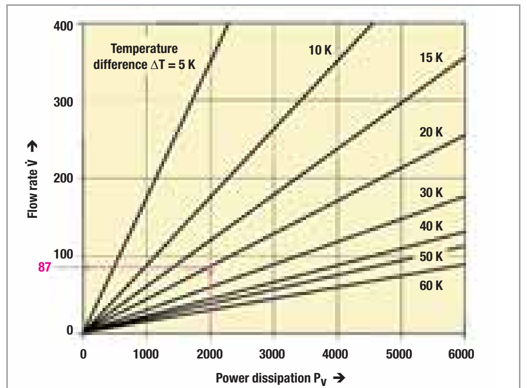


Fig. 5: Required airflow rate for active ventilation

Avoid hot spots: Processor cooling
However, the permissible mean rise in temperature says very little about the temperature of the various components. The required calculations involve considerably higher costs. Computer programs are available for thermal simulation that also enable the calculation of the flow velocity and rise in temperature (**Figure 6**). In the case of electronic components with high power dissipation, in particular processors, high junction temperatures often occur even when units are force ventilated. Heat sinks can be of assistance as they increase considerably the heat transfer surface so that the temperature of the components drops. The following example explains the facts:

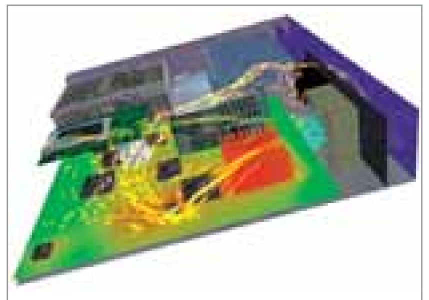


Fig. 6: Illustration of velocity vectors by thermal simulation (FLOMERICS)

Fig. 7: Chip cooler for cooling processors

The temperature of a chip with an output of 20 W and a basic area of 50 x 50 mm increases by approx. 140 K. If a heat sink also with a basic area of 50 x 50 mm and 23 mm high is employed, the temperature of the chip only increases by 107 K. However, this is still relatively high. The cooling effect can be improved by using a fan that blows air into the heat sink. These types of chip coolers (**Fig.7**) are available in different versions. They are extremely compact and are easy to integrate in the devices. The cooling effect that they achieve is remarkable. **Fig. 7** illustrates the results for the above-mentioned chip: At a mean flow velocity of 1 m/s, the rise in temperature is reduced to 36 K, at 2 m/s to 24 K (green curve). The turbulent exhaust currents of the fan have a favourable effect on the heat transfer since considerably higher temperatures are reached (blue curve) when air is suctioned out of the heat sink.

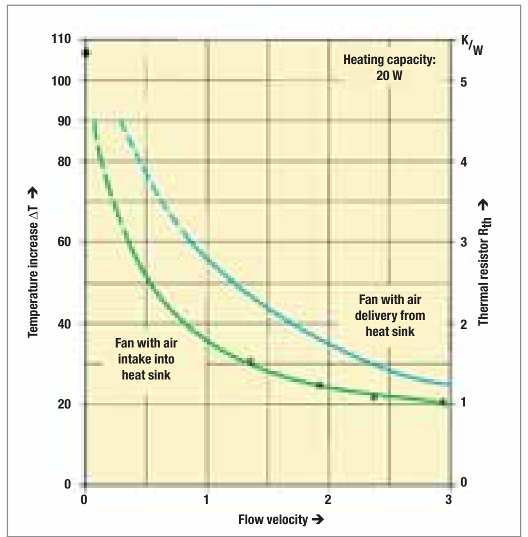


Fig. 8: Influence of flow velocity on the cooling effect of a chip cooler

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Methods and tools for developing blowers for commercial vehicles

Fans and blowers made by ebm-papst Mulfingen provide perfect air-conditioning for commercial vehicles: construction and agricultural machines as well as busses and coaches owe their comfort to them. A systematic approach and making use of state-of-the-art methods and technologies were the basic requirements for our successful development.

Blower lines

In the past two years, ebm-papst Mulfingen GmbH & Co. KG, market leader in the segment fan and external-rotor motor, has been developing two new lines of axial fans and centrifugal blowers for use in commercial vehicles, a step guaranteeing continuous success and growth. At the centre of attention were the proven modular and system integration approaches with their integration of the electronic commutation circuits in the motor housing, optimally adjusted to the blower contours. The advantages lie in the best possible utilisation of the mounting spaces together with an optimisation of aerodynamic characteristics. Unobstructed air intake zones result in a good cooling of the electronic components and reduce noise emission. **Figure 1** shows a centrifugal blower with electronically commutated motor and an axial fan with the motor positioned behind the impeller hub.

Fig. 1: Centrifugal blower (left) and Axial fan (right) with electronically commutated motors

The centrifugal blowers and axial fans have been mainly developed for use in vehicles with 24 V on-board supply systems. When air-conditioning a bus, six centrifugal blowers and four axial fans are required on average. Double-deckers even have downright aerodynamic power stations with twelve centrifugal blowers, mounted in a limited space (**figure 2**) and having the task of making sure that the cabin is properly ventilated from rear to driver seat. The air conduction tunnels can be as long as 15 meters in such cases.

ebm-papst blowers for commercial vehicles offer precise control of the cabin temperature in these vehicles. To this end, an electric interface with various input and output signals is available, especially one for Tach output and the additional option of operating mode recognition. The blowers can be continuously controlled across the entire speed range.

Axial fans are available in impeller diameters 280 mm and 300 mm. The impeller is particularly robust because of its circumferential ring with a radius facilitating optimal air intake and is therefore of perfect aerodynamic design. The most powerful variant taken from the axial fan line provides typical air - volume

"The latest development methods are the major prerequisites ..."

Fig. 2: Aerodynamic power station in a double-decker bus

flows of 2,000 m³/h at a pressure difference of 100 Pa.

Centrifugal blowers with various flange dimensions can provide a typical airflow of 1000 m³/h at a pressure difference of 200 Pa in their most powerful variant.

Using electronically commutated motors, both blower ranges have marked advantages over the products with commutator motors so far used in this market. As there is no longer any commutator brush system, prone to wear-and-tear, the service life of the newly developed motors is significantly higher - at 25,000 h. The electronic control circuit makes it easy to influence the starting points at which electric current is provided. With a brush-type motor, this would correlate with a spatial displacement of the brushes along the circumference, which, however, could not be made use of because of the fixed position of the brushes. With electronically commutated motors, the torque performance and therefore the air performance of the blowers can be influenced across a wide range. Due to their better overall efficiency, the negative effect on the environment is also reduced. Especially when operating an average of 10 blowers in a bus top air-conditioning unit, this comes as a positive side effect. The electromagnetic emission no longer depends on the current state of the pressure on the brushes, but is defined and constant. Electromagnetic compatibility as regards the line-bound interference quantities corresponds with the highest interference suppression class. The units comply with the European directive 72/245/EWG and are thus allocated the e1-designation.

Use of state-of-the-art development methods

The combination of the ebm-papst core competences motor technology, electronics and aerodynamics is the cornerstone on which the mastery of complex interrelations and the perfect adaptation of the individual components rest. Getting customers involved as early as possible is an absolute must in order to be able to work out the interfaces and to plan the field tests. A strict and stringent project management system and making use of the latest development methods are the major prerequisites for accomplishing a timely market launch.

Prior to starting on the development, market studies need to be carried out, forming the basis for a catalogue of specifications and requirements. Customer requirements and expectations, sometimes not easily deducted from explicitly stated or measurable quantities, but for instance supposed to contribute to the customer image or the customer's claim to innovative leadership, are evaluated and find their way into the product design, always in order of their importance to the customer. The systematic application of prophylactic measures to avoid mistakes, such as FMEA – carried out in a specific form at ebm-papst, namely the matrix FMEA – in all system levels is a matter of course today; critical characteristics, once established, automatically make their way into part drawings and process control plans.

In order to meet the objectives set, commonly known simulation and calculation methods are used throughout the development phase. Examples of such simulation calculations carried out are illustrated in **figure 3**. All simulations still have the one objective: to arrive at an optimal prediction of all desired characteristics, to avoid costly and time-consuming repetitive action, and, generally, to have the chance to intervene as early as possible in all areas of product and process development. All this would not need to be mentioned if there were clear rules for the design of an "optimal" product. The real challenge, however, lies in designing the most suitable product for the market and the organisation in the time set in relation to the turnover one expects to make on the one hand and the means one has at ones disposal on the other hand. When developing motors, electromagnetic field calculations and electronic simulations

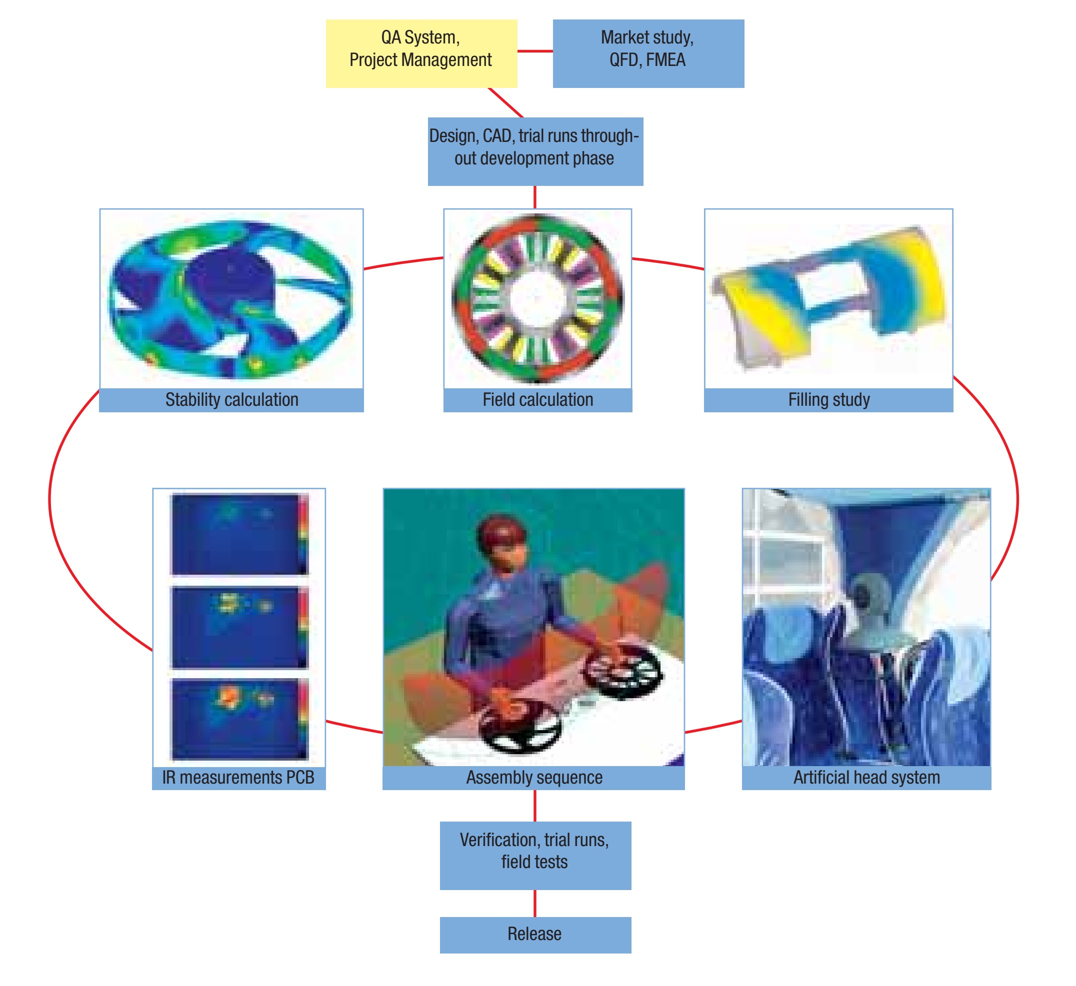

Fig. 3: Development sequence

"ebm-papst is specialist for development support in close co-operation with customers"

are employed. The geometries of the blade contours are calculated in advance, taking optic criteria into account. When it comes to construction, 3D design tools are used throughout. The records thus generated are then adopted by other programmes, especially for calculating sturdiness, analysing modes, simulating flow, for magnetic field gradients, but also for examining the filling behaviour of moulded plastic parts, and, of course, also for rapid prototyping. These data also serve as the basis for development tools for the construction of operating material, for production planning, and by now also for simulation and optimisation of the production processes.

Parallel to the project and design work, first studies and measurements take place already. In the room for precision noise measurement, preliminary studies are carried out to determine the vibratory behaviour of the critical components and of the finished units. Throughout the development phase, the acoustic measurements make use of the artificial head system, and it can also help customers when carrying out measurements in the vehicles themselves. The preferred choice for examining the thermal behaviour of strip conductors on printed circuit boards is the infrared camera. Measuring electromagnetic compatibility, i.e. special and line-bound quantities, is done in our own lab, whereas emission and interference emission immunity are measured at an external institute. Aerodynamic designs are verified via LDA method. Checking the designs on air, torque and thermal test stations round off the spectre of measurement work required for the optimal product.

The third development stage consists of comprehensive trials in order to establish limit loads as well as resistance to ambient conditions. To this effect, the burst speeds of the impellers and the permissible shock loads are checked. Salt spray, vibration and temperature stress are also checked in accordance with the different customer specifications. It is especially the aspect of our blowers being used in vehicles of different manufacturers that requires frequent verification of the individual specifications. Furthermore, special fields of application also require additional adjustments with respect to the material to be selected. Product field tests are usually carried out together with and assisted by the customers under extreme conditions in countries with hot climate, with much frequented stretches of bad roads, and where the products are in operation almost around the clock.

As the specified profiles get increasingly more complex, especially with an extensive amount of diverse application products, it is vital to conscientiously follow the release procedures and painstakingly review the trial runs on the basis of the customer specifications. The smooth co-operation of all the departments involved, first in the development process and later on in the production process, relies on stringent knowledge of and familiarity with systematic procedures and their execution. The basis for this is a quality management that is perfectly adapted to the requirements of customers in the automotive industry. At first glance, planning and documentation consume a lot of time and effort, but the continuous application of the quality standards soon reveals that this is, indeed, the only possible way to make sure that the complexity continuously to be managed matches the reliability and safety of the product later on. Especially in large organisations, efficient training methods and daily practise on the job are simply an important must. Thus, the quality management system in use throughout ebm-papst is certified according to TS 16949.

In conjunction with the environmental certification, the commitment throughout the company focuses on saving energy. Optimising efficiencies across a large part of the product range is one of the main issues. Comprehensive balancing methods illustrating the consumption of the materials used and the generation of substances, also illustrating the flux of energy, allow inferences on possible health hazard potentials and their effects on the environment.

Profitable planned use

ebm-papst is specialised on development support in close co-operation with customers, offers a large range of derivative product variants, generally responding quickly to changes in specified profiles. In doing so, a systematic approach is one prerequisite for the successful realisation of set development objectives.

For ebm-papst, penetrating this market segment proved to be a new and innovative growth step in its focus on further growth. The new products can be fitted into existing and new vehicles all over the world. Exchangeability and compatibility were what customers had specified. In agricultural and construction vehicles, cranes, tractors, city busses and coaches as well as in trains, these products are used to provide reliable air-conditioning in driver and passenger cabins throughout their long service life.

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HMS-Controller optimising temperature-controlled ventilation systems

Introduction:
ebm – papst, leading manufacturer of motors and fans, has come up with an HMS-Controller especially designed for temperature-controlled ventilation systems.

This microprocessor-driven controller board easily meets all specific customer requirements as to complex alarm and control options (**figure 1**). It is quite simple to programme an almost unlimited number of various alarm and control options via terminal software, thus allowing the user to enjoy their quick realisation in his application.

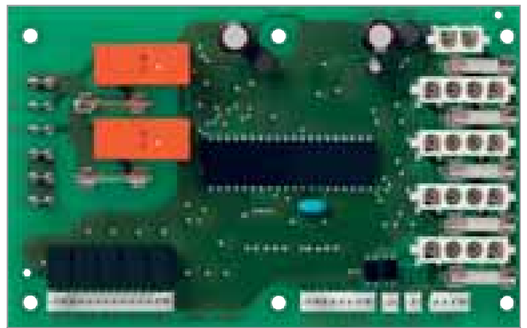

Fig. 1: MS - Controller board

Matching the ebm-papst EC product range, this HMS-Controller can be used for any size of fan and blower. Typical fields of application for this HMS-Controller are telecommunications and IT industry, as well as refrigeration and air-conditioning and special industrial systems.

Hardware configuration of the HMS Controller:
The HMS-Controller has an input voltage range of 16-57 VDC. Depending on the input voltage, one needs either 24 VDC or 48 VDC fans, all of which are additionally protected via selective safety fuse. Each of the maximally connected four fans (see **figure 2**) has to have an open-collector tach output and a control input (0-10V or PWM).

There are various alarm options to choose from. Making use of the four status outputs as open-collector (10 mA),

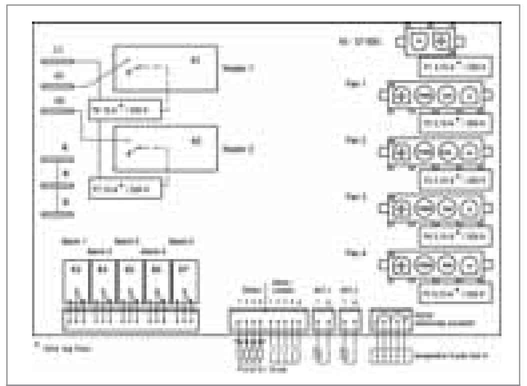

Fig. 2: Connection diagram

optical signals such as a blinking with speed lower than specified or when activating an alarm can be given via LEDs. There are also five channels with floating alarm contacts (relays, 125 VAC / 0.5 A), which can be used to activate, for instance, a buzzer or a modem. Two integrated load-controlled circuit relays (250 VAC / 12 A) serve as controls for a specific application, such as a heating system. Apart from the alarm option, there are four status signal inputs for external circuit breakers, such as used for signalling an open control cabinet door. The user can use the terminal software to allocate these status signal inputs to the alarm output he thinks important, just as he can do with the two temperature sensors (NTCs). For programming purposes, there is a terminal for an electrically isolated RS232 – interface. This allows the desired setting parameters to be written onto the EEPROM and re-read. The microprocessor then processes the EEPROM data.

The HMS – Controller board is available as PCB module, as illustrated in **figure 1**. The outer dimensions of this electronic unit are 100 x 160mm and make it easy to mount this fit-in component in control cabinets.

"HMS-Controllers offer the user a vast range of options ..."

Setting parameters of the HMS-Controller:

The relevant terminal software is free and available on request. It is a software based on Windows 9X, 2000, XP and NT. The terminal programme makes use of the serial interface of the PC or laptop to accomplish data transmission.

After successful software installation, the programme is accessed like any other Windows programme and the window as shown in **figure 3** comes up.

On the user interface for setting the parameters (**figure 3**), it is possible to allocate an individual temperature – speed profile to any of the connected fans. In order to check the connection between Controller and PC, the ACTUAL temperature of both connected NTC's is displayed in the relevant boxes. When

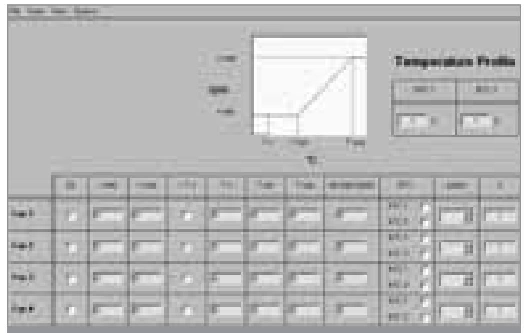

Fig. 3: User interface for setting parameters

entering the desired temperatures and speeds, the respective boxes are marked in red; once data transmission has been completed successfully, the red designation changes to white. After this, the Controller board runs on by itself and the PC is no longer needed. A comprehensive and detailed description of the interrelation of the various input functions can be found in the relevant operating manual.

On a second user interface (see **figure 4**, "Configuration of alarms"), the user has the option to generate different application-specific alarms. The five alarm options set as priorities can be triggered off by different signals: if there is, for example, a door contact installed in the control

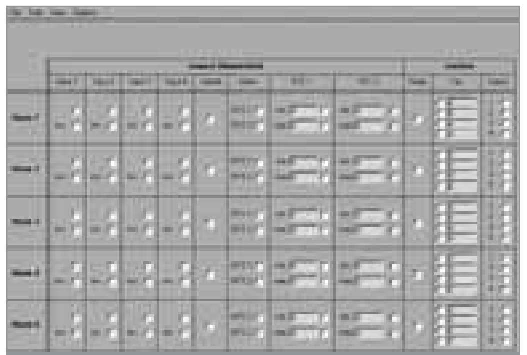

Fig. 4: User interface for alarm configuration

cabinet door, then an open door brings all the fans to a standstill and triggers off a red warning signal. There are four floating alarm inputs to choose from. Further options for generating alarms are failure detection for the temperature sensor, over- and under-temperature detection and detection for fans operating below required speed. Various reactions can be allocated to all of these input signals. The user can chose among five floating alarm relays, four status inputs (Open Collector) and an option to influence the speed of the fans.

There are also two load-controlled circuit relays that lend themselves to controlling a heating system, for instance. Setting the relay parameters is identical to the procedure for the alarm configuration, with relay1 having higher priority than relay2.

Summary:

With their HMS-Controller, ebm-papst offer a complete system precisely matched to their fans and offering the user a vast range of options in having his specific requirements integrated in the system. Effectively used, the energy consumption and the acoustic performance of the fans can be adjusted to the specific ambient conditions. Evaluating and coupling the various alarm signals creates a redundant system that makes servicing a lot easier in emergency situations. As described above, the HMS-Controller is mainly used for applications in telecommunications and the IT industry.

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