

Press News

The theory and practice of small fans (1)

What is the correct type of fan: Axial, radial, diagonal?

Fans are as varied in their construction as they are in their applications. These "air-donors" are primarily differentiated according to the physical principle of the transfer of energy to the gas medium. Depending on the design, each fan is suitable for a number of different uses. In this article we will cover the different fan types, the physics pertaining to them and the practical effects that their design has. (An upcoming article is planned that will cover other distinguishing features, such as the selected drive motor, materials employed and the use of control electronics integrated into the fans).

Air that is moved contains kinetic energy. This energy has to be applied to ambient air in order to create an airflow. Perhaps the best-known example of this is an aircraft propeller. A rotating profiled impeller transfers the shaft output to the air, creating a vectored airflow. However blower wheels with radial impellers and shafts with fins running lengthwise as well as hybrid designs are also suitable for gas delivery.

Axial fans – lots of wind, not much pressure

For axial fans, the propeller principle is employed. The airflow through the blower wheel with the (propeller) blades is conducted to a great extent parallel to the axis of rotation, hence the name axial fans. The rotating blades have a complex shape in order to achieve a good efficiency factor. As well as the curvature of the whole blade, (fig.1), its profile alters with the diameter. The reason for this is the rising circumferential velocity of the individual blade sections as the distance away from the drive shaft increases. Essentially the principle of operation can be described thus:

The air is sucked in and flows from all parts of the room towards the inlet, during which the outer housing acts as the suction funnel. The inlet edges are therefore rounded. On the outlet side the air is forced out in the direction of

the axis of rotation. This is done by the blades, which as it were push the air through the fan. The aim is to achieve as homogeneous a flow of air as possible without creating vortices. A fan designed in this way can run very quietly. Outside of this optimum working point, i.e. with an increasing rise in pressure, the situation changes dramatically. The positive displacement is increasingly superposed by air delivery due to centrifugal acceleration of the gas molecules. This is because additional energy can only be supplied by means of an increase in speed. The geometry of the blades, optimised for a particular speed, cannot handle the new situation. With increasing counter pressure, the delivery caused by centrifugal acceleration of the gas molecules becomes ever more important. The effect of this is that the air stream begins to detach itself from the inner part of the blower wheel, near the hub, and pushes outwards, leaving vortices to form in that vacated inner area (fig. 2). These cause turbulence and in consequence noise. The vortex zone also then requires even more energy. As the counter pressure increases, the fan efficiency drops away and the noise level rises.

Whisper-quiet operation requires expertise

Axial fans with a complete external housing are the primary method of cooling electronic components. The compact design with mounting holes incorporated in the flanges make for space saving installation. However a disadvantage of this compact solution comes in the form of essential struts linking the motor housing to the external housing. If during operation the blade edges of the rotor sweep across the struts then inevitable pressure surges are caused that can increase the running noise of a fan quite considerably. Everyone will recognise this effect, as something quite similar can occur when sitting at a red light in a car, waiting to turn. If a truck goes past it can cause pressure waves that can cause the whole car to shake and that can - acoustically - sound as if the car has been hit.

Help can be had in avoiding this problem by optimising the design geometry of the blade edges and sections, as well as the actual number of blades and sections. In principle it is best to have a smooth transition from blade to section. The preferred choice would be for spirally curved struts that are distributed asymmetrically round the circumference of the housing – these lead to less noise creation. If fewer vortices occur, then the acoustic behaviour of the fan is improved. The audible sound produced by an odd number of blades and sections is easier on the human ear than that produced by an even number. Ideal results can be achieved through constant improvements based on special software simulations.

Airflow with extra pressure

For applications that require high pressure but at a limited flow rate, then axial fans are the better choice. With these fans the whole airflow exits the blower wheel at the outer diameter. The higher potential kinetic energy of the air molecules creates a higher pressure than the axial blower, whose circumferential velocity is limited at the wheel hub. If for example the air stream has to be conducted round an angle of 90° or if component parts, filters etc. are impeding free airflow then radial fans are more effective. Here again the complete fan model with housing is available. However the range of fans available from the ebm-papst company of St. Georgen, Germany also includes various motor/blower wheel combinations for applications where the routing of the airflow for static pressure can be integrated into the unit. In this instance a distinction has to be made between two different blower wheels. There are blower wheels, where the blades are curved forwards in the running direction and blower wheels where the blades curve backwards (fig. 3). Blades that are curved forwards permit a more powerful direction of the air stream and achieve a higher energy conversion. The disadvantage here is the higher vortex torque of the exhaust air, which then has to be converted into pressure in a subsequent control device. The simplest solution to this is a scroll housing that can be integrated into the fan housing (fig. 4), although baffles or diffusers within the device can also do this. Blades that are curved backwards do not achieve such a high energy conversion proportional to their size, however they do have the design advantage that the static pressure is built up primarily within the blower wheel itself, so generally eliminating the need for a spiral housing. Just such an application can be found in the cooling of electronics, where a free airflow is often required, so the principle of backward curved blades can be applied without requiring a control device.

For greater airflow performance, so-called double-inlet radial blower wheels can be used, where the air can enter from both sides into the blower wheel. The drive then sits between the two blower wheels. One particular version of the radial fan is the so-called drum impeller (fig. 5). Fitted with forward curved blades, this impeller is used in applications requiring small radial dimensions.

Hybrid Solution: the diagonal fan

The so-called diagonal fan occupies an intermediate position between the two types of fans discussed above. With this principle, use is made of both the “scooping effect” of the fan impellers as well as the centrifugal acceleration. This layout gives an airflow similar to the widely-used axial fans whilst at the same time achieving a

higher static pressure. This provides a simple solution to the problem of counter pressure normally encountered with radial fans, which would otherwise require changes to the design of the unit. Devices, which subsequently have components built in that impede the airflow, can quickly be equipped with a suitable quiet-running fan. The most important characteristic of a diagonal fan is its conical rotor hub. A diagonal fan to a large extent also sucks in the air axially. The hub that is shaped like the surface of a cone has a small cross-section in the area of the inlet. On the delivery side the diameter increases. The associated higher circumferential speed of the blade tips at the outlet means a higher centrifugal acceleration of the air (fig. 6). The flow path is thus adapted to the aerodynamic processes. For the same overall size, more energy is transmitted to the air, so increasing the pressure that can be achieved. Vortex formation is minimised thanks to the conical shape of the blower wheel. The benefit is thus that even at high speeds or with a high static pressure the fan runs very quietly. For applications requiring large volumes of air but at low pressure then the cross flow principle is the most suitable. Air flows in a radial direction through a roller shaped blower fitted with many small blades (fig. 7) - at the suction point from the outside to the inside and at the exhaust point from the inside to the outside. Guide ducts along the inside or outside of the blower shaft create vortexes in the roller, which guarantee a steady flow of air through the blower wheel. The main field of application for cross flow blowers is with devices requiring a large-surface airflow.

Fans whose design construction is adapted to the application in question, whilst cleverly using the physical flow properties described above, ensure the best airflow, as well as guaranteeing the lowest running noise and minimum power consumption. The practical implementation of the necessary drives, materials and control options will be discussed in a future article.

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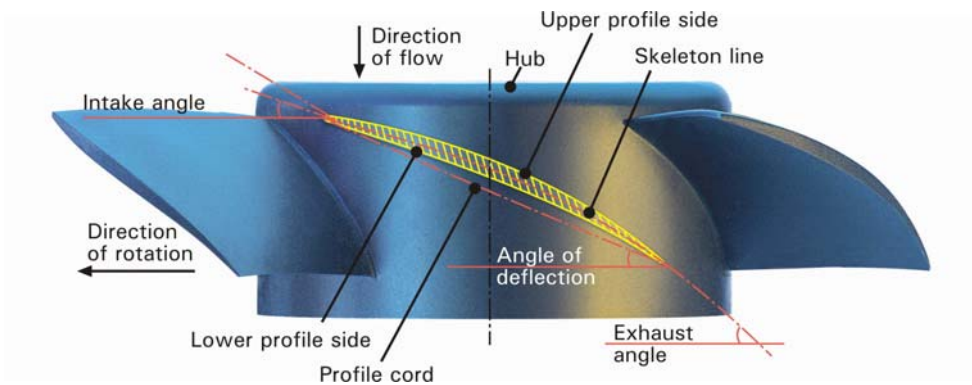


Fig 1: Sectional view of blade profile

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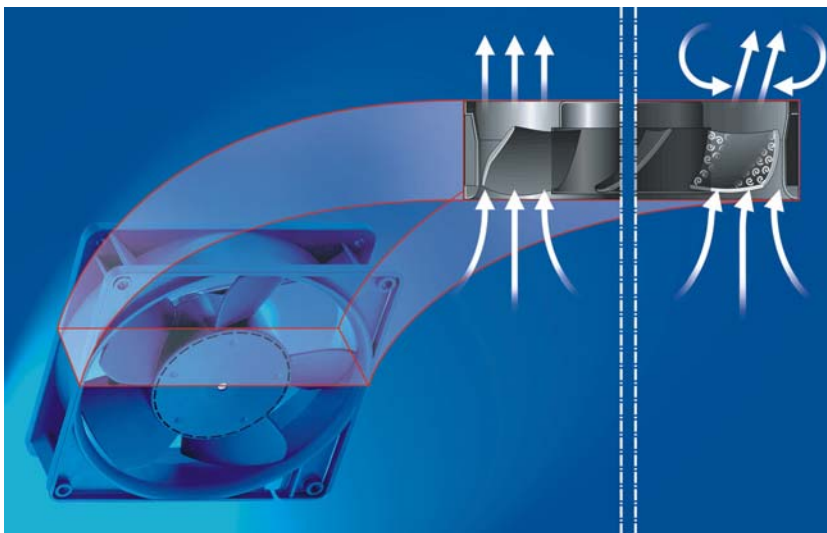


Fig 2: Vortex displacement at the hub

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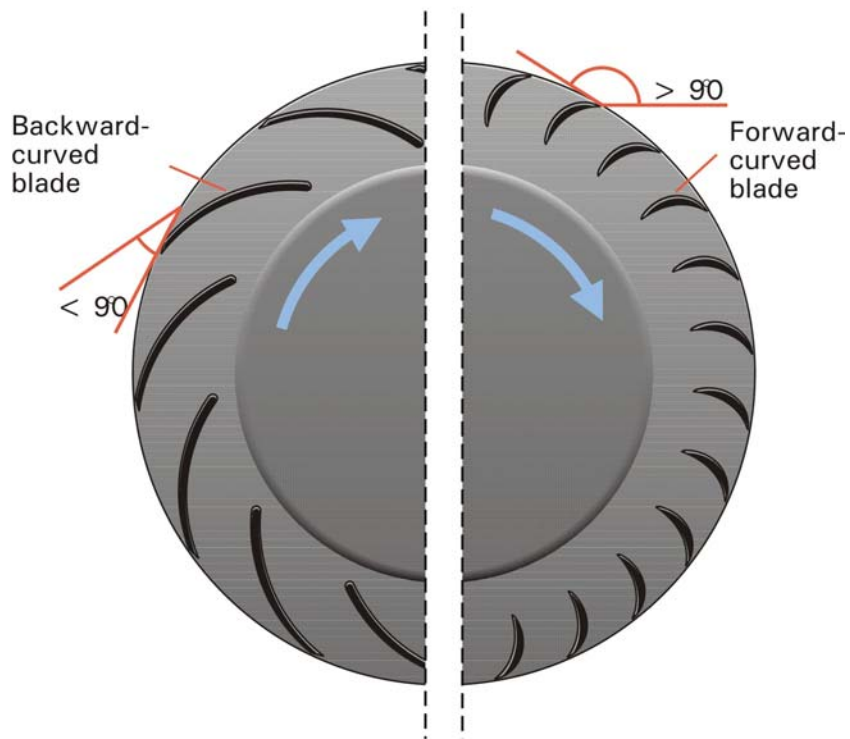


Fig 3: Radial fan blower wheel, with forwards/backwards curved blades

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Fig 4: Radial fan with integrated spiral diffuser

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Fig 5: Drum rotor for very small radial dimensions

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Fig 6: Sectional view diagonal fan

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Fig 7: Cross flow blower