Media information

Hoval

Carryover in heat wheel

The internal leakage of a rotor results from the seal leakage and the carryover. While leakage depends on the seal quality and the pressure difference, the carryover is due to functional reasons; it can be prevented using a purge sector under certain conditions, depending on the arrangement of the fans. You must take account of this condition during the design phase.

Carryover has many effects

Due to the carryover, the mass flows of extract air/exhaust air and outside air/supply air are changed; the planned values (= without leakage) are no longer achieved. This has many effects:

- Correction of mass flows
  The extract air and outside air mass flows must be corrected in such a way that the planned and required supply air and exhaust air volumes (= without leakage) are achieved.
- Increased air flow rate of the fans
  To achieve the nominal outputs of extract air and supply air, at least one fan, but often both depending on the fan arrangement, must also convey the carryover.
- Reduced supply air quality
  If there is carryover from the extract air to the supply air, the quality of the supply air can be impaired. This criterion is also handled in VDI 6022 sheet 1, whereby heat recuperators with carryover in the supply air are only allowed if the use of recirculated air is also compliant with hygiene standards.
- Technical data
  Technical data (temperature efficiency and pressure loss) can change due to carryover or a purge sector. They therefore must be checked and adjusted if necessary.

Due to these changes, carryover must be kept as low as possible, which must be considered during planning and design.

Carryover: How does it work?

Operation

For functional reasons, air is "rotated" from one air stream to the other as it flows through the rotor; this is called carryover. In image 1, you can see that all extract air which enters within angle α first exits on the outside air/supply air side. The volume of carryover (and therefore angle α) depends on the flow time and the rotor speed of rotation.

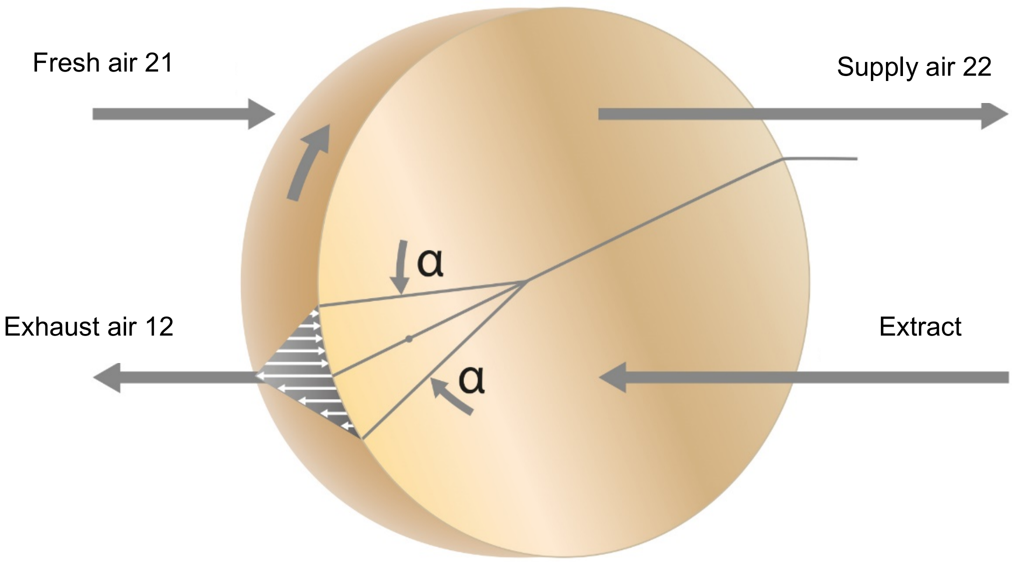

Image 1: Carryover from extract air to supply air

Simplified calculation of carryover

Flow time $t = T/v = d^2 \cdot T / 8 \cdot V$	[s]	[01]

with rotor depth T

speed $v = V/f$

and half of rotor area $f = d^2 \cdot \pi / 8$

Angle $\alpha = \phi \cdot t = 6 \cdot n \cdot T / v$	[°]	[02]

with angle speed $\phi = n \cdot 360 / 60 = 6 \cdot n$

Carryover $M = V \cdot (\alpha/180) = v \cdot f \cdot (\alpha/180)$	[m³/s]	[03]

(It is interesting that you can also get the carryover from the rotor volume x speed of rotation product (in 360/60 s).)

Relative carryover Mr = M/V = 10·n·T / 3·v [%] [04]

Under normal framework conditions, there was a carryover of about 3 – 13% of the nominal air stream; this is a variable which has to be considered. You get smaller values at a low speed of rotation and high air speed (impact).

Caution: The calculation above is idealised for visualisation purposes: The filling of the rotor - the rotor structure created from micro channels through winding - is ignored! (The rotor filling is usually defined by fill level FG = fF / f, whereby fF is the area covered by filling. This reduces the free section, the flow speed is increased by about 5 - 10%, angle α and therefore the carryover are reduced.)

Carryover occurs on both sides

It is important that the carryover occurs twice in the rotor:

- Once from the extract air to the supply air
- Once from the outside air to the exhaust air

The volumentric current balance is therefore correct at first glance: The missing outside air is replaced by the corresponding extract air. But it is exactly this that must be avoided, or at least compensated for by higher air flow rates.

The purge sector helps

When using the rotor in the ventilation technology, consideration was given to how carryover could be prevented. Since these ideas depend on the configuration of the system (→ fan arrangement), the constellation in image 1 is always the basis for the following considerations.

A cover does not work

The first idea for eliminating carryover is to cover the area of angle α (A-B and/or A-C) (see image 2). This (presumably) prevents air from entering or exiting the hazardous area; carryover is not possible. This is (unfortunately) a misconception, since a vacuum would have to be created behind the cover.

This is not possible, however; the air stream behind A-B would come to a stop due to a lack of propulsion and be transported out into the outside air/supply air when rotated.

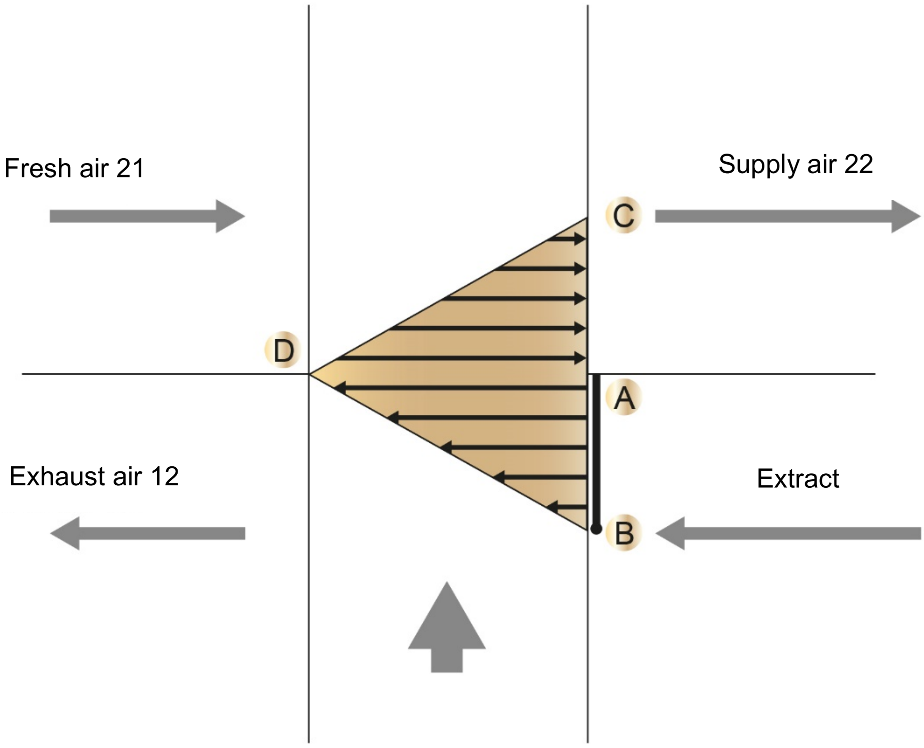

Image 2: A cover does not work

Purge sector in extract air

After the failed attempt with a cover, it is clear that the air flow of the carryover would have to be redirected to create a functioning solution. One possibility is to expose the zone of angle α to supply air. To do so, a purge sector with size A-B is required on the extract air side (image 3). Supply air flows through this to the affected area and is transported back to the supply air through rotation. There is then no more carryover.

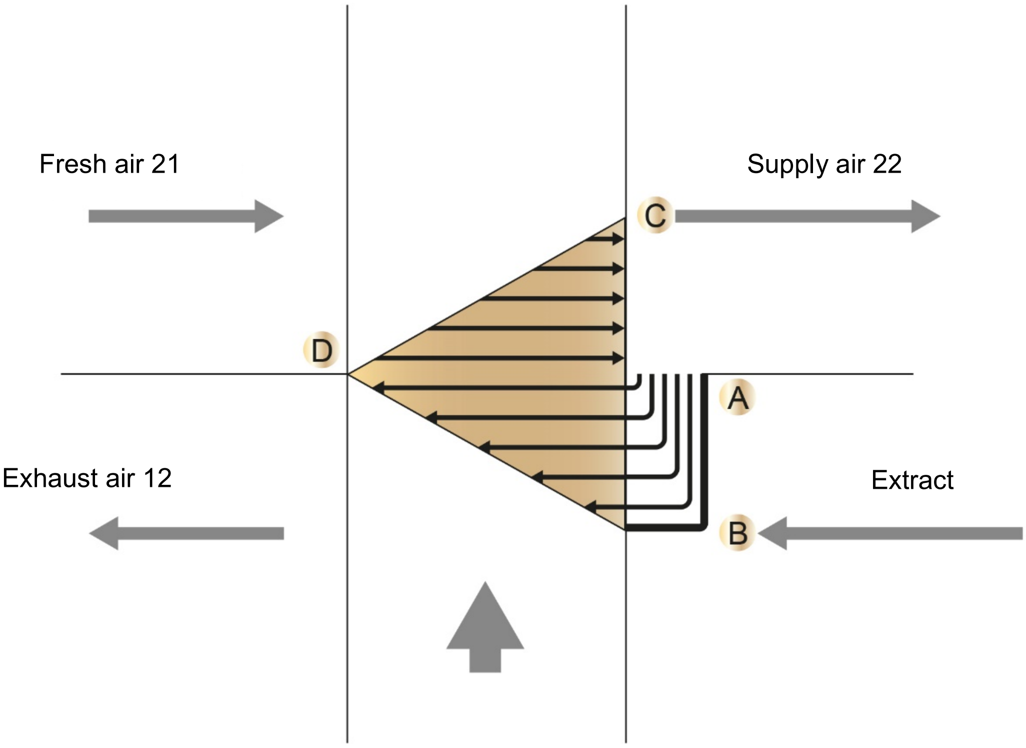

Image 3: Purge sector in extract air

Corresponding pressure are needed for this to work. The pressure difference between p22 and p12 must cover the pressure drop of the purge air for purge sector ΔpS and the flow of rotor $\Delta p1S$.

$p22 = p12 + \Delta p1S + \Delta pS$ [05]

Pressures p22 and p12 are known due to the fan arrangement. ($\Delta pS + \Delta p1S$) are therefore also known, as is the pressure drop of the purge air in the purge sector and in the rotor. The associated purge air speed vS and therefore the purge zone size αS can now be calculated by the rotor manufacturer. A good seal between the purge sector and rotor is required for this arrangement to work.

Purge sector in supply air

Another option is to collect the carryover on the supply air side and to lead it back to the extract air in the purge sector from C to A (see image 4). The corresponding pressures are also needed here:

The pressure difference between p21 and p11 must cover the pressure drop of the purge air for the flow of rotor $\Delta p2S$ and purge sector ΔpS.

$p_{21} = p_{11} + \Delta p_{2S} + \Delta p_S$ [06]

Pressures p21 and p11 are known due to the fan arrangement. ($\Delta pS + \Delta p2S$) are therefore also known, as is the pressure drop of the purge air in the purge sector and in the rotor. The associated purge air speed vS and therefore the purge zone size αS can now be calculated by the rotor manufacturer. A good seal between the purge sector and rotor is also required here.

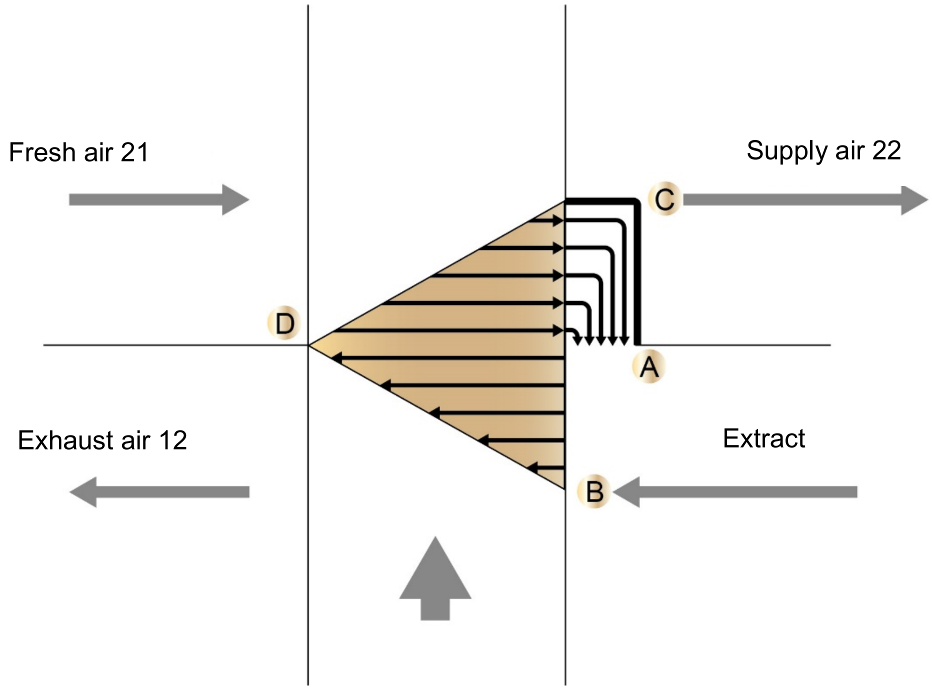

Image 4: Purge sector in supply air

Double purge sector

Early on, there was the idea to combine the purge sector in the extract air and the purge sector in the supply air - the double purge sector was born (image 5). The same air (in theory) always recirculates in this zone without something having to be transferred to the supply air or the exhaust air.

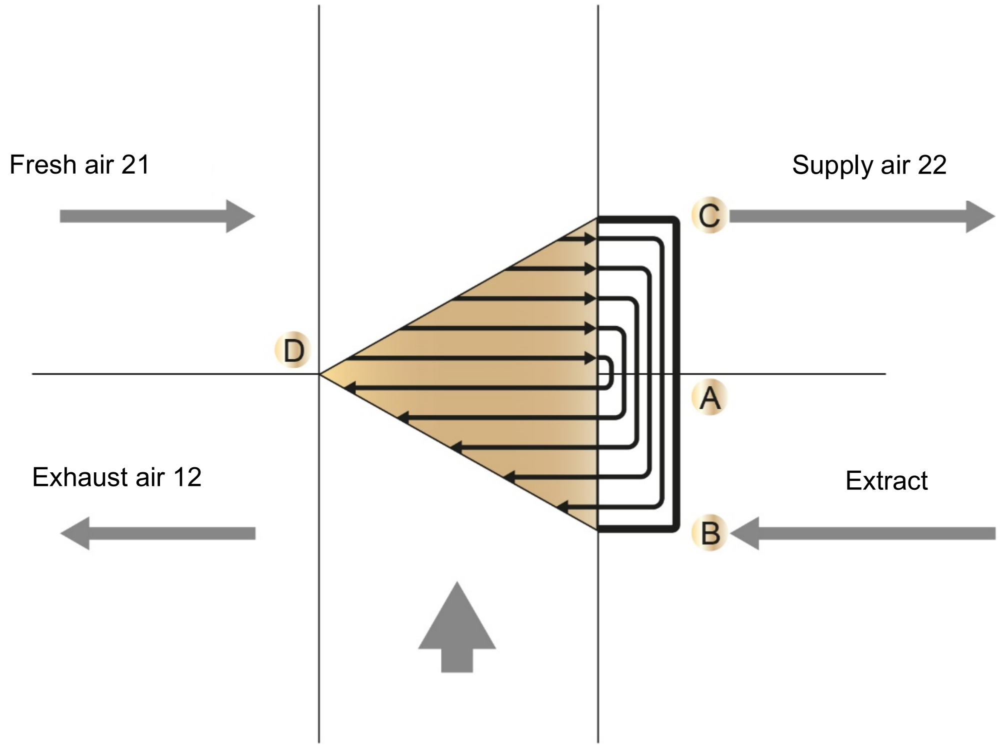

Image 5: Double purge sector

Corresponding pressure are needed for this to work. The pressure difference between p21 and p12 must cover the pressure drop of the purge air for double purge sector ∆pS and the double flow of the rotor (∆p1S + ∆p2S).

$$p21 = p12 + \Delta p1S + \Delta p2S + \Delta pS \qquad [07]$$

Pressures p22 and p12 are known. ∆pS depends on the design/sizes of the double purge sector is therefore a specification of the manufacturer. It is similar for the pressure drops of the purge air in rotor ∆p1S and ∆p2S; they must also be calculated. A good seal between the purge sector and rotor is required for this arrangement to work.

Boundary conditions and details

The functions of the purge sectors shown above are theoretical; in practice, there are many reasons for deviations. You have to accept that the carryover can be reduced, but not completely eliminated.

Seal quality

An absolute seal between the rotor and purge sector is required for the theoretical function. This is not possible in practice, and carryover cannot be completely avoided.

Seal profile

In the theoretical considerations, it is assumed that the seal is thread-shaped, meaning it is attached in a line. This applies not only for the seal between the rotor and purge sector, but also between the two air streams; only in this way is exact sizing possible. In practice, however, the seals (e.g. brush seals) are also applied as a flat area, meaning the purge sectors are usually sized somewhat larger.

Mass inertia/Continuity rate

In the models, it is assumed that, for example, the direction of the air stream in the rotor is reversed without delay and a pressure drop. In practice, however, you have to assume deflections, non-uniform impact and reaction times.

Pressure conditions

As shown, the function of a purge sector is heavily dependent on the pressure conditions (see equations 05, 06 and 07), meaning on the fan arrangement. For the four options, common values are listed in table 1 as an **example**.

Var.	OUT (2) fan	EXT (1) fan	p_{11} Pa	p_{12} Pa	p_{21} Pa	p_{22} Pa	$p_{22} - p_{12}$ Pa	$p_{21} - p_{11}$ Pa	$p_{21} - p_{12}$ Pa
a	B (sucks)	C (pushes)	120	20	-170	-270	-290	-290	-190
b	A (pushes)	D (sucks)	-330	-430	560	460	890	890	990
c	A (pushes)	C (pushes)	120	20	560	460	440	440	540
d	B (sucks)	D (sucks)	-330	-430	-170	-270	160	160	260

Table 1: Pressures on rotor

When it comes to the possible purge sectors, the different variants can be evaluated as follows:

Variant a

With this popular constellation, no purge sector is possible, since p22 – p12 and p21 – p11 and p21 – p12 are all negative (negative pressure). According to equations 05, 06 and 07, however, a pressure gradient is required to cover the pressure drops of the purge air in the rotor and in the purge sector. With a purge sector, extract air/supply air would be suctioned into the supply air.

Variant b

Concerning the pressure difference, this is a critical arrangement; a very high purge air speed results. The purge sector should be correspondingly small. In the selected example, vS = 6.5 m/s and αS = 2 – 4 ° (depending on the speed of rotation of 12 or 20 U/min) are to be expected.

With such high purge air speeds, proper operation of the purge sector is no longer ensured. Many manufacturers therefore recommend limiting the pressure difference to maximum 500 Pa. An additional baffle plate in the purge sector for increasing the pressure drop is also possible.

Variant c

The pressure difference is still acceptable; a moderate purge air speed results. The purge sector should correspond to this. In the selected example, vS = 4.5 m/s and αS = 3 – 6 ° (depending on the speed of rotation of 12 or 20 U/min) are to be expected.

Variant d

The pressure difference is very small here; a correspondingly low purge air speed results. The purge sector should be correspondingly large. In the selected example, vS = 2.5 m/s and αS = 6 – 10 ° (depending on the speed of rotation of 12 or 20 U/min) are to be expected.

Sizing

At the given rotor depth, the size of the purge sector (angle αS), depends in particular on the rotor speed of rotation and the purge air speed vS – and therefore on the pressure conditions. The converted equations 05, 06 and 07 apply for the calculation of the different purge sectors:

$p22 - p12 = \Delta p1S + \Delta pS$ [05a]

$p21 - p11 = \Delta p2S + \Delta pS$ [06a]

$p21 - p12 = \Delta p1S + \Delta p2S + \Delta pS$ [07a]

With the values for (Δp1S + ΔpS), (Δp2S + ΔpS) and (Δp1S + Δp2S + ΔpS) as known from table 1, the required or resulting purge air speed vS can now be calculated. This is required for the calculation of purge sector size αS in keeping with equation 02:

Angle $\alpha S = 6 \cdot n \cdot T / vS$ [°] [08]

The size of the purge sector is that which (theoretically) exactly prevents carryover. In practice, that would result in customised designs for each system, which would be (nearly) impossible for production reasons. That is why there are two to three standard sizes depending on the pressure condition and the speed of rotation; minor deviations from the ideal solution are accepted.

Reminder:

Purge sector too small → low carryover

Purge sector too large → A small amount of outside air goes into the exhaust air

Speed control

The output of a rotor is typically regulated via the speed of rotation, which depends directly on the size of the purge sector. With lower speeds of rotation, a smaller purge sector would be necessary, which is not possible. That is why the purge sector is typically sized for the nominal rotation speed and lower output (= speed of rotation) is accepted so that some outside air is led into the exhaust air.

Technical data

The installation of a purge sector - no matter which design - influences the output and the pressure drop of the rotor. Specific corrections depend on the type of purge sector and the system constellation.

Summary

Due to functional reasons, carryover exists when a rotor is used in both air streams, which "rotates" the outside air into the exhaust air and extract air into the supply air. This special form of internal leakage has various negative effects and is therefore undesirable - especially the extract air in the supply air. A purge sector can prevent this, but this requires system-specific sizing. There are limits on this design quality in practice due to theoretical calculations, missing data and the amount of effort required in design and production: 100% operational purge sectors are nearly impossible. However, a purge sector leads to an improvement in the supply air quality under known framework conditions and with the right arrangement/design. An inspection of the function is not possible in practice (or only without disproportionate effort).

Equation symbols used

d	rotor dimension [m]
f	half of rotor area [m2]
T	rotor depth [m]
ϕ	angle speed of rotor [°/s]
α	angle of carryover [°]
αS	angle of purge sector [°]
t	flow time [s]
n	speed of rotation [1/min]
f	angle speed [°/s]
V	volumentric current [m3/s]
v	flow velocity in rotor [m/s]
vS	flow velocity of the purge air in rotor [m/s]
p	pressure [Pa]
Δp	pressure drop [Pa]

If you have questions, contact:

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