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Rethinking the Centrifugal Fan Selection

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The centrifugal fan is one of the most prevalent fan types used in the HVAC industry today. Two main categories of centrifugal fans are those that use impellers with forward curved (FC) blades and those that use impellers with backward curved (BC) blades. Each category is descriptive of the direction of the blade curvature relative to the direction of the impeller rotation.

A very common type of centrifugal fan, typically referred to as a centrifugal blower, uses a squirrel cage type wheel with many FC blades (Figure 1). The blades are shallow with a substantial curvature in the direction of rotation that results in a higher blade tip speed than a BC blade. This means the impeller can move a large volume of air at a relatively low speed in a small footprint, providing advantages in acoustic noise and size reduction. Combining these advantages with an inexpensive lightweight construction has led to FC centrifugal blowers being the default choice for many lower pressure HVAC applications such as residential furnaces, central station air handling units and packaged rooftop air conditioners. While they are often the favored option, there are additional factors to consider.

Figure 1: Example of squirrel cage type FC centrifugal impeller. Source: ebm-papst Inc.

The favorable power and performance curves allow backward curved centrifugal blowers to serve as a viable alternative in applications where forward curved centrifugal blowers are traditionally used, such as in packaged rooftop air conditioners.

FC Impeller Considerations

A substantial portion of the total energy of the air leaving an FC centrifugal blower is in the form of velocity pressure. A scroll housing (Figure 2) is required to convert that velocity pressure into usable static pressure that can move air against the system resistance present in the application. Completing this conversion in the most efficient manner requires an outlet duct of the same size as the fan outlet and of sufficient straight length to allow a uniform air velocity to develop across the duct. These housing and duct requirements diminish the advantage of the compact impeller size.

A second challenge lies with the performance and power curves of an FC impeller (Figure 3). To the right of the peak efficiency operating point, the power curve rises steeply and continuously with lower system resistance. Operation in this area could overtax the blower motor. To the left of the peak efficiency operating point, the performance curve can dip noticeably, creating an area where the fan may stall or hunt between similar system resistance points. This can result in system pulsations that generate noise or even damage the blower or ducting if a system resonance condition occurs.

Figure 2: FC centrifugal blower scroll housing. Source: ebm-papst Inc.

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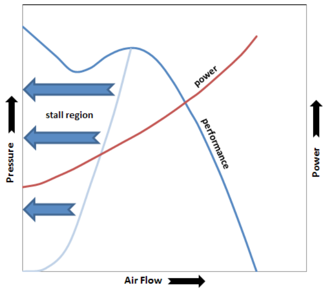

Figure 3: Characteristic curves of an FC centrifugal blower. Source: ebm-papst Inc.

Additionally, the comparatively low FC impeller efficiency is further degraded by the commonly used arrangement of an induction motor driving the blower wheel through a V-belt and sheaves (Figure 4), with the motor speed controlled using a variable frequency drive (VFD). As cited by the Department of Energy's Advanced Manufacturing Office, smaller horsepower VFDs operating at full load and newly installed V-belt drives perform with typical peak efficiency levels of 95 percent. Improperly installed or maintained belt drives can quickly lose efficiency, while part-load operation can substantially decrease the efficiency of both the VFD and drive motor. A VFD may require filters for EMI/RFI, a supply voltage for an external sensor, a motor protection switch, shielded cables, filters to prevent common mode currents from damaging the motor bearings, or use of an inverter-duty rated induction motor, all of which can increase upfront or maintenance costs.

Figure 4: Typical FC centrifugal blower with a V-belt and sheaves setup. Source: Grainger

Assessing these factors during selection of a blower, especially if the operating point is not well understood or is variable, may lead to a better option that simplifies installation, saves energy and lowers future maintenance costs.

Backward Curved Impeller Considerations

BC impellers have deep blades with a long cord length that provides efficient expansion of the airflow within the blade passages (Figure 5). This means conversion of the velocity pressure to static pressure with a uniform velocity distribution occurs prior to the air exiting the blower, eliminating the scroll housing and lengthy outlet duct requirements of an FC impeller.

BC impellers also offer more forgiving performance and power curves. They provide greater efficiency across the entire speed range, a non-overloading power curve at reduced system resistance and no substantial dip at the higher end of the pressure curve that could result in hunting or stall conditions.

Figure 5: Backward curved centrifugal impeller. Source: ebm-papst Inc.

The favorable power and performance curves allow BC centrifugal blowers to serve as a viable alternative in applications where FC centrifugal blowers are traditionally used, such as in packaged rooftop air conditioners. This is especially true when they operate over a variable speed range or when higher system resistances are involved.

ebm-papst RadiPac EC Centrifugal Fans

An even more aerodynamically efficient and acoustically improved subset of the BC impeller uses an airfoil blade. These blades are hollow and shaped like an airplane wing to decrease weight and drag (Figure 6).

Figure 6: Airfoil blade. Source: ebm-papst Inc.

ebm-papst offers BC airfoil impellers in their RadiPac centrifugal fans (Figure 7). The "Pac" in RadiPac is short for packaged, as all required control and sensing functions are bundled into the fan assembly. The airfoil impellers are combined with high-efficiency, direct drive GreenTech EC external rotor motors. Under the right circumstances, this combination can substantially reduce power and space requirements when compared to the classic VFD controlled, shafted induction motor and belt driven FC impellers. RadiPac eliminates the need for ancillary components that are common with these traditional systems (Figure 8).

Figure 7: RadiPac centrifugal fan. Source: ebm-papst Inc.

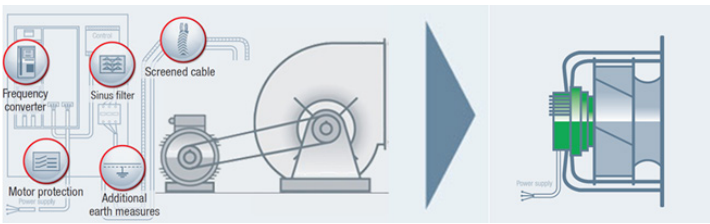

Figure 8: Common FC centrifugal blower and drive arrangement versus RadiPac BC centrifugal module with integrated EC external rotor motor. Source: ebm-papst Inc.

Comparison Testing

RadiPac and FC centrifugal blower airflow and power measurements were made in an air test chamber that meets AMCA 205 and ISO 5801 requirements. Input power comparisons are shown (Figure 9) at two matching operating points along the FC blower air performance curve — OP1 (Operating Point 1) with the RadiPac running at full speed and OP2 (Operating Point 2) with the RadiPac speed reduced to 88 percent of full speed. As indicated by the green arrows, these operating points represent potential RadiPac power savings of 21.5 percent and 28.6 percent, respectively.

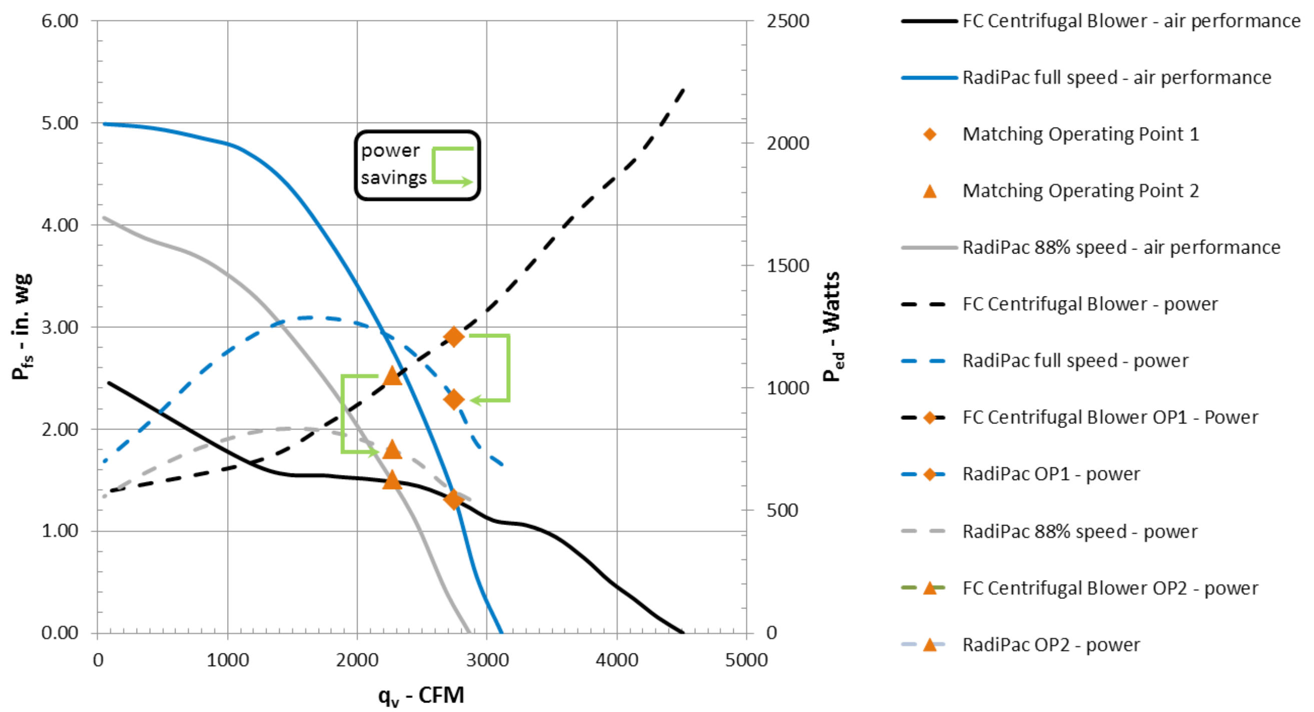

Figure 9: Potential power savings when replacing an induction motor and V-belt driven FC centrifugal blower with a RadiPac EC centrifugal fan. Source: ebm-papst Inc.

Beyond the Power

RadiPac modules offer many benefits beyond the power savings, including:

- An external rotor motor design (Figure 10) positions the spinning rotor onto the outside of the stator instead of the reverse as on standard internal rotor induction motors. Mounting the impeller directly onto the rotor shell creates a very compact unit that allows dynamic balancing of the entire rotating assembly, reducing vibration and prolonging bearing life.
- Integrated electronics for commutation and control replace the external VFD and eliminate the need for ancillary components to provide grounding or shielding measures. The electronics and motor form one unit and are perfectly matched to one another, eliminating labor-intensive adjustments before commissioning.

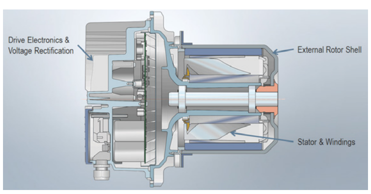

Figure 10: External rotor motor. Source: ebm-papst Inc.

- Internal monitoring functions of a RadiPac EC motor are easily accessed in the application, providing feedback including error codes, motor life, motor temperature and speed. RadiPac fans also come standard with other beneficial features including soft start, locked rotor protection, current limitation, thermal overload protection, undervoltage detection, phase failure detection, a status relay and an RS485 MODBUS-RTU interface for bus communication.

Conclusion

When properly applied, ebm-papst RadiPac EC centrifugal fans can provide significant advantages over traditional VFD-controlled, belt-driven FC centrifugal blowers in many applications. The aerodynamic efficiency of an airfoil impeller driven by modern GreenTech EC motors achieves high operating efficiencies even under extreme part-load conditions. A host of standard control, monitoring and safety features adds to the value of the package. Design engineers are presented with an attractive alternative for FC centrifugal blowers that can substantially reduce power and space requirements.

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