FANS & BLOWERS

Fan Energy Index:

A new metric for fan efficiency

The FEI metric provides a way to characterize a fan's efficiency over its entire operating range.

by joanna mauer

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In early 2018, the Air Movement and Control Association International (AMCA) published a standard (ANSI/AMCA Standard 208-18) for calculating a new metric for fan efficiency: the fan energy index (FEI). FEI addresses a longstanding problem in characterizing fan efficiency, which is that a fan's peak efficiency often has little relationship to a fan's actual operating efficiency. As a "wire-to-air" metric, FEI also provides for capturing more of the fan system than just the fan itself. FEI has the potential to be applied as a metric for minimum efficiency standards, building energy codes, and utility incentive programs to drive the market to improved fan selections to reduce energy consumption.

Fan Peak Efficiency vs. Operating Efficiency

Every fan has an efficiency curve, and the highest point on that curve represents a fan's peak efficiency. However, at operating points (i.e. airflow and pressure points) away from the peak efficiency, the operating efficiency can be significantly lower. Figure 1 shows an example of a fan curve and its corresponding efficiency curve (based on total pressure) along with a system curve. The system curve intersects the fan curve at a point far to the right of the fan's peak efficiency point, and the actual operating efficiency is therefore significantly lower than the peak efficiency.

Because of the nature of fan efficiency curves, a fan's peak efficiency usually does not reflect its actual operating efficiency in the field, and fan selection plays a huge role in determining actual efficiency and energy use. If not selected appropriately, a fan with a very efficient design can perform very inefficiently in a particular application.

The FEI Metric

The FEI metric provides a way to characterize a fan's efficiency not just at its peak efficiency point, but over its entire operating range. FEI also provides a simple way to evaluate the relative power consumption of different potential fan selections at a customer's actual design point.

FEI is calculated as the ratio of the electrical input power of a reference fan to that of a given fan at a particular duty point (i.e. airflow and pressure point). The use of electrical input power allows for capturing motor, transmission, and drive losses in addition to the efficiency of the fan itself.

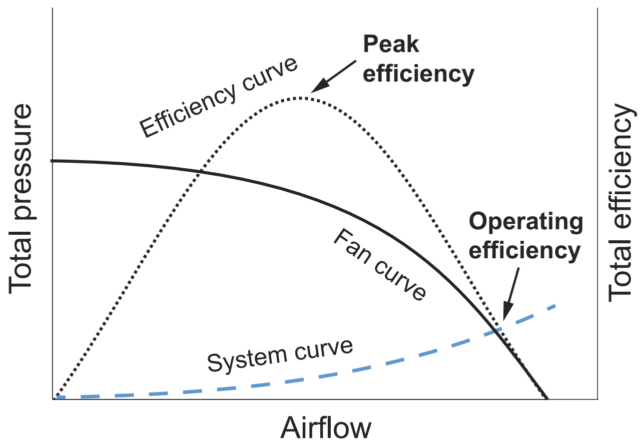

Figure 1. Example where a fan's operating efficiency in a given system is significantly lower than its peak efficiency.

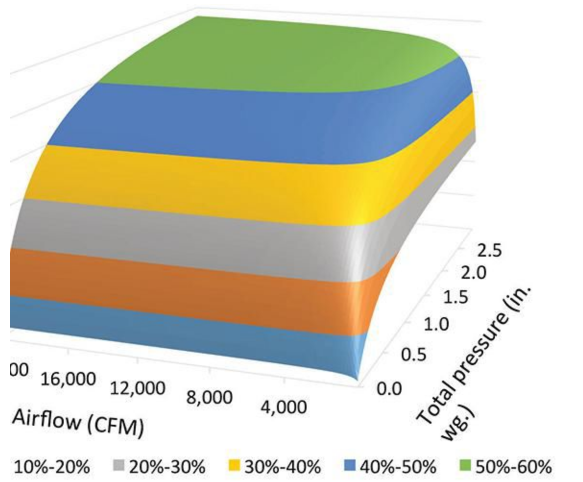

Figure 2. Required total efficiency as a function of airflow and total pressure for an FEI of 1.0.

FEI can be calculated based on total efficiency ($FEI_{t,i}$) or static efficiency ($FEI_{s,i}$). (The subscript i refers to the specific duty point.)

$$FEI_{t,i} \text{ or } FEI_{s,i} = \frac{\text{Reference Fan Electrical Input Power}}{\text{Actual Fan Electrical Input Power}} = \frac{FEP_{ref,i}}{FEP_{act,i}}$$

A fan's total pressure is composed of static pressure and velocity pressure components. The use of total pressure is appropriate for fans installed with an outlet duct since ducted fans can use both static pressure and velocity pressure to overcome system pressure losses. On the other hand, for unducted fans, the velocity pressure is essentially wasted, and therefore static pressure should be used to characterize unducted fans. For fan types that are virtually always installed without an outlet duct including centrifugal unhoused (plenum) fans, panel (prop) fans, and power roof ventilator exhaust fans, ANSI/AMCA 208 requires the use of static pressure for calculating FEI. For most other fan types, FEI can be calculated using either static or total pressure depending on whether the fan is tested with or without an outlet duct.

Higher FEI values indicate higher efficiency and lower power consumption. The simplicity of the FEI metric as a ratio of power consumption allows for easily calculating energy savings associated with higher FEI levels. For example, a fan with an FEI of 1.25 at a specific duty point consumes 20% less power than a fan with an FEI of 1.00 at the same duty point (1.25 – 1.00 / 1.25).

ANSI/AMCA 208 provides methods for calculating the actual fan electrical input power for fans sold in various configurations including without a motor, with a motor but without speed control, and with a motor and speed control. For fans sold without a motor, ANSI/AMCA 208 specifies default motor efficiency and transmission efficiency values for use in calculating electrical input power. For fans sold with motors, the manufacturer always has the option of conducting a wire-to-air test to directly measure electrical input power, and there are also options for calculating electrical input power using specified motor efficiency values (from ANSI/AMCA 207) or motor efficiency data determined through testing in accordance with specific test standards.

The calculation of the reference fan electrical input power incorporates a reference fan shaft power and reference motor, transmission, and motor controller efficiencies. The reference fan shaft power is a function of the airflow and pressure at the specific duty point. Since the achievable efficiency of a fan can vary significantly depending on the airflow and pressure delivered, the equations for reference fan shaft power account for these variations in inherent efficiency. Figure 2 shows how the required total efficiency for a ducted fan for an FEI of 1.0 increases with both airflow and pressure.

The reference motor and transmission efficiency values for the reference fan are the same as the default values used for calculating actual fan input power for fans sold without a motor. Finally, the reference motor controller efficiency is set to 1 since the reference fan is defined as a fan without speed control.

Potential Use of FEI for Standards, Codes, and Incentive Programs

FEI can be used to drive fan efficiency through policy mechanisms including minimum efficiency standards, building energy codes, and utility incentive programs. Since FEI can be calculated at any duty point, it can be applied across a fan's entire operating range. Just as fan performance tables today typically include information about operating speed (RPM) and brake horsepower at each operating point, FEI can be calculated at each of those same points.

Minimum efficiency standards could require a minimum FEI level. Since the FEI metric accounts for variations in efficiency with airflow and pressure, a single FEI level could be applied across all fan types, thus encouraging fan substitution across types to achieve greater efficiency. The minimum FEI level would apply to a fan's entire operating range. Manufacturers would certify the compliant operating range of each fan model and would be able to offer fans for sale at only those operating points that meet the minimum FEI. For example, fan selection software would be able to return only those selections that meet the minimum FEI level at the design point. In this way, an FEI standard would encourage more efficient fan selections at the customer's actual design point. Manufacturers would also have an incentive to improve fan designs in order to be able to advertise a larger range

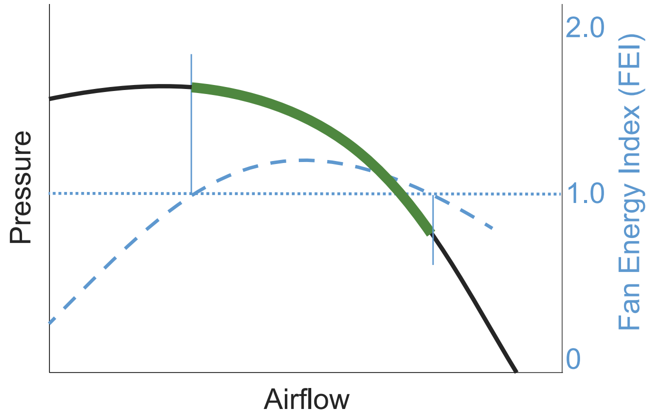

Figure 3. Points on a fan curve with an FEI of at least 1.0.

of compliant operating points. Further, since FEI is a wire-to-air metric, an FEI standard would encourage not just more-efficient fans and fan selections, but also more-efficient motors, transmission, and motor controllers.

As shown in Figure 3, for a constant-speed fan (i.e. a direct-drive fan without speed control), an FEI standard would limit the range of allowable fan selections along the fan curve. For a belt-driven fan or a direct-drive fan with speed control, an FEI standard would limit the range of allowable fan selections to a "bubble" of operating points.

In 2017, the California Energy Commission (CEC) initiated a rulemaking to establish state efficiency standards for commercial and industrial fans, and fan manufacturers and efficiency advocates submitted a proposal to CEC to establish standards based on the FEI metric. The proposed standards would apply to fans used in typical commercial and industrial applications such as general ventilation, roof exhaust, industrial processes, and material handling.

Building energy codes, such as ASHRAE 90.1, could also require a minimum FEI level. For every fan in a commercial building with a specified design point (airflow and pressure), a code official could verify that the fan meets the minimum FEI requirement at the design point. Similarly, utility incentive programs could offer rebates based on a fan's FEI level at the customer's design point. As with minimum efficiency standards, building codes and incentive programs for fans using FEI would also help achieve fan efficiency improvements at the customer's actual design point.

Conclusion

A fan's efficiency varies significantly over its operating range. Fan selection thus plays a huge role in determining actual fan energy consumption in the field. The new FEI metric, whose calculation is specified in ANSI/AMCA 208, provides the ability to characterize a fan's efficiency across its entire operating range and incorporates motor, transmission, and drive losses. As the ratio of the power consumption of a reference fan to that of a given fan, FEI provides an easy way to communicate the relative power consumption of various potential fan selections at a given duty point. Minimum efficiency standards, building energy codes, and utility incentive programs can all utilize the FEI metric to encourage improved fan selections, ultimately reducing energy consumption and providing savings for building owners. ■