

Axial Fan Stall

In an ideal world, fans create a constant volume of airflow at a constant fan speed and fan blade pitch angle. If the system pressure or any physical parameters like number of blades, fan diameter, etc., do not change, then the volumetric flow in cubic feet/minute (CFM) should not change. Some fan applications do not achieve steady-state operation because the fan is in a stall condition. The phenomenon of fan stall primarily impacts axial fan performance rather than centrifugal or other fan types. The purpose of this paper is to address the concepts of fan stall and what can be done to remedy those effects.

Fan stall is an unstable and inefficient operating condition in which there may be large fluctuations in volumetric flow for a given operating point. As fan pitch increases, pressure differential across the fan increases. The pressure differential generated may stay stagnant, or even decrease as the fan pitch is increased. This is the point of fan stall. Axial fan stall causes a sudden drop in pressure rise and airflow delivery. The pressure difference across fan blades decreases rapidly, reducing air flow movement efficiency. The air flow progressively separates from the blade profile and slides towards and off the tip of the fan blades. As the fan moves deeper into stall at a critical pressure rise the air flow moving through the fan could approach zero. Figure 1 shows the slight fluctuations in volumetric flowrates in a controlled environment at constant static pressure, fan speed and fan blade pitch. These slight variations in air flow are very common.

Figure 2 shows a fan in stall with large fluctuations in volumetric flowrate in the same controlled environment at constant static pressure, fan speed, and fan blade pitch.

In cooling tower applications, operating in a stall condition can lead to higher outlet water temperatures than predicted. Overall energy consumption of the system could increase significantly. Continued operation in stall conditions can also create cyclical loading on fan blades and mechanicals. Fan blade materials prone to fatigue,

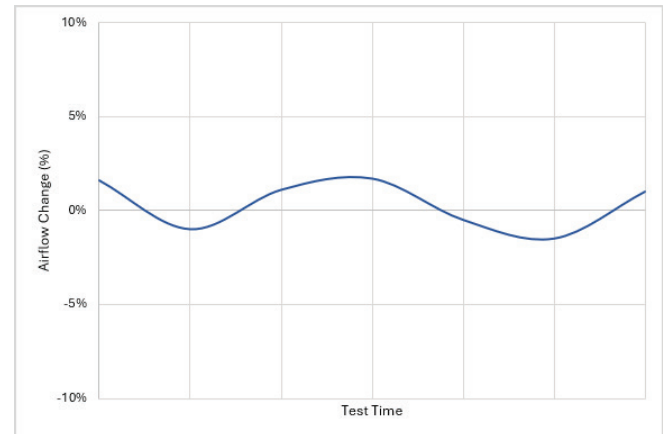


Figure 1: Controlled, Normal Fan Operation

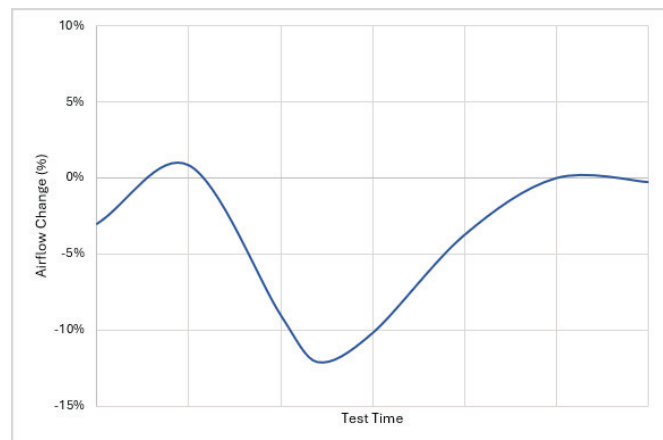


Figure 2: Unstable, Fan Stall Condition

such as aluminum, could wear out and crack prematurely. Other tower components and connections within the tower may also see higher than normal vibration levels causing premature failures.

Below are four conditions that can cause a fan to go into stall at a defined static pressure and CFM fan duty.

1. Fan speed is too low for the fan configuration.
2. Insufficient fan blade quantity or fan blade solidity (width of the blade) for the duty.
3. Required fan horsepower (HP) is too high for the fan configuration.
4. System static pressure is too high for the fan configuration.

To help avoid these issues select a fan at the design conditions such that the rated fan speed can provide, by an increase in fan pitch, a minimum of 10% increase in CFM with a corresponding pressure increase per API 661. Based on a square relationship between static pressure and flow, the consequence of a 10% increase in flow results in a 21% increase in static pressure. The requirement in API 661 is to prevent stall and inefficient operation of the fan, it is not necessary that the resulting increase in power requirement govern the driver or motor selection.

Following years of operation, many customers desire to improve cooling tower efficiency or want more heat rejection out of their cooling towers. There are multiple pitfalls to consider when pursuing those upgrades. Common changes in cooling tower retrofits that can lead to the above-mentioned fan stall conditions include:

- Higher gear ratios (lower fan speed)
- Fan blade solidity too low or fan geometry not suited for the desired airflow/pressure demand of the tower
- Higher efficiency fill or additional fill, leading to higher system static pressure
- Higher fan pitch and/or motor HP

Often a fan in stall will have a noticeable sound increase. The noise generated can have a deep drone or growl sound. Sound characteristics may be subtle and should not be the only indicator of a fan stall condition. Due to the inefficiency of a fan in stall the power draw may never be able to reach design power from the motor as the fan pitch is increased. Vibration levels may also increase above acceptable levels.

Remedies

Below are four remedies to mitigate fan stall if the fan is showing the signs of stall as mentioned above:

1. Speed the fan up with a lower gear reducer ratio
2. Reduce fan pitch at the same speed to decrease airflow and static. A consistent condition is often more efficient and can decrease risk of harming other mechanical components than operating in a stall condition
3. Select a fan with higher solidity or greater blade count at the same speed
4. Replace clogged fill with new lower pressure drop fill

Key Takeaways

- Fan stall is an unstable and inefficient operating condition. Stall results in less predictable performance, potentially poorer sound and/or vibration characteristics.
- Operating at or near stall condition should be avoided.
- Refer to Remedies section for suggestions to correct fan stall.
- Consult a knowledgeable supplier to assess whether fan stall is impacting your application.

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