

Research on the Causes and Prevention Technologies of Stall and Surge in Induced Draft Fans of Large Thermal Power Units

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Abstract: In large thermal power units, induced draft (ID) fans are critical auxiliary equipment for maintaining stable and reliable operation. Owing to their complex operating conditions, ID fans are prone to stall and surge phenomena, which can reduce operational efficiency, increase energy consumption, and even cause equipment damage, thereby threatening unit safety. This study systematically analyzes the operating principles and characteristics of ID fans in large thermal power units, elucidates the mechanisms of stall and surge, and investigates monitoring and diagnostic technologies. Furthermore, prevention and control measures are proposed from the perspectives of design optimization, operational adjustment, installation of auxiliary devices, and control strategy improvement. By integrating multi-parameter monitoring with intelligent control methods, the probability of stall and surge can be effectively reduced, enhancing the operational stability and economic performance of power units. The findings provide a valuable technical reference for the safe and stable operation of large thermal power units.

Keywords: Large thermal power units; induced draft fan; stall and surge; monitoring and diagnosis; prevention and control technologies

Introduction

In large thermal power units, the induced draft fan is a key auxiliary component that plays a vital role in ensuring stable unit operation. Under complex and variable operating conditions, ID fans are susceptible to stall and surge phenomena. These abnormal conditions not only degrade unit efficiency and increase energy consumption but may also lead to equipment damage and pose serious safety risks. Therefore, an in-depth investigation into the causes and prevention technologies of stall and surge in induced

draft fans is of great practical significance for ensuring the safe, stable, and efficient operation of thermal power units, as well as for improving the reliability and stability of power supply.

1. Working Principle and Characteristics of Induced Draft Fans in Large Thermal Power Units

1.1 Basic Structure and Working Principle of Induced Draft Fans

As critical auxiliary equipment in large thermal



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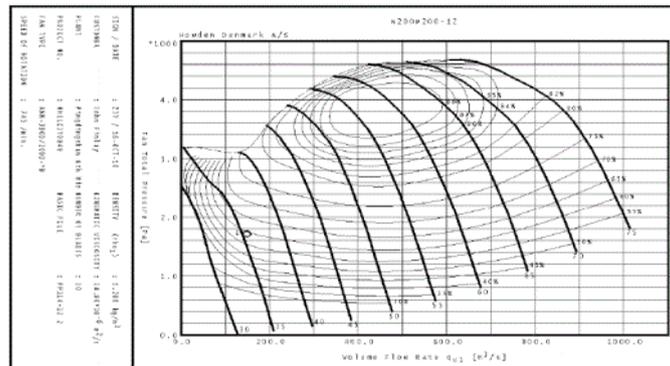
power units, induced draft fans mainly consist of key components such as the impeller, casing, inlet, and outlet. The impeller is typically designed with backward-curved or radial blades and is manufactured from high-strength alloy steel through casting or welding processes to ensure long-term stable operation in high-temperature flue gas environments. The casing adopts a volute-shaped flow passage, which effectively guides gas flow and reduces energy losses. The inlet and outlet are designed with gradually contracting and expanding structures to optimize the flow field and minimize flow resistance [1]. During operation, flue gas discharged from the boiler passes through dust removal equipment and enters the fan inlet. Driven by the rotation of the impeller, centrifugal force accelerates the gas, generating a high-velocity flow. Through the work performed by the blades, the kinetic energy of the gas is converted into pressure energy. The pressurized flue gas is then discharged through the outlet and conveyed to

the flue gas desulfurization and denitrification systems. This process follows the principle of conservation of angular momentum, and the separation of the boundary layer on the blade surface has a direct impact on the fan's energy conversion efficiency.

1.2 Performance Parameters and Characteristic Curves of Induced Draft Fans

The core performance parameters used to evaluate induced draft fans include flow rate, pressure, power, and efficiency. Flow rate refers to the volume of gas passing through the fan per unit time, pressure reflects the fan's capability to overcome system resistance, power represents the shaft power required to drive the fan, and efficiency indicates the effectiveness of energy conversion. These parameters vary with rotational speed following specific patterns, and a complete set of characteristic performance curves can be obtained through experimental testing.

4. ANN-3600/1800B Fan Whole-Life Performance Curve



5. GAF37. 5-20-1

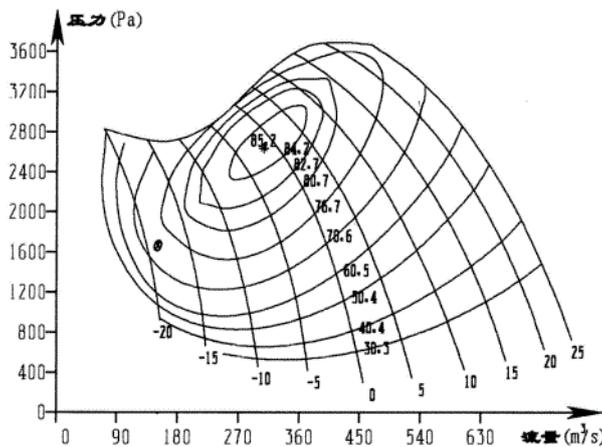


Figure 1. Performance Curves of the ANN-3600/1800B Induced Draft Fan at Rated Operating Conditions

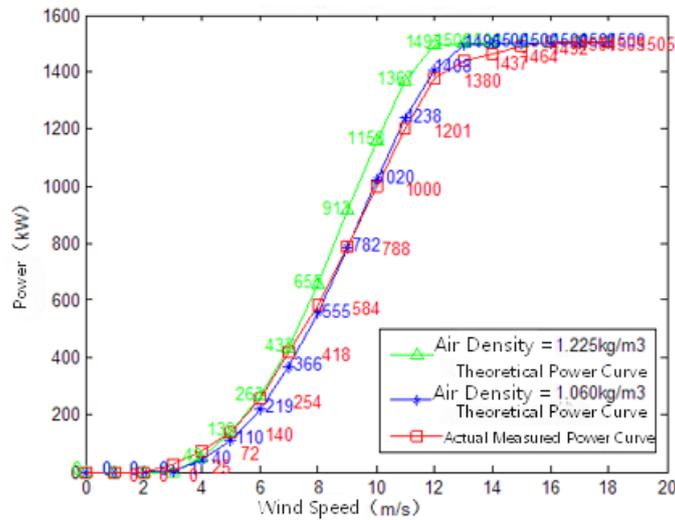


Figure 2. Performance Curves of the GAF37.5-20-1 Fan

As shown in **Figure 1** and **Figure 2**, the flow–pressure characteristic curves of the induced draft fans exhibit a typical “hump-shaped” profile. The rising section on the left side of the curve corresponds to the stable operating region, whereas the descending section on the right side is associated with an increased risk of stall. The power curve increases continuously with increasing flow rate, and the growth rate accelerates as the operating condition approaches the design point. The efficiency curve shows a single-peak distribution, with the maximum efficiency point generally occurring within 80%–90% of the design flow rate.

These characteristic curves directly determine the operating economy of the fan. Deviation of the

operating point from the high-efficiency region not only leads to increased energy consumption but may also induce unstable phenomena such as surge.

1.3 Operating Conditions of Induced Draft Fans in Large Thermal Power Units

When unit load changes, the induced draft fan needs to adjust the guide vane opening to maintain stable furnace negative pressure. Under low load conditions, reduced flue gas flow causes the fan to operate in a low-flow region. The increased angle of attack at the blade inlet can easily trigger rotating stall. Under high load, the system resistance may increase, shifting the operating point to the right. When it approaches the peak of the performance curve, there is a risk of surge.

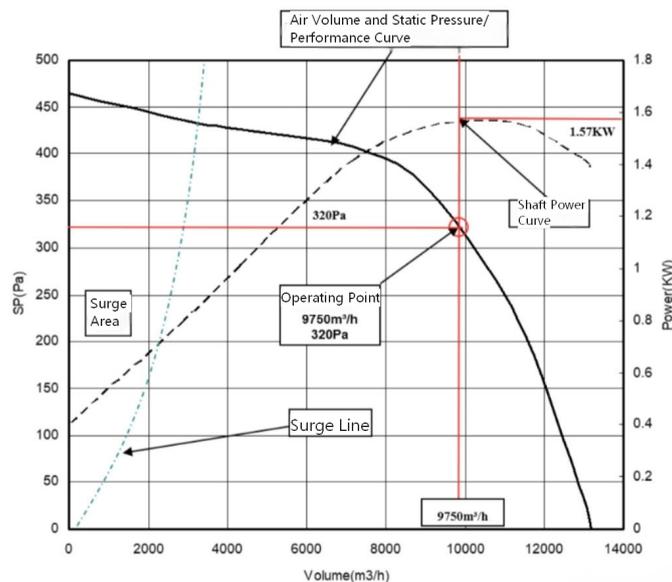


Figure 3. Schematic Diagram of Air Volume - Static Pressure Curve + Operating Point

Taking **Figure 3** as an example, the “operating point” of the induced draft fan (e.g., 9750 m³/h, 320 Pa) must avoid the “surge area” (the low-flow zone on the left side of the performance curve peak). When the unit operates under low load, if the fan’s operating point falls into the surge area, precursors to stall such as low-frequency flow pulsation and severe pressure fluctuations will occur. It is necessary to promptly adjust the guide vane opening to pull the operating point back into the stable zone.

The induced draft fan is tightly coupled with the boiler combustion system. Changes in fuel quantity alter the flue gas generation rate, requiring the fan to have fast response capability. Its matching with the turbine system is reflected in backpressure control. Fluctuations in the resistance of equipment such as the desulfurization tower and electrostatic precipitator can indirectly regulate the turbine exhaust pressure by affecting the fan outlet pressure. This multivariable interaction makes the operation and control of the induced draft fan a critical link in the unit’s coordinated control system, and its regulation quality directly impacts the operational stability of the thermal system.

2. Mechanism Analysis of Stall and Surge in Induced Draft Fans of Large Thermal Power Units

2.1 Basic Concepts and Characteristics of Stall and Surge

Stall refers to an aerodynamic instability caused by a deviation between the fluid flow direction within the impeller and the blade geometric angle, whereas surge is a system-level periodic oscillation resulting from the interaction between the fan and the connected duct network. The fundamental distinction between the two lies in scale: stall is a localized flow field disorder, while surge represents a global energy imbalance of the fan–system coupling. When stall occurs, the inlet incidence angle of the impeller exceeds its critical value, leading to boundary layer separation on the blade surface and the formation of rotating stall cells. This phenomenon results in low-frequency pulsations in flow rate. During surge, the outlet pressure of the fan and the pressure of the pipeline network periodically counteract each other, inducing large-amplitude oscillations in flow rate. Surge is typically accompanied by sharp aerodynamic noise, sudden increases in

equipment vibration levels, and violent fluctuations in instrument readings.

2.2 Causes of Stall in Induced Draft Fans

From a fluid dynamics perspective, stall arises when the balance between impeller rotational speed and fluid velocity is disrupted, causing distortion in the pressure distribution over the blade surfaces. For backward-curved blades operating away from their design point, an increased inlet incidence angle leads to premature flow separation on the suction surface. The separated vortices propagate circumferentially, forming rotating stall patterns. Blade geometry has a significant influence on stall characteristics. Forward-curved blades can increase the pressure coefficient but generally exhibit weaker stall resistance. Radial blades, due to their large flow passage diffusion, are more susceptible to flow separation under variable operating conditions ^[2]. Increasing the blade installation angle can enhance work input to the fluid but simultaneously narrows the stable operating range. Variations in impeller diameter directly affect circumferential velocity; a smaller impeller diameter results in lower peripheral speed at the same rotational speed, thereby reducing the critical flow rate at which stall occurs.

2.3 Causes of Surge in Induced Draft Fans

Surge is essentially a dynamic process arising from an imbalance between the energy supplied by the fan and the energy demanded by the duct system. The operating stability is determined by the intersection of the duct resistance characteristic curve and the fan performance curve. When the slope of the resistance curve exceeds that of the fan performance curve at the hump region, the system enters an unstable operating zone. The volume of the duct system plays a regulating role in surge frequency. Systems with larger volumes exhibit greater inertia, leading to longer surge periods but larger oscillation amplitudes. When the operating point deviates from the design condition and falls on the right-hand side of the hump in the performance curve, even minor disturbances may trigger periodic oscillations of pressure and flow rate. Under low-load operation, reduced system resistance shifts the operating point leftward, making the system susceptible to surge near the stall boundary. Under high-load conditions, increased duct resistance raises the outlet pressure; if the response of the regulating mechanism is delayed, the system may likewise enter an unstable region.

2.4 Interaction Between Stall and Surge

Stall often serves as a precursor to surge. When rotating stall cells develop to a certain extent, they induce periodic fluctuations in outlet pressure. These pressure oscillations may resonate with the duct system, and when the oscillation frequency approaches the system's natural frequency, continuous energy accumulation can lead to the onset of surge. During variable operating conditions, stall and surge may exhibit a progressive transformation relationship: localized stall phenomena appear first, and as disturbances intensify, they evolve into full-annulus surge. The combined effects of stall and surge significantly accelerate equipment degradation. Flow pulsations induced by stall increase blade fatigue, while mechanical vibrations caused by surge may lead to bearing loosening, rotor bending, and other severe failures, ultimately threatening the safe and stable operation of the entire power unit.

3. Monitoring and Diagnostic Technologies for Induced Draft Fan Stall and Surge in Large Thermal Power Units

3.1 Selection of Monitoring Parameters for Stall and Surge

The precise monitoring of induced draft fan stall and surge relies on the collaborative analysis of multiple parameters. Flow parameters serve as the core indicators. During stall, rotating stall cells within the impeller cause periodic changes in the flow passage area, triggering low-frequency flow oscillations. In the surge stage, an imbalance in system energy leads to significant flow pulsations, with fluctuation frequencies related to the inherent characteristics of the piping network. Among pressure parameters, the inlet-outlet static pressure differential directly reflects the fan's working capability. In the initial stage of stall, pressure fluctuations are of small amplitude; as the stall cells propagate, the frequency of pressure pulsations gradually approaches the blade passing frequency. During surge, the energy of pressure fluctuations increases significantly, forming periodic oscillations dominated by the system's natural frequency. Vibration signals contain rich fault characteristics. The airflow pulsations induced by stall are transmitted through the impeller to the bearing housing, causing an increase in vibration acceleration amplitude within specific frequency bands. In the surge stage, mechanical

vibration couples with airflow excitation forces, resulting in vibration energy exhibiting broadband characteristics. Temperature parameters primarily monitor equipment overheating anomalies. Mechanical friction or airflow blockage caused by stall/surge may lead to local temperature rises, providing auxiliary information for fault localization. These parameters work in coordination: flow and pressure constitute the primary monitoring channels, vibration is used for fault identification, and temperature provides anomaly warnings.

3.2 Design and Implementation of the Monitoring System

The monitoring system adopts a hierarchical distributed architecture, consisting of a field perception layer, a data transmission layer, and an analysis and decision-making layer. Sensor selection emphasizes environmental adaptability. For flow measurement, thermal mass flowmeters are selected to avoid errors in low-flow regions common with traditional differential pressure sensors. Pressure monitoring employs three-wire piezoresistive sensors with ranges covering both normal and extreme surge conditions. Vibration monitoring is configured with IEPE accelerometers, whose frequency response range (0.5-10kHz) covers the characteristic fault frequency bands. The data acquisition unit features a modular design supporting multi-channel synchronous sampling, with a sampling frequency of no less than 20 kHz to meet the needs of high-frequency vibration signal analysis. The transmission network uses an industrial Ethernet ring topology, employing the OPCUA protocol for standardized data transmission to ensure the real-time performance of key parameters. The signal processing module integrates digital filtering and feature extraction algorithms, extracting time-domain statistical features and frequency-domain energy distribution parameters from the denoised raw signals. The analysis and decision-making layer is deployed on an edge computing platform, performing state assessment through a pre-built fault model library. Monitoring data is simultaneously uploaded to a cloud server for long-term storage and analysis.

3.3 Research on Diagnostic Methods for Stall and Surge

The Threshold Judgment Method enables rapid

warning by setting thresholds for parameters like flow fluctuation rate and pressure pulsation amplitude. While simple, it is susceptible to interference from operational fluctuations. The Trend Analysis Method utilizes a sliding window to calculate parameter change rates, identifying early fault signs by monitoring trend slopes. It is effective for progressive faults but struggles to capture sudden failures. The Pattern Recognition Method, based on Support Vector Machines (SVM) or deep learning models, establishes classification boundaries through training on labeled samples, offering high diagnostic accuracy but requiring substantial annotated data. The Comprehensive Diagnostic Method fuses multi-parameter features: it first uses trend analysis to identify abnormal parameter trends, then applies threshold judgment to determine fault severity, and finally confirms the fault type through pattern recognition.

4. Research on Prevention and Control Technologies for Induced Draft Fan Stall and Surge in Large Thermal Power Units

4.1 Prevention and Control through Design Optimization

The design phase of the induced draft fan constitutes the fundamental line of defense against stall and surge, necessitating improvements to the design scheme starting from the core component structures. Optimizing the impeller design can enhance airflow uniformity by adjusting the blade distribution density. Improving the blade shape using streamlined profiles reduces airflow separation. Reasonably setting the installation angle allows for better alignment between the airflow incidence direction and the blade motion direction. Precisely selecting the impeller diameter ensures the equipment matches the system's air volume requirements. These design optimization measures directly impact the fan's aerodynamic performance, not only broadening the stable operating range but also improving the characteristics of the stall onset point. By employing fluid dynamics theoretical calculations to construct airflow motion models and combining them with numerical simulation analyses of flow field distributions under different design schemes, the actual effectiveness of design optimization in suppressing stall and surge can be clearly verified.

4.2 Prevention and Control through Operational Adjustment

The scientific adjustment of operating parameters is a crucial means to avoid stall and surge, requiring the development of flexible control methods for core parameters such as flow rate, pressure, and rotational speed. Based on the patterns of unit load variation, the adjustment ranges for parameters under different operating conditions must be defined—for instance, appropriately increasing rotational speed under low load to maintain stable airflow, and optimizing the inlet-outlet pressure balance under high load. Specific operational guidelines should be formulated based on these patterns to ensure operators can respond swiftly according to real-time conditions. Operational adjustments must balance safety and economy. By analyzing the impact of parameter changes on coal consumption and auxiliary power consumption rate, adjustment strategies can be optimized to avoid the stall/surge risk zone while ensuring no significant decline in the overall operational efficiency of the unit.

4.3 Prevention and Control by Adding Auxiliary Equipment

The addition of auxiliary equipment provides hardware safeguards against stall and surge. Solutions such as installing anti-surge valves and setting up bypass pipes have been applied in practice. Anti-surge valves disrupt the conditions for airflow stall formation by real-time regulation of bypass flow, while bypass pipes enable airflow diversion when anomalies occur in the main flow path. Both can suppress surge by altering the flow field state. When selecting auxiliary equipment, factors such as the fan model and system parameters must be considered to determine appropriate specifications, pressure ratings, and control response speeds. During installation, emphasis should be placed on interface sealing and pipeline resistance balance to ensure the equipment works synergistically with the original system and avoids operational interference.

4.4 Prevention and Control through Control Strategies

The application of advanced control theories is driving the intelligent development of stall and surge prevention, with methods such as fuzzy control, neural network control, and adaptive control demonstrating significant advantages. Control systems designed

based on these theories integrate data from devices like pressure sensors and flow monitors to achieve real-time perception of the fan's operating state. The core algorithm of the control system can automatically adjust control parameters based on changing conditions—for example, handling multivariable coupling relationships through fuzzy control, or utilizing neural networks to learn from historical data to optimize control logic.

Conclusion

The issue of stall and surge in induced draft fans of large thermal power units is complex, involving multiple aspects such as design, operation, equipment, and control. By employing comprehensive prevention and control technologies—including design optimization, precise adjustment of operating parameters, installation of auxiliary equipment, and adoption of advanced control strategies—the risk of stall and surge

occurrence can be effectively reduced. In practical application, it is necessary to flexibly utilize these technologies according to the specific conditions of the unit, continuously enhance the operational stability of the induced draft fan, ensure the safe and efficient operation of the thermal power unit, and thereby provide solid support for the stable development of the power industry.

References

- [1] Shi Cheng. Analysis and Preventive Measures for Stall in Axial Flow Induced Draft Fans of 300MW Units[J]. *Fluid Measurement & Control*, 2022, 3(01): 10-12.
- [2] Luo Renda, Wang Zhengxian, Guo Ronghe, et al. Vibration Fault Diagnosis and Field Dynamic Balancing of Induced Draft Fans in Thermal Power Plants[J]. *Light & Lighting*, 2021(4): 74-75.