RIGHT SIZING MECHANICAL DRAFT FANS
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SYNOPSIS

Mechanical draft fans are some of the largest parasitic loads in any production process. More often than not, existing fans are improperly engineered for peak efficiency due to the designer’s fear of creating a system limited by fan draft. Cost-effective modifications to these fans can significantly increase performance and reduce operating costs, saving hundreds of thousands of dollars per year. This article pays special attention to the types of draft fans found in cement plants, but the principles outlined herein can be applied to all industries looking to optimize their air and gas handling systems.
INTRODUCTION

The mechanical draft fans used in cement production — including the preheater ID fan, the raw mill fan and the kiln baghouse ID fan — are some of the largest parasitic loads required in the process. More often than not, these fans are not operating at their peak efficiency. Given today’s competitive business climate, evaluating the performance of these fans and their systems to adjust their capacity to match the systems and their resistances, as well as examining possibilities to improve efficiencies, is a smart business decision.

Mechanical draft fans have a peak efficiency point on their fan curve, normally located just to the right of the peak of the capacity curve. A fan manufacturer will normally size and design the fan so that the performance curve and the system resistance curve intersect at an efficient point. If the system resistance curve is not accurately predicted, fan performance and/or operating efficiency are likely to suffer. The performance of the fan changes depending on the shape and slope of the system resistance curve (Figure 1). Therefore, one can easily see the importance of “right sizing” fans.

DESIGN SPECIFICATIONS

Oversized fans often require considerable inlet dampering, which itself is inefficient. The fear of many design engineers is that the fan will be too small and will become a limiting factor in the high demand times of operation, so larger than needed safety factors are applied. In many cases, the excess sizing is a result of an accumulation of safety factors added by the owner, the architect/engineer and ultimately the fan manufacturer. If the volumetric flow rate is overstated, the fan will be selected too wide and the fan will operate closer to the peak of the pressure-volume curve and there will be opportunity for unstable operation. If the pressure is overstated, the fan will require excessive dampering to reach its point of operation.

Designing for too little flow rate or pressure will leave the fan short and unable to provide the draft requirements at process peak loads. Therefore, it is imperative that the design engineer has a good understanding of the volumetric flow rate needed for the process and the pressure requirements of the system.
PROJECT 1

As an example of “right sizing” fans by changing the actual design, ProcessBarron was asked by a cement producer located in the Southeastern United States to evaluate its kiln ID fans. After a field performance test was conducted, it was determined that the two existing open paddle wheel–type radial blade fans were improperly sized and operating at an inefficient point of operation. Two rim type or shrouded radial blade rotors that were larger in diameter and narrower in width were designed to meet the actual tested conditions during peak operation. This upgrade of the existing fans with new rotors resulted in a 10% increase in clinker production without an increase in fan motor size.

TIPPING AND DE-TIPPING

Often, the fan impeller can be tipped or de-tipped to enhance the performance characteristics so they better fit the actual operating system. Tipping and de-tipping alters the effective diameter of the fan impeller without changing the effective width of the impeller. The affinity laws or fan laws are different for tip modifications versus a full geometric scale up of the diameter. See equations 1–3 in Figure 2.

When considering a rotational speed change, equations 1–3 in Figure 2 would also apply here for a speed change, since the diameter term will be unity for a constant diameter.

If a fan is being dampered by 40% or more at maximum or peak loads, it is an excellent candidate for de-tipping (removing some of the blade tip to decrease the effective diameter). A smaller diameter will decrease the pressure generating capability of the impeller and thus allow the damper to be opened more and lower the required horsepower.
Conversely, if more capacity is needed, increasing the effective diameter by adding tips may be a suitable option. It will increase the overall pressure generating capability of the impeller, change the point of rating on the fan curve, and generally allow for more volumetric flow rate. Since the impeller is now performing more work, it will require more horsepower. The horsepower approximately varies to the fourth power of the change in effective diameter.

A very effective method to alter performance, as well as improve the capacity or efficiency of a fan, is to change the existing impeller design to a different blade design. The payback can be immediate when evaluating the savings in power consumption. Typical blade designs include radial, radial tip, forward curved, flat backward inclined, backward curved and airfoil. The static efficiency is different for each of these designs, with radial blades being the least efficient and airfoil shaped blades being the most. For these two designs, there is approximately a 15% difference in the amount of power required to do the same amount of work. Often, a more efficient wheel can be designed to fit into the existing housing with little to no modifications and replace the existing design. Or, if the housing is not suitable, it may be possible to retrofit a new housing onto the existing foundation and mate to the existing ductwork.

PROJECT 2

Another example of a blade design change, as well as a “right sizing” of a fan, was on a preheater ID fan in the Western United States. It was suspected that the fan was operating inefficiently after changes were made to the system that reduced the resistance; afterward, the fan was being operated at higher volumes aiding in the increase in production. The original fan was a radial blade design installed in the early 1980s with a performance curve (volume vs. static pressure and volume vs. power) represented in yellow in Figure 3. The original predicted system resistance curve is shown in red.

A field performance evaluation revealed that the actual system resistance had a less steep curve (represented in green). This new point of operation was at a very inefficient place for the existing design. A decision was made to retrofit a new backward curved impeller into the existing...
radial blade housing. A backward curved rotor was designed for the higher-volume and lower-pressure requirements. The performance curve is shown in blue in Figure 3. Note the savings in power from original design to the new design. The actual power savings were over 400 BHP (brake horsepower) offering over US$200,000 in power savings per year and showing a full payback of investment, including installation, to be less than one year of operation.

PROJECT 3

Upgrading a fan may require the combination of multiple approaches. One such example is a coal mill fan at a cement plant in Southern California. After a performance evaluation was conducted, it was determined that the fan was grossly oversized in its pressure generating capability and that there was a substantial pressure drop across a damper near the fan inlet. The plant management wanted to be able to replace the fan with one that would fit into the space of the existing fan. Also, it was their desire to increase the operating efficiency of the fan to the maximum extent possible. After evaluation, the existing radial blade design operating at 1200 rpm was changed out for a backward curved design operating at 900 rpm. This new fan fit into the existing fan envelope with minimum duct modifications. The brake horsepower was lowered by almost 200 horsepower with annual savings exceeding US$125,000 based on US$0.095 per kW-hr. The total payback on the entire project, including the installation, was approximately 10.5 months. Even though this was a small fan, it had a big impact on the bottom line.

OTHER ISSUES

When making an impeller modification, there are other design issues that must be addressed. The rotor will change in weight and that will affect the shaft critical as well as the stresses in the blade and surrounding components. Also, the inertia of the rotor (WR2 or WK2) will change and will affect the starting characteristics of the fan. The motor will need to be examined to be sure that it is capable of accelerating any additional loads. The clearances in the housing, particularly in the cut-off area, will need to be reviewed. As the impeller gets closer to the cut-off, noise can become an issue. Annoying pure tones can become predominant. If the impeller diameter is reduced too much, the distance from the cut-off can become too great and possibly cause a loss in performance. Generally, you would want a gap between the tip of the impeller and the cut-off bar of 6–12% of the effective diameter.
PROJECT 4

A cement plant in the Midwestern United States invited ProcessBarron to carry out a performance audit on all of its fans. In this evaluation, it was determined that the raw mill ID fans were grossly inefficient. Since the existing fans were old and worn, it was decided to replace them with new more efficient designs of increased capacity. Realized savings on the new fans was approximately 80 brake horsepower equating to US$30,000 per year. Since the fans desperately needed to be replaced, the power savings were just an added benefit.

CONCLUSION

It has hopefully been demonstrated that there are potentially large operational savings to be had from right sizing fans, if one knows where to look. Finding candidates for improvement is as simple as doing performance testing and an energy audit of all the fans, or at least the major power consumers, in the process, including the preheater ID fan, raw mill fan, baghouse ID fan, coal mill fans, finish mill fans and clinker cooler fans.

This discussion is only intended to be an overview of possibilities for improving the operation and efficiency of mechanical draft fans. It is recommended that the services of a qualified engineering company or fan manufacturer be employed to evaluate completely the health and potentials of fans and their accompanying draft systems.