TAD Optimization:

Production Gains vs. Reduced Utility Costs

Part 2 of article on optimizing Thru-Air Dryers looks at operating cost trends and presents a Q&A analysis of various mill operating scenarios.

— By Joe Pilsbury

This is the second of a two-part series on optimizing a Thru-Air Drying (TAD) machine for maximum energy and production efficiency. Part 1 in last month's issue of PaperAge (July/August 2003) focused on the overall energy consumption of a TAD system, and examined various operating approaches with respect to humidity.

A case study presented in Part 1 compared system dynamics as a certain production rate of tissue or paper is dried by an air stream with varying levels of humidity. Two operating scenarios (Conditions 1 and 2) within the case study were defined and comparatively analyzed. Fan power/volumetric flow rates and burner energy were specifically analyzed as a function of supply air humidity.

This Part 2 of the article includes further analysis and discussion of the case example established in Part 1, and provides several question-and-answer scenarios based on results and conclusions of the study conducted by Metso. If Part 1 of this series is not readily available, it can be found on PaperAge.com when the July/August 2003 issue is posted on that site. Otherwise, email PaperAge at info@paperage.com for an electronic or printed copy.

Operating Cost Trends

The step change in TAD system humidity, as discussed in the case study in Part 1 of this article, results in an overall increase in total energy usage for the same rate of production, thereby reducing the overall thermal efficiency of the system. Depending on utility costs, however, the operating cost of the system might not increase as one would think.

For this study, rather than select utility cost data from different regions, utility costs are examined as a ratio of electrical cost to natural gas cost. The utility cost ratio of electricity to natural gas-calculated by dividing the electrical utility cost (Euro/kw-hr) by the natural gas cost (Euro/kw-hr)-at which operating Conditions 1 and 2 are financially the same for this system, is about 3.9. Any ratio below 3.9 leads to an increased utility cost with lower system humidity.

A utility cost ratio above 3.9 results in an operating cost minimum value that, in this particular case, occurs with a supply air humidity of about 0.17 kg H_2O/kg dry air. While this humidity and cost ratio that provide for maximum cost efficiency are specific to the system described in the case study, they represent variables that are predictable on any TAD system if the correct system data is collected through a process survey.

Figure 1 below shows the cost trend over a range of supply air humidity at different cost ratios.

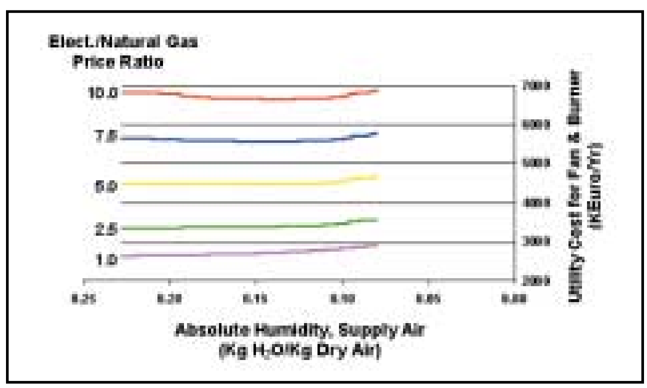

Figure 1. Operating cost trends of fan and burner for different electricity/natural gas ratios versus supply air humidity.

Initially, as the electrical price is equal to the natural gas price (Ratio = 1.0), the operational utility cost increases with a decrease in humidity. This is expected, since overall thermal efficiency decreases with a decrease in humidity and the prices for electricity and natural gas are equivalent.

As the energy cost ratio grows larger, the operational cost difference becomes noticeable, as the shape of the cost trend begins to resemble the fan power vs. humidity curve shown in Figure 5 of Part 1 of this article. These data are based on many assumptions and do not necessarily reflect a machine currently in operation. Cost and energy efficiency analyses are machine and product specific-the trends may be similar from machine to machine, but predicted values for energy consumption and cost will most likely be very different.

The cost savings by operating under Condition 2 versus Condition 1 are not substantial under any typical utility cost ratios that exist today. So why would it be advantageous to operate a TAD machine at lower humidity levels? The most compelling reason to operate at lower system humidity is production capacity. The potential for increased production capacity is the result of two major effects that happen when the system humidity is reduced:

- **Fan Flow.** The fan is able to move more total mass flow for relatively the same volumetric flow rate. This point was discussed in the "Fan Power" section of Part 1.
- **Supply Temperature.** Quite commonly, tissue producers limit roll exhaust temperature as a convenient variable that may correspond to acceptable fabric life or product concerns. By decreasing the humidity and increasing the heat transfer rate, as discussed in the "Supply Air" section of Part 1, the supply air undergoes a higher temperature decrease as it passes through the sheet. This decreases the exhaust temperature, which allows for an increase in supply temperature.

With an increase in supply temperature available and the fan able to move higher mass flows for a fixed volumetric flow rate, significant increases in production are available. Using a fan curve provided by Howden Buffalo Inc., operating under Condition 2 produced 16% more product than Condition 1. Table 1 below shows the overall TAD system performance of Conditions 1 and 2 using the specified fan at maximum speed, flow, and differential pressure.

Note that Condition 2 is about 8% less efficient than Condition 1 when considering the energy required to evaporate equivalent amounts of water, shown as kJ/kg H_2O. This is a sacrifice that a tissue producer may be willing to make in an effort to increase production when the system is otherwise dryer limited.

	Condition 1	Condition 2
Hood Supply Temperature, °C	210	235
Roll Exhaust Temperature, °C	118	118
Burner Duty, kw	20,600	27,400
Fan Power, kw	5.368	5,121
Total Thermal Input, kw	25,968	32,521
Line Speed, m/min	900	1,043
Paper Produced, metric tpd	197	228
Evaporation, kg H_2O/hr	23,706	27,429
Thermal Efficiency, kJ/kg H_2O Evaporated	3,799	4,110

Table 1. Machine data illustrating an increase in production capacity with lower humidity.

TAD Scenarios

Taking all of this information into account, the following are answers to some questions that might be asked by TAD users to help them with production:

Question: *If the main fan is currently running at its maximum speed, how can production be increased without increasing the supply air temperature?*
Answer: If there is additional capacity on the burner, lowering the system humidity will increase the production rate of the machine by lowering the specific volume of the air that enters the fan, effectively allowing the main fan to move more air mass. In some cases, the operating cost penalty will be small.

Question: *If the system is at its maximum exhaust temperature limit and the fan is at maximum speed, how should the humidity be adjusted to increase production?*
Answer: Lowering the system humidity (introducing more fresh air) will reduce the exhaust temperature. The adiabatic saturation temperature (AST) decreases (see Figure 8 in Part 1) with humidity, and increases the heat transfer rate by increasing the temperature differential between the supply air and the sheet. This will cause the exhaust temperature to decrease because the amount of heat required to dry the sheet remains constant and the system is accomplishing this drying with less overall mass flow to the hood (air and water vapor).

Question: *For a fixed production rate, how can the utility costs be reduced by changing the humidity?*
Answer: It depends on utility costs, air system design, and

product being made. It can be determined scientifically by performing a system process survey to gather data, or by trial and error over several months. In general, a reduction in humidity decreases fan power and increases burner duty. Consequently, in most cases increasing humidity results in lower utility costs.

Question: *With the fan at maximum speed, supply and exhaust air temperature increases being allowable, but the burner at a maximum firing rate, how will changes in the humidity affect production?*
Answer: This information is machine specific and should be analyzed on a case-by-case basis from field-measured machine data.

Question: *Are the effects of varying humidity the same for a system with an exhaust fan (Configuration A, Figure 1 in Part 1 of this article) as they are with a system with no exhaust fan (Configuration B, Figure 1 in Part 1)?*
Answer: They are not the same, but they are similar. Configuration A could potentially be exhaust limited due to exhaust fan capacity. If the exhaust fan has the capacity to remove the extra air that would be brought into the system, an increase in production is possible, since the rest of the system will have a similar fundamental response to Configuration B. Benefits to running Configuration A at a low humidity will depend on many things (product, air system design, utility costs, etc.) and should be evaluated on a case-by-case basis.

Question: *What are the effects of varying humidity on other configurations, such as a system with two inline TAD machines or a TAD with two supply temperature zones?*
Answer: These systems may have the potential for a production increase because the basic fundamentals are the same. It depends on the temperature limits that are set for the machine. Typically, these systems are designed to run the maximum allowable supply temperature in the first drying section (either TAD-1 of two inline TADs or Zone-1 of a two-zone system) and maximum exhaust temperature in the second drying section (TAD-2 or Zone-2).

Therefore, a supply temperature increase as described above to increase production may only be possible in the second drying section. If this is the case, the system response in TAD-2 of a double inline TAD system would most likely respond as the single TAD in the case study has. However, the production increase will likely not be of the same magnitude, since the humidity of TAD-2 is typically relatively low and cannot be reduced by as much as was shown from Condition 1 to Condition 2 in the case study.

Conclusions

This article attempts to develop a broad understanding of the impact of system humidity on TAD air system performance. Without question, a reduction in system humidity decreases the overall thermal efficiency of a TAD air system.

If the ratio of electricity to natural gas cost is high, it may be more economical to run at a lower humidity due to the rates of change of the fan and burner duties. But this is not normally the case. The rates of change for the fan and burner differ significantly as humidity changes. Points exist where operating at a low humidity is beneficial and points where it is not.

The information provided in this article may be useful in optimizing a TAD toward certain goals, such as increased production or reduced utility cost. It may become even more useful as utility costs will undoubtedly change throughout the lifetime of a TAD. The time and resources spent to develop an understanding of a TAD system's response to humidity changes will be well invested over the course of time.

Metso uses advanced process models to analyze current operating data and predict future outcomes.These models have been continuously refined using field data from the company's large reference list. An effective process study requires more than the collection and reporting of raw data. It requires an interpretation of the data (e.g. causes and effects), a critical analysis of improvement areas, and a recommended course of action.

In addition to TAD knowledge, expertise in the science and process of papermaking is essential to drawing concrete conclusions. A clear understanding of the total process and how one change will affect the rest of the process is vital. It is important that any changes made to the air system do not adversely affect the core function-making quality paper.

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