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If aerospace companies designed dryers...

A thorough understanding of the drying processes involved in gypsum wallboard manufacture is essential to producing high-quality product on a consistent basis. Ryan Holbird of Grenzebach Corporation describes an innovative modelling tool based on Computational Flow Dynamics, allowing for more accurate predictions of drying performance.

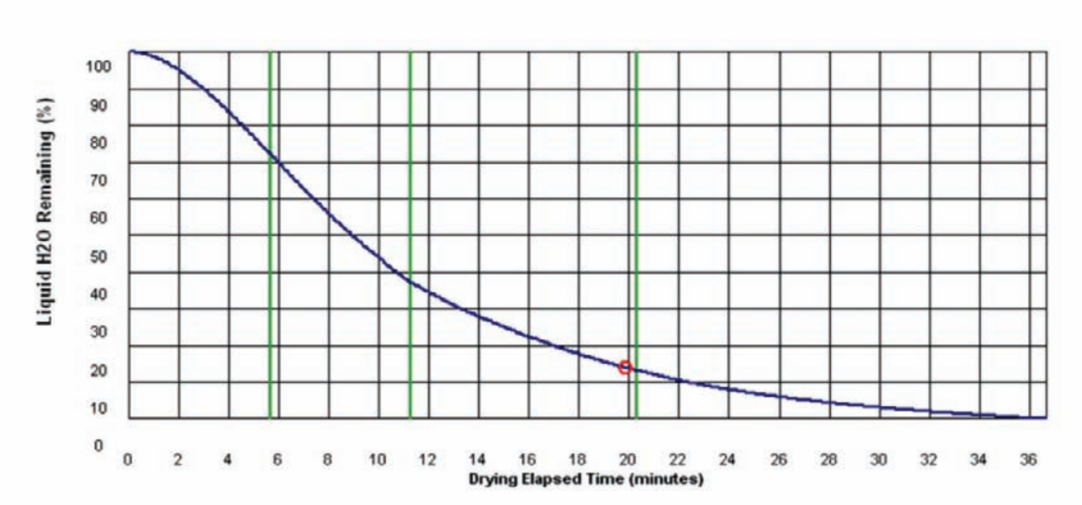
If you put five engineers into a room to solve a puzzle with more variables and uncertainties than constants and answers, you are certain to get no fewer than six solutions – all of which sound good in theory, but none of which earns the full confidence of everyone involved. To complicate matters, if the task is to change a process – especially one which has been around for decades but is known to be less than ideal – the combined forces of hesitation and resistance can overpower the motivation to move forward with proposed improvements. This type of conundrum applies to nearly every player in every industry, and successful companies are identified as those able to find solutions to such challenges.

Thanks to recent improvements in computing ability and technological contributions made by Douglas Aircraft, Boeing, Lockheed, and NASA, Grenzebach – a world class supplier of wallboard dryer design and engineering – has been able to confidently provide solutions to the challenges that have plagued designers since the world's first dryer was put into operation. Computational Fluid Dynamics (CFD) is an analytical method that allows airflow trends to be calculated and observed, and it is Grenzebach's newest tool to solving challenging dryer performance issues.

Process improvement

The first attempts at calculating dryer performance used basic thermodynamic principles: a fixed amount of water is to be removed, water requires a certain amount of energy to be removed, so the necessary amount of energy is provided. Dryers were built without much regard to energy cost and efficiency since energy was relatively cheap at the time. As the understanding of drying processes improved, mass and energy balance (MEB) methods were used to track energy use per zone within a dryer. While these methods were beneficial in sizing and measuring dryer performance, the actual drying process was not directly considered nor taken into account. The inherent flaws to these approaches led Grenzebach to the development of the Dryer Performance Model (DPM). The DPM breaks the dryer into discrete segments and allows for a finite-elemental approach to modelling the actual drying process. Energy and mass transfer equations describing forced-

Right: Drying curve generated by DPM

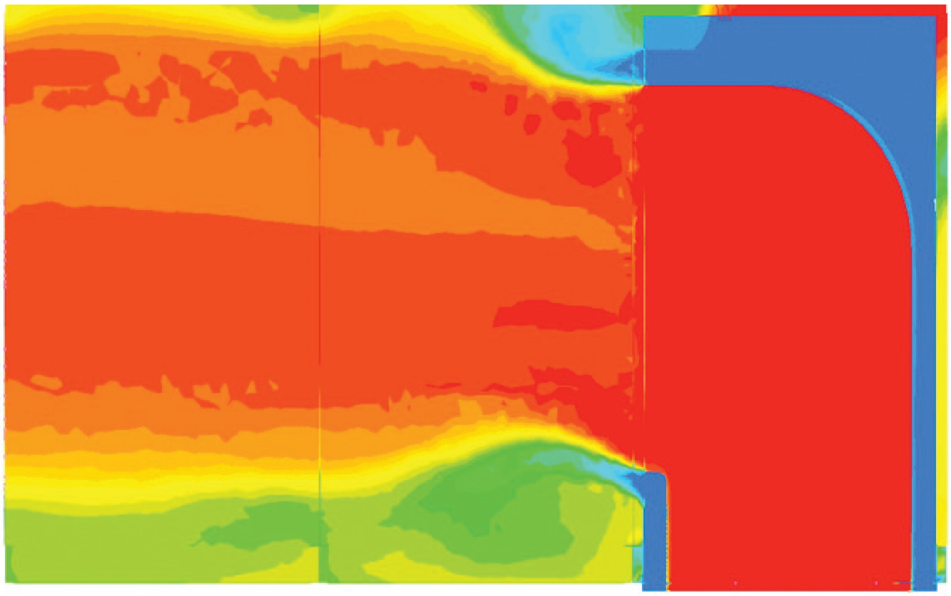


convection and conductive heat transfer are coupled with models to accurately model moisture diffusivity through the board and into the air stream. This rigorous model is capable of calculating – quite accurately – many useful factors in board drying. Figure 1 shows typical results for water remaining in the board at each stage within the dryer.

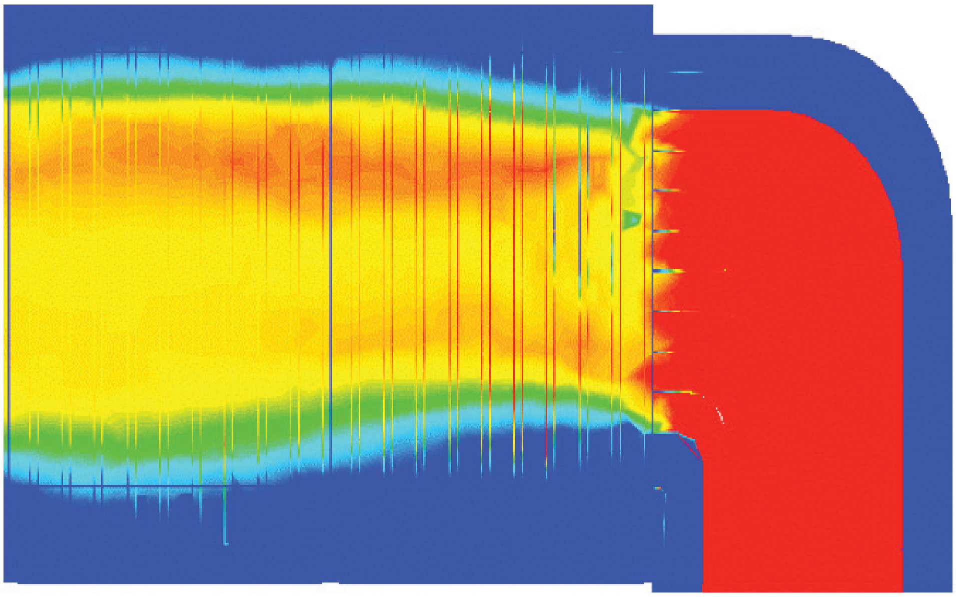
While the DPM is Grenzebach's workhorse for designing new dryers as well as evaluating existing dryers for rebuilds, it is not without the same limitations present in all mathematical models, namely that it is based upon key assumptions. Deviations in those assumptions can adversely affect the results. The equations that govern mass and energy transfer within a dryer are strongly sensitive to variations in temperature and velocity. These two factors can affect product dwell time, air stream properties, evaporative ability, and excess energy consumption. Every dryer currently exhibits some form of deck-to-deck and side-to-side deviation in air stream velocity and temperature, but if one can correct for these deviations in future designs and make these properties more consistent, the DPM becomes more accurate, and the end result to wallboard manufacturers is a more efficient dryer producing more consistent quality product.

CFD is the new modelling tool that allows Grenzebach to test equipment designs for airflow and temperature stratification before any portions of the dryer are actually fabricated. Historically, the only way to accurately test design concepts for improved air flow – aside from actually building the final product – was to use scale models and apply similitude in laboratory experiments. Wind tunnels and water tanks were common in these tests but it took a great deal of time and effort to get useful results. If the results weren't positive, models had to be rebuilt and tested again. With CFD however, models can be created in most popular 3D design packages within minutes and airflow results can be viewed within an hour. Designs typically undergo many changes in the course of their evolution, but these changes can be made quickly and final solutions to most questions can be developed in less than a week. With the proper iterative approach and foresight, even the most daunting challenges can be approached and resolved before fabricating a single part. CFD also allows engineers to see into areas that, due to the convoluted design and harsh environment within a dryer, are typically inaccessible and not conducive to rigorous testing. Figure 2 shows the cross section of a typical single-side delivery nozzlebox in a longitudinal dryer. In this particular simulation, an "edge tempering" process is shown where cooler air is passed along the outside edges of the board while warmer air travels along the board centres.

In Figure 2, the temperature stratification that would be present in a real-life application is seen and can be either accepted or refined as necessary. With the appropriate software and experience, running dozens of scenarios to improve this design can be performed quickly and easily. By continuing to refine the mechani-



Below left: Figure 2: Thermal simulation of edge tempering in a longitudinal dryer



Bottom: Figure 3: Refined version of edge cooling application in longitudinal dryer cal design of critical sections within the dryer, designs giving desirable operating conditions can be tested and finalized before the dryer is built. Figure 3 shows the same nozzlebox design with some added deck baffles (not shown) and additional air paths devoted to edge tempering process air. Prior to the application of CFD, challenges like this results could take several generations of equipment installations-and hundreds of thousands of dollars in continued research to achieve.

Mechanical Durability and Performance

In addition to using CFD as a tool to improve the drying process, it is also being used to improve known maintenance issues and to provide solutions to reduce equipment downtime for customers, for example:

- In facilities where product accumulation within the dryer is problematic, CFD is being used to design equipment that maintains adequate velocities with minimal pressure drops in critical areas to ensure airborne particles have no chance of accumulating in low velocity eddies. Also, to facilitate maintenance and minimise dryer downtime, fallout points are intentionally designed and incorporated into new and rebuild designs to allow faster and less frequent cleaning.
- In plants where products require excessively high delivery temperatures, CFD is used to design better combustion chambers to ensure burner tubes do not overheat and deform and steel chamber walls to not degrade under the thermal stress.
- In situations where fan and bearing manufacturers specify upper limits to thermal exposure, CFD can predict the path taken by hot air to ensure it is diluted enough by the time it reaches critical components. Careful steps are taken to ensure temperature stratification at fan inlets is uniform and process sensors are placed in appropriate places so as not to be masked by undesirable flow patterns.

Other situations arise where CFD can also be an invaluable tool. The cost to operate electrical equipment is a significant portion of the overall operating expense of a dryer in many countries. When systems are designed with large pressure drops, they require larger fans and motors to provide adequate circulation. As a result the electrical cost to run the system is often higher than it needs to be. By shifting away from the concept of using dampers to control air flow and, instead, designing equipment that is designed to be more balanced without the use of dampers, electrical costs can be reduced. The end result is still achieved in that sufficient air is delivered to the appropriate places within the dryer, but the path to get there is designed to be more natural and without the loss of momentum inherent to a damper system. Figure 4 shows a before-and-after concept of a thermal mixing system. The original manufacturer had incorporated a series of “targets and windows” to mix the airflow. Ultimately, CFD showed that this addition had minimal improvement over a chamber with no means to mix the air. Further, the pressure drop through this design was almost 300Pa. A newly designed mixing method gives a more even temperature distribution and at a pressure drop of less than 25Pa. The qualitative and quantitative differences are clear indicators that CFD is indeed a tool well worth the investment.

The Future of Intelligent Engineering and Design

Computational fluid dynamics, by itself, is not a single solution cure-all for drying issues; however, when coupled with the appropriate industrial and experience and engineering intuition, it has the potential to revolutionise dryer concepts and shift stubborn design paradigms, resulting in a better service to our customers and improved quality to their customers. CFD is the perfect complement to Grenzebach’s Dryer Performance Model and will play a pivotal part in the future of truly engineered solutions. It is also finding use in other industries in which Grenzebach is involved, such as;

- Veneer dryers.
- Insulation and ceiling tile applications.
- High-speed vacuum-driven glass conveyors and stackers.
- Calcining operations and heat transfer analysis.

By continuing to invest in cutting-edge technology and engineering talent, Grenzebach will continue to develop and provide superior performance and quality equipment to all of its customers.

Right: Figure 4: Two approaches to mixing air streams. The improved chamber on the right is more effective at mixing and has approximately 250Pa less pressure drop than the original chamber on the left.