

Computer Simulation Helps Increase Life of Impeller in Alumina Hydrate Precipitation from 2 to 8 Years

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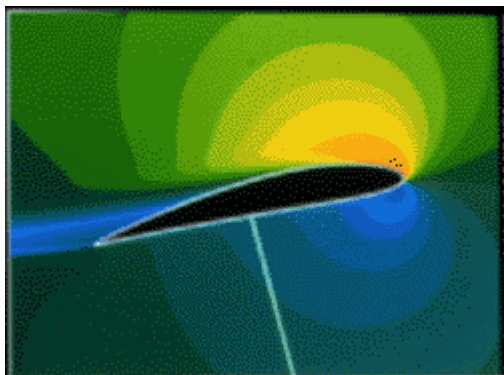


Fig 1. Velocity contours

Simulating the impeller and tank of a draft tube mixer using computational fluid dynamics (CFD) helped us extend the life of the impeller from two to eight years. The mixing process involved precipitation of alumina hydrate used in the production of aluminum.

Experience has shown that the rate at which the impeller wears is a strong function of the velocity at the leading edge with an exponent between two and three.

The computer simulation, using FLUENT CFD software from Fluent Inc., Lebanon, New Hampshire, made it possible for us to quickly evaluate the leading edge velocity of several proposed new designs. In addition, the analysis further helped us fix the problem by predicting the locations of wear patterns so that we could optimally place wear-resistant coatings at those sites.

Introduction

LIGHTNIN is one of the leading producers of mixers with over 1,000,000 units currently in the field. Among the variety of systems that are blended, alumina hydrate precipitation is one of the most difficult erosive mixing applications. In this case, a draft tube that separates the inside and outside of the tank is used to improve circulation. The tank is 10 meters in diameter and 30 meters tall. The single impeller is positioned at the top of the tank so a short drive shaft can be used. This eliminates the need for a bearing within the fluid that would cause maintenance problems. Fines are added to a supersaturated liquor to expedite crystal growth. The precipitative alumina particles are on the order of 100 microns in diameter, have a density of $2,500 \text{ kg/m}^3$ and are abrasive. The solids concentration is typically 20% to 40% by weight.

The size of the tank means that a large impeller with a high tip speed needs to be used. A 3.2 meter high efficiency airfoil-type circular impeller with a detachable blade is mounted inside the draft tube. The impeller blades are constructed from an 8 mm thick top and bottom skin. The original blades had a NACA 4412 airfoil shape. The 4412 airfoil has 4% camber (meaning that the camber is 4% of the chord length or the width of the blade). These blades were failing due to erosion on the leading edge. The blades could be repaired and then lasted another two years before they were discarded. Field data showed the

rate of erosion of the original blade was proportional to the radius with an exponent of 2.8. Since the velocity of the slurry impinging on the blade is proportional to the radius, erosion is proportional to velocity to this same 2.8 exponent. This exponent is similar to that observed in other erosion phenomena.

Analysis of the Impeller

The first step we took was to analyze the existing blade using FLUENT to better understand the problem. Selecting the structure of the computational grid to use for the analysis of problems was critical. If care is not taken to provide a fine mesh in the areas of high velocity gradients and fine geometry detail, then the simulation will not give accurate results. In order to minimize numerical problems, it is also important to minimize the skewness of grids.

Therefore, we used an "O" type grid that wraps around the airfoil and helps immensely in minimizing the skewness at the trailing edge. An axisymmetric model was created with 25,000 cells with appropriate refinement to capture the flow details near the airfoil surface.

Validation of Modeling Results

Experimental data was available for the NACA 4412 airfoil that shows that the maximum velocity occurs at the leading edge, which is also where the observed maximum erosion occurs. The maximum velocity for this airfoil was 13.6 meters per second for an upstream velocity of 6.5 meters per second. The simulation results were compared with the NACA data and correlation was found to be excellent. The experimentally observed maximum erosion takes place at the leading edge, which is consistent with the position where maximum velocity occurs, according to the simulation (figure 2). These correlations provided us with a high level of confidence in using FLUENT software to predict maximum velocities and distributions for other airfoil shapes, which we wanted next to evaluate for this application.

Particulate Interactions

In addition to examining velocities, the solid particle interactions with the airfoil were also examined using the computational analysis results. A stagnation point was observed on the bottom side of the airfoil at the

leading edge, where the particles diverged. Some of the particles then wrap around the top surface at the leading edge in the very high velocity region. Some of these particles move away from the airfoil near the trailing edge. The analysis results show that the bottom surface at the leading edge receives high erosion from the impinging particles and the top surface or suction side receives high erosion from sliding erosion (figure 3). This information was very useful in selecting an alternative airfoil design in an effort to reduce erosion.

Based on these results and engineering judgment, we selected a new airfoil as a proposed impeller design.

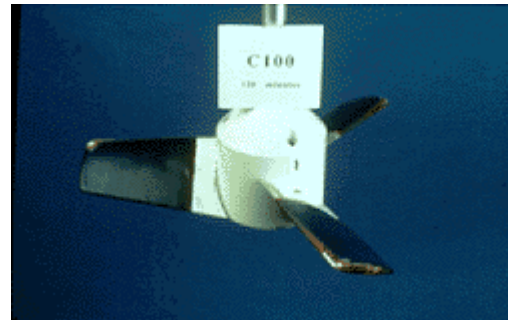


Fig 2. Accelerated abrasion tests with a model impeller show that reducing the leading-edge velocity cuts wear.

My background in aerospace engineering was useful during this process. The new airfoil is symmetric and thinner near the leading edge. The new airfoil also has a larger amount of camber. These factors reduce the airflow velocity in the vicinity of the leading edge. Analyzing the new design with FLUENT at the same 6.5 m/s up-stream velocity showed a reduction in maximum velocity to 10.7 m/s, which is 20% less than the original design. With nearly a cubic relationship between velocity and erosion, this change in itself reduces erosion by 50%.

Applying Coating Optimally

We also considered the idea of coating the blades. Generally, applying a 0.040 inch wear-resistant coating will increase life by 100% but also increase the cost of the blade by the same amount. Knowing exactly where high velocities would be experienced in this case made it possible to cover the critical areas while only coating 20% of the blade. Protecting the leading edge of the blade prolongs the life of the leading edge and also prevents erosion from occurring downstream of this layer. With this change, we predicted that the life of the blade would be



Fig 3. A real C 100 blade after four years' wear

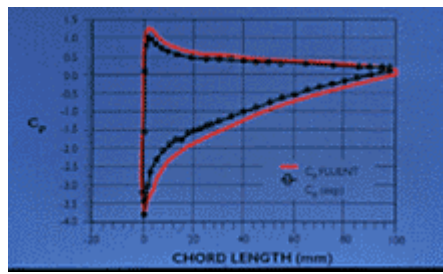


Fig 4. Calculated values of fluid velocity agree with experimental results

that will give numerical instabilities in the computational model need to be avoided. The axisymmetric model had over 9,000 cells. The software produced a predicted path of 100 micron particles, which are injected into the flow field. Based on previous particle studies, it appeared that performance would be good. The new impeller was installed in the application and has provided excellent performance.

extended

by a factor of four. A test apparatus was used to validate these predictions. Two steel coupons were run in a sand slurry for 24 hours. The coupons (one coated and one uncoated) were then weighed to determine material loss. These tests showed dramatic reductions in wear on the order of the amount that had been predicted.

Testing the Redesigned Impeller

The next step was creating a full tank model of the blade in order to determine whether particle distribution in the tank would be sufficient with the new blade. A full-size prototype of the impeller was built and tested in water in a 15-meter square tank in our lab and at an alumina installation in Australia. Flow measurements were obtained using an Ott propeller meter and a Marsh McBirney Eddy Current Velocity Meter. The full scale measurements were obtained either at the outlet of the draft tube or over the vertical section above the lip of the draft tube. A Laser Doppler Velocimeter (LDV) was also used to generate velocity profiles in a 1.2 meter tank with a 0.41 meter impeller. We used a two-dimensional DANTEC Series 60 Fiber Optic System with enhanced burst spectrum analyzers for processing. The flow number of 0.62 measured with the LDV was within 5% of the measurements taken in the 15m tank and the field installation. A new FLUENT model of the entire tank was also constructed. The integrated flow measurements were then used as inputs through the draft tube. Specific details such as the thickness of the draft tube were critical in this model as well. Care is needed when modeling the draft tube inlet because highly skewed cell structures

Conclusion

I have been using FLUENT since 1989. I have found it considerably easier to use than other programs I have looked at. The Fluent code is user friendly and allows you to do complex simulations. Another advantage is that the program provides immediate graphical feedback during grid generation, model creation, and the solution process. One more thing that we have appreciated over the years is the outstanding technical support provided by Fluent Inc. The developer listens to me and has made a number of enhancements to the software based on my needs.

We have used the program in quite a number of other areas including blending studies where we introduce a second species into the tank and determine how it is redistributed over time. We have also looked at gas dispersion, transitional flow, solids suspension and blending in other analyses. In the future, we are planning to create a model that will include the full tank yet provide fine enough detail to cover the impeller, thus eliminating the need for the experimental measurements described above. FLUENT has recently introduced the sliding mesh and unstructured grid capabilities needed for this type of

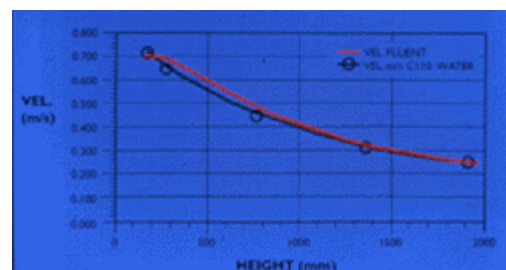


Fig 5. Calculated and measured velocities for water agree well

analysis. Beyond that, we plan to incorporate chemistry into the CFD analysis so we can measure the effect of the mixer on the reaction. All in all, the use of CFD has given us a competitive advantage in improving our product line and developing custom products for specialized applications.