Brad Foote and 3M

Collaborate on Testing of Ground Parts

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Efficiency improvements, cost savings and better quality production are goals that any gearing company strives to achieve. However, it can be difficult and time-consuming to find routes to meet these goals. Nonetheless, the potential benefits are enticing enough to justify investment in testing and redesigning materials and technologies in order to ensure a competitive advantage. This article will describe the testing carried out by Brad Foote Gearing in its search for a better abrasive wheel.

Brad Foote Gearing makes fully integrated precision gearing solutions, from design and engineering to specialty weldment and testing. With a long background in tight-tolerance gearing for wind turbines, the company is now expanding into broader energy and infrastructure markets. The company applies precision down to the fraction of a millimeter or micrometer to meet the tightest tolerances and the highest industry standards, which of course places significant demands on its abrasive materials.

The Challenge for a New Wheel

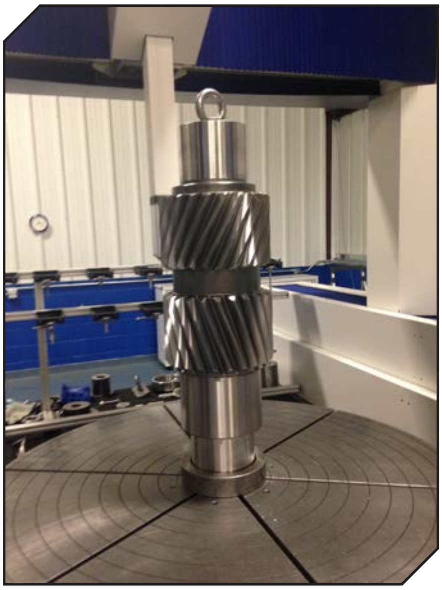
Brad Foote recently conducted testing on abrasive wheels for the production of low speed pinions and bull gears used in wind turbines. These two jobs were selected due to the fact that they are on the high end of difficulty for the parts that are ground at Brad Foote. The high quality standards for these parts, as well as the materials used and modifications required, mean that these jobs are difficult to mass-produce quickly. In the competitive gearing market, any innovation that reduces cycle time has the potential to help increase profitability, so this testing was performed with an eye toward uncovering opportunities for improved efficiency. Furthermore, any potential to improve the quality of the gear being produced was of course welcome as a way to demonstrate added value to the customer.

The parts being produced in the test were made of CrNiMo material, which cracks very easily in grinding, similarly to glass. Additionally, the specifications for the parts are extremely tight. Therefore the tooling and grinding strategies used for these parts are critical. The existing two wheels that had been in longtime use for the pinion and bull gear will be hereafter referred to as wheel A (a finer wheel used for both parts) and wheel B (a coarse wheel that was used for the bull gear prior to finishing with wheel A).

Although wheels A and B were part of well established procedures, Brad Foote conducted testing to attempt to find a wheel solution that could achieve a number of different goals, chiefly reducing cycle time and tool usage. Achieving these goals had a strong potential to create cost savings, even if the abrasive cost per part was higher than the existing wheels.

Alternative Abrasive Technology

The challenger product that Brad Foote selected for full scale testing was a 3M Cubitron II Vitrified Wheel, which the manufacturer claimed could achieve significant improvements in productivity and tool usage. The wheel is capable of these improvements due in part to the grain technology it uses, which is quite different from any other conventional grinding wheel. Most conventional



Brad Foote converted its processes for the pinion and bull gear to utilize the Cubitron II wheel. The company has also begun implementation of the wheels for additional grinding applications in the mining industry.

bonded wheels currently on the market use grains that are irregular in shape, which "plow" through metal, resulting in friction. This friction generates heat, dulls the grain, and adds time to the cutting process. However, the Cubitron II wheels utilize technology from 3Ms microreplication platform to create "precision-shaped grains." The resulting grains are tiny, triangle-shaped structures that continuously fracture during grinding to form new edges and points, allowing the material to self-sharpen. Instead of the plowing action seen with conventional abrasives, precision-shaped grains "slice" through metal. Not only does this reduce damage and discoloration of parts due to heat, but it also allows the wheels to cut cleaner and fast-

Table 1 Low Speed Pinion Grinding Results

Low Speed Pinion Grinding Results		
	Wheel A	3M Cubitron II Wheel
RH Cycle Time	107 minutes	46 minutes
LH Cycle Time	107 minutes	46 minutes
Total Cycle Time Per Complete Piece	3.34 hours	1.32 hours
G ratio		~2X wheel A

Table 2 Comparison for Equal-Sized Batches of Ground Parts (Low Speed Pinion)

Comparison For Equal-Sized Batches of Ground Parts*: Low Speed Pinion		
	Wheel A	3M Cubitron II Wheel
Abrasive Cost	$7,574	$10,787
Machine Cycle Time	297 hr, 36 min	128 hr, 8 min
Machine Cost (@ $50/hr)*	$14,880	$6,407
Total Cost of Operation	$22,454	$17,194
Savings		$5,260 per batch

*For comparison purposes only. Actual machining costs proprietary to Brad Foote.

er than conventional wheels, and to last longer.

Low Speed Pinion Production

The existing production process for the low speed pinion utilized wheel A for tooth grinding, with the wheel able to perform both roughing in and finishing, although it required frequent dressing. Each hand required a separate program for grinding, with the cycle time per hand running at 107 minutes. To produce a complete part using wheel A, total cycle time was just over 3.5 hours. Wheel A also had a lifespan of just 2.5 parts per wheel. The long cycle time for this part made it a challenge to meet the customer's high production demands, and also monopolized a machine, which was dedicated to this job alone. In addition to reducing cycle time and tool usage, testing for this part was designed to find a product that could maximize machine capacity. When the Cubitron II wheel was used for the same task, it reduced the cycle time per hand to 46 minutes, and the total cycle time per one complete part to 1.5 hours. In addition, the wheel ground 5 complete parts before needing a tool change, and improved the flank finish and general appearance at nital etch inspection. It was evident that the Cubitron II wheel was able to remove more stock with less dressing, without glazing the wheel.

As seen in the comparison tables, while the total abrasive cost of the Cubitron II wheels was higher, the machine cycle time required to produce the same number of parts was less than half that of wheel A, reducing the total cost of the operation by almost 25 percent. Because fewer wheels are needed to produce the same number of parts, the Cubitron II wheels also save storage space. The additional machine capacity enabled by the Cubitron II wheels allows the company to pursue additional business instead of having the machine tied up year-round solely for production of the pinion.

Bull Gear Production

Brad Foote's existing process to grind a bull gear, a double helical gear, involves two separate processes for each hand, with two different grades of wheels required. Wheel B, the roughing wheel, was not able to meet the flank finish requirement, and thus wheel A was used for finishing. Wheel A was not suitable for roughing, as its grit was too fine and would burn the material. The roughing cycle per hand averaged 8 hours, with two wheels used in the roughing stage. Wheel A was then interchanged to achieve the desired flank finish, for which it barely met the required standard. Two wheels were also required in the finishing cycle, a very long-running cycle with many challenges.

The photo shown here is not the bull gear being discussed, but is included as an example of what happens to this type of material with the incorrect tooling or grinding strategy (all photos courtesy of Brad Foote).

The photo shown is not the bull gear being discussed here, but is included as an example of what happens to this type of material with the incorrect tooling or grinding strategy. As previously stated, the material has the potential to crack like glass. Due to the limitations of wheels A and B, which affect how quickly and aggressively the wheels can grind, the bull gears are ground very slowly with extreme caution. The challenges in grinding the bull gear were therefore even greater than for the pinion. Like the pinion testing, the goals for a new wheel for the bull gear included reduction of cycle time and tool usage, but with the additional goals of eliminating the two-wheel process and improving the quality of the gear.

Testing showed that the Cubitron II wheel met all of these goals. One single Cubitron II wheel grinds both the rough and finish processes, versus the four wheels required by the old method. The wheel dresses less often, avoiding wear on the tool so that both hands can be ground with one wheel. Cycle time is reduced by more than 50 percent, to 5.66 hours per hand. (Testing is ongoing, with additional cycle time improvements possible.) While with wheels B and A, there was a struggle to keep the flank finish under the maximum allowable, with the Cubitron II wheel the flank finish after grind falls .30 microns below maximum. These capabilities allow operators to rapidly produce parts to quality specifications.

The comparison tables for the bull gear present an even more compelling case than those for the pinion. Because only one Cubitron II wheel is needed to perform the same work of four of the old wheels, an abrasive cost savings of more than $8,500 can be realized per batch of parts. In addition to this, the cycle time is again less than half that of the original process. Adding the abrasive and machine savings, the total cost of this operation was reduced by nearly 50 percent with additional time savings possible with more optimization.

Table 3 Bull Gear Grinding

Bull Gear Grinding			
	Wheel B- Rough Grind	Wheel A- Finish Grind	3M Cubitron II Wheel
RH Cycle Time	8 hours	4 hours	5.66 hours
LH Cycle Time	8 hours	4 hours	5.66 hours
Total Cycle Time for Completion	24 hours		11.3 hours* * Does not exhaust full potential of the wheel

Persuasive Results

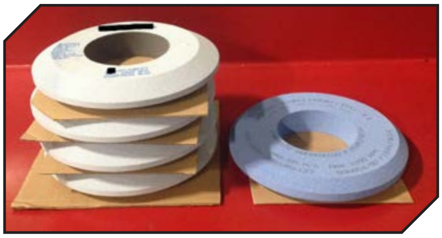
This testing was performed in late 2012 and early 2013, and based on its conclusive results, Brad Foote converted its processes for the pinion and bull gear to utilize the Cubitron II wheel. The company has also begun implementation of the wheels for additional grinding applications in the mining industry.

Several other wheels were also considered in the early stages of this trial, but none of the products was able to match the performance of the Cubitron II wheel. In particular, the Cubitron II wheels' ability to achieve the surface finish on the flanks was particularly hard for other wheels to match. Furthermore, none of the parts burned or cracked during testing with the Cubitron II wheel, even when testing conditions were set to push the wheel to its maximum. This was a notable achievement for working with such a challenging material.

The Value of Free Machine Time

This testing is an excellent demonstration of the capabilities of the Cubitron II product line. When an abrasive can slice through metal instead of just plowing through it, it works faster and longer, and with less heat generation. The cumulative benefits of these attributes are shown in the tables of this article—dramatic reductions in cycle times, and more parts created with fewer wheels.

The value of the machine time regained from use of the Cubitron II wheels is perhaps one of the most important aspects to consider, and also one that is hard to precisely calculate. But it is clear that when machine time is freed up, the company can take in new projects for which it simply did not have the capacity before. Projected over the course of many months, the advantages of Cubitron II wheels are not only lower total wheel costs, but dramatically increased production capacity. In addition, the company gains the ability to turn out parts more quickly and reliably, helping ensure that products consistently reach the customer on time. With benefits in efficiency, cost and part quality, Cubitron II wheels have conclusively proven their worth at Brad Foote.



Cubitron II wheels utilize technology from 3Ms microreplication platform to create "precision-shaped grains." The resulting grains are tiny, triangle-shaped structures that, continuously fracture during grinding to form new edges and points allowing the material to self-sharpen. Instead of the plowing action seen with conventional abrasives, precision-shaped grains "slice" through metal.

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Table 4 Comparison for Equal-Sized Batches of Ground Parts (Bull Gear)

Comparison For Equal-Sized Batches of Ground Parts*: Bull Gear			
	Wheel B	Wheel A	3M Cubitron II Wheel
Total Cost of Wheels	$14,702	$14,702	$20,940
Machine Cycle Time	825 hours		337 hours
Abrasive Cost	$29,504		$20,940
Machining Cost (@$50/hr)*	$41,250		$16,850
Total Cost of Operation	$70,754		$37,790
Total Saving			$32,964

*For comparison purposes only. Actual machining costs proprietary to Brad Foote.

Table 5 11-Month Results for Low Speed Pinions and Bull Gears

11-Month Results for Low Speed Pinions and Bull Gears		
	Wheels A and B	3M Cubitron II Wheel
Total Operating Hours**	1122.6	465.13
Total Cost of Wheels	$36,978	$31,727
Machine Costs	$56,130	$23,257
Total Costs	$93,108	$54,984
Total Savings		$38,124 / 41% cost reduction

**Does not include re-work or 1st piece article.