Ultrasound to Improve Metals

ULTRASONIC IMPACT TECHNOLOGY (UIT) by Applied Ultrasonics uses ultrasonic energy and mechanical impact to improve metals. The ultrasonic device oscillates at a rate of 27,000 times a second, making it an effective and rapid way to reorient the grains in metal and impart beneficial compressive stresses into the material. Using a transducer to energize pins that impact the metal, UIT crafts a tight, pancake grain structure which is resistant to cracks and failure.

The UIT process was developed in the 1960s by Russian scientists to strengthen Cold War era submarines. Kept secret for decades, the technology arrived with its inventor in the U.S. in the 1990s. The technology has been refined by Applied Ultrasonics into an application that can be used for ships, aircraft, vehicles, bridges, dragline…any structure or component that uses metal.

One such application was for CF Industries' phosphate mining operation in Wauchula, Florida (acquired by Mosaic Co. in 2013). Their Bucyrus 1370 walking draglines routinely suffered typical cracking problems in the masthead. The cracks in the mastheads had to be repaired about every six months. These repairs typically required about five days of downtime, an expensive proposition with downtime averaging about $10,000 per hour.

The dragline manufacturer offered a suggested redesign to the masthead which involved doubling the plate thickness at the masthead and thermally stress relieving the field welds. While this redesign offers longer life than weld repairs to the cracked areas, it is much more involved. It requires lying the dragline boom down and takes thirty to 45 days to complete. The estimated cost of downtime for this repair is $7-10 million (that does not include the cost of the repair).

The personnel at CF Industries were interested in finding a way to extend the life of their weld repairs that would allow them to complete the repair in days instead of weeks and would not require them to detach the boom. Applied Ultrasonics had previously utilized its UIT technology at CF Industries on several applications over the years, and based on those successful repairs, CF Industries was convinced that Applied Ultrasonics' UIT was effective in extending the life of weld repairs.

Previous Dragline Experience with CF Industries

On a project that took place about two years before dealing with the masthead issue, CF Industries maintenance manager devised a field test to evaluate the effectiveness of the UIT process in his operation. In this situation, they were trying to address recurring cracks on the walking structure of the dragline (known as the propel structure). This structure sees enormous stress loads when the machine is walked from one location to the next, and repair of these cracks is a constant fact of life for dragline owners and operators.

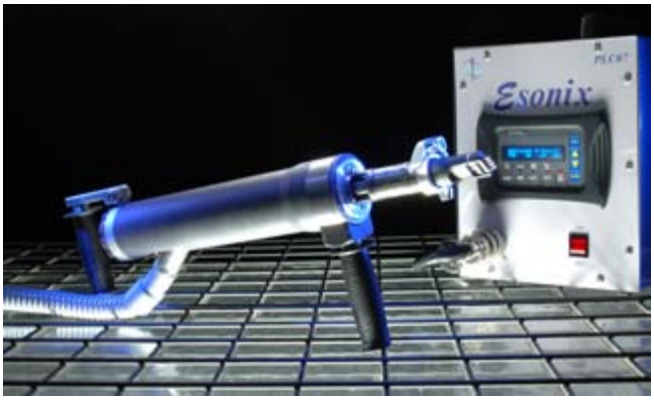
The CF Industries maintenance manager realized that the recurring walking frame cracks repeatedly occurred on both sides of the walking structure, which gave him an excellent opportunity to compare the UIT process to the traditional weld repair process. He had Applied Ultrasonics personnel treat the weld repairs on one side of the walking structure of the dragline. The other side, which had cracks in almost identical locations, was repaired using the same welding procedures, but they were not treated with the UIT process.

The results were dramatic. One year after the repair, the side that was not treated with UIT required weld repairs at the typical six-month mark and again at the one-year mark. Meanwhile, the weld repairs that were treated with UIT had no cracks in spite of seeing identical stresses and workloads.

Based on this success story, CF Industries was convinced that UIT was an effective repair solution, and made the decision to employ UIT on the masthead repair.

Masthead Repair with CF Industries

Applied Ultrasonics deployed a team of UIT technicians to CF Industries' Wauchula phosphate mine site along with a state-of-the-art UIT 1000 System. CF Industries provided welders who worked to the CF Industries approved welding procedure. This procedure called for the cracks in the masthead to be completely gouged out until viable, sound material was reached. In the event of through cracks, the material was removed completely and prepped at a forty-five degree included angle.



The Esonix UIT handheld device from Applied Ultrasonics.

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Once the material was properly prepped and welding began, Applied Ultrasonics' UIT technicians worked as a team with the welders, treating each weld layer as soon as the welder completed the final pass in the layer. Treating each layer allows the welder to continue working until the complete layer is laid down. Technicians treated the root pass, which is the first weld layer. Then, when the second layer was completed (typically consisting of the second and third pass), technicians treated the entirety of the second layer. The UIT process was applied to the toe of the weld, the weld body and the heat-affected zone (HAZ).

Applied Ultrasonics' UIT 1000 System is fast and easy to use. The UIT process is roughly 1.5 to three times faster than welding, and UIT can operate at typical inter-pass temperatures, so when the welders completed a weld layer, the UIT technician was ready to jump in and treat that weld layer. Based on the ability to treat quickly and at elevated temperatures, the UIT process did not add any appreciable amount of time to the total repair process. As with previous repairs which did not include UIT, the total time required for the masthead repair was about five days.

Results

The masthead repair was completed in May 2011, and as this publication goes to press, the masthead that was treated with UIT has experienced *no cracks in the 4+ years since the repair.*

Considering that cracks in the masthead used to require five days of downtime at $10,000 per hour, each of these downtime periods cost the mine about $1.2 million. By delaying the onset of cracks for over four years and allowing CF Industries to avoid eight of these repair cycles, Applied Ultrasonics' UIT helped CF Industries save $4.8 million.

Additionally, the walking structure cracks that were treated with UIT have now run for over six years, and like the masthead, CF Industries have experienced zero cracks in the areas treated with UIT.

The UIT Equipment and Process

Applied Ultrasonics' UIT is highly portable, easy to use and repeatable. The UIT 1000 System, which was utilized on the CF Industries applications, consists of three primary components: the generator that houses the electronics, software and PLC-based controller and operator interface; the water cooler which is a pump and heat exchanger system that circulates water through the hand tool; and the hand tool which is utilized to impact the treated surface.

The UIT 1000 System is capable of packing into two hard-sided containers that are suitable for shipping anywhere in the world. The system runs on 110V or 220V and can be powered from a wall outlet or a suitable electrical generator. With its quick connect attachments, modular design and ease of use, the UIT 1000 System can be set up within about 5 minutes of arriving at the work site.

The hand tool is lightweight, ergonomically designed and spring loaded and does not rebound or recoil to any significant extent, creating a very comfortable operator experience. In the type of applications at CF Industries (i.e., treatment of weld repairs), the UIT process creates a dimpling of the treated surface and a groove at the weld toe. This plastic deformation makes visual QA/QC an easy and straightforward process, and it ensures the process is repeatable.

The UIT 1000 System is fast as well. Typical linear treatment speed is about three times faster than welding. As a result of this treatment speed, UIT is very cost-effective.

Broad Application Possibilities

While the work at CF Industries was on weld repairs of cracked materials, UIT is in no way limited to that type of application. Applied Ultrasonics has effectively employed UIT on a wide variety of materials and applications. Materials successfully treated with UIT include: carbon steels, stainless steels, high strength steels, aluminum, titanium, bronze, Inconel and others.

While most of Applied Ultrasonics' UIT commercial experience to date is on repair welds, the process is also proven on machined surfaces and base metal. For example, Applied Ultrasonics has treated crankshafts and drive shafts with UIT in the manufacturing process. In most cases, the entire shaft does not need to be treated, just the high stress areas that are most prone to cracking and failure. Shafts can be treated immediately after machining or at any time in the life of the shaft. After treatment with UIT, shafts typically see triple their normal fatigue life or better.

Applied Ultrasonics' UIT is also well suited to automated applications. In many cases the most effective treatment methodology consists of controlling the UIT device by means of a robot, CNC machine or similar automated device. The level of control and repeatability afforded by such an automated solution obviously exceeds that possible through manual applications. In this type of setup, the body of the UIT tool is beefed up to withstand the rigors of higher run rates, and the automated process is capable of achieving better surface finishes than those typically found in manual applications.

Tool with Countless Possibilities

Applied Ultrasonics' UIT is a proven process with a strong track record in laboratories as well as a broad range of industrial applications. It has earned a reputation for saving millions of dollars in downtime avoidance and asset life extension. "But, is it right for me?" you ask. If you are experiencing cracks and failures in metal structures and components, it may be. If you have a critical weld subject to higher stress levels, it may be. If you are dealing with stress corrosion cracking, it may be. If you would like less downtime and more peace of mind, Applied Ultrasonics' UIT may be the right answer for you.