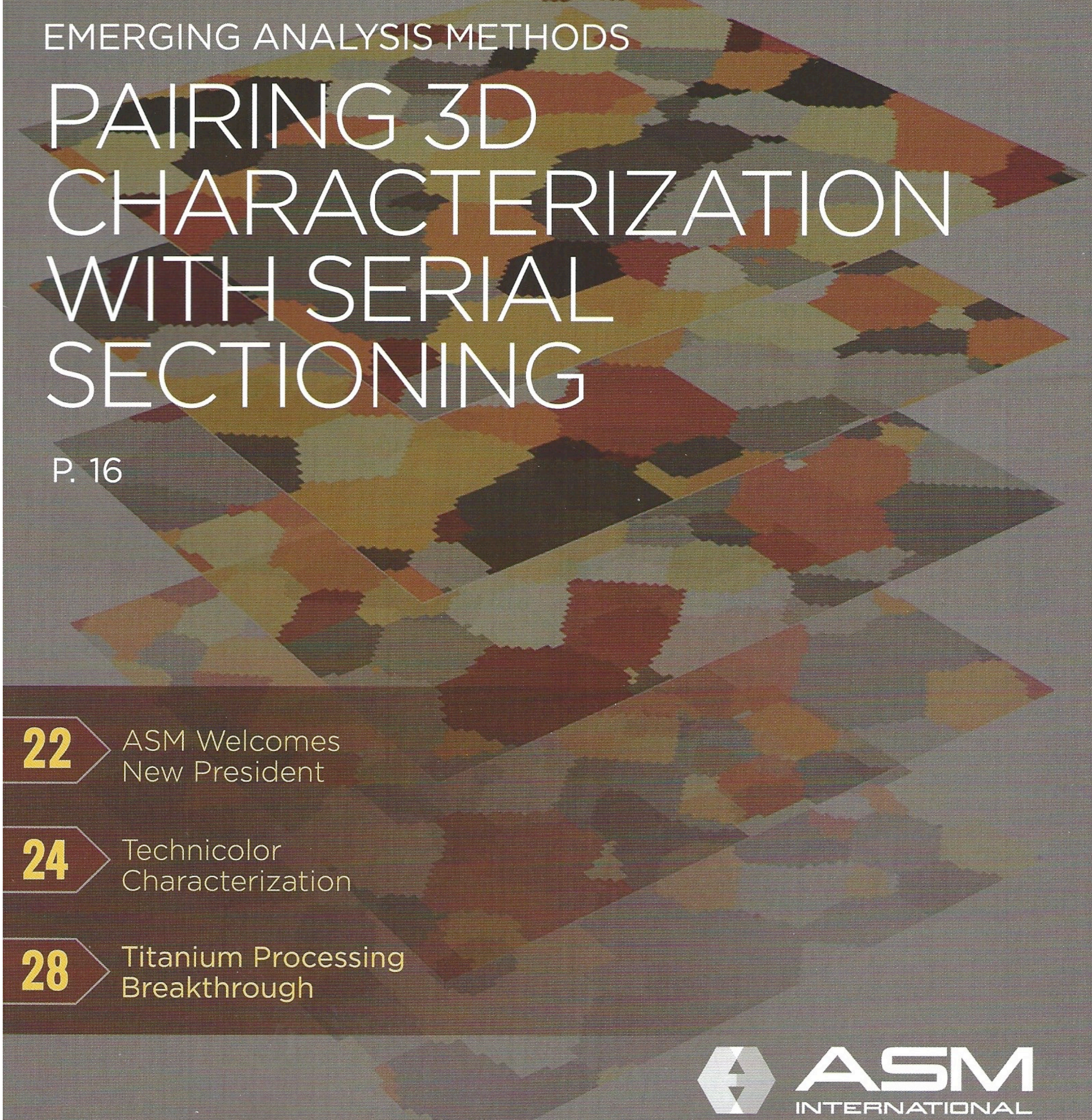
JANUARY 2020 | VOL 178 | NO 1

ADVANCED MATERIALS & PROCESSES

AN ASM MATERIALS SOLUTIONS PUBLICATION



EMERGING ANALYSIS METHODS

PAIRING 3D CHARACTERIZATION WITH SERIAL SECTIONING

P. 16

ASM INTERNATIONAL

TECHNICAL SPOTLIGHT

PROCESSING BREAKTHROUGH IMPROVES TITANIUM YIELD

A chance discovery is enabling significant efficiency gains in titanium conditioning, one of the most costly steps in titanium metal production.

When Jim Clasquin began experimenting with titanium, he was trying to solve a specific problem: How to precisely color code the titanium components used in medical implant surgery. What he ended up discovering was the first major cost-saving innovation for titanium processing in more than 25 years. This article summarizes Clasquin's journey.

Any product form that will fit in the tank can be conditioned by the MetCon process. As many pieces as the tank can hold can be treated at one time.

COLOR CODING SURGICAL KITS

Patients who need musculoskeletal replacements come in different sizes, so the titanium implant components and surgical tools must be sized accordingly. For maximum safety and efficiency, manufacturers have developed systems to assist in distinguishing the parts in a surgeon's kit for different sized patients and specific procedures. Color coding, which can be an important aspect of the differentiation, should be straightforward: Simply anodize the titanium implant components so they are color matched to the tools, instruments, and packaging. Yet the reality is not that simple.

Consider that the various components used in a joint replacement surgery may all be produced by different methods—forging, casting, or CNC machining—giving them different surface finishes. Unlike anodizing other metals where color is produced by surface dye coloration, anodization of titanium produces an oxide layer that determines the color. The carefully controlled, exceptionally thin oxide layer acts as a prism and the layer depth governs the color. Light bouncing off the layer interferes with light passing through it and reflected by the metal surface finish below. Because component surfaces vary depending on how they were produced, the light returned through the prismatic oxidation layer of titanium anodized parts is perceived as different colors by the human eye.

Clasquin, operating a surface finishing and color anodizing business for medical parts and other industries, struggled to produce matching colors for components with different finishes. During the day, he followed strict procedures required by his medical component customers. But after hours, he kept searching for a way to make the titanium surfaces uniformly smooth regardless of how they were manufactured in order to produce a uniform and matching color. He was familiar with methods of passivating stainless steel using mild acids and controlling titanium anodization with rectification, so this is where he started. His goal was to suggest alternative surface preparation methods for his customers to evaluate, potentially leading to better color anodizing procedures across the industry.

TREATING TITANIUM SURFACES

Because Clasquin is a chemical engineer, he never studied how to treat titanium surfaces, as many metallurgical engineers do. If he had, he would have been taught that titanium only reacts to aggressive acids that must be handled with specialized equipment and extreme caution. Due to the natural corrosion resistance of titanium and where the metal ranks on the electrochemical tables, it has long been accepted that only a small number of concentrated mineral or inorganic acids will have any effect on the metal. These acids, and hydrofluoric (HF) acid in particular, are among the most dangerous known. The acceptance of historical scholarly knowledge and the nature of these acids suggest limited incentive to explore alternative chemical means to treat titanium.

Electropolishing of titanium has long been a standard technique employed in labs to prepare titanium samples for metallographic study and analysis. However, the recognized titanium electrolytes used are even more dangerous than the HF pickling acid. Metallurgy students are taught as a matter of course to electrolytically micropolish their titanium samples using these acids. They also learn stringent safety procedures and how to employ the elaborate safety equipment that is mandatory with their use.

The procedures Clasquin began experimenting with were suggested by his knowledge of anodizing titanium and passivating stainless steel. These techniques employ weak acids and a range of electrical currents and voltages in open air without requiring hazardous material precautions. Eventually, after extensive experimentation, he noticed the titanium components he was treating were taking on a brighter, shinier, and more similar appearance, which encouraged him to conduct further trials and also to study the titanium literature. However, he could find no mention of similar processes yielding similar results. He also found no mention of any effective processes that were as safe and green as what he was doing. At this point, Clasquin decided it was time to find some backers, ideally people with a working knowledge of the titanium business who might be interested in funding further development efforts.

IMPROVED CONDITIONING

The search led him to Kurt Faller, a titanium industry consultant with metallurgical training and in-depth corporate experience in the titanium industry. In time, as Faller became more familiar with Clasquin's techniques, he realized

As forged incoming material displaying cracks and alpha case, requiring conditioning.

The same material fully conditioned by the MetCon process, ready for forging or rolling. Crack tips have been removed and more parent material is preserved than by traditional conditioning methods.

there were implications that went far beyond creating a uniform surface for medical components. What he saw was the opportunity to change one of the most time-consuming, wasteful and hazardous steps in the processing of titanium from ingot to mill products—the conditioning process.

Processing titanium from ingot to finished mill product form and size requires multiple steps in which the material is heated, reshaped by mill forging, mill rolling, or extrusion, then allowed to cool. Conditioning must be done after each step to remove the brittle, ceramic-like oxygen enriched phase of titanium called alpha case that covers the surface at high temperatures and the cracks that can extend into the material to a depth of 5% or more with cooling. Traditional subtractive conditioning methods—grinding, machining and acid pickling—remove 3 to 7 vol% of the piece being processed as waste during each step.

Faller knew it is the significant conditioning losses that largely drive the high cost of titanium, and anything that can improve yield is highly valuable. Based on preliminary analysis, he saw the potential to substantially increase the yield of each conditioning step, giving producers much more material to sell at virtually no extra cost. The potential cumulative yield improvement suggested a step change in the cost of making titanium. However, there were concerns: Would the process work as effectively on large metal forms? Was it scalable? Were the economics really as good as they seemed?

MetCon LLC, the company that Faller and Clasquin formed, answered these questions. In comparison to traditional methods the MetCon process removes much less material—just

0.5 to 3 vol% per step. The company is now processing a wide variety of titanium forms for titanium producers, from large forged slab, bloom, and billet to small cross section reroll stock, thin alloy sheet, and coiled wire. As producers have become more experienced with the new conditioning technology, they have learned how the improved material yield positively impacts their bottom line. Development has continued as the business has grown, and additional applications beyond conditioning have been demonstrated. One example involves careful material removal. The key process benefit of being able to remove precise amounts of surface material electrochemically allows the production of thin gauge, full size (36 x 96 in. and larger) titanium alloy sheets from 0.010 to 0.016 in. thick, which has not been possible with other methods.

The patented electrochemical process developed by MetCon reportedly improves ingot to finished product yield by 10% to more than 20% and represents the largest cost reduction breakthrough for titanium in over a quarter century. In addition, the process offers greatly accelerated throughput and is environmentally friendly, providing additional production cost and safety benefits. **~AM&P**

For more information: Kurt Faller, president and CEO, MetCon LLC, 1817-B Pennsylvania Ave., Monaca, PA 15061, 724.888.2172, kfaller@metconllc.net, metcon.net.

CONDITIONING PROCESS SAVES TIME AND COSTS

In contrast to grinding or machining, the MetCon electrochemical process takes place with the material submerged in electrolyte in a large tank. The material is subjected to a range of electrical currents and voltages that remove the alpha case and open the cooling cracks rounding and blunting the crack tips. The electrochemical process is inherently much faster than traditional mechanical grinding or machining. Because the piece is submerged, this process has the advantage of conditioning all surfaces simultaneously. In addition, multiple pieces (as many as the tank can hold) can be treated at one time.

Current tanks accommodate full heat quantities (conditioning an entire heat at one time is a breakthrough) and there are no technical restrictions to scaling the tank sizes larger. Material is ready for the next forming step five to 50 times faster than with traditional conditioning methods. Further, for operations that rely on pickling to reveal defects after grinding, the MetCon process eliminates the need for that step, cumulatively shaving weeks off the traditional processing time.