THE TRUTH BEHIND MECHANICAL POLISHED SURFACES

Author: Ken Kimbrel

It has been an unwritten rule for years that the best passive and corrosion resistant stainless steel surfaces will have a Cr/Fe ratio in excess of 1.5/1 which in many cases is easily achievable. It is also well known and standard practice in the Pharmaceutical Industry, the acceptable roughness average of material in production vessels and water systems is a 15-25Ra value, many times achieved through a mechanical polishing procedures. It is this procedure that in this writer’s opinion causes many of the problems experienced today with the formation of the “gray residue” and Class 1 rouge that has plagued end users for years.

The definition of mechanical polishing is a hand sanding process using various forms of abrasive media to remove scratches, gouges and other damage from the surface of materials. The media is applied to the surface using hand held power equipment resulting in surfaces compliant with ASME-BPE surface finish standards roughness average readings.

The truth of the matter however, is mechanical polishing is actually damaging the surface of stainless steel leaving behind scratches and contamination. This damaged surface is known as the “Bielby Layer” and is usually in the range of .003” to .005” in depth. (Figure 1).

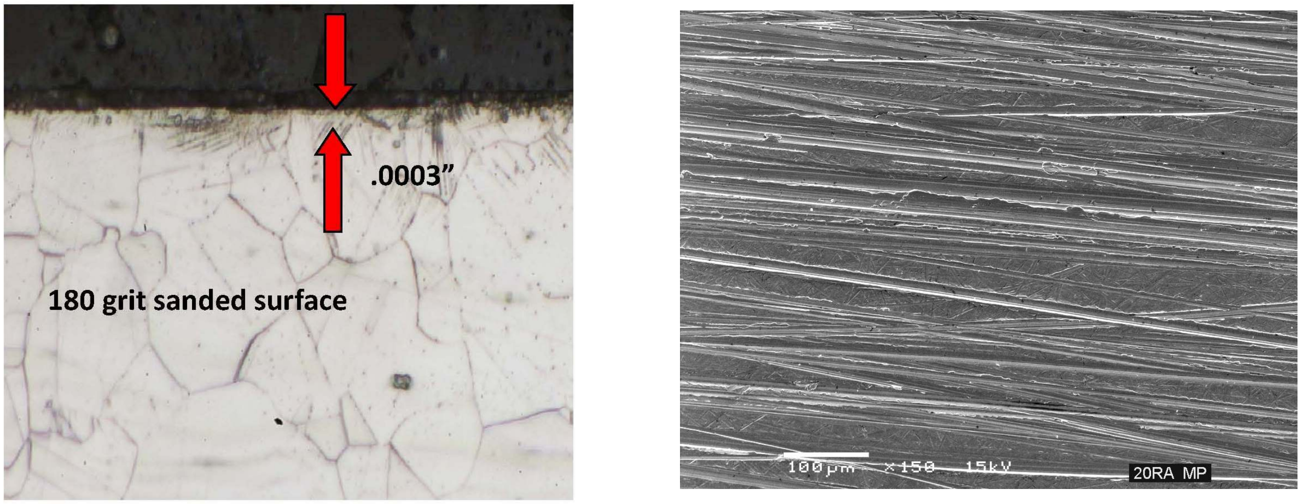


Figure 1

The damages in the upper most grains can be seen in the illustrations above. Both are a 180 grit mechanical polished surface reading a 20Ra using a profilometer, giving a clear indication of the actual surface left behind. In a study done by J. Wulf, this damaged layer was identified to have up 7 distinct layers. The illustration below, Figure 2, shows these results. This study looked at 3 distinct surfaces, honed, ground (or mechanically polished) and electropolished.

On the honed sample a layer of “Austenite and Cold Deformed Ferrite” sits atop of a layer of “Cold Deformed Ferrite” to a depth of 5 µm (.00002”). The ground sample had seven distinct layers of non-austenite material atop the pure stainless.

The seven layers top to bottom;

7. Oxide (0-5µm)

6. Deformed Oxide with Grit Inclusions (5-18µm)

5. Deformed Austenite (18-22µm)
4. Cold Deformed Ferrite and Deformed Austenite (22-25µm)
3. Cold Deformed Ferrite (25-29µm)
2. Austenite and Cold Deformed Ferrite (29-34µm) = (.00134”)
1. Austenite only

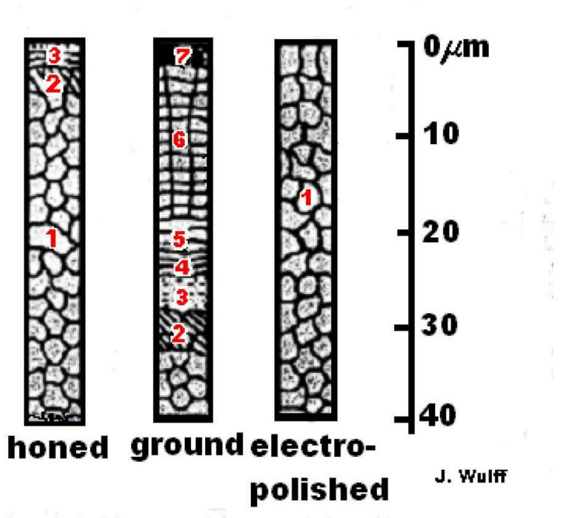


Figure 2

This study found the honed surface had up to three distinct layers; the mechanically polished surface had up to seven distinct layers while the electropolished surface demonstrated only one layer of pure austenite.

Looking back at the mechanical polishing illustration on the right in Figure 1, notice the layers of the material folded over on the surface. Studies have shown underneath the “folds” are trapped particles of abrasives, oxides, polishing compounds, dyes, greases and other contaminants all embedded in the distorted crystal structure. Studies further show, no amount of cleaning or passivation can remove these contaminants. Once the systems is placed into service and under normal operating conditions of heating and cooling cycles, does the material expand allowing these contaminants to release onto the surface and into the product stream.

With stainless steel being an alloy containing approximately 64% iron, it is only logical the grinding dust released during this process will contain iron particles being distributed and then deposited downstream on piping and equipment walls contributing to Class 1 rouge.

Electropolishing offers the ultimate product contact surface by providing an optimum micro-surface finish, a reduction in total surface area and providing pure alloy without contamination or damage at the materials product contact interface surface. Electropolishing surfaces offer optimum cleanability, sterility, corrosion resistance, and a reduction to rouge formation.

During the electropolish process, approximately .005” of material is actually removed from the surface of the steel. This ultimately removes all of the damaged layer and subsequent contaminants trapped under the smeared material on mechanically polished surfaces. (See Figure 3)

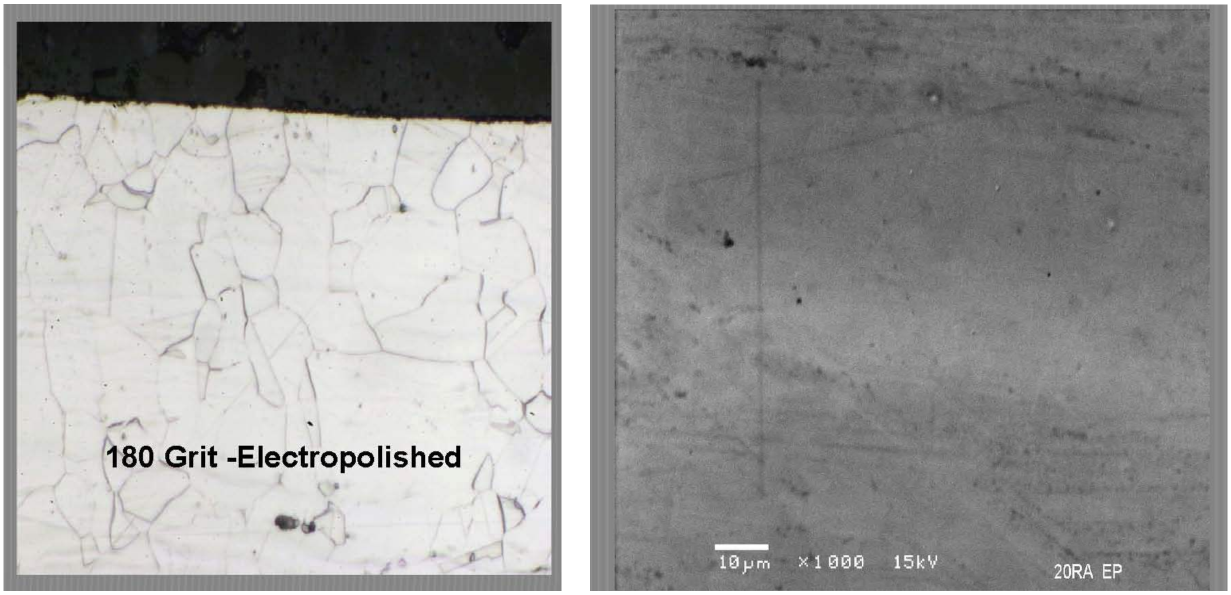
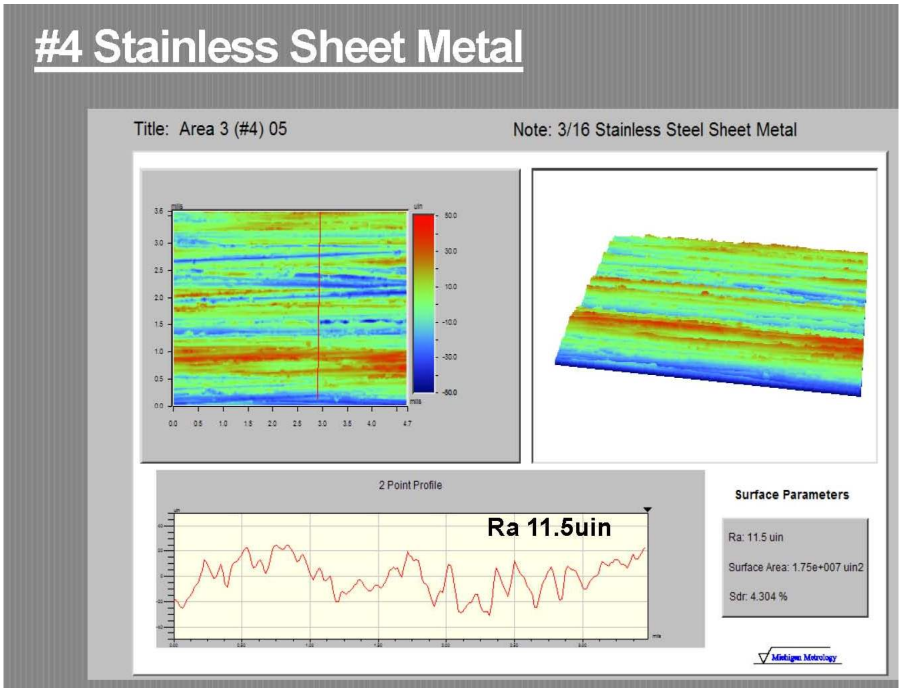


Figure 3

In addition to offering an ultraclean surface, electropolishing also offers a reduction in total surface area as shown in Figures 4 and 5. In these examples, samples were provided for a White Light Interfermetric Surface Analysis to look microscopically at the surface profile.



Title: Area 3 (#4) 05

Note: 3/16 Stainless Steel Sheet Metal

Surface Parameters

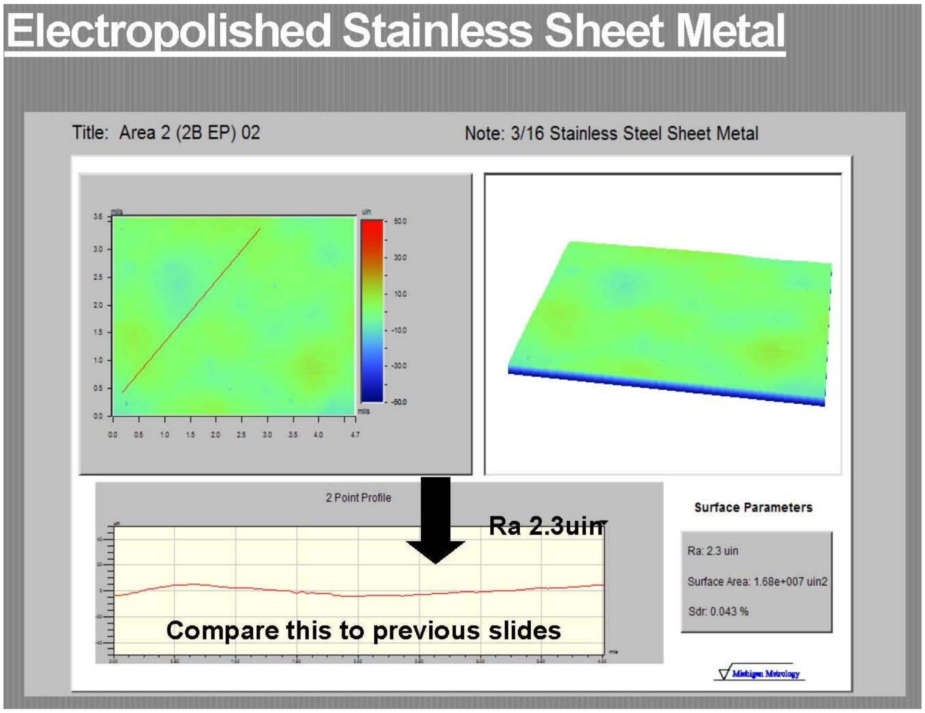
Ra: 11.5 uin

Surface Area: 1.75e+007 uin2

Sdr: 4.304 %

Figure 4 shows the cross section and surface profile on mechanically polish 11.5 Ra stainless steel sheet metal. The red line in the box shows the actual surface profile highlighting the peaks and valleys of the surface.

Figure 4



Electropolished Stainless Sheet Metal

Title: Area 2 (2B EP) 02

Note: 3/16 Stainless Steel Sheet Metal

2 Point Profile

Ra 2.3uin

Compare this to previous slides

Surface Parameters

Ra: 2.3 uin

Surface Area: 1.68e+007 uin2

Sdr: 0.043 %

Figure 5 shows the cross section and surface profile on mechanically polish 11.5 Ra stainless steel sheet metal followed by electropolishing to a final Ra of 2.3. The red line in the box shows the actual surface profile showing the lack of peaks and valleys of the surface and indicating a microscopic featureless surface, and reduction in the total surface area.

Figure 5

When comparing Figures 4 and 5, the improvement to the surface is undeniable. The surface area is reduced and the damaged layer from the mechanical polishing process is eliminated along with the sub-surface contaminants.

In addition to the obvious benefits to the surface via the electropolish process, ASTM B-912-02 specification recognizes electropolishing and electrochemical cleaning as an acceptable form of passivation. In order to meet ASTM-B-912-02 a Nitric Acid or Citric Acid and water passivation solution is applied at ambient temperature to a surface and is a very fast and effective alternative to conventional passivation procedures. Following passivation, a final rinse using DI water at ambient temperature is performed. Duration of the rinsing process will be determined by testing the water to ensure that the effluent conductivity is within 1μS of the influent.

In conclusion, processors must be more concerned with product contact surfaces well beyond the Cr/Fe ratio. By proper material selection and surface conditions, the actual need for repetitive passivation treatments to correct iron contamination and cleaning inefficiencies could be reduced.

The author:

Ken Kimbrel is Product Manager Special Alloys at VNE Corporation and the author of multiple technical papers. He attended Tulsa Community College and has an extensive background in engineering, equipment manufacturing, and is a NACE International Board Certified Corrosion Technician. He is Chair of the ASME-BPE, Past Chair of the sub-committee on Metallic Materials and the sub-committee on Surface Finish. He is a member of the International Society for Pharmaceutical Engineering (ISPE), ASM International,