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PEM® REF/ SURFACE FINISHING SHEET METAL ASSEMBLIES



SUBJECT: SURFACE FINISHING SHEET METAL ASSEMBLIES WITH SELF-CLINCHING FASTENERS

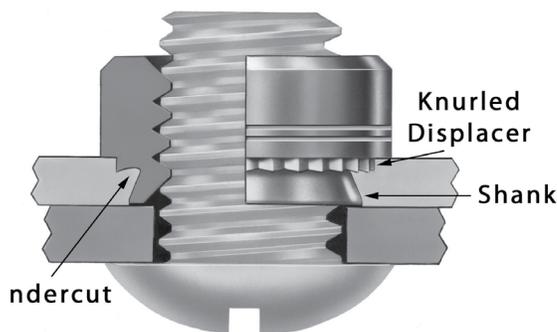
Introduction

Steel and aluminum panels in assemblies often will undergo surface finishing for reasons ranging from cosmetics to performance, while stainless steel panels may require passivation. For any assembly subject to surface finishing and requiring self-clinching hardware, a central question will arise: How and when should a metal panel be surface finished without degrading the installed performance of the self-clinching fasteners? A basic understanding about self-clinching fastener technology and the issues associated with surface finishing can help guide the way toward best practices.

In the discussion following, we will use the terms “assembly/assemblies” to mean panels and/or chassis with self-clinching fasteners already installed (unless noted otherwise.)

Basics of Self-clinching

Figure 1



Self-clinching fasteners provide permanent and reusable load-bearing threads in thin metal sheets and historically have been specified in sheet metal too thin to allow for secure fastening by any other method. Upon installation (usually during the fabrication process), they become integral parts of an assembly, will not loosen or fall out (even when the mating thread is removed), and never have to be restrained from rotation with a tool. Clinching of these fasteners is enabled by a non-round displacer feature, which embeds into the host panel and displaces panel material into the fastener's undercut. (See Figure 1.)

This results in the fastener's permanent attachment in a panel with the capability to withstand rotation (because of the non-round displacer) and axial force (because of the displaced panel material in the undercut). Panels must always be sufficiently ductile to cold flow without fracturing and fasteners must always be sufficiently harder than the panel to prevent fastener deformation, even as the panel is deformed during the installation process.

Although it is always preferable to avoid surface finishing an assembly after self-clinching fasteners have been installed, sometimes this approach may be necessary.

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Reasons why Assemblies may need to be Surface Finished

The first reasons involve the cosmetics / performance of the final assembly. These include:

- Concern for scratching or otherwise damaging a finished panel during installation handling.
- A desire to achieve the same color and texture on both the panel and the fasteners. When zinc plated (with clear chromate) fasteners are installed into a panel that has been zinc plated and clear chromated there is often a slight color variation because it is likely that both were not plated in the same process.
- Achieving surface properties on the fastener that are not present with the standard fastener finish. These may include low light reflectance, color fastness and “non-stick” properties for clean room applications.

A second group of reasons for needing to finish an assembly involves surface treatments on the panel that are detrimental to the self-clinching process if performed before fastener installation. These are less common and include:

- Hard-coat anodizing of aluminum panels and nitriding of steel panels. These panel treatments increase the hardness and decrease the ductility of a panel’s surface - making the panel surface more resistant to the cold flow required during installation of a self-clinching fastener.
- Powder coating a panel too, becomes an issue because the typical coating thickness prevents full installation of the displacer feature on the fastener. In essence the fastener will “clinch” in to the coating and not into the metal.
- Thin brittle platings such as hardened electroless nickel will also prove problematic. These platings can crack and/or flake off from the severe deformation they must undergo during fastener installation.
- Thick hot dip galvanizing will likely exhibit some of both the hard panel and brittle plating issues discussed here.

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Hazards of Surface Finishing Assemblies

Now let's examine the potential hazards involved in finishing a panel or chassis that already has fasteners installed.

Since most surface finishing processes are wet processes, we will focus our discussion in this area.

There are three primary types of these hazards:

- **The first hazard: Fastener damage from an incompatible finishing process.**

An extreme example is installing a steel fastener into an aluminum panel and then anodizing the assembly. The anodizing solution will almost totally destroy the steel fastener.

Sometimes the incompatibility will be less obvious. A frequently reported issue involves zinc plating a steel panel with steel fasteners installed. Since both are steel a typical presumption is that a plating process appropriate for the panel is also appropriate for the fasteners. This may not be the case. Steel panels are typically low carbon steel in a slightly work hardened condition – generically cold rolled steel. Because self-clinching fasteners must be harder (typically by about 20 points on the HRB or HRC scale) than the host panel, most steel fasteners are heat treated.

Important to note here is that fasteners can be produced using either heading/forming or machining processes.

Fasteners produced by heading or forming are low carbon steel that have been neutral hardened (aka through hardened) and generally are not difficult to electroplate.

However, steel fasteners produced by a machining process are typically low carbon free machining (re-sulfurized and re-phosphorized) leaded steel which has been carburized (or case hardened). Typically, this will cause high carbon and numerous inclusions on the fastener surface. As a result these fasteners may experience degradation during a pre-treatment that is designed solely for cold rolled steel. The fasteners may also be susceptible to hydrogen embrittlement from exposure to atomic hydrogen during acid cleaning or electroplating. Another example of an incompatible process is a panel treatment such as nitriding whose temperatures may be detrimental to the fasteners.

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- **The second hazard: Unique to wet processing it involves trapped caustic solutions.**

Figure 2



The fastener-to-panel connection is all metal and may not always be liquid tight. Although this joint may be water tight in the classic sense of preventing liquid from passing through, there are almost always crevices, particularly on the shank side of the fastener which can trap processing solutions. A typical example is a self-clinching standoff. (Note the crevice beyond the fastener head as shown in Figure 2)

When processing solutions become trapped, troubles follow. If the solution is caustic, the solution will continue to attack the surrounding metal which can degrade the strength of the clinch connection and/or cause a cosmetic problem on the surface of the panel and/or the fastener. Even if effective rinsing renders any trapped solutions non-caustic, their entrapment under the finish can flash to steam -- causing the plating to bubble if the assembly is subsequently heated above the boiling point of the trapped liquid.

- **The third hazard: Tight threads from excessive plating build up in the threads.**

This plating buildup effect will cause "tight" or non-gageable threads. Most self-clinching fastener manufacturers produce threads in their steel parts with the appropriate allowance to accept the plating thickness that is provided as standard. Common plating thickness is a minimum of .0002 inch (5 microns) which allows for a maximum plating thickness of .0004 inch (10 microns). But this value should always be confirmed with the fastener manufacturer and never assumed. Even if the allowance is known, plating an assembly can still present pitfalls. If the fasteners were previously plated, the plating must be completely stripped from the threads in order for the original allowance to be available for the re-plating. It is also important to note that stainless steel and aluminum fasteners typically have no thread allowance for any type of additive plating or coating.

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Table I

Commonly Cited Reasons For Surface Finishing a Panel Only After Self Clinching Fasteners Have Been Installed	Alternative Techniques Allowing For Panel Finishing Before Fastener Installation
To avoid damaging panel finish during fastener installation	<p>Mitigate potential for panel damage by breaking sharp edges on all contact tooling (installation punches and anvils) and covering or radiusing all corners and edges of fastener feed tooling. Develop procedures for operating handling of panels.</p> <p>Choose a more damage resistant panel finish</p>
To achieve same appearance on panel and fasteners. Concern over variations in hue between zinc plated panels and zinc plated fasteners is common.	<p>Ask the surface finisher who plates the panel to match the fastener.</p> <p>Purchase unplated fasteners and have them plated by the panel surface finisher.</p> <p>Ask the fastener manufacturer to match the plating on the panel.</p>
To achieve a special purpose finish on the fastener. An example is a very specific color definition associated with a product brand.	<p>Ask the fastener manufacturer to supply the special purpose finish.</p> <p>Purchase unplated fasteners and have the special-purpose finish applied by the panel surface finisher.</p>
Surface finish will make the outer surface of the panel too hard and/or too brittle for self-clinching. Examples include hard coat anodizing of aluminum panels or nitriding or other surface hardening of steel panels.	<p>Mask the mounting hole ID and an annular ring around it on the side from which the fastener will be installed.</p> <p>If high hardness is the only issue, check with fastener manufacturer about purchasing a higher hardness fastener.</p> <p>Consider alternate means of fastener captivation, such as broaching instead of self-clinching.</p> <p>If fastener is a nut which does not need to be flush on the shank side, a blind threaded insert can be used.</p>
Additive coating is too thick to allow full installation of the displacer component of The self-clinching fastener. Examples include powder coating or very thick paint.	<p>Mask the mounting hole ID and an annular ring around it on the side from which the fastener will be installed.</p> <p>Purchase a special self-clinching fastener with an intentionally oversized displacer height.</p>
Additive plating or coating is too brittle to deform without fracturing during fastener installation. Hardened electroless nickel plating is one example.	<p>Mask the mounting hole ID and an annular ring around it on the side from which the fastener will be installed.</p> <p>Thermally treat the coating to increase ductility.</p> <p>Choose a more ductile coating with similar corrosion resistance and appearance.</p>

Table 1 - outlines alternative techniques to installing fasteners before finishing.

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Guidance for Mitigating the Hazards

When valid reasons to surface finish an assembly and none of the avoidance techniques (see Table I) are feasible there are ways to plate an assembly successfully with self-clinching hardware already installed. While some issues may arise, the following guidelines can help optimize outcomes.

- **Anodizing or Conversion Coating Aluminum Panel Assemblies**

For non-heat treatable aluminum alloy panels such as 5052, aluminum fasteners, (which are always made from a heat treatable aluminum alloy) can be used. In these cases, the entire assembly can be anodized or given a conversion coating.

Typically there are no major issues with assemblies processed in this manner as long as rinsing is adequate to eliminate potentially trapped caustic solutions. It should be noted that when aluminum assemblies are clear anodized, the fasteners may have a slightly different appearance (usually darker) after anodizing due to the alloying elements present in the fasteners. Common alloys for aluminum fasteners are 2024 in the T4 condition and 7075 in the T6 condition. Although marginal on strength for clinching, 6061-T6 is used for some aluminum fastener components not containing the clinch feature.

Panels made from heat treatable aluminum alloys in the hardened condition are typically too hard for aluminum fasteners which have a maximum panel hardness limit of HRB 50. As a result 300 Series stainless fasteners are often specified. When this is the case, the assembly cannot be anodized, but a conversion coating can be applied. Experience has shown that the conversion coating process may need to be adjusted slightly to keep the stainless fasteners from darkening. Darkening of the 300 series fasteners is most common with machined fasteners using type 303 (UNS S30300) which has high sulfur content for improved machinability. The high sulfur content reduces corrosion resistance and makes this alloy more susceptible to darkening. The adjustment will involve making the acid etch step (prior to the actual chromate conversion step) less aggressive.

- **Electroplating Steel Panel Assemblies.**

The most common practice with steel panels is to use steel fasteners and the most common surface finish on steel panels is zinc electroplating. However, these recommendations are also applicable to electroplating with other increasingly popular metals or alloys such as zinc-nickel or tin-zinc. The lowest risk procedure will be to plate the panel first and then install plated fasteners.

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When this can not be done, the second lowest risk procedure is to purchase unplated steel fasteners, install them and then plate the assembly. This eliminates the need to strip the zinc plating from the fasteners which could potentially damage the surface of the fastener. Unfortunately unplated fasteners are typically not stocked and therefore their use requires appropriate planning, but does have the benefit of not needing to strip the fasteners.

When plated fasteners are used, extreme care must be used in stripping the plating from them. Case hardened fasteners are particularly susceptible to acid damage during stripping because of the high carbon content of their surface. A contributing factor is that many inhibitors used in acids are much less effective in preventing attack of high carbon steels than they are in preventing attack of low carbon steels, such as the typical cold rolled steel panel. Through- or neutral-hardened fasteners are only slightly more susceptible to acid attack than cold rolled steel and, generally are not damaged by acid during stripping and re-plating an assembly.

All case hardened parts and high hardness through hardened parts are susceptible to hydrogen embrittlement and should be appropriately baked after plating, unless it can be established with certainty that a particular plating process is not embrittling to a particular fastener. Fasteners used in tension, such as a self-clinching stud in a critical application, should always be appropriately baked for hydrogen relief if the hardness is at or above the value at which the applicable plating standard requires baking. (The fastener manufacturer can be consulted for fastener hardness values to determine the need for baking and the appropriate baking process parameters.)

Although less common, 300 series stainless steels are sometimes used in steel panels. Because the process needed to electroplate 300 series stainless steel is so different from the process for plating a carbon steel panel, attempts to plate an assembly of a steel panel with 300 series stainless steel fasteners are rarely - if ever - successful. (The most common problem is poor plating adhesion on the fasteners.)

Adequate rinsing is the best way to manage the hazard of trapped solutions. In some cases a neutralizing soak is the most effective way to ensure that any retained solution is not caustic. Many assemblies are rack plated and the orientation of the fastener is important. Shank down is the preferred orientation and shank up is the worst orientation. Some fasteners with complicated geometry are made from alloy steel powdered metal and are particular susceptible to retained solutions because of the porosity of the base metal. A porosity sealant is typically used and alleviates this problem, but may not totally eliminate it.

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- **Passivating Stainless Steel Panel Assemblies.**

An important consideration in passivating stainless steel assemblies is choosing a passivation process that is appropriate for both the panel alloy and the fastener alloy. The most common stainless steel panel alloy is type 304, with type 316 also used, but less frequently. Because of the required differential hardness, self-clinching fasteners used in type 304 or 316 panel will not be 300 series. When corrosion resistance is not a controlling requirement, fasteners from type 410 or type 416 stainless steel offer a cost effective solution. When greater corrosion resistance is needed a precipitation hardening grade such as 17-4 (UNS S17400) or A286 (UNS S66286) will be used for the fastener. Regardless, if an assembly must be passivated the fastener manufacturer should be consulted for the exact alloy of the fastener for proper guidance relative to industry standards. As an example, SAE AMS 2700 can be used to find a passivation process valid for both the panel alloy and the fastener alloy. Table 4 of AMS 2700 shows that method 1 (Nitric Acid) types 1, 2, or 3 are applicable to any combination of 304 or 316 panel and 410, 416, 17-4 or A286 fastener. Note that method 1 type 6 although applicable to and commonly used for type 304, is not applicable to any of the above fastener alloys and therefore should not be used for an assembly.

- **Paint or Powder Coating Assemblies (Any Material).**

With the possible exception of very thin paint, paint or powder coatings are too thick for the standard thread allowance of self-clinching fasteners. Therefore threads should be masked prior to painting or powder coating an assembly. In some cases fasteners can be ordered with mask pre-applied from the manufacturer. For example PEM® Blu-Coat™ is available from PennEngineering for this purpose. Other options include plugs and caps specifically designed for this purpose to mask internal and external threads respectively. Both are commercially available in a variety of sizes suited for thread masking. However, masking with caps and plugs can create multiple crevices for entrapping solutions if they are applied before any wet process pre treatment step. Ideally they should be applied after any wet processing. (A heavy layer of grease applied to the threads can also serve as an effective mask, but the grease must be capable of surviving the pretreatment or be applied after pretreatment.)

Trapped solutions from wet process pretreatment represent a real concern. Even if effectively neutralized to be non-caustic, if they remain in a crevice or metal pore and the paint or powder coating is applied over them, there is a risk of their flashing to steam during a subsequent heating process, especially during the curing cycle for powder coating. Flashing to steam causes volume expansion which can cause the coating to bubble and burst, leaving a blemished surface. The risk can be mitigated by hot air drying between pretreatment and painting or powder coating.

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Another item to check is the effect of the paint or powder coating curing temperature on the strength of the fastener. Generally this is not a problem with heat treated steel fasteners as most can withstand at least 600°F with no permanent reduction in strength. Type 410 and 416 stainless steel fasteners are most susceptible in this regard and could begin to see a permanent reduction in strength if exposed to temperatures over 300°F (150°C). 300 series stainless steels and precipitation hardening stainless steels used for fasteners are even more robust in this regard - typically not seeing any permanent strength reduction unless exposed to over 900°F (482°C). If the curing cycle (time and temperature) is supplied to the fastener manufacturer they should be able to comment on any strength reduction effect it will have on their fastener.

- **Nitriding Ferrous Panel Assemblies**

Steel and stainless steel or any other ferrous metal panel can be nitrided. Although nitriding is actually a form of case hardening it is sometimes used as a means of applying a durable black surface finish.

Nitriding is a specialized form of heat treatment performed mostly by highly specialized shops. When the need arises to nitride an assembly, the fastener manufacturer should first be consulted for the fastener alloy and heat treatment. That information should then be provided to the nitriding shop (along with the panel alloy to determine if there is a process that will be compatible with both alloys).

If the alloys exhibit significantly different carbon content, the difference in critical temperatures may be a problem. The effect of nitriding on corrosion resistance of some stainless steel fastener materials also needs to be evaluated. Similarly, the effect of nitriding on the ductility of any ferrous fastener material should always be evaluated, as it typically has a negative effect.

In conclusion

While finishing a panel before installing self-clinching fasteners will always be the preferred process, these guidelines can help reduce inherent risks. There are many combinations of panel material, fastener material, and surface finish - even more than outlined here. Ultimately, the best practice is to consult the fastener manufacturer to ascertain the specific details on the fastener material and seek expert advice about the particular combination of finish and fastener, based on real-world experience. Surface finishers, too, can serve as key sources for technical information and relevant guidance.

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Summary / Index of Panel and Fastener Combinations for Assembly Finishing

Panel Material and Finish	Fastener Material			
	Aluminum	300 Series Stainless Steel	Steel	400 Series & PH Stainless Steel
Aluminum/Conversion Coated	See page 6	See page 6		
Aluminum/Anodized	See page 6			
Steel/Electroplated			See page 6	
Steel/Powder coated or painted		See page 8	See page 8	
Steel/Nitrided		See page 9	See page 9	
300 Series Stainless Steel/ Passivated				See page 8

Color Key:



Can be plated as an assembly with caution - see listed page



Not a compatible combination for self-clinching



Not a compatible combination for finishing as an assembly



Not a cost effective combination - seldom if ever done