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Chrome plating: A guide for selecting the type of chrome plating for use in contact with Bal Seal® spring-energized seals in rotary and reciprocating service

Technical Report

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Contents

1.0 Summary

This report outlines the types of chrome plating available, including their advantages, disadvantages, and effects on Bal Seal® spring-energized seal performance in order to make the proper chrome plating selection for use with Bal Seal® spring-energized seals in rotary and reciprocating services. Thin dense chrome plating provides superior properties over hard chrome plating for use in contact with Bal Seal® spring-energized seals in rotary and reciprocating services.

2.0 Purpose of Chrome Plating

Chrome plating is generally used for one of two purposes: for decorative uses or for engineering purposes. This report deals with the engineering uses of chrome plating and its effect on Bal Seal® spring-energized seal performance in rotary and reciprocating services.

Chrome plating is used to provide a very high degree of hardness on the surface of a metal to enhance wear resistance, reduce friction, provide anti-galling properties, and, in some cases, improve corrosion resistance. Chrome plating is an electrolytic process that can be applied to regular steel, stainless steel, aluminum, and other materials. This report details the application of chrome plating to various steel surfaces.

3.0 Types of Chrome Plating

There are two basic types of chrome plating: hard chrome plating and thin dense chrome plating. Hard chrome plating leaves a layer of chrome from 0.0008 to 0.0050 in. (from 0.020 to 0.127 mm) thick on the surface of the metal. In contrast, thin dense chrome plating has a thickness from 0.0002 to 0.0006 inch (0.005 to 0.015 mm). The thickness of chrome plating varies depending on the application.

Chrome plating can be used over a wide temperature range from –70 °F to 800 °F (–57 °C to 427 °C) and can withstand pressures up to 30,000 psi (2068 bar). The temperature and pressure limits depend on the type of chrome plating, material substrate, and operating conditions. In most cases, thin dense chrome plating will provide better performance because of its greater resistance to fatigue.

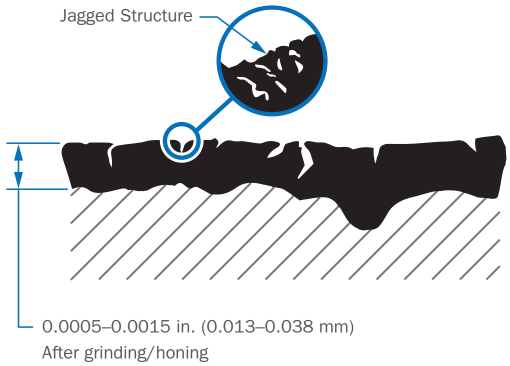

Figure 1.

Magnified section (50X) view of a hard chrome-plated surface per SAE-AMS-QQ-C-320, Class 2E showing jagged structure.

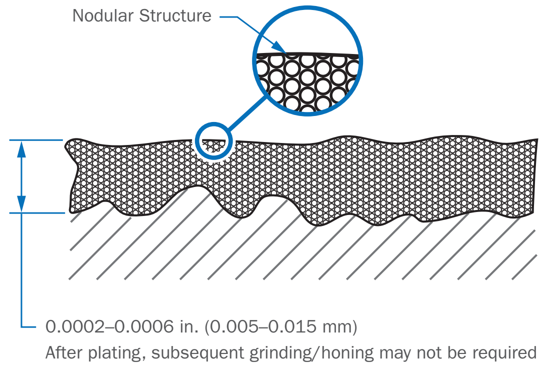

Figure 2.

Magnified section (50X) view of a thin dense chrome-plated surface per MIL-DTL-23422, Class 2 showing nodular structure.

Figures 1 and 2 illustrate typical magnified surface cross sections of hard chrome plating and thin dense chrome plating.

3.1 Hard Chrome Plating

Hard chrome plating is used in applications where parts will be subjected to a very high degree of wear, requiring a thicker layer of chrome. The added thickness induces cracks and greater porosity on the chrome surface. The cracks increase as the chrome thickness increases. Further machining, such as grinding, polishing, or honing, is necessary to improve the hard chrome-plated surface so that it can be used in contact with Bal Seal® spring-energized seals. A coarse surface finish significantly decreases the wear resistance of the Bal Seal® spring-energized seal.

Hard chrome plating is used in approximately 95% of all applications with the remaining 5% of applications using thin dense chrome plating (refer to Table 1 on page 8). Hard chrome plating is generally applied to exterior surfaces where subsequent machining is easier.

Bal Seal® spring-energized seals operate best against a hard chrome-plated surface when used with a lubricant, which promotes a film between the plated surface and the seal surface. The lubricant can be wet, dry, or a combination of both. Wet lubricants may need to be applied on the chrome-plated surface at low speeds under 500 ft/min (152 m/min), pressures under 50 psi (3.2 bar), and temperatures under 70 °F (21 °C) to fill in the surface irregularities and subsequently reduce seal adhesion.

3.2 Thin Dense Chrome Plating

Thin dense chrome plating is a process that results in improved fatigue life, smoother surface finish, and higher corrosion resistance. Because the layer is very thin, from 0.0002 to 0.0006 in. (from 0.005 to 0.015 mm), and dense, it does not have the porosity, large crevices, or openings that are found in conventional hard chrome plating; therefore, thin dense chrome plating provides improved corrosion resistance.

Thin dense chrome plating is applied to interior surfaces and inside diameters. It allows for closer tolerances, better surface finishes, and better uniformity, and it tends to reduce or eliminate subsequent grinding or honing of the plated surfaces.

Thin dense chrome plating is applied very slowly in comparison with hard chrome plating. It has much greater density and higher hardness at approximately 70 HRC versus 65 HRC for hard chrome plating.

Prior to plating, the surface should be as smooth as possible and should not exceed 10 µin. RMS (0.229 µm Ra). After plating, stress relieving may be necessary to reduce stress cracking.

Thin dense chrome plating is recommended over hard chrome plating when in contact with Bal Seal® spring-energized seals, but it is much thinner than hard chrome plating and may tend to wear through at high speeds. Wet lubrication is recommended as a means to provide reduced friction and improved wear resistance of the mating surfaces.

Dry lubrication is not recommended on thin dense chrome plating. Because the plating is very smooth, the dry lubricant cannot be secured to the plated surface.

3.3 Electrolyzing Process Using Thin Dense Chrome Alloy

A proprietary chrome plating process developed by the Electrolyzing Company deposits an extremely hard, thin, dense, and non-magnetic alloy on the surface of the base metal. The metal deposited is a high chromium alloy that provides very high wear resistance, low coefficient of friction, high corrosion resistance, excellent anti-galling properties, high hardness (70–72 Rockwell C), and an extremely smooth surface finish. Of all the chrome plating methods, this process seems to provide the highest hardness. The surface finish is smooth with a nodular structure compared with the rough-jagged finish of conventional hard chrome plating. These two factors, hardness and surface finish, lead to a great improvement in wear resistance. The lack of any cracks or crevices in the plating gives it a high resistance to corrosion. Electrolyzing Company reports coefficients of friction from 0.04 to 0.09 with this thin dense plating alloy.

4.0 Cost Considerations

Thin dense chrome plating is usually higher in cost than hard chrome plating because it uses a bath with a fluoride catalyst. This fluoride catalyst can attack unmasked metal parts. The cost varies depending on the amount of masking and setup required. Hard chrome plating may cost anywhere from equal to half the cost of thin dense chrome plating.

5.0 Specifications for Chrome Plating

Whenever possible, chrome plating should be processed to these specifications to ensure greater quality control.

5.1 Hard Chrome Plating – Specification SAE-AMS-QQ-C-320, Class 2E

Specification SAE-AMS-QQ-C-320, Class 2E is the most widely used for hard chrome plating for dynamic services. It is recommended for use in contact with Bal Seal® spring-energized seals whenever the application involves long-term service. This specification has the following general requirements:

a. Proper cleaning of parts must be done prior to plating.
b. Shot peening must be done to ensure better bonding with greater resistance to fatigue.
c. Baking at 375 °F (190 °C) must be done immediately after plating to reduce hydrogen embrittlement, increase strength, and reduce cracks.

5.2 Thin Dense Chrome Plating – Specification MIL-DTL-23422, Class 2

This specification has some restrictions by the Department of Defense and may not be available.

a. Proper cleaning of parts must be done prior to plating.
b. Surface finish must be from 4 to 10 µin. RMS (from 0.102 to 0.254 µm Ra) prior to plating with no visible nicks, marks, or inclusions.
c. Surface after plating should be homogeneous, uniform in color, and free of blisters, pinholes, pits, and nodules. It should exhibit no cracks under 150X magnification.
d. Stress relieving may be deleted if parts are not subjected to stress concentrations to provide better wear resistance.

6.0 Base Metal Hardness and Surface Finish Prior to Plating

Chrome plating can be applied to either a soft or a hard surface. The harder the surface is, the greater the adherence and the better the plating will be. It is recommended that the surface has a hardness of RC 40 or higher to comply with Specification SAE-AMS-QQ-C-320, Class 2E. If a softer surface must be used, it should be plated to Specification SAE-AMS-QQ-C-320, Class 2E. With conventional hard chrome plating, a rough surface from 16 to 31 RMS (from 0.406 to 0.787 µm Ra) is required prior to plating. Thin dense chrome plating requires a smooth surface finish before plating, because the amount of chrome to be applied is minimal. The better the surface finish prior to plating, the smoother the surface finish after plating. In all forms of chrome plating, the material must be clean. Small amounts of contaminants or hard particles, such as from grinding operations left embedded in the metal surface, will affect the fatigue life of the plated part.

7.0 Operating Conditions Affecting Selection of Chrome Plating Methods

When selecting the proper type and class of chrome plating to be used, one must consider both the following conditions under which the parts will be used and the required design specifications, including:

a. Is the base metal compatible with the method of plating to be used?
b. How much friction and abrasion will be experienced?
c. At what speed, temperatures, and pressures will the parts operate?
d. How much corrosion resistance is required?
e. What lubrication will be available?
f. How important are anti-galling characteristics?

Although the cost of thin dense plating is much higher than conventional hard chrome plating, thin dense plating should be considered if it facilitates proper design operation. Cost considerations become secondary to safety considerations, especially in critical applications such as in the aircraft and medical industries where thin dense chrome plating is often specified.

Table 1 (See page 8) details the main forms of chrome plating, including the properties of each form and base metal requirements such as hardness, surface finish, and surface preparations.

8.0 Effects of Plating on Bal Seal® Spring-Energized Seal Performance

The life of Bal Seal® spring-energized seals in contact with chrome plated rotary or reciprocating shafts is affected by the hardness and surface finish of the shaft material. By chrome plating a shaft to improve the hardness, the seal life is greatly extended. Increased hardness reduces adhesion between the metal part and the seal; therefore, increasing Bal Seal® wear resistance.

9.0 Lubrication of Mating Surfaces

Lubrication is important, especially under high-speed and high-pressure conditions where lubricant breakdown may occur. Bal Seal® spring-energized seals are self-lubricating, significantly reducing the need for additional lubrication. However, wet lubricants provide a lubricating film, which tends to carry heat away and thus reduces friction. Dry lubricants are desirable when filling the cracks and surface irregularities on hard chrome surfaces. These dry lubricants reduce seal abrasion.

10.0 Electroless Nickel Plating as an Alternative to Chrome Plating

Electroless nickel plating is generally used for housing/bore or parts with intricate shapes. This type of plating deposits a uniform coating of approximately 0.0003–0.0008 in. (0.0076–0.0203 mm) onto the surface. The hardness of electroless nickel plating is 48–52 HRC for non-heat treated and 58–64 Rockwell C for heat-treated to 750 °F (400 °C) for one hour. After plating, polishing of the surface is required. Electroless nickel plating provides better corrosion resistance than chrome plating.

Table 1: Various Types of Chrome Plating: Properties and Applications

<table>
<tr><th rowspan="2">Type of Chrome Plating</th><th colspan="2">Plating Thickness</th><th colspan="2">Shaft or Bore Surface Hardness After Plating</th><th rowspan="2">Typical Shaft or Bore Materials</th><th rowspan="2">Shaft Or Bore Hardness Prior To Plating (Approximate, Rockwell C)</th><th colspan="3">Surface Finishes</th><th rowspan="2">Applications</th></tr>
<tr><th>As Deposited</th><th>After Grinding/ Honing</th><th>Vickers Hardness Number</th><th>Rockwell C Scale Equivalent</th><th>Before Plating</th><th>As Plated</th><th>After Grinding/ Honing/ Polishing</th></tr>
<tr><td rowspan="4">Hard chrome plating per SAE-AMS-QQ-C-320, Class 2E, for use on soft shaft materials</td><td rowspan="4">0.008–0.005 in.
(0.020–0.127 mm)</td><td rowspan="4">0.0005–0.0015 in.
(0.0013–0.038 mm)</td><td rowspan="4">746–800 HV</td><td rowspan="4">62–64 RC</td><td>303 SS, 316 SS, Nitronic 50 and 60</td><td>28</td><td rowspan="4">16–24 RMS
(0.366–0.550 µm Ra)</td><td rowspan="4">16–24 RMS
(0.366–0.550 µm Ra)</td><td rowspan="4">4–8 RMS
(0.091–0.183 µm Ra)</td><td rowspan="3">For general-purpose applications where a hard surface of low friction and good wear resistance is required. Class 2C plating is used on soft materials with a Rockwell C hardness <40</td></tr>
<tr><td>SAE 1020</td><td>20</td></tr>
<tr><td>Alloy steel A-286</td><td>30</td></tr>
<tr><td>Heat treated materials 17-4 PH, 15-5 PH</td><td>44</td><td rowspan="4">The most commonly used chrome plating is Class 2E for long-term service when plating hardened shafts or bore materials with a Rockwell C hardness >40.</td></tr>
<tr><td rowspan="3">Hard chrome plating per SAE-AMS-QQ-C-320, Class 2E, for use on hardened shaft or bore materials</td><td rowspan="3">0.008–0.005 in.
(0.020–0.127 mm)</td><td rowspan="3">0.0005–0.0015 in.
(0.0013–0.038 mm)</td><td rowspan="3">746–800 HV</td><td rowspan="3">62–64 RC</td><td>SAE 1045</td><td>58</td><td rowspan="3">16–24 RMS
(0.366–0.550 µm Ra)</td><td rowspan="3">16–24 RMS
(0.366–0.550 µm Ra)</td><td rowspan="3">4–8 RMS
(0.091–0.183 µm Ra)</td></tr>
<tr><td>Alloy steels 4140, 4340</td><td>50</td></tr>
<tr><td>D-2 Tool Steel 440C</td><td>62</td></tr>
<tr><td rowspan="4">Thin dense chromium plating per MIL-DTL-23422, Class 2, anti-galling Types I through VI, depending on the shaft or bore material. SAE-AMX 2438</td><td>0.0002–0.0006 in.
(0.005–0.015 mm)</td><td>0.0002–0.0006 in.
(0.005–0.015 mm)</td><td>1176–1245 HV</td><td>70–72 RC</td><td>Type I: Austenitic stainless steels, e.g., 304, 316</td><td>28</td><td rowspan="4">4–8 RMS
(0.091–0.183 µm Ra)</td><td rowspan="4">4–8 RMS
(0.091–0.183 µm Ra)</td><td rowspan="4">4–8 RMS
(0.091–0.183 µm Ra)</td><td rowspan="4">Applications requiring excellent corrosion resistance, low friction, anti-galling properties, and high hardness; used in moderate service conditions; little or no further polishing or honing is required after plating.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Type II: Martensitic stainless steels, e.g., 17-4 PH, 15-5 PH, after hardening</td><td>44</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Type IV: Carbon and low alloy steels, e.g., 4340 after hardening</td><td>50</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Type VI: Precipitation hardening steels, e.g., A-286</td><td>30</td></tr>
</table>

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11.0 References

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