White Paper

FORMING AND CRAZING OF ANODIZED ALUMINUM

Introduction

All anodized aluminum can experience crazing when subjected to extreme temperatures and severe forming. This article will explain how anodized aluminum can be formed to minimize crazing of the oxide layer. It will also describe the differences between crazing and cracking of anodized aluminum .

What is anodize crazing?

Anodize crazing is a term used to describe micro fracturing of the anodic layer after anodized aluminum has been subjected to forming, fabrication, and in most cases, extreme heat or cold. Crazing can sometimes be confused with "cracking" of the aluminum. This will be explained in more detail later in this article. Crazing that can be seen with the naked eye at certain angles and will appear frosted or dull in appearance. This type of anodize crazing is referred to as "mechanical" crazing. If you view crazing through a microscope, you will see hairline surface cracks on the top of the oxide layer only. Crazing will not break through to the base (raw) aluminum. In addition, if the anodized aluminum is subjected to high temperatures, the anodize crazing appears like a spider's-web. This type of anodize crazing is referred to as "thermal" crazing.

What causes anodize crazing?

Anodize crazing is typically caused by one of two conditions: Temperature (Thermal) or Fabrication (Mechanical):

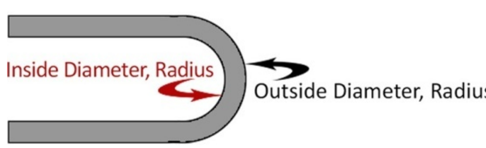
Temperature

Thermal crazing occurs when the anodized aluminum is subjected to excessive heat or cold. The coefficient of thermal expansion of aluminum is about five times greater than that of the aluminum oxide layer. As a result, the oxide layer will craze and in some extreme cases crack because of these thermal stresses.

Fabrication

Mechanical crazing occurs during forming and fabrication of an anodized aluminum part or flat rolled sheet . The oxide layer is very durable and about three times harder than the raw aluminum itself. As a result, when bending, stamping, roll-forming, cutting, or drilling the anodized aluminum part or flat sheet, the oxide layer does not give and won't stretch equally with the raw aluminum substrate. Therefore, the oxide layer crazes as a result of the stretching that occurs with the aluminum.

For example, when forming a flat sheet into an 180° bend, the outside diameter of the flat sheet is longer (stretches or expands) than the inside diameter (compresses or shrinks) of the flat sheet . In other words, the length of the outside diameter will always be longer than the length of the inside diameter. Reference the diagram.



Length of ID Curve= Pi* ID Radius

Length of OD Curve= Pi * (ID Radius+ Metal Thickness)

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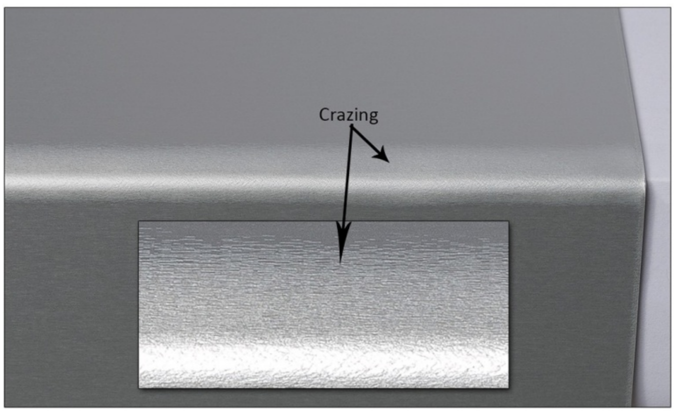
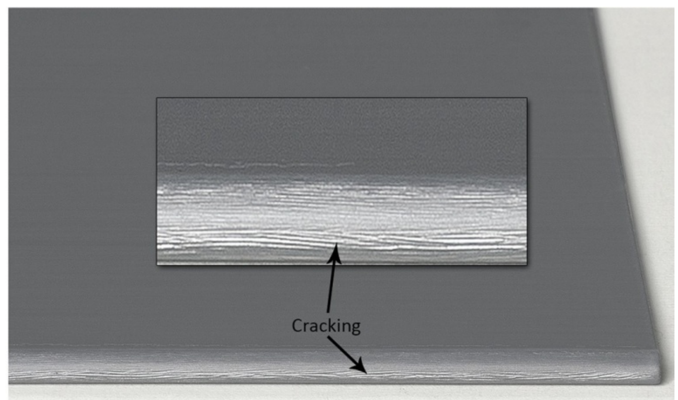
What is the difference between anodize crazing and cracking?

As mentioned, anodize crazing describes the micro fracturing of the anodic layer after the anodized aluminum has been subjected to forming or extreme temperatures . Under magnification, anodize crazing appears as very fine hairline scratches typically running against the rolling direction of the aluminum.

Anodize crazing will not break through the oxide layer and into the base (raw) aluminum. On the other hand, anodize cracking is considered to have occurred when the oxide layer has been compromised by forming or extreme temperatures and the base aluminum is damaged. When this occurs, the oxide layer has been separated from the base aluminum and no longer acts as a protective layer. Cracking of the oxide layer and the base aluminum is not within the scope of this arti cle. The images shown below illustrate the differences between anodize crazing and cracking.



Anodize CRAZING



Aluminum CRACKING

Can anodize crazing be eliminated?

Anodized aluminum crazing can be eliminated if the fabricated part or sheet is batch anodized and not subjected to any additional forming or extreme temperatures after anodizing. Batch anodizing, sometimes known as piece-part anodizing, is very labor intensive, requiring racking and un-racking of thousands of parts. Since the part is already fabricated and then anodized, it will not experience any crazing unless the part requires further fabrication. Conversely, a continuous coil anodizing process requires coils of aluminum to be unwound through a series of tanks. The oxide layer is formed and then rewound back into a coil. Coil anodized aluminum will have a light degree of anodize crazing when removed from the production line because the coils are subjected to bending over rolls following the process to build the oxide layer.

How can thermal anodize crazing be minimized?

We have determined through a series of test samples with a 0.250 mils (6 micron) film thickness , that the anodic layer will thermal craze when temperatures exceed 320° F {160° C). "The coefficient of thermal expansion of aluminum is five times greater than that of aluminum oxide. As a result, anodize coatings tend to craze mainly because of the thermal stresses. Cracking of the coating may occur during fabrication and/or during operati on . Any environmental change that cause differential expansion or shrinking between the coating and the substrate will introduce stresses into the coating. If the stresses are large enough, crazing will occur" . [1] Therefore, we suggest that the anodized aluminum part or sheet does not come in contact with temperatures exceeding 320° F (160° C) in order to avoid and/or minimize thermal crazing.

How can mechanical crazing be minimized?

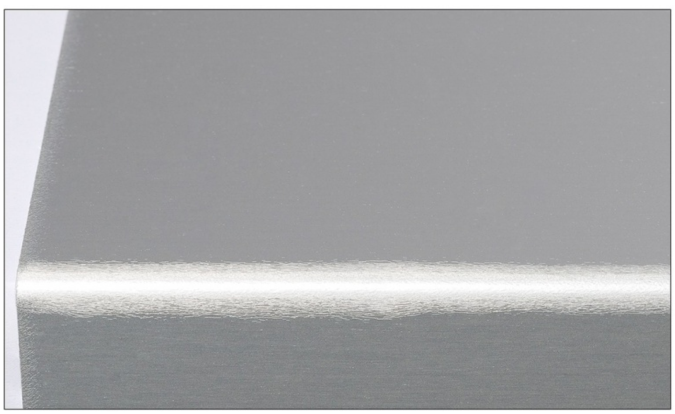
We have determined through research, that mechanical crazing can be hidden and/or minimized by doing one or a combination of the following:

1. **Changing the Bend Radius can reduce the amount of visible crazing.**

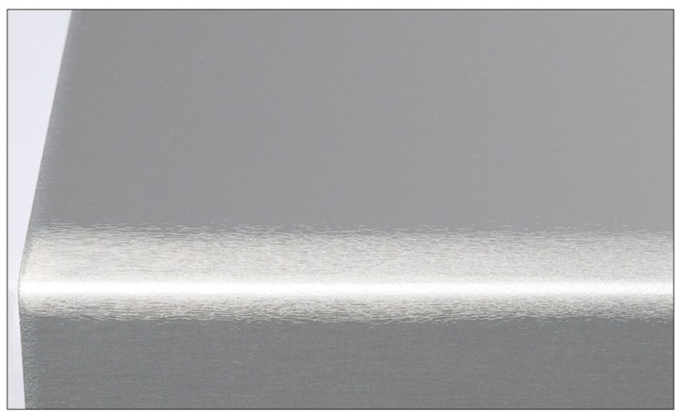
By decreasing the bend radius, the crazing is confined more to the edge and does not expand significantly onto the formed sheet or part. The diagrams below illustrate this point. However, some aluminum alloys and tempers may require increasing the bend radius to prevent cracking of the aluminum. Further comparative testing should be considered by the customer to determine what degree of crazing is considered acceptable for the specific application. A majority of the time, crazing is an aesthetic quality and usually not a concern for its intended use. Even considering aesthetic requirements crazing is often visually acceptable as the crazed area of the bend is hidden by the light it reflects as is the case with any bent material along its bend radius.

ClearMatt ® with a 0.750 mils {19 micron) film thickness
- 180° bend - 0t radius -

ClearMatt® with a 0.750 mils {19 micron) film thickness
- 180° bend - 2t (2 mm) radius -



ClearMatt ® with a 0.750 mils {19 micron) film thickness
- 90° bend - 0t radius -



ClearMatt® with a 0.750 mils {19 micron)film thickness
- 90 ° bend - 2t (2 mm) radius -

2. **Decreasing the anodize film thickness will reduce the amount of visible crazing.**

Decreasing the thickness of the anodic layer will reduce the amount of visible crazing . Thinner coatings are typically used for interior applications because UV exposure and environmental conditions are not a concern for the designer. In addition, the finished anodized aluminum products are typically at a close proximity to the viewer in which crazing may be more of a concern. On the other hand, exterior applications usually require thicker anodic coatings that are farther away and less visible to the viewer. The images on the next page illustrate this point.

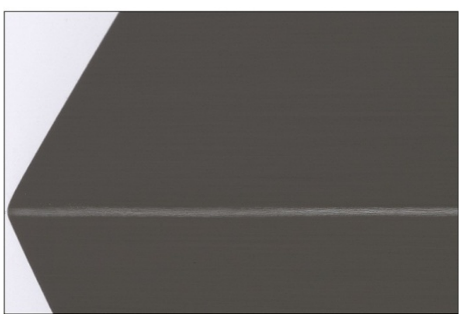
ClearMatt®- 0.250 mils (6 micron) *film thickness*
- 180° bend - 2t (2 mm) radius -

ClearMatt®- 0.450 mils (11 micron) *film thickness*
- 180° bend - 2t (2 mm) radius -

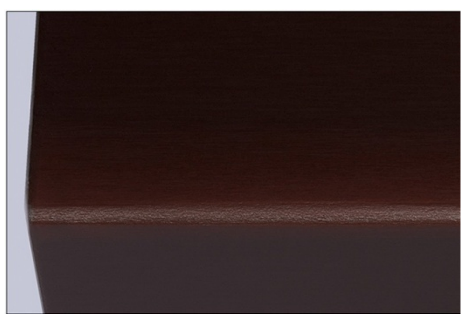
ClearMatt®- 0.750 mils (19 micron) *film thickness*
- 180° bend - 2t (2 mm) radius -

Anodized aluminum color and surface finish can hide and minimize visible crazing.

Additional testing revealed that when fabricating or forming lighter colored anodized aluminum, it shows more anodize crazing than darker anodized colors . The oxide layer is slightly opaque and translucent which refracts light rather than reflects light. "Reflection occurs when a light wave hits a boundary and returns immediately to its original medium.
Refraction occurs when a light wave passes from one medium to another and is bent; that is, the light wave deviates from the straight-line path it would have otherwise followed." [2] For example, light passing though the aluminum oxide layer is bent when it enters and reaches the base aluminum . It then bends again when it leaves the aluminum oxide layer. Because light travels at different speeds, we will see an image (crazing) that appears to change or take on a different shape because its light waves are refracted creating a sort of optical effect . Therefore, the glimmering (crazing) oxide layer is more apparent on lighter colors because lighter colors reflect more light than darker colors which absorb more light. The images below illustrate this effect on anodize crazing.



AnoZincr® I with Arconic Tectur-Al ™- 0.750 mils {19 micron) film - 90° bend, 2t {2 mm) radius



Medium Antique Copper - 0.450 mils {12 micron) film thickness - 90° bend, 2t {2 mm) radius

ClearMa tt® - 0.425 mils {19 micron) film thickness - 90° bend, 2t {2 mm) radius

Summary

The natural properties of anodized aluminum make it unique and striking in appearance. Unlike paint, the anodic layer creates a dynamic visual effect by refracting the light, thus making the aluminum come alive. Anodized aluminum is not flat, static, or one dimensional. Depending on the angle it is viewed, it can achieve differing looks due to variables such as the amount of light, time of day, or even the time of year. With so many natural variables, anodized aluminum shines. Why not take a closer look?

1 NASA-Goddard Space Flightt Center, Technical Me m o 1046 22, "Preventing Cracking of Anodized Coatin gs", 1995.
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