Design, Converting and Handling Techniques for Electro-Plating ABS and ABS/PC Alloys

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**HANDLING OF FORMED PARTS FOR PLATING**                                  | 17   |
Overview
The enormous demand for plated plastics in recent years has resulted in an exponential growth around the world. The transportation, appliance, communications, hardware and marine industries have been in the vanguard of that demand. Much of the growth is attributable to the many advantages that plated plastics offer manufacturers who traditionally had utilised plated metal products. Among the advantages are design freedom, weight reduction and lower costs. ABS/PC alloys, available in application-oriented grades, gives the designer, molder and electroplater superior features to facilitate plating techniques.

Design for Plating
The success of a metal plated ABS/PC part starts with design.

A design must accommodate moulding, plating and part performance. Easy-to-plate contours will invariably provide a more uniform distribution of the electro-deposited metal and will provide a finish having better performance at a reduced processing cost. Many of the suggestions and design recommendations that follow are based on actual experience acquired in electroplating ABS plastics. Some are based on good plastic design principles while others are similar to those for metal parts which are to be electroplated.

If followed, these recommendations will help assure plated ABS or ABS/PC parts of high quality appearance, also good functional and part performance. For further guidance, designers should consult the electroplater and or molder.

1. As they aid plated part appearance.
2. As they improve part performance or function.
3. As they facilitate ease of racking and plating parts.

Design Considerations to aid Plated Part Appearance
Appearance is a key factor in the acceptance level of plated plastics because more than 90% of current applications are decorative parts. The part's final appearance begins with the application of proper design practices and is further influenced by molding, plating and handling techniques.
Since surface defects are more pronounced on a highly reflective metal surface than on the bare plastic material, the following practical design considerations will help optimize the surface appearance of the plated part.

**Integral Parts**
Whenever possible, components should be designed as one piece since good plating appearance is difficult to achieve over welded or cemented joints. Parts are sometimes plated and then assembled via screws, hot staking, snap fits, etc.

**Planes**
Large planes should be crowned with a curvature of about 0.06 mm / 100mm. Crowning tends to camouflage minor surface irregularities because the eye is not as capable of focusing on a wide expanse of curvature as it is on a flat surface (figure 1.)
As an alternative, shallow, well radiused texturing can be used to effectively break up flat areas and mask minor molding, thermoforming, handling or plating imperfections.

![Figure 1](image)

**Gates**
Gates should be located on non-critical appearance surfaces, as gate and trimming marks, too, are exaggerated by the metal plate. If this is not practical, a feature can be made of the gate area. For instance, on a small plated knob, with a slightly peaked convex top surface, the gate could be placed at the apex, where it may be noticeable, but not objectionable.

**Ribs and Bosses**
Care should be taken in locating ribs, bosses or other heavy sections on the reverse side of appearance areas. Unless properly designed, they will cause sink marks which are more noticeable after plating.
**Edges and Corners**
Sharp edges and corners will cause high current density areas which can result in undesirable plating build-up (figure 2)

![Original Design Suggested Correction](image)

*Figure 2: Plating build-up will occur on sharp edges. The build-up in Type A will produce an uneven edge, which is detrimental to the appearance and fit of mating parts.*

**Parting Lines**
Mold parting lines leave visible marks on the bare plastic, which will also be greatly magnified by the bright metal plate. If possible locate them in non-critical appearance areas.

**Design Considerations to Improve Plated Part Performance**
Performance of the electroplated part can be improved by controlling wall thickness and plate deposition (thickness and uniformity). Adequate wall thickness should be specified by the designer to obtain good mold-ability, sufficient rigidity for racking and maximum adhesion between the metal plate and plastic substrate. The designer should also design the part to facilitate uniform deposition of the plate for the express purpose of achieving maximum top plate corrosion resistance and thermal cycle resistance. Because of its intrinsic nature, plastic never corrodes as metal does; however, both plated metal and plated plastic parts are subject to corrosive surface attack due to galvanic action between the plate components. Additionally, plate thickness is important in designing parts having close tolerance fits; for example, threads, snap fits and interference fits.

**Wall Thickness**
The wall thickness is generally dependent upon part size and shape and is further governed by its strength and rigidity requirements. An ideally designed part is one with a uniform wall thickness. Wall thickness variations can result in more performance problems than overall thin wall sections. For this reason, we suggest using a wall thickness in the range of 2.3 - 3.8 mm for ABS/PC parts, whenever possible gradual transitions from one wall section to another via tapers, radii, or fillets should be specified (figure 3). This will minimise local flow variations and surface stresses that can cause poor plate adhesion

![Original Design Suggested Correction](image)

*Figure 3: ...*
Plate Adhesion

- At a given injection speed and stock temperature, plate adhesion increases with part thickness.
- For a given part thickness and stock temperature, plate adhesion increases with slower injection speed.
- Plate adhesion increases also with higher stock temperature (within the acceptable range) for a given fill time and part thickness.

Therefore, to achieve optimum plate adhesion and thermal cycling performance it is necessary to consider injection speed, stock temperature, part thickness, as well as parts design, appearance and cycle time.
Thermal cycle performance can be improved if excessive bulk is removed from thick cross sections (figure 4). In this way a more uniform wall thickness is obtained, and the plastic has less tendency to expand and overcome the strength of the metal plate.

![Figure 4.](image)

The heavy mass electroplated spherical ball (far left) failed three cycles -17 °C - 70 °C.

After internal mass was removed and part was designed into two parts using a snap fit (top right), the required three cycles of 30 °C - 82 °C was met.

Removing excess internal bulk (left centre) provides a more uniform cross section; adding external serrations (left) acts as expansion joints which accommodate plastics thermal expansion.

**Plate uniformity**

Uniformity of electroplate thickness is improved by designing parts with gently curving convex surfaces. Non-uniformity of thickness is caused by an unequal distribution of current density on the part. Technically, this problem arises because the recessed areas of a part (slots, grooves, blind holes, etc.) are normally low current density areas. These areas are starved of their share of the electroplate, while the high current density areas (corners, edges, ribs, fins and other features) are apt to have plate build-up out of proportion. Low current density areas may have less than one-fourth the amount of electroplate generally deposited on the part’s surface. (figure 5).

These thinly plated areas are commonly the site of first failure from abrasion, corrosion or wear.

Auxiliary anodes can be used in low current density areas to improve plate uniformity, but the designer must be aware that this technique may be more expensive than standard plating practices. The minimum coating thickness recommendations for ABS are given in Table 1.

![Figure 5.](image)

Thickness variations for electroplated nickel in a groove with a width-to-depth ratio of 0.85.
Table 1 Recommended Electroplate Thickness

<table>
<thead>
<tr>
<th>Service Conditions</th>
<th>Recommended Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MILD</strong> - Exposure indoors in normally warm dry atmospheres</td>
<td>Nickel strike Adequate to cover Bright acid copper 15 - 20 µm Bright nickel 05 - 08 µm Conventional chromium 0.2 - 0.4 µm</td>
</tr>
<tr>
<td><strong>MODERATE</strong> - Exposure to high humidity and mildly corrosive atmosphere.</td>
<td>Nickel strike Adequate to cover Bright acid copper 15 - 20 µm Semi-bright nickel 08 - 10 µm Bright nickel 05 - 08 µm Conventional chromium 0.2 - 0.4 µm</td>
</tr>
<tr>
<td><strong>SEVERE</strong> - Exposure to high humidity, wide temperature variations and severe corrosive atmosphere.</td>
<td>Nickel strike Adequate to cover Bright acid copper 15 - 20 µm Semi-bright nickel 10 - 15 µm Bright nickel 08 - 10 µm Special nickel 2.5 µm Conventional chromium 0.2 - 0.4 µm</td>
</tr>
</tbody>
</table>

* Required for inducing micro porosity or micro cracking

**Design for Plate Uniformity**

**Angles**

All angles should be as large as possible. Minimum inside and outside radii of 0.8 mm and 0.8 mm respectively are suggested. Sharp angles increase plating time and costs for plate uniformity and reduce the durability of the plated part.
Edges
Sharp edges are undesirable. Beading will occur which may destroy the design concept. They should be rounded to a radius of at least 0.3 mm, preferably 0.8 mm.

Flat Bottom Grooves
Round flat-bottomed grooves or indentations and limit their depth to 50% of their width. Edges, both internal and external, should be chamfered or rounded. If chamfered, the minimum angle defined by the chamfer should be 100 degrees. If rounded, adopt the minimum radii recommended in Table 2

Table 2 Recommended Radii for Indentations of Various Depths.

<table>
<thead>
<tr>
<th>Depth of indentation, in mm</th>
<th>1.6</th>
<th>3.2</th>
<th>6.4</th>
<th>9.6</th>
<th>12.7</th>
<th>25</th>
<th>38</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Radii of Angle between perpendicular planes, in mm</td>
<td>R0.4</td>
<td>R0.8</td>
<td>R1.6</td>
<td>R2.4</td>
<td>R3.2</td>
<td>R6.4</td>
<td>R9.5</td>
</tr>
</tbody>
</table>
**V Grooves**
Reduce the depth of concave recesses as much as possible and avoid scoops with a depth greater than 50% of the width. Deep V-shaped grooves are extremely difficult to plate because of low current density factor at the bottom of the groove. Shallow, rounded grooves are better.

**Blind Holes**
If blind holes are functionally necessary, design depth to less than 50% of the width. Whenever possible, provide drainage holes so that solutions are not carried from bath to bath. Through holes are better for complete drainage and rinsing during the electroplating process. Incomplete drainage will create bath contamination problems for the plater. Avoid blind holes with a diameter less than 5.5 mm deep, small holes entrap insulating air that prevents electrode position.

**Slots**
Slots, as well as indentations, should be at least twice as wide as they are deep. Rounded corners will reduce plate build-up in the high current density areas and plate starvation in adjacent areas.
Ribs

Ribs are frequently chosen to provide additional strength. When ribs are used, their thickness should not be greater than \(\frac{1}{2}\) of the adjacent part wall thickness, nor should the height exceed \(1\frac{1}{2}\) times the wall thickness. For instance, when using a wall thickness of 3.2 mm, the ribs should be no more than 1.6 mm thick or 4.8 mm high. If greater stiffness is required, two or more ribs can be used at a lesser height rather than increasing the rib height. A fillet of 1.6 mm or more, at the rib and wall intersection will give further strength and will provide for better material flow. Space parallel ribs so that the distance between centres is four times their width. Radius tips at least 1.6 mm.

Bosses

Bosses are heavy areas usually provided around holes for reinforcement, while studs are more frequently used for mounting purposes.

Both bosses and studs should be as short as possible. Better plating results will be obtained if their height does not exceed twice their diameter. Inside and base angles should be rounded generously. Tips must be similarly rounded and tapered or the inevitable thick metal deposits will occur, increasing dimensions beyond acceptability. Draft angles of at least \(1^\circ\) are normally needed to facilitate removal of parts from
mold cavities without the use mould releases. Bosses with hollow centres should be oriented 90° from the major plane of the part. The base thickness of hollow bosses should not be greater than 70% of the intersecting wall thickness. Sometimes drain holes may be required to avoid the costly supplementary hand rinsing that might otherwise be required. All bosses and studs should face in the same direction.

The plating deposited on the inside or shielded area of a part is approximately one-fourth of the thickness values given in Table 1. For example, plate thickness is limited to 0.005 mm 0.008 mm when bosses and studs are threaded conventionally. Special threads must be adopted if thicker coatings are required in order to allow sufficient clearance. Chamfering of threaded holes is recommended to minimize electroplate build-ups at their periphery and to expedite the insertion of fasteners after plating. More metal will be deposited on the threads when the edge of the hole is relieved.

Raised Details

Raised areas of decoration (symbols, letters, figures, etc.) should not be elevated more than one-half the width. A height of 0.25 mm is commonly accepted for adequate detail. All corners should be radiused. Shallow indented symbols filled with a wipe in paint will provide a pleasant contrast with the bright metal plate.

Design Considerations to Accommodate Racking

At this point the designer should consult with the plater because quite often, properly located gates can be used as efficient cathode points and in some cases, the runners can be left attached to the parts to accommodate racking. The best and most efficient electroplating results can be realised if plating racks are specifically made for each part design.

There are many reasons for this. Part size, of course, is the major one. Part design is another, because each rack has to be made so that the rack tips will contact the part in an area where the lack of plate will not affect final appearance or performance. Also, the racks should be designed to hold the part in such a way as to prevent the loss of electrical contact.

For economic reasons, the rack design should take full advantage of plating bath size, yet no plastic component should be too close to the tank bottom or surface of the solution. The uppermost component on a rack should always be immersed to a depth of at least 37
- 50 mm below the solution surface and the lowest component should be about 150 mm above the tank bottom.

Other considerations include variations in tank size as well as differences in heights that the work rod may be placed above the solution. Otherwise, parts to be plated may fail to be submerged in one or more of the plating baths. Rack splines and hooks constructed of copper, bronze, or brass and vinyl coated for protection against acids used in the cleaning and etching solutions are recommended.

Rack tips of 316 stainless steel are recommended. They can be chemically stripped without damaging the points. Rack splines, tips and hooks must be of ample size to allow current to pass without overheating. (Overheating reduces plating efficiency and destroys the rack coating.) A safe figure for copper is 0.64 amp/m² of cross section; however, this can be extended to 1.29 amp/m² if the plating cycle is short, the solution cool, and good contact is made between the tips and the parts. Brass (60-40 Cu-Zn) has a conductivity 28% that of copper. Stainless steel type 316 has a conductivity 2.2% that of copper. Provide for auxiliary anodes or shields which sometimes may be required.

Finally, the part should be sufficiently rigid to be held on the rack in agitated solutions at electroplating temperatures (up to 68 °C) without warpage. Generous wall thickness will provide the necessary rigidity, or ribs can be used as an alternative.

**Converting Methods And Processing**

Moulding and extrusion techniques for converting pellets to plastic products – suitable for quality electroplating – are dealt with in this section, including operating conditions, procedures and recommendations. Typical properties are given in table 3.
Mould Design and Specifications
Any conventional two-plate, three-plate, hot runner, or runnerless type mould can be used with resins. Kirksite castings or other low cost mould materials may be used for prototype work, but for actual production another choice should be made. *Copper beryllium alloys, unless chrome plated, are not recommended* as mould materials. These alloys tend to react with ABS and cause a film on the mould surface which can result in low plate adhesion.

Mould Surface
The quality of appearance for any plated part is dependent upon the quality of the mould surface. As with surface irregularities, the bright metal plate will accentuate rather than hide roughness caused by the mould. Therefore, when optimum appearance is necessary, the mould finish should be specified in micro meters and the best non-porous tool steel and finishing techniques should be used. A mould finish of 0.38 - 0.45 µm is recommended. Usual terms for defining the mould finish such as “highly polished”, “mirror finish”, or “high lustre”, do not adequately describe what is needed for superlative results.

Texturing
Textured surfaces of various designs can be produced in the mould surface and reproduced in the plated part with fine definition. These often enhance the part’s appeal as well as camouflage slight imperfections. Texturing eliminates the mirror image, but does not reduce the brightness of a decorative plate. Special plating solutions are recommended to produce satin or mat finishes.

Mould Shrinkage
The mould shrinkage of 0.6 ± 0.2% should be used These resins freeze quickly to a at mould temperatures, so mould cavities for parts having threads, undercuts, or texturing should not be designed for straight stripping.

Gating
Conventional gates and gating methods – such as sprue or centre, edge, disc or diaphragm, ring, tab, tunnel, fan and multigating can be used. Whenever possible, the gate should be located in a non-appearance area. A typical full-round edge gate in a section 3.2 mm thick is 2.4 mm - 3.2 mm in diameter. For a rectangular edge gate it is 4.8 mm - 6.4 mm in width. (Material drag and orientation will be reduced if, on a rectangular gate, the corners are rounded). Land length for these gates should be 0.75 mm maximum.
Single or multiple tab gates will minimise jetting, blush and gate strain, all of which are detrimental to plating. Tab gates should have dimensions in the range 12.7 mm - 19 mm long; 10 mm - 16 mm wide; and 2.4 mm - 3.2 mm deep.

Tunnel gates can be used to avoid gating at the parting line of the mould and to provide automatic degating. A large tunnel tapering 20° or more to a gate of approximately 2.4 mm diameter is machined from the runner to the cavity, to a sub-surface tab machined into the core, or to a ground flat on a knock-out pin. The length of the subsurface tab should extend about 6.4 mm beyond the tunnel entrance.

**Venting**

Moulds must be well vented to eliminate any possibility of gas being trapped as a part is moulded. The vents are located wherever gas build-up is likely to occur. These should be milled slots approximately 6.4mm wide and no more than 0.05 mm deep. About 3.2 mm back from the part the slot depth should be increased for better venting. Alternately, knock-out pins may be used as vents. Such venting will help keep the part free of surface blemishes. Kirksite and other soft mould materials are difficult to vent at the mould parting line, as clamping pressure tends to deform and eventually close off the vent opening.

**Nozzles**

The use of an unsuitable nozzle in moulding can lead to defects such as short shots, jetting, lamination and colour streaking of the material. However, these problems can be minimised by the nozzle having a large orifice and very short land length.

Orifice diameters of 5 mm - 10 mm (depending on the machine size and shot) and land lengths not exceeding 3.2 mm are recommended. A small orifice or long land length will create surface stress which adversely affects plate adhesion.

Shutoffs or other flow obstructions in the nozzle should be avoided.

**Moulding Conditions and Procedures**
Typical Processing Conditions

<table>
<thead>
<tr>
<th>Conditions</th>
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<tbody>
<tr>
<td>Temperature of pallet bed of de-humidified drier</td>
<td>00 °C</td>
</tr>
<tr>
<td>Minimum time pallets at desired Temperature</td>
<td>3 - 6 h</td>
</tr>
<tr>
<td>Die Temperature</td>
<td>60 - 100 °C</td>
</tr>
<tr>
<td>Nozzle</td>
<td>Do Not Exceed Stock</td>
</tr>
<tr>
<td>Stock Temperature</td>
<td>240 - 290 °C</td>
</tr>
<tr>
<td>Zone 1 (Rear)</td>
<td>225 - 265 °C</td>
</tr>
<tr>
<td>Zone 2 (Middle)</td>
<td>235 - 275 °C</td>
</tr>
<tr>
<td>Zone 3 (Front)</td>
<td>245 - 285 °C</td>
</tr>
<tr>
<td>Fill Speed</td>
<td>Slow</td>
</tr>
<tr>
<td>Screw Speed</td>
<td>40 - 60 RPM</td>
</tr>
<tr>
<td>Back pressure</td>
<td>0.1 - 0.5 MPa</td>
</tr>
<tr>
<td>Injection Pressure</td>
<td>Minimum</td>
</tr>
<tr>
<td>Clamp Tonnage</td>
<td>4 - 8 kN / ²</td>
</tr>
</tbody>
</table>

Machines
Where a choice is available, a screw injection machine should be used rather than a ram type. The screw injection machine will deliver stock with a more uniform temperature from beginning to end of the shot and produce a moulded part with a minimum of surface stresses.

Regrind
Clean, dry, non-degraded regrind will not adversely affect adhesion values. It can be mixed with virgin pellets of the same grade up to a 20% level. However, the proportion should be kept constant throughout the run, so that the stock temperature and rate of feed will not vary. Heavy duty grinders with 8 - 10 mm screens are recommended with fine material removed.
Purging
Clean up when changing from resins to alloys or vice versa, or from one grade or color of either material to another - or from ABS to a different material - purging rarely presents any problem. If difficulty occurs in purging, however, the machine may be satisfactorily cleaned by purging with ground acrylic 204°C - 225°C with the nozzle still attached, allowing two to three minute intervals between shots.

HANDLING OF FORMED PARTS FOR PLATING
Clean and careful handling of moulded parts for electroplating is imperative. Anything less is apt to result in inferior, and perhaps unacceptable parts.

Attention should be focused on the fact that the slightest blemish on a part surface will stand out after a bright metal finish has been applied. Therefore, caution should be taken when removing runners or trimming thermoformed parts, not to leave surface defects too large for plating success.

Gates and parting lines located in prime appearance areas may necessitate buffing. Low or non-greasy compounds such as Matchless 4B-28 are recommended. Wheel speeds 150 – 180 RPM (250 - 300 mm wheel) and stitched unbleached muslin wheels of medium weave are common. A clean wheel is used to remove excess compound and reduce the cleaning cycle during the plating process.

parts to be plated must be handled in a manner to prevent any surface marring or contamination. Cotton gloves should be worn when removing parts from the mould in order to prevent excessive fingerprinting. Fingerprints may leave an oily film which, when imbedded in the hot plastic surface, will prevent strong plate adhesion if the plating system does not include a cleaning bath as its first step.

Parts can also be soiled by grease or other such contaminants in and around the moulding equipment, particularly in the mould cavities themselves, making the parts more difficult to plate. Moulds must be free from all preservatives and lubricants.

The production parts should be kept out of any area where mould lubrication might be under way. Mould releases, especially silicone sprays, can contaminate the air and be attracted to the parts by static charge, not to be noticed until the parts prove difficult to wet in the plating process.

Once removed from the mould, the parts should be adequately protected in shipping containers to prevent scuffing and scratching. Cotton gloves again are normally used in handling the parts just prior to plating. The finished parts are usually wrapped individually and shipped in strong packing containers to the end users.
Parts to be packaged in polyethylene bags must be cooled to below 37°C before packaging.