Secondary Post-Processing for HP Multi Jet Fusion

Tuning your HP MJF technology to the design

Introduction

Secondary post-processing is an optional step in the end-to-end workflow for parts printed with Multi Jet Fusion technology. While the raw part—once it has been suitably cleaned by bead blasting or water jet blasting—can be used as is, without further treatment, the specific application of the final part may require processing to fulfill technical requirements, such as a colored finish or a smooth tactile surface.

The techniques included in this step have been classified as either providing **cosmetics**, or reducing surface roughness; however, some techniques may provide both attributes. For example, electroplating gives color and finish to the part, but also acts a functional coating, minimizing **surface roughness.**

Cosmetics

The cosmetics category can be subdivided into techniques that provide color uniformity in the raw part, such as dyeing and graphite blasting, and those that provide coloring, different to that offered by the raw part; however, since some techniques (dyeing, for example) provide both uniformity and coloring, this distinction has not been made.

The cosmetic category includes five key techniques:

- Dyeing
- Graphite blasting
- Smoothing blasting
- Painting
- Electroplating

Dyeing

Dyeing involves immersing the part in a hot dye for a prescribed period of time so that the dye penetrates the part completely, until a specific color or color homogeneity across the entire part surface is achieved.

Dyeing is currently the most commonly used secondary post-processing technique for Multi Jet Fusion 3D printed parts. It is suitable for applications where the part is visible, or subject to wear since the color penetrates the interior. The results obtained depend on the color starting point of the raw part, either gray or white printed parts depending on the HP Multi 3D Jet Printing Solution. The range of colors and tones that can be achieved is much greater when using a white raw part than a gray part.

Figure 1. Dyed grey parts- color possibilities

Figure 2. Dyed white parts-color possibilities

Manual dyeing is an inexpensive, efficient technique that uses a dye bath or vat, and a hotplate. The dye mix is made up in the dye bath and then conditioned. It is then heated to 80-100 °C and the parts immersed in the mix for approximately 8 minutes. The dyeing time will depend on the color of the raw part and the desired color intensity. The newly dyed parts are then transferred to the rinse bath containing water heated to 60 °C, in order to remove any excess dye from the parts and avoid staining. The parts are then left to dry, either naturally or by placing them in a drying oven at 50 °C.

Figure 3. Dyeing process of HP Multi Jet Fusion printed parts

Automatic dyeing solutions are a convenient and efficient alternative that requires less operator intervention. The principle is identical, but these solutions offer specific programs for dye bath mixing, conditioning, dyeing, part rinsing, dye disposal, and dye bath cleaning. In some automatic dyeing machines, the dyeing mix can be reused up from 5 to 10 times and stirring features ensure the dye solution is always homogeneous, achieving better results.

Dyes are available in powder and liquid format. The concentration of the dye mix depends on the dye specifications and the desired color intensity, with approximately 7 g/L for powder dyes, and a ratio of 0.1 L dye to 10 L water for liquid dyes. The dyeing temperature also varies according to the format used: 100 °C for powder dyes and 80 °C for liquid dyes.

For the best results when dyeing, parts must have been thoroughly cleaned to ensure they are completely free of any unfused material. Parts must be able to move freely within dye mix, so the dye bath should be adequate for the volume of parts to be dyed. Small fragile parts should be placed in a mesh bag to protect them from the effects of stirring in the dye mix.

If stains appear on the parts due to scratch marks or where the dye has become too concentrated—even after rinsing—such marks can be removed by bead-blasting the parts or by using smoothing blasting process.

Figure 4. Dyed part with scratch marks (left) that are removed by using bead blasting (right)

Furthermore, in parts prone to warpage such as large, thin and flat parts thinner than 2 mm, there may be increased warpage due to thermal shock and tension caused by the technique. There can be a slight impact on tensile strength, elongation at break, and tensile modulus in dyed parts due to a minimal water absorption

Figure 5. HP Multi Jet Fusion printed part before (left) and after dyeing (right)

Graphite Blasting

The principle of graphite blasting is similar to bead blasting, although its intent is different. While the purpose of bead blasting is to clean parts of unfused powder without coloring or impacting the part's surface roughness, graphite blasting provides color uniformity. Parts are processed in a blasting chamber, where a mix of glass bead media and graphite are blasted at parts to achieve a uniform color across the parts. Then any excess graphite and blast media dust must be removed by air blasting.

Parts processed with graphite blasting obtain a metallic-looking surface, which is highly attractive in some applications. Furthermore, the technique provides other desirable attributes such as reducing friction between moving parts, making it suitable for functional and mechanical parts where its lubricative benefit may be an advantage. Its impact on dimensional and mechanical properties, as well as surface roughness, is neutral, since any impact on the surface of the part is caused by the glass beads themselves.

Figure 6. HP Multi Jet Fusion printed part before (left) and after graphite blasting (right)

Since graphite blasting uses the same equipment as bead blasting, the factors for achieving the best results are similar in nature. The blast media mixture consists of glass beads of 70–110 µm and graphite, with graphite representing 0.7% of the total media mix. A 5 kg glass bead-graphite mixture is suitable for 1–2 full print jobs.

The settings for air pressure and distance to part are similar to manual bead blasting, being 3 bars depending on the part fragility and 10–15 cm distance to part. Since graphite blasting is necessarily a two-step process, as parts are blasted first in the bead chamber and then air-blasted to remove excess graphite, the total time required is around 2–5 minutes per part, allowing 1–5 minutes per part for bead blasting in an automatic chamber and a subsequent 5 seconds per part for air blasting. As with bead blasting, small and fragile parts can be processed in batches using a sinter box.

Graphite-blasted parts are prone to staining due to excess graphite on the surface, the degree of which varies depending on the blasting time; however, air blasting can reduce the level of staining. Graphite blasting is recommended for visual prototypes, but not for final parts that receive frequent handling, as it is not wear-resistant and fades over time.

Smoothing blasting

Smoothing blasting, also known smoothing blasting, involves propelling an abrasive media, onto the surface of the part at high pressure.

With an operating principle similar, if not identical, to bead blasting, the main purpose of smoothing blasting is to give a better surface finish, usually in combination with dyeing process. This is achieved by using a more abrasive and round formed blast media, usually plastic or ceramic rather than glass used in bead blasting, and a higher pressure.

The surface finish achieved can range from matt to glossy finish depending on the type of media used, and the processing time, and the surface becomes more resistant to scratches, dirt and liquid absorption.

As with bead blasting, the key factors that affect the result are air pressure, blast media, and time required. Since it is usually done by an automated system, both nozzle diameter and distance to part is controlled. For example, with a minimum distance to part of 200 mm and a pressure of 5 bar, a batch of parts can be cleaned in around 10 to 20 minutes, depending on the material and finish.

This process reduces slightly the surface roughness, but this effect is more noticeable when combined with other processes such as vibratory finishing.

Painting

Painting involves the application of a pigmented liquid composition to the part in thin layer, which converts to a solid film when dry. This results in improved color uniformity and surface roughness on the part. Other desirable properties such as UV resistance, wear and scratch resistance, and water tightness can also be achieved depending on the formulation of the paint used.

Both solvent and water-based paints can be applied to Multi Jet Fusion parts. Depending on the final application where the part will be used, the raw part can be painted directly or pre-processed first. As with any of the secondary post-processes, the raw part must be thoroughly cleaned and be free of any unfused material before painting. For best results, the raw part should be primed and then sanded to achieve a uniform surface, as any minor imperfections in the surface will be seen after painting. Several layers may be required according to the final application.

The surface roughness of HP Jet Fusion 3D printed parts can be improved by adding layers of paint, the greater the number of layers, the smoother the surface.

Paint can be applied manually or automatically using a spray gun.

Data courtesy of Skorpion Engineering srl *Data courtesy of SuperFeet*

Figure 7. HP Multi Jet Fusion printed parts before and after painting; Color possibilities: from metallic to vivid colors

Electroplating

Electroplating and metal coating are techniques used to add a layer of metal to the surface of a printed part. This is done to improve the look and feel of the part for cosmetic applications or to improve physical properties such as conductivity, EMI/RFI shielding, mechanical strengthening, and heat conductivity, as well as other desirable attributes as a functional coating like antibacterial properties.

Electroplating can be performed on raw parts, however, given the initial roughness of the part, the look and feel required for most cosmetic applications may not be achieved. For a better, mirror-like finish, raw parts must be pre-processed to reduce surface roughness to 1 or 2 µm, using a vibratory tumbler, chemical polishing, or smoothing blasting, although small holes due to porosity may still be observed.

Figure 8. HP Multi Jet Fusion printed part after electroplating

Electroplating involves adding a thin layer of metal to a metallic object. At a basic level, it consists of dissolving one metal in a solution and subsequently attaching it to another metallic surface using an electric current. The target surface must be able to conduct electricity.

Since Multi Jet Fusion 3D parts are printed in polyamide, a semi-crystalline thermoplastic, the part must be treated to make the surface conductive before the electroplating process. There are three methods to do this:

- Electroless plating
- Gas activation technology
- Conductive coating

The method chosen to make the surface of the raw part conductive depends greatly on the application and desired attributes for the final part. The most commonly used method, however, is electroless plating.

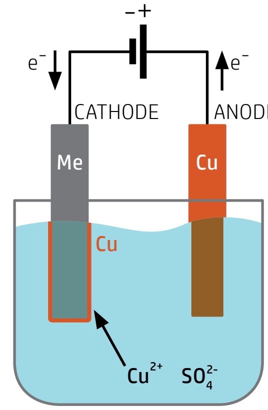

Figure 9. Functional diagram of the electroplating process

Electroless plating

Electroless plating adds small particles of palladium inside micro-cracks in the part's surface, which will create an initial layer of metal. It is a complex process, which is dependent on the geometry of the part for its effectiveness.

Electroless platting is a multi-step process in which first the part needs to be etched mechanically, i.e. sand blasting with an abrasive media, to enhance the surface-adhesive capabilities of the part. For raw or tumbled parts, processing the part with mechanical etching is sufficient; however, for parts treated with chemical polishing, chemical etching may be required. In chemical etching, the surface is attacked chemically using a chromic acid-based solution. Any excess chromic acid is then neutralized. Next, a solution consisting of palladium and tin salts is applied to the part. The part is then submerged in an electroless plating solution, which coats the surface of the material with either nickel or copper depending on the solution, creating a pre-plate layer.

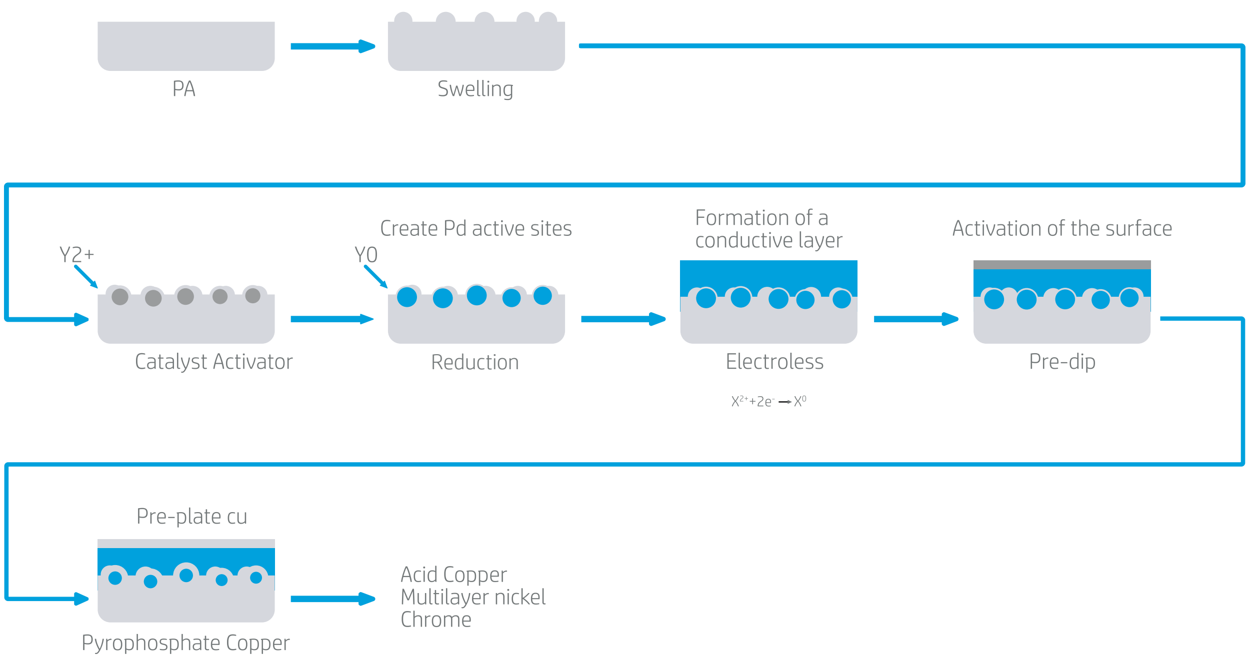

Figure 10. Swelling process

Gas activation technology

Gas activation technology uses an ionized gas to make the surface conductive. It does not require mechanical or chemical etching to prepare the surface. It is fast and gives selective metallization, however, it results in a small area where the electrode is connected without electroplating.

Conductive coatings

Coating the part is the easiest and the most economical way to make the surface conductive. However, it is not a very robust solution, as adhesion of the coating to the surface is weak, meaning it does not provide durability over time.

Once the surface has been made conductive by electroless plating, gas activation, or with a conductive coating, the standard procedure for electroplating can be done, deposing a metal coating on the surface of the part. Various metals can be used to plate the surface: notably, nickel, copper, chrome, and precious metals such as gold or silver.

To overcome possible porosity or irregularities on the surface, a priming spray paint can be applied after mechanical polishing and before electroplating for the best results.

Surface roughness

Given the nature of powder bed fusion technologies such as Multi Jet Fusion where the distribution of particles may be non-uniform, surface roughness is usually inconsistent across the part's surface. Secondary post-processing treatments help to homogenize the surface finish and reduce roughness. There are two main techniques that can smooth the printed part's surface:

- Vibratory finishing
- Chemical polishing

Vibratory finishing

Vibratory finishing, also known as tumbling, involves vibrating parts in a tumbler with an abrasive media, causing the media to rub against the parts. The abrasive media have a lapping effect on the surface of the part. It is an automatic process that requires low operator supervision. However, care should be taken when using this process, as it can cause damage to fragile parts, tends to round corners, and may affect the dimensional specifications of the part, particularly if the time is excessive or the media type and size are inadequate

Figure 11. HP Multi Jet Fusion part before (left) and after tumbling (right)

Vibratory finishing can be either a wet or a dry process, with the media being adapted accordingly. In wet vibratory finishing, coarse ceramic and plastic media are usually used, resulting in a more polished finished. The wear on the media tends to be less and the overall process is usually quieter. However, the waste resulting from the liquid-abrasive media mix needs to be filtered and treated. Dry vibratory finishing, on the other hand, is a cleaner process, resulting in easier treatment of waste output (only worn dry media). However, it tends to be more aggressive, depending on the media.

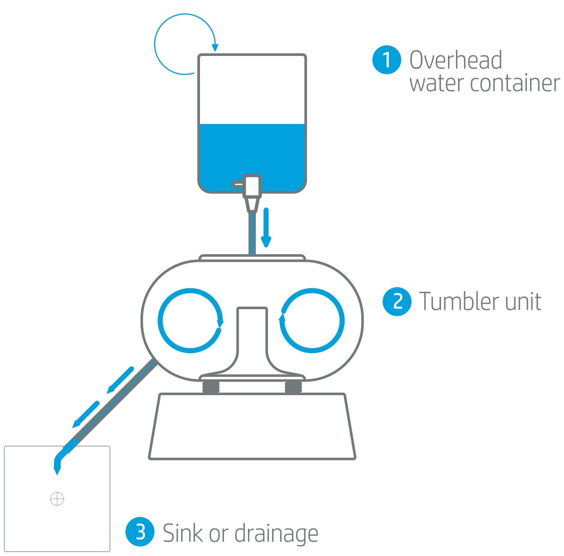

Figure 12. Functional diagram of wet tumbling equipment

Figure 13. Printed parts being processed in the tumbler

There are several key factors that influence the results achieved in vibratory tumbling: abrasive media, time, and revolutions per minute.

The abrasive media play an important role in the Ra value ultimately achieved. The media used in vibratory tumbling is usually ceramic or plastic, though other materials such as steel, synthetic and organic media may be used according to the target roughness value. With a higher density and greater hardness, ceramic media tends to be more aggressive than plastic. Plastic media remove less material during the process, allowing small details to be preserved, but require usually longer processing times. The shape of the media can vary according to the desired effect and the size and shape of the parts.

Figure 14. Different blasting media used in tumbling process: ceramic, plastic, and steel (from left to right)

Similar to sanding, the size of the media used should progress from large to small. The tumbling process should be started initially with a larger particle and then move onto a finer particle size as progress towards the desired roughness is made. If the part is small or fragile, a finer size may be more appropriate. Larger-sized media do not reach smaller areas of the part, while smaller-sized media may become lodged in smaller crevices of the part, requiring an additional cleaning step afterwards.

The revolutions per minute of the vibratory tumbler and the time required to achieve the desired result depend on the abrasive media and the manufacturer specifications. The effectiveness of the process is not constant over time, tending to be more efficient at the beginning of the process when the media is newer, losing efficiency as the process progresses. Optimal tumbling time should be studied for the desired application, but it usually lasts several hours

Chemical polishing

Chemical polishing, also known as chemical smoothing, is a physio-chemical process that smooths the surface of thermoplastic polymer parts, including internal cavities. It is a non-line-of-sight process; in other words, it acts on the surface of the part without degradation of the part's mechanical properties and can achieve a surface finish with a roughness of value of less than 1 μm and different levels of glossiness. It can be used on polyamide (PA 11 & 12), as well as other thermoplastic polymers such as TPE and TPU.

Figure 15. Surface roughness improvement after chemical polishing

Since the process can be controlled, it can result in matt, gloss or shiny surface without losing any fine detail on the part or affecting the part's dimensional accuracy to any great extent.

If chemical polishing is used on gray parts, since the process acts on the surface layer, it can cut through the partially fused outer layer to give a piano black part, avoiding the need for an additional dyeing step.

Figure 16. Image of raw part, and two chemically polished parts with varying degrees of processing

For very thin sections that are less than 1 mm, there is a risk of structural deformation with chemical polishing. Furthermore, the process is not very efficient with sharp edges.

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