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Improving Aesthetics Through Post-Processing for 3D Printed Parts

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Abstract

3D printing is increasingly used for manufacturing final parts. The look and feel of final parts can be important, especially if they are intended for visible or wearable applications. We find that after parts are printed and cleaned, their aesthetic qualities can benefit from a variety of finishing processes. In this paper, we describe our post-processing work, largely for parts printed using HP's Multi-Jet Fusion (MJF), and with an emphasis on techniques that scale sufficiently to be useful in manufacturing workflows. We detail our efforts using vibratory tumblers for smoothing, and coatings and dyes for visual appearance, as well as how we have used some of these techniques and methods for specific wearables.

Context

Though generally associated with prototyping, increasingly 3D printing is moving towards manufacturing final parts [4]. The finish of final parts, especially if they will be visible or touched, may benefit significantly from various methods of post-print processing.

This is often the case with *wearables*. These are objects that people don on their bodies, like jewelry and clothing. Plastic jewelry has a respectable history, and Bakelite bracelets are now a valuable, collectable item [1]. However, the surfaces of some types of 3D printed parts differ from the smooth, bright sheen most consumers expect from a plastic jewelry product, and the surfaces may feel rough against human skin. Powder-based processes may have perceivable, partially-fused powder particles on the surface, while others, like Fused Deposition Modeling (FDM), can result in visible and rough layering. It is important to explore methods to modify the visual and tactile qualities of 3D printed part surfaces, to enable 3D printing to revolutionize the manufacture of cosmetic parts [3].

Post-processing is an existing part of many manufacturing workflows. For example, plastic glasses frames may be tumbled in vibratory tumblers for a lengthy duration, to achieve a smooth, polished finish. We can potentially apply these methods to 3D printed parts to achieve a variety of finishes and expand their applicability to more contexts and uses.

Objective

Our goal was to find ways to modify the visual and textural finish of parts produced with Multi Jet Fusion (MJF) technology, both those printed in color and in monochrome gray. We wanted to find solutions that are both scalable for potential use in manufacturing, and that are appropriate for the types of wearable applications we are exploring.

Multi Jet Fusion technology

Multi Jet Fusion (MJF) is HP's 3D print technology platform. Our post-processing work focuses on this form of 3D printing. MJF is a powder-based process that deposits agents on a bed of powder via a print bar and then fuses them with thermal energy. The platform allows the use of different agents to control voxel-level properties, such as color, conductivity, and translucency. Our work looks at both HP's 4210 product, which prints using a black fusing agent, as well as test beds in HP Labs that use the same premise of agent and powder printing but that incorporate different properties, like color.

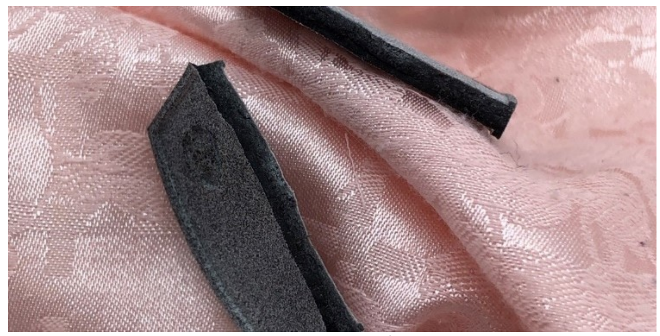

Figure 1: A Multi Jet Fusion part broken in half, showing the grey appearance of the surface as well as the dark black color of the interior.

Though the agent in HP's 4210 Jet Fusion printer is black, the parts appear naturally grey. Indeed, if you cut into the part, as in Figure 1, you see the jet black color in the middle. The grey on the surface is the result of partially fused powder particles, leaving a rough surface that scatters light.

For many HP MJF parts, this is a non-issue. Though it may look loose, the powder is fused on and does not come off. More sandblasting results in a darker grey, or parts can be dyed black. Additionally, many MJF parts today are used as internal components, so a particular color is not essential. However, some final parts have cosmetic importance, and we can address these use cases through post-processing. Additionally, when printing with different colors, the visual impact of the partially fused powder on the appearance becomes a larger issue.

Tumbling and Coating Experiment

We undertook a structured experiment to determine how vibratory tumbling and various coatings influence both the color values and the surface roughness of color parts that are 3D printed in Nylon-12 plastic with the Multi Jet Fusion process.

Method

We began with vibratory tumbling because of its existing use in plastic polishing, and because the process is largely hands-off, which makes it appropriate for manufacturing applications. We chose to use a process recommended to us by a tumbling media supplier. This involves three steps—first wet-tumbling with ceramic media, then wet-tumbling with synthetic plastic media, and finally dry-tumbling with walnut shell media for the final polish. Figure 2 shows the abrasive media. In a method similar to using increasingly fine grits of sandpaper, we increased the amount of tumbling time with the softness of the media. We used four conditions: None, with no time spent tumbling; Low, with 1 hour of ceramic, 2 hours of synthetic, and 3 hours of walnut; Medium, with 18 hours ceramic, 18 hours synthetic, and 28 hours walnut, and High, with 30 hours ceramic, 38 hours synthetic, and 52 hours walnut.

Figure 2: From left to right, ceramic media, synthetic media, and walnut media used in the tumbling experiment.

Our test objects were cuboid bars (Figure 3), measuring 35mm x 12mm x 12mm. We tested the blocks in three solid colors with RGB values of red (255,0,0), green (0,255,0), and blue (0,0,255).

On top of each of these tumbling durations, we tried the following surface treatments: None, clear coat, mineral oil, super glue, and wax. We tested one version of each type of coating, looking for general trends, though we realizie results may vary between specific coating products. We had one test piece for each combination of color, tumbling, and surface treatment, for a total of 60 pieces.

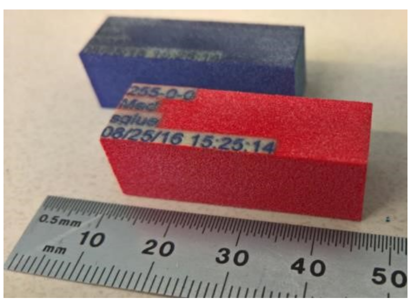

Figure 3: The test objects, printed with labels.

For all the samples, we measured the lightness, chroma (with the EyeOne Pro spectrophotometer), and surface roughness (with the Keyence 3D laser scanning confocal microscope).

Results for Tumbling and Coating

Our measurements from the tumbling and coating experiment show that our experimental process significantly reduces the surface roughness (S_a) and lightness (L*) while increasing chroma. The surface coatings themselves did not improve the quantitative roughness measurements. However, they did improve chroma and lightness, indicating their usefulness for future post-processing. See Table XX and Figures 8 and 9 for the results.

Chomra, L* Results Summary

Tumbling alone: All tumbled parts with no coating (n=9)	chroma +7.7 L* -9.0
Surface coating alone: All coated parts with no tumbling (n=12)	chroma +1.6, L* -2.04
Combined tumbling + coating: All parts with tumbling and coating (n=36)	chroma +3.8, L* -12.0

S_a Results Summary

None S_a	15.2
Low S_a	11.5
Med S_a	5.2
High S_a	3.8
Uncoated S_a	14.4
Coated S_a	14.9

Results from the experiment of the tumbled-only parts, when plotted in Figure 8, show how our three metrics change over the course of the experiment from tumbling alone. Figure 9, the surface scans, also clearly show how the rough initial surface is smoothed over time. The visual impact of tumbling the surface is clearly perceptible in Figure 10, and that end-user impact reflects our ultimate goals. Figures 9 and 10 focus on the tumbled-only parts, as the coatings did not improve roughness.

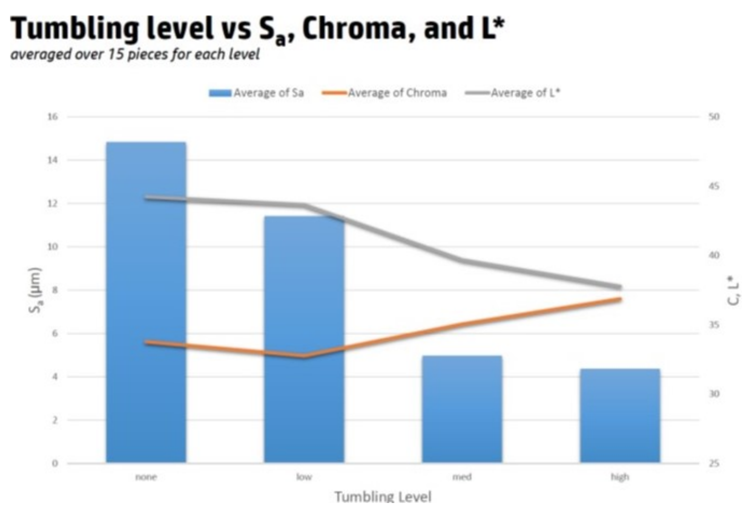

Figure 8: A chart showing the changes in S_a (blue bars), Chroma (orange line), and L (grey line) from tumbling.*

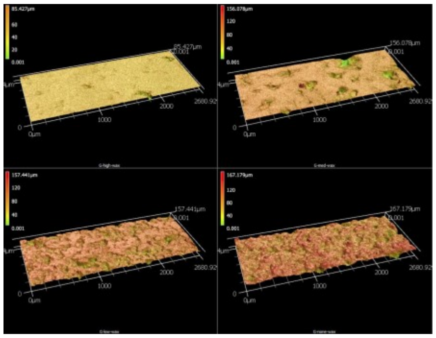

Figure 9: Surface scans of parts using the Keyence 3D laser, with High, Medium, Low, and None conditions.

Figure 10: A part with no tumbling or surface coating on the left, and a part with the high tumbling condition and no coating on the right.

One observation is that the payoff for tumbling seems to peak and start to taper off, as the amount of improvement between the "low" and "medium" tumbling settings is much greater than the amount of improvement between "medium" and "high." We also noted that tumbling affected the average part weight and dimensions by less than 1%.

Additional Experiments

We used and expanded upon our tumbling and coating explorations in the contexts of jewelry, false fingernails, and fabric-like structures. Finished appearance matters greatly for these applications. For these post-processing experiments, we did not conduct measurements. Rather, we have begun initial tests, based on the desired experiences of particular forms, to identify what future areas we should delve into for more formal experimentation.

For jewelry, we created pieces where 3D printed parts encased small electronics (Figure 4). We tumbled the parts to decrease roughness, as many touched the skin very closely. We also coated them with a clear coat, to further improve the appearance of part color.

Figure 4: A tumbled and clear coated brooch, with wings that move, and a tumbled and clear coated pendant with a bottom tassel that rotates.

We also experimented with metallicizing monochrome grey jewelry prints, with spray paint coatings (instead of clear) and gold leafing (Figure 5). We determined gold leafing was not scalable, because it requires careful application of the leaf by hand, and even by hand it is difficult to completely coat some of the fine detail 3D printing allows. Spray coating improved both visual and perceived textural qualities, and spray coating is already a viable part of some manufacturing workflows [2].

Figure 5: On the left are the spray coated bracelets, and on the right is the gold-leaved sample.

We used coating to improve 3D printed false fingernails (Figure 6). We tumbled the nails, but the thin structures were prone to warping and the results still differed in quality from the look and feel of existing professional manicures or fake nails. This led us to use a clear coat only, with no tumbling. For this application we used a clear nail polish, which gave the nails a familiar texture and reduced the visual impact of the surface powder.

Figure 6: 3D printed false fingernails, without clear varnish on the left, and with clear varnish on the right.

We also explored color-coating a variety of interlocking, textile structures printed in monochrome grey (Figure 7). Fabric-like structures may not touch skin directly, as they are not traditional fabric. Assuming such parts would likely be layered over clothing, or perhaps on hair, we prioritized changing visual appearance over texture. We have used a dyeing process, where we add dye purchased in either powder or liquid form to boiling water. We then submerge the parts, varying the amount of time spent in the dye bath to modulate the final color result. When using colored dye as a coating for these parts, we observe that unevenness in the underlying surface quality carries over into uneven color in the final part. We have also begun using standardized parts to assess the color we can achieve through dyeing, as we experiment with different colors and brands of dye.

Figure 7: On the left, a dyed head piece. On the right, a reference part used to evaluate the viability of different colored dyes.

Novelty and Conclusions

3D Printing has immense potential as a new method for manufacturing, but appropriate aesthetics and feel will be important for some applications, such as wearables, in which final will be seen or touched. Our work is a survey of potential directions for post-processing MJF parts to improve appearance and usability, which is an area that has received much less attention than that of developing 3D printing technology itself. So far, our results point to the effectiveness of tumbling, coating, and dyes for improving and expanding the aesthetics of 3D printed parts.

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Author Biographys

Alex Ju received her BFA in jewelry and metalsmithing from the Rhode Island School of Design (2016). Since then she has worked as a research engineer at HP Labs in Palo Alto, CA. Her research work spans several facets of 3D printing, including applications, experiences, post-processing, and education.

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