Accelerated Weathering Test: Color resistance

February 2020

Executive summary

The objective of this test is to characterize the outdoor color durability of Multi Jet Fusion parts that have been postprocessed with different methods. The material selected to run the test is PA12 and the postprocesses tested are the following ones:

Postprocess family	Postprocess name	Sample color	Company provider of the postprocess
None	Natural parts		None
Paint	UV resistant paint		Automotive paint
Hydrographics	Hydrographics without UV clear coat		GoProto
	Hydrographics with UV clear coat		GoProto
Chemical polishing	PostPro 3D vapor smoothening		AMT
	Dyemansion Vapor smoothening		Dyemansion
Dyeing	Dyemansion standard black dye		Dyemansion
	Dyemansion automotive dye		Dyemansion
	Rit Dye		Rit
Powdercoating	Matte black with MJF substrate		Keyland Polymer
	Low Gloss Blue with MJF substrate		Keyland Polymer

The accelerated weathering test method used is aligned with **SAE J2527/ASTM D2565**, which is a standard adopted by the automotive industry. The test uses with a daylight filter and it involves spurring on fading using high intensity Xe-Arc lamps combined with water sprayed in controlled conditions inside an ATLAS weatherometer.

Delta E is the metric used to **quantify the change in color as observed by a human**. In this study, we used the simplest version of Delta E—the Euclidian Delta E—which is the distance between the two points in an L*a*b* color space.

Summarizing, below is included the list of postprocesses tested, ordered from the best performance (less color fading) to the worst performance (more color fading):

Postprocess	ΔE after 1000h
Painting	0.8
Powdercoat - Matte black	3.3
Hydrographics with UV clear coat	4.0
Natural parts	4.0
Hydrographics without UV clear coat	5.4
Powdercoat - Low Gloss Blue	5.4
AMT smoothening	9.8
Dyemansion automotive dye	13.1
Dyemansion standard black dye	13.9
Dyemansion Vapor smoothening	17.4
Rit Dye	26.9

The paint included in this test is an UV resistant paint used in automotive applications. This postprocess is the one that performs the best in terms of color fading. The Hydrographic process uses as a color background a paint that is UV resistance as well, which is the main contributor of the low color fading showed in this samples. In addition, the Powdercoated samples have a similar performance as the Hydrographics ones with UV clear coat. **Painting, powdercoating and hydrographics are the top 3 of all the postprocesses tested to keep the color of the parts in outdoor conditions.**

On the other hand, the **RIT Professional Dye** is the postprocess showing the highest color fading of all the samples tested and, therefore, it **is not recommended its use for parts that will be exposed outdoors**.

About the Test

The ability of a plastic material to resist fading of optical properties caused by exposure to light, heat and water can be very important for many end use applications. The purpose of this test is to characterize the outdoor durability of MJF parts, both natural parts (without any postprocess) and with third party postprocessing options. All the post-processes tested (unless none) were produced by third parties. The sample parts were black, blue and brown, as these are colors requested to be evaluated for existing customers. The following table shows the combination of post processes tested. In Annex 2, there is included more information about these postprocesses.

Postprocess family	Postprocess name	Sample color	Company provider of the postprocess
None	Natural parts		-
Paint	UV resistant paint		Automotive paint
Hydrographics	Hydrographics without UV clear coat		GoProto
	Hydrographics with UV clear coat		GoProto
Chemical polishing	PostPro 3D vapor smoothening		AMT
	Dyemansion Vapor smoothening		Dyemansion
Dyeing	Dyemansion standard black dye		Dyemansion
	Dyemansion automotive dye		Dyemansion
	Rit Dye		Rit Professional Dye
Powdercoating	Matte black with MJF substrate		Keyland polymers
	Low Gloss Blue with MJF substrate		Keyland polymers

An HP outdoor weathering method, with a daylight filter, aligned with SAE J2527/ASTM D2565 was used. This test was adopted from the automotive industry. The method involves inducing fading using high intensity Xe-Arc lamps along with sprayed water in controlled conditions inside an ATLAS weatherometer. Figure 2 shows the cycle's characteristics.

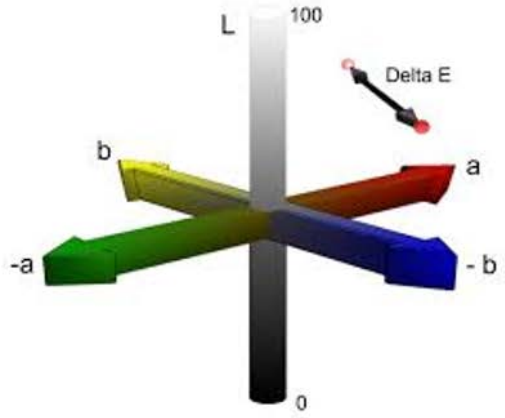
Program	Segment	Event	Time (min)	BPT (°C)	Air T (°C)	RH (%)	Irradiance (W/m^2)	Filters
Outdoor **(SAE J2527)**	1	Dark+Spray	60	38±3	38±3	95±5	0	**Atlas Weather-Ometer:** Quartz / Borosilicate Type S
	2	Light	40	70±3	47±3	50±5	0.55 @ 340 nm	
	3	Light+Spray	20	70±3	47±3	50±5	0.55 @ 340 nm	
	4	Light	60	70±3	47±3	50±5	0.55 @ 340 nm	

Figure 1: Cycle for weathering test

Above: RH is relative humidity and BPT is the uninsulated black panels temperature, a parameter which represents the temperature of the samples.

In these type of tests, there is no threshold defined that says whether a part is UV resistant or not. It usually depends on the application's requirements. The exposure time used was 1000 machine hours, with an intermediate measurement at 500 hours. The correlation of quantity of hours to years of exposure is defined by each company as well, as this standard doesn't include a correlation formula to use for that purpose. HP's internal correlation formula indicates that 1000h of exposure is the equivalent of 4.3 years of outdoor exposure. However, the correlation may vary depending on the geography and the weather conditions (sunlight, strength of the UV radiation, quantity of rain per year, etc.)

To quantify the color change, the CIELAB color space was used. It expresses color as three numerical values—*L** for lightness and *a** and *b** for green–red and blue–yellow color components. CIELAB was designed to be perceptually uniform with human color sight, meaning that the same amount of numerical change in these values correspond to about the same amount one would visually perceive [1]. In this study, the simplest version of Delta E was used, which is the distance between two points in an L*a*b* color space. Color coordinate values (L*, a*, b*) were measured with an X-Rite D65 at 2 degrees, each measurement tripled, as they were taken at three various locations of the sample.



$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

Figure 2: Delta E

Test Results

Several samples of each postprocess have been tested and the color variation of each sample has been measured in 3 different points.

The representation of the results is done by using Box-and-Whisker plots. In this type of graphs, there are represented not only the median of the values measured, but also the lower and upper quartiles and the maximum and minimum measurements. This type of graph is used to show the shape of the distribution to understand as well as the variability that occurs between the different samples and measurements taken.

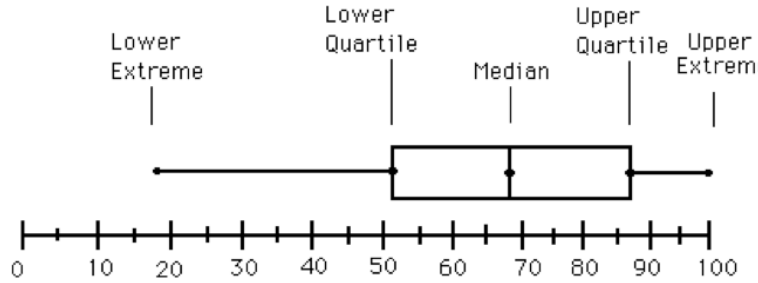


Figure 3. Box-and-Whisker Plot. How to read the values represented.

The samples were measured after 500h and 1000h of exposure. The following graphics are including the results of those measurements:

ΔE after 500h of exposure

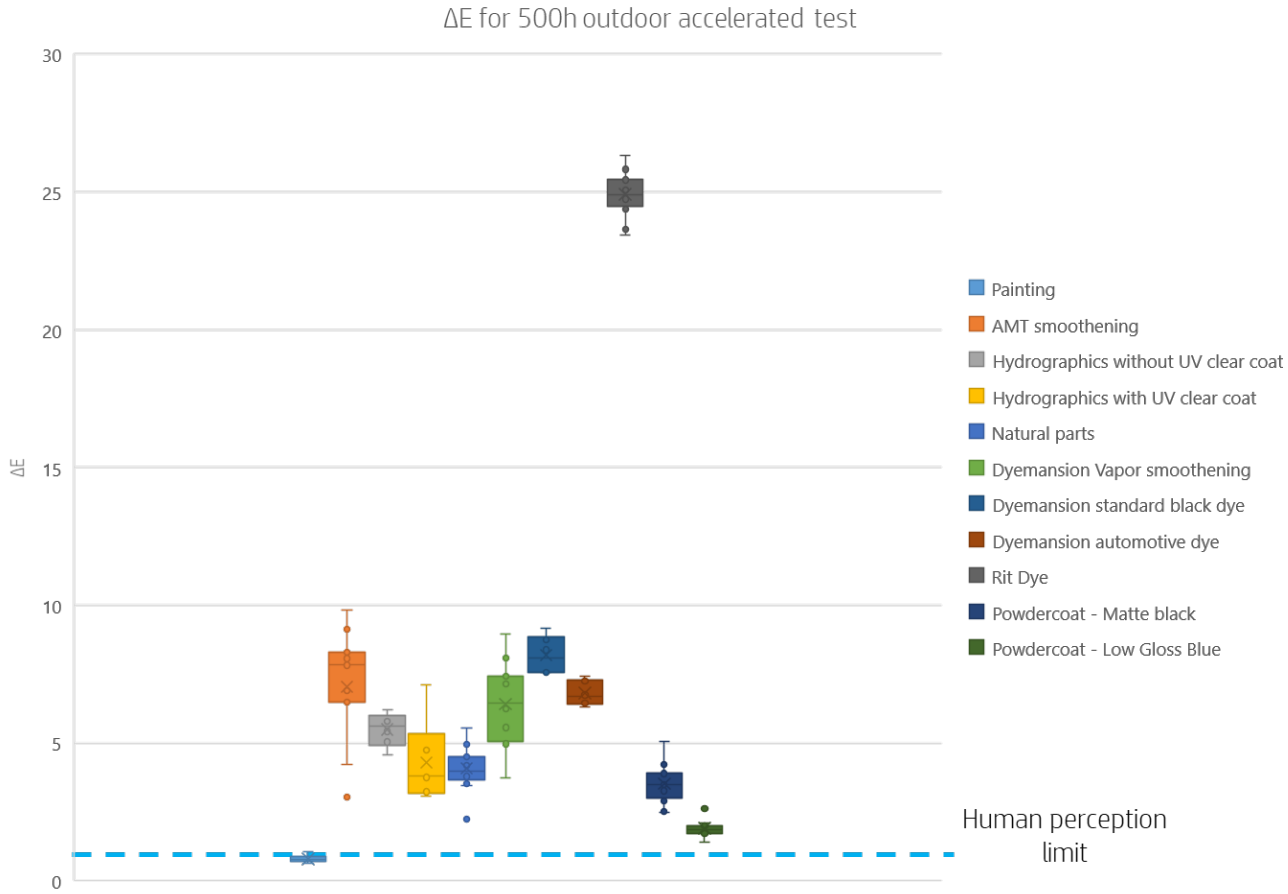


Figure 4: Box-and-Whisker Plot with Delta E after 500h of outdoor accelerated test

ΔE after 1000h of exposure

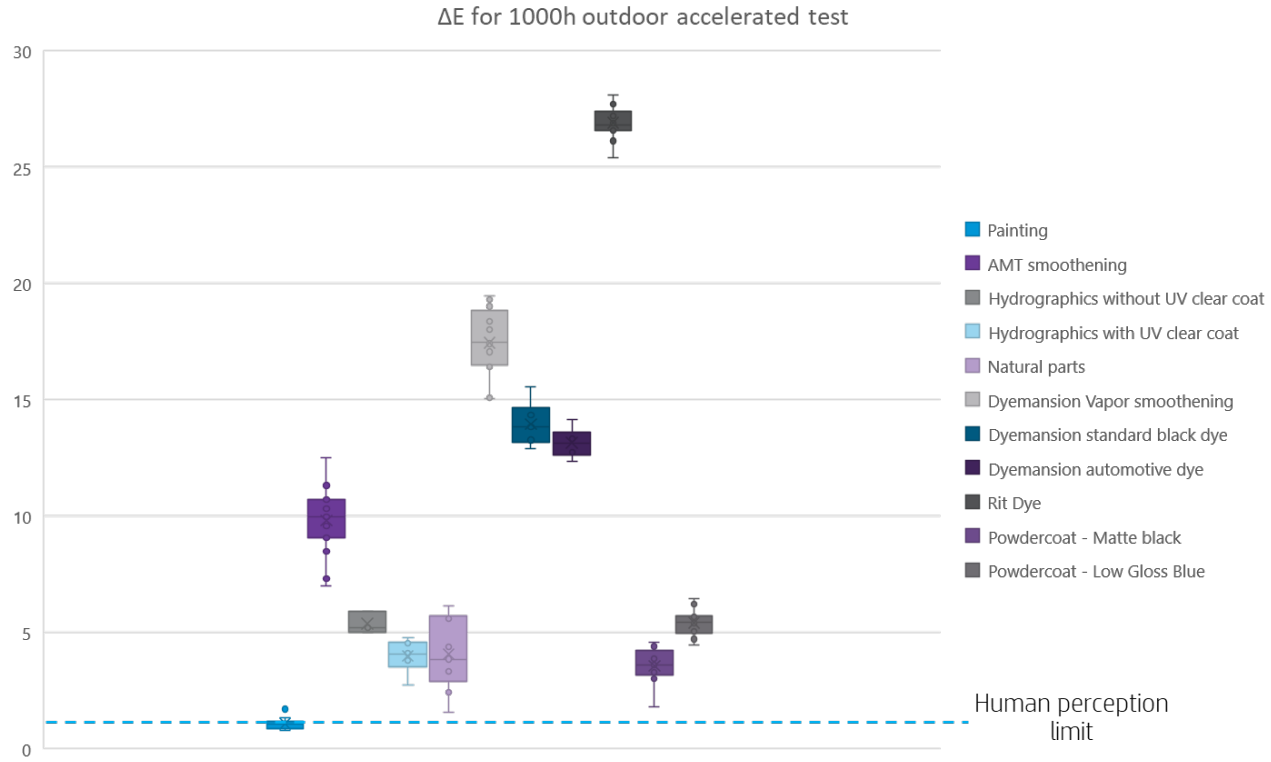


Figure 5: Box-and-Whisker Plot with Delta E after 1000h of outdoor accelerated test

Conclusions

The following table includes the list of postprocesses tested, ordered from the best performance (less color fading) to the worst performance (more color fading):

Postprocess	ΔE after 1000h
Painting	0.8
Powdercoat - Matte black	3.3
Hydrographics with UV clear coat	4.0
Natural parts	4.0
Hydrographics without UV clear coat	5.4
Powdercoat - Low Gloss Blue	5.4
AMT smoothening	9.8
Dyemansion automotive dye	13.1
Dyemansion standard black dye	13.9
Dyemansion Vapor smoothening	17.4
Rit Dye	26.9

The paint used in the painted parts is UV resistant, which correlates with the results, as is showing the best performance in terms of color fading. The Hydrographic process uses as a color background a paint that is UV resistance, which is the main contributor of the low color fading showed in this samples. In addition, the Powdercoating samples show a similar performance than the Hydrographic ones. That will position them three in the top performers to keep the color of the parts under outdoor conditions. On the other hand, the UV clear coat applied on top of the part provides an additional improvement (~25% improvement) versus the part without it. Therefore, this option could be an option to consider, but it should be taken into account that this is an additional step that could be avoided if the results of the hydrographics without the UV coat are already satisfactory.

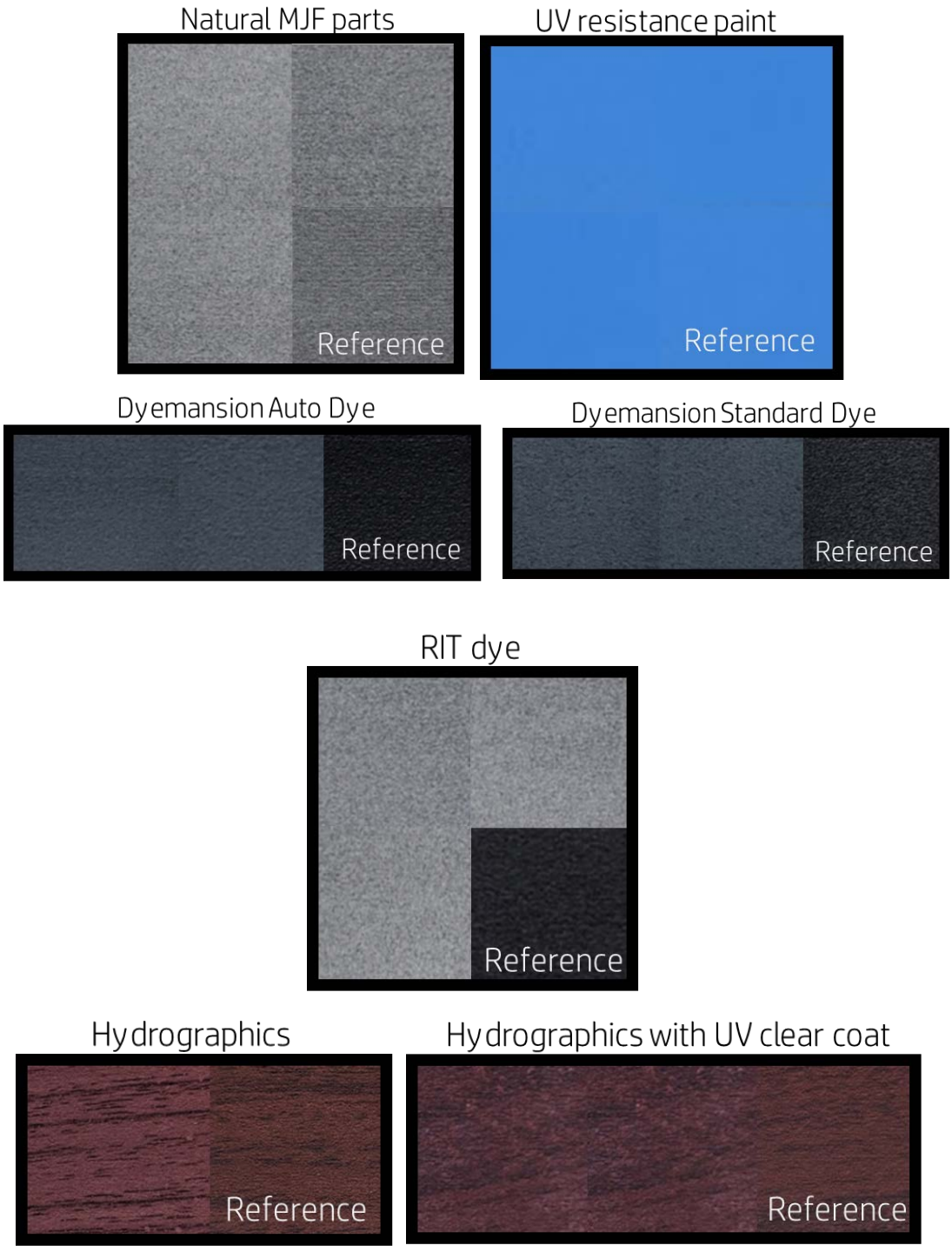
The vapor polishing options and the Dyemansion Dyes provide results slightly worse than the postprocesses just mentioned. Therefore, depending on the cost per part of each postprocess and the expected outdoor exposure of each specific final part, it may still be an option in some cases.

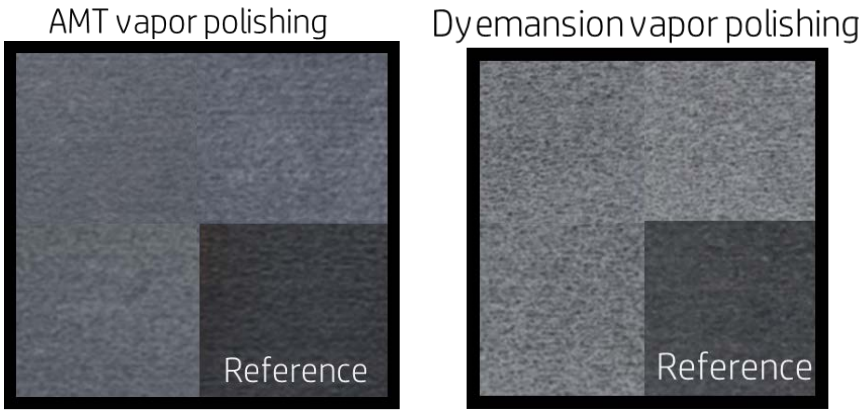
On the other hand, the RIT Professional Dye is the postprocess showing the highest color fading of all the samples tested and, therefore, it is not recommended its use for parts that will be exposed outdoors.

ANNEX 1: Pictures

The following pictures show a comparison between the samples that have been exposed and the reference sample that was keep as a control without being exposed.

After 1000h





ANNEX 2: Post-Process Links

Dyemansion dyeing system: https://dyemansion.de/en/

RIT dye: https://store.ritdye.com/5-pound-dye/black-proline-dye-5-lb/

Vapor polishing: https://amtechnologies.com/

Keyland polymer: https://www.kpuvpowder.com/

References

[1] Hoffmann, Gernot, [Online]. Available: http://docs-hoffmann.de/cielab03022003.pdf. [Accessed May 2018].