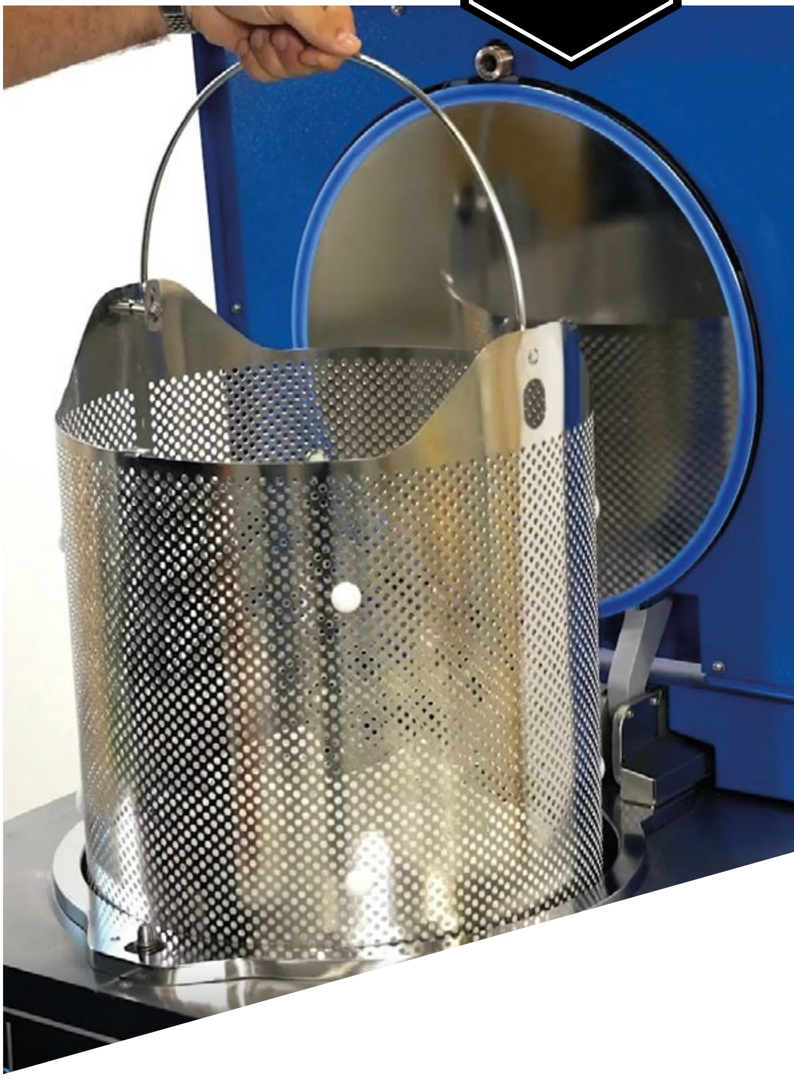


MANUAL POT DYEING VS. INDUSTRIAL DEEPDYE COLORING

EXECUTIVE SUMMARY

When powder bed 3D-printing was mainly used for prototyping, pot dyeing became a pretty popular method. For this process cooking pots and conventional textile dyes were mainly used. With the evolution of 3D-printing from prototyping to serial manufacturing the required standards for 3D-printed products are changing as well. Whoever produces for the automotive, aerospace, fashion or medical industry knows how demanding these standards are. In addition to a reproducible dyeing process, not only a detailed knowledge is required, but also a professional, controllable and traceable dyeing solution. The manual process using cooking pots and textile dyes often cannot serve these standards. However, today there are finally alternatives that meet the requirements for end-use applications. The market leading coloring solution for industrial manufacturing is DyeMansion's DeepDye Coloring (DDC) process and the system behind it, called DyeMansion DM60.

This whitepaper compares pot dyeing and DeepDye Coloring, their functionalities and fields of application. The results show how manual pot dyeing and the industrial DDC process differ and thus affect the part properties. Therefore, various parameters, such as light and heat resistance (in colloquial language often named UV-stability), color fastness and scratch resistance were evaluated on different materials (EOS PA 2200 & HP 3D HR PA 12). Also the impact of surface treatment and dyeing was tested. In addition, an overview of certifications required by various industries is given and it is pointed out how the two processes differ regarding these.

POT DYEING

Figure 1: Typical manual pot dyeing set-up

FUNCTIONALITY

Pot dyeing is a very simple, but also manual process. Therefore the 3D-printed plastics are put in a conventional cooking pot. First the textile dye is poured directly into pre-heated water, then the parts are added to the dyebath. Since the size of a cooking pot is limited, you may need many different pots when scaling up your volumes.

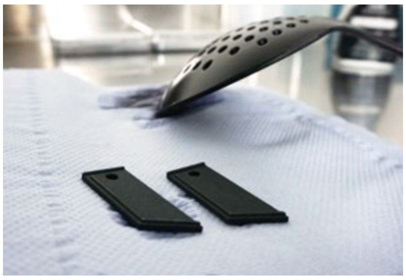


Figure 2-4: Pouring textile dye into the water, putting the parts in the pot, drying the parts

FIELDS OF APPLICATION

With the increasing use of 3D-printing for series manufacturing, the demands on 3D-printed parts have also been raised. These include improved part properties and compliance with certain standards. Since pot dyeing often cannot meet these industrial requirements, it is not suitable for dyeing them at all. However, a manual dyeing process is suitable for dyeing individual pieces that do not require exact color accuracy, for parts that are not visible or for prototypes. In addition, for black parts that are not exposed to external conditions like UV-light pot dyeing can also be feasible.

CERTIFICATIONS

It is hard to track down the exact ingredients of conventional textile dyes and therefore their fulfillment of industrial health and safety standards or other certifications. When looking at the tests for Skin Irritation or Cytotoxicity on 3D-printed nylon parts, no data can be found for the commonly used textile dye.

LIMITATIONS

Since all dyestuff handling must be done manually, pot dyeing is a hardly controllable technique. Furthermore, pot dyeing requires a manual cleaning of the cooking pots, which results in a quite uncomfortable process and a high probability of contamination, if not done carefully. For many applications dyed in the pot, black is the common color. But even with this dark color, reproducibility is not 100% given, as it will be shown in this paper. Another challenge with pot dyeing is that the colors can fade quickly when exposed to UV light and heat. When it comes to color variety or matching a specific color according to color systems such as RAL or Pantone, the process quickly reaches its limits. Color variety and the possibility to reproduce colors, however, is extremely important for visible end-use products. At this point it is again important to emphasize that the textile dye used for pot dyeing are not tested or certified for the usage on 3D-printed parts, so no ISO certifications regarding Cytotoxicity or skin safety can be guaranteed like mentioned above. When it comes to different materials, only a trial and error process can be used in terms of cycle time and temperature.

DEEPDYE COLORING (DDC)

Figure 5: DyeMansion DM60 coloring system

FUNCTIONALITY

The leading industrial coloring solution for industrial end-use parts at scale on the market is the DyeMansion DM60, using the company's proprietary DeepDye Coloring (DDC) process. This automated system enables a reproducible process that could not be easier for the user and can be reproduced at any time. Exact color recipes in the form of color cartridges that are equipped with RFID technology ensure a traceable QM-ready process without any manual pigment handling. A certain color formula is always manufactured depending on base material, surface finish and volume of the parts. The operator only has to scan the chip, insert the cartridge into the system and fill it with parts. The rest of the dyeing process is fully automated. Additionally working with the DM60 includes different process parameters e.g. heat, time, stirring speed and after-treatment, that can be regulated. After the DDC process, an automated cleaning cycle guarantees the next dyeing of parts to be flawless. Thanks to the integrated cleaning program, a fast color change is no problem at all.

Figure 6-8 LTR: The DeepDye Coloring (DDC) process: scanning a color cartridge, inserting the cartridge into the basket, filling the basket with parts

FIELDS OF APPLICATION

3D-printed products can be found in many different industries today, whether it is perfect fit eyewear or tailor-made orthotics.

INDUSTRY	RANGE OF 3D-PRINTED PRODUCTS
CONSUMER GOODS	Eyewear, jewelry, shoe soles, sporting goods, interior etc.
AUTOMOTIVE	Spare parts, interior parts, air conductors etc.
MEDICAL	Orthoses, prostheses, medical aids etc.
INDUSTRIAL	Cases, industrial grippers etc

Figure 9: Eyewear by Götti Switzerland

Figure 10: Spare parts by Daimler Buses

Figure 11: Bionic orthosis by HKK Bionics

Figure 12: Hand scanner by ProGlove

Thanks to the biggest certified color data base on the market, DDC can be used for most 3D-printed end-use products. The DDC process also offers maximum flexibility: Individual color whishes can be done with the DyeMansion Color Matching based on physical samples or color references (such as RAL or Pantone). If special part properties like an advanced UV-stability is needed, there are specific options for those kinds of requirements. The DyeMansion Colors^X are a good example here. The Automotive^X and Neon^X Colors address the special requirements of individual industries. On the one hand the demand for bright, vibrant colors in the consumer sector, on the other hand colors with improved light and heat resistance in the automotive sector. Such individual solutions cannot be offered with pot dyeing.

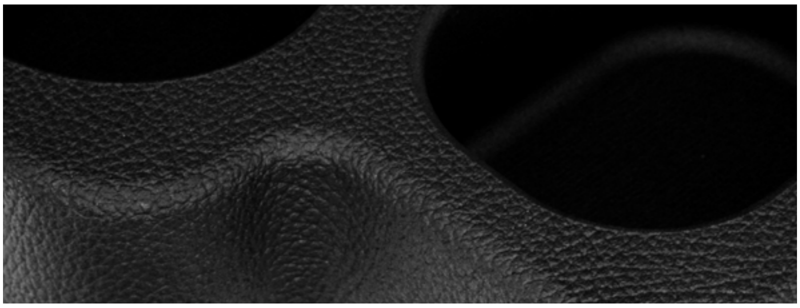


Figure 13: HP 3D HR PA 12 cup holder, finished with PolyShot Surfacing & dyed with Automotive Black^X

WHITEPAPER: AUTOMOTIVE BLACK^X

Learn more about Automotive Black^X, which opens up new possibilities for 3D-printed polyamide car interior parts. The color line has been developed according to the well-known hot irradiation standards of the ISO 105-B06 norm.

CERTIFICATIONS

All the end-use applications mentioned above (see fields of application) are exposed to sunlight or in contact with human skin. So manufacturers of those products should be aware of topics like skin safety or light and heat stability. With the DDC process, which was developed for the use of 3D-printed plastics, there are various ISO certifications available. This makes DDC a trusted technology to use in all different industries (see fields of application). The following certificates can be presented for colors applied with DDC in the DM60:

✓ CYTOTOXICITY (ACCORDING TO ISO 10993-5 & 10993-12) [1]

✓ SKIN IRRITATION (ACCORDING TO ISO PROTOCOL TC 194 WG 8 & NORM 10933-12) [1]

✓ COLOR FASTNESS[2]:

Rubbing (ISO 105-X12)
Washing (ISO 105-C06)
Bleaching (20105-N01)
Perspiration (ISO 105-E04)

✓ SCRATCH RESISTANCE (PV3952)[2]

✓ LIGHT AND HEAT RESISTANCE (ACCORDING TO ISO 105-B06, METHOD 3)[3]

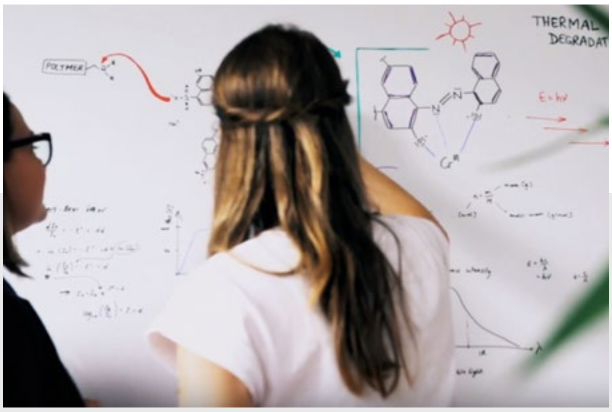
In addition, REACH (regulation EC 1907/2006), TCSA (Toxic Substance Control Act), RoHS (EU Guideline 2011/65/EU) and AOF (Animal Origin Free) statements are available for colors applied with DDC.

LIMITATIONS

Compared to pot dyeing, a limitation of the DeepDye Coloring process with the DM60 is the process time. Even though the holding time is less than with pot dyeing, the DM60 needs longer to ensure controlled heating and cooling. For safety reasons, the parts can only be taken out of the DM60 when the process is finished. In case of pot dyeing, especially cooling is not necessary as you can take out the parts at any time. Due to the fixed size of the basket, the dyeing volume is limited to the dimensions of 360mm in height and 390mm in diameter, which on the other hand is much larger than most available cooking pots. Another point to mention is the infrastructure needed like compressed air and demineralized water.

[1] Tested on EOS PA 2200 with PSS & DDC finish and all dyes and chemicals used in the standard and RAL colors.
[2] Tested on EOS PA 2200 with PSS & DDC finish and DM Black 01.
[3] Tested on EOS PA 2200, EOS PA 1101 and HP 3D HR PA 12 with PSS & DDC finish in Automotive Black[X].

EXAMINED PART PROPERTIES



The quality of a dyeing solution can be evaluated very easily by the following measurements. For end-use products, light and heat resistance, scratch resistance and color fastness are particularly important.

LIGHT AND HEAT RESISTANCE

Due to the organic nature of dyes they tend to fade in the sunlight. Artificial light allows one to perform accelerated testing of light and heat resistance. During this test, dyed parts are exposed to certain irradiation, heat and humidity conditions. The change of color induced by the weathering is measured after the exposure.

SCRATCH RESISTANCE

Looking at end-use products scratches are difficult to avoid in everyday life. For this reason, it is important to achieve scratch-resistant surfaces in order to maintain the appearance of a color. The test setup consists of a mechanical motion of a tip with a certain force on the surface of the dyed part. The color change was measured to determine the scratch resistance.

COLOR FASTNESS

Apart from sunlight, dyed plastics can also fade by means of mechanical and chemical forces. Especially washing and bleaching agents, as well as sweat that are in contact with the 3D-printed part. Thus their influence regarding color fastness should be tested. There are different test setups to simulate the individual influences in the best possible way. In general, the dyed part is exposed to the respective chemicals under different mechanical loads with different fiber fabrics. Afterwards, both, the dyed part and the transfer media used, are evaluated for color changes.

EXAMINED PART PROPERTIES

The basis for the comparison between pot dyeing and DDC are nylon parts produced with Selective Laser Sintering (SLS) and Multi Jet Fusion (MJF) technology. The parts were dyed black with the two different methods and corresponding dyes. For pot dyeing, a widely commercially available black dye was used (in the following: textile dye). It was selected with the help of several videos and instructions on how to dye 3D-printed nylon. It was used accordingly to the instructions found in the packaging. For the DDC process, the proprietary formula for DyeMansion's standard black, called DM Black 01 and a color cartridge in size M was used in the DM60. The exact test setup can be found in table 1 & 2 (next side).

TECHNOLOGY	SYSTEM	MATERIAL	MATERIAL DECLARATION	LAYER THICKNESS
SLS	EOS Formiga P 110	PA 12	EOS PA 2200	100µm
MJF	HP Jet Fusion 3D 4200	PA 12	HP 3D HR PA 12	80µm

Table 1: Used printing technologies and parameters

Figure 14: Raw, unfinished EOS PA 2200 sample

Figure 15: Raw, unfinished HP 3D HR PA 12 sample

PROCESS	DYE	DYEING TIME (WITHOUT HEATING & COOLING)	TEMPERATURE
Pot dyeing	Textile dye	approx. 60 min.	90°C | 194°F
DeepDye Coloring	DM Black 01	approx. 30 min.	115°C | 239°F

Table 2: Used dyeing parameters

Figure 16: EOS PA 2200 sample part after dyeing with textile dye and DM Black 01 – parameters see table 2

NOTE

The results of pot dyeing and DeepDye Coloring with the DM60 are very different. While the parts dyed with DM Black 01 were black, the parts dyed in the cooking pot turned out slightly blue in different shades depending on the printer, material or printing technology.

The test results were evaluated and visually inspected using a grey scale. The grey scale is a method for evaluating the change and brightness in color (ΔE) in a standardized way.

It consists of 5 grades and can be interpreted as follows:

GRADE 1: Highest change of color, worst result

GRADE 5: No change of color, best possible result

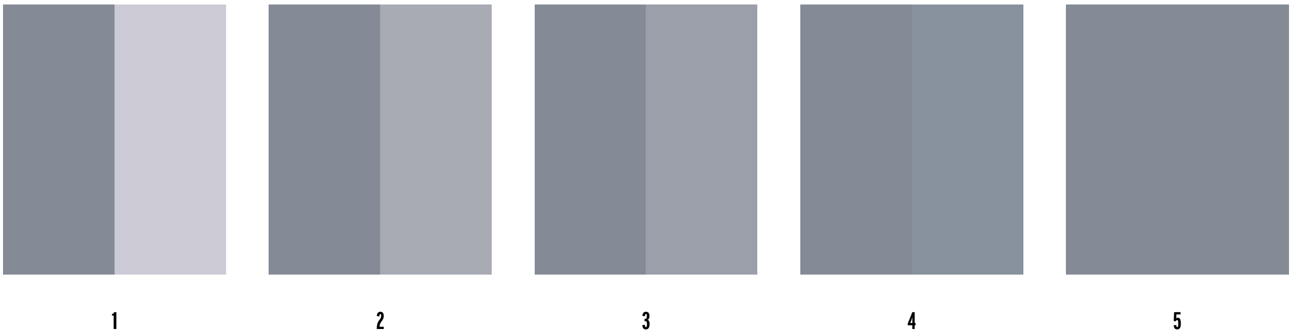


Figure 17: Grey scale

Figure 18: Visual comparison of a sample part (before and after the test) with the grey scale

LIGHT AND HEAT RESISTANCE

ISO 105-B06, METHOD 3

The parts were colored with the DDC process in DM Black 01 and through pot dyeing with the textile dye respectively. In a lightfastness testing device (Q-Lab Xe3-HBS), the parts were exposed to solar radiation. The lightfastness was tested according to the hot irradiation standards DIN EN ISO 105-B06 method 3 (table 3), performed by many automotive companies for interior parts. The performed lightfastness test, according to DIN EN ISO 105-B06, comprises a constant heating at a chamber air temperature of 65 °C and a relative humidity of 30 %. The 3D-printed and dyed parts were exposed to three Xenon lamps, each with an irradiance intensity of 60 W/m². Three cycles, with a duration of 45 h per cycle leading to a total of 135 h of radiation, were performed.

PARAMETER	VALUE
Insulated Black Panel Temperature	100 °C
Chamber air temperature	65 °C
Relative humidity	30%
Irradiance (TUV Sensor 300-400 nm)	60 W/m²
Number of cycles	3
Cycle Time	45 h
Total Time	135 h

Table 3: Used lightfastness parameters according to DIN EN ISO 105-B06 method 3

The results of the two materials (EOS PA 2200 and HP 3D HR PA 12) colored with the two different dyes (textile dye & DM Black 01) are depicted in Table 4 (page 11). To determine the influence of surface treatment prior to dyeing, both untreated (next side) as well as parts treated with DyeMansion's PolyShot Surfacing (PSS) were tested. During the automated, mechanical process beads accelerated with compressed air equalize the peaks and lows of the part's surface, achieving a more homogeneous part quality.

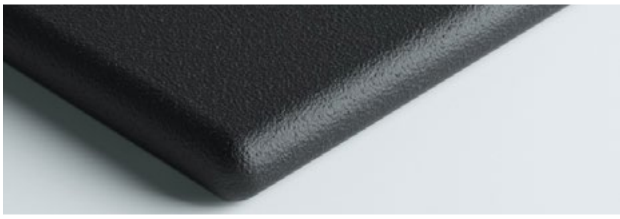



Figure 19 & 20 LTR: Visualization of a HP 3D HR PA 12 sample dyed with DDC without surface treatment and a part treated with PolyShot Surfacing (PSS) before dyeing

WHITEPAPER: STATE-OF-THE-ART SURFACING

If you are interested in different surfacing options, this whitepaper will help you find the right finish for your application. It compares our PolyShot Surfacing (PSS) and VaporFuse Surfacing (VFS), which delivers injection molding like surfaces.

The conventional pot dyeing with the textile dye shows a high color fading (grey scale 1 – 1.5). In contrast, the DM Black 01 coloring with the DDC process completed the lightfastness testing of the ISO 105-B06 standard with a grey scale value of 3.5 – 4. This underlines, that pot dyed parts should only be used for non- visible parts, which have low requirements in terms of stability against sunlight and heat.

MATERIAL	TECHNOLOGY	COLOR	FINISH	ΔE	GREY SCALE
EOS PA 2200	**SLS**	Textile dye	Raw	24.57	1 - 1.5
			PSS	23.13	1 - 1.5
		DM Black 01	Raw	5.38	3.5 - 4
			PSS	4.11	3.5 - 4
HP 3D HR PA 12	**MJF**	Textile dye	Raw	16.39	1 - 1.5
			PSS	17.90	1 - 1.5
		DM Black 01	Raw	5.98	3.5 - 4
			PSS	3.89	3.5 - 4

Table 4: Results of the lightfastness testing

EOS PA 2200

Figure 21: DM Black 01 on EOS PA 2200 (PSS) before vs. after lightfastness testing

Figure 22: Textile dye on EOS PA 2200 (PSS) before vs. after lightfastness testing

Figures 21 & 22 show the material EOS PA 2200 (white raw material), finished with PSS and colored with DM Black 01 (figure 21) and textile dye (figure 22). Each image shows the parts before (left) and after (right) the lightfastness testing.

HP 3D HR PA 12

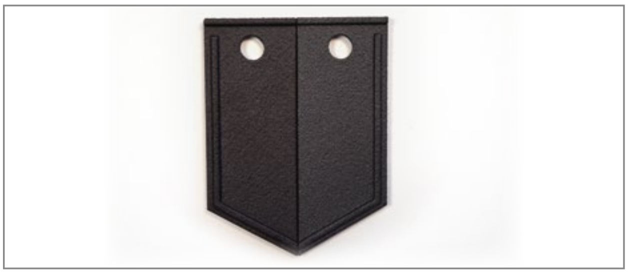


Figure 23: DM Black 01 on HP 3D HR PA 12 (PSS) before vs. after lightfastness testing

Figure 24: Textile dye on HP 3D HR PA 12 (PSS) before vs. after lightfastness testing

Figures 23 & 24 depict the material HP 3D HR PA 12 (grey raw material) finished with PSS and dyes mentioned on the left before and after the lightfastness testing. In both cases, a slight improvement can be observed with the PSS finish compared to the raw material. With Automotive Black^{X}, the ISO 105-B06 can be fulfilled, as grey scale values of 4.5 – 5 can be achieved after the weathering test.

SCRATCH RESISTANCE

PV3952

In the following tests, the whitepaper will focus on the materials EOS PA 2200 and HP 3D HR PA 12 colored with the textile dye and DyeMansion's standard black DM Black 01. Before testing, the samples were conditioned in normal climate (23 °C, 50 % r. h.) for 48 h. Scratch resistance is the resistance of a material against a mechanical impact. To simulate this property, a tip (1 mm) with a force of 5 N was used. Using a multiple use scratch device, a grid pattern with a line distance of 2 mm was applied to the surface. The used test parameters are summarized in Table 5. To evaluate the results, the color was measured before and after testing to determine the color change.

PARAMETER	VALUE
Normal Climate	23 +/- 5 °C; 50 moisture
Force	5 N
Scratch Velocity	1000 mm/min
Line Distance	2 mm
Tested Area	40 x 40 mm
Tip	1.0 mm
Color Measurement	45°/0° geometry, D65 light

Table 5: Scratch resistance testing parameters according to PV3952

The ΔE value shows the change in color of the material before and after the scratch resistance test. The results, depicted in Table 6, show that the choice of dye has no effect on the scratch resistance of the material. With both dyeing processes, similar results were achieved with only a slight color deviation compared to the reference.

MATERIAL	TECHNOLOGY	FORCE	COLOR	FINISH	ΔE
EOS PA 2200	**SLS**	5 N	Textile dye	PSS	1.32
			DM Black 01	PSS	1.29

Table 6: Results of the scratch resistance testing according to PV3952

COLOR FASTNESS

COLOR FASTNESS TO WASHING: ISO 105-C06 METHOD C1S

The samples of both materials, colored in DM Black 01 and the black textile dye, respectively, were brought in contact with different fabric materials e.g. cellulose acetate (CA), cotton (CO), polyamide resp. nylon (PA), polyester (PES), polyacrylate (PAC) and virgin wool (WV)

ABBREVIATION	MEANING
CA	Cellulose acetate
CO	Cotton
PA	Polyamide resp. Nylon
PES	Polyester
PAC	Polyacrylate
WV	Virgin Wool

Table 7: Material abbreviations

PARAMETER	VALUE
Temperature	60 +/- 2 °C
Laundry detergent	4 g/L ECE
Liquor volume	50 mL
pH	10.5 +/- 0.1
Steel Balls	25
Testing time	30 min

Table 8: Testing parameters according to ISO 105-C06 method C1S

Subsequently, the combination of part and fabric was mechanically agitated in a soap solution, rinsed and dried. Afterwards the part and the fabric were separated and the staining of the fabrics as well as the color deviation of the samples were assessed with the grey scale.

The results of staining consist of the average of the individual washing tests with the corresponding fabric materials. Figures 25 and 26 show the results of the color fastness test to washing between the textile dye and DM Black 01 on the different fabric materials.

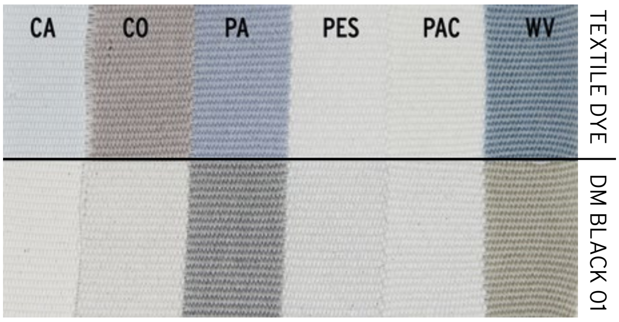


Figure 25: Results for EOS PA 2200 parts

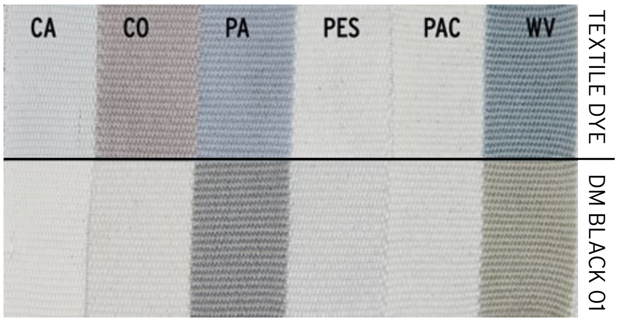


Figure 26: Results for HP 3D HR PA 12 parts

MATERIAL	TECHNOLOGY	COLOR	FINISH	STAINING MEAN	CHANGE ON DYED PART
EOS PA 2200	**SLS**	Textile dye	Raw	2.5 - 3	4 - 5
			PSS	2.5 - 3	3 - 4
		DM Black 01	Raw	3 - 3.5	4 - 5
			PSS	3 - 3.5	4 - 5
HP 3D HR PA 12	**MJF**	Textile dye	Raw	2.5 - 3	4
			PSS	2.5 - 3	4
		DM Black 01	Raw	3 - 3.5	4 - 5
			PSS	3 - 3.5	4 - 5

Table 9: Results of the color fastness testing to washing according to ISO 105-C06

Table 9 shows that coloring with the DDC process in DM Black 01 achieves slightly better results than coloring with the textile dye. For both materials EOS PA 2200 and HP 3D HR PA 12 dyed with the black textile dye, the mean grey scale value in staining is 2.5 – 3. Whereas, the mean staining value for both materials colored in DM Black 01 are 3 – 3.5. For the pot dyed materials, a color deviation between 3 – 4 and 4 – 5 can be observed, depending on the finish and material. The materials dyed in the DDC process with DM Black 01 score a color deviation of 4 – 5. To sum up, this means that materials dyed in DM Black 01 offer a slightly higher color fastness to washing compared to the pot dyed parts. Concurrently, the PSS treatment shows no significant influence on the fastness.

In the following color fastness tests, only the results achieved with the PSS finish will be depicted due to the similarity of the values.

COLOR FASTNESS TO HYPOCHLORITE BLEACHING: ISO 105-N01

In this test, the color resistance of the samples, dyed in DM Black 01 and textile dye was determined to the action of bleaching baths containing sodium hypochlorite in concentrations normally used in commercial bleaching agents at a temperature of 20 +/- 2 °C for 30 minutes. The change in color was assessed with the grey scale.

PARAMETER	VALUE
Liquid	Sodium hypochlorite
Liquor ratio	+/- 1:50
Temperature	20 +/- 2 °C
Time	30 min
Storage	Dark

Table 12: Testing parameters according to ISO 105-N01

The results of the color fastness test to bleaching for both materials dyed with textile dye and DM Black 01, respectively, are depicted in Table 13. In case of EOS PA 2200, a slight improvement was achieved with the DDC process compared to the pot dyeing. HP 3D HR PA 12, dyed with DM Black 01 scores a grey scale value of 4 – 5 whereas the pot dyeing only results in a color change value of 3 – 4.

MATERIAL	TECHNOLOGY	COLOR	FINISH	CHANGE ON DYED PART
EOS PA 2200	**SLS**	Textile dye	PSS	4
		DM Black 01	PSS	4 - 5
HP 3D HR PA 12	**MJF**	Textile dye	PSS	3 - 4
		DM Black 01	PSS	4 - 5

Table 13: Results of the color fastness testing to bleaching according to ISO 105-N01

COLOR FASTNESS TO PERSPIRATION (SWEAT): ISO 105-E04

The samples colored in DM Black 01 and textile dye were brought in contact with adjacent fabrics soaked in two different solutions (acidic and alkaline). The samples on the fabric were placed between two plates at a specified pressure in a test device. All details of the test parameters are summarized in Table 14 (next page). After the test period, the samples and the adjacent fabrics were dried separately and the change in color of each sample, as well as the staining of fabric were assessed by comparison with the grey scale.

	PARAMETER	VALUE
PH	basic	8 +/- 0.2
	acid	5.5 +/- 0.2
PRE-TREATMENT	Liquor ratio	+/- 1:50
	Time	30 min
TEST CONDITIONS	Time	240 min
	Temperature	37 +/- 2 °C

Table 14: Testing parameters according to ISO 105-E04

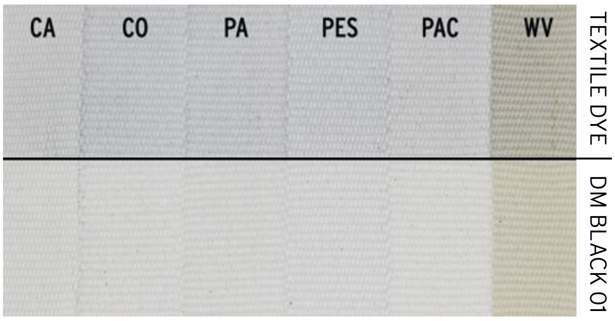


Figure 27: Results for EOS PA 2200 parts

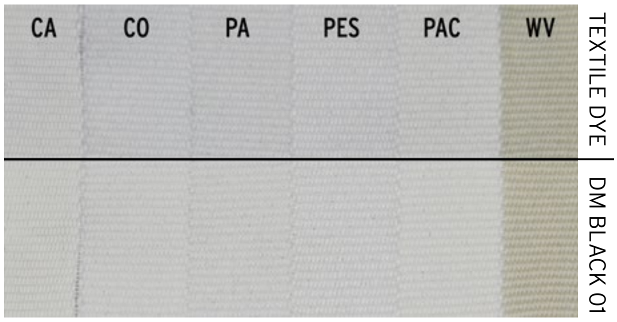


Figure 28: Results for HP 3D HR PA 12 parts

Figures 27 & 28 show the results of the individual color fastness tests to sweat with the different fabric materials. In Table 15 the mean values of the different staining values as well as the color deviation for the acidic and alkaline perspiration tests are listed.

MATERIAL	TECHNOLOGY	COLOR	FINISH	ALKALINE		ACIDIC	
				STAINING MEAN	CHANGE ON DYED PARTS	STAINING MEAN	CHANGE ON DYED PARTS
EOS PA 2200	**SLS**	Textile dye	PSS	3.5 - 4	4 - 5	2.5 - 3	3 - 4
		DM Black 01	PSS	4.5	4 - 5	3 - 3.5	4 - 5
HP 3D HR PA 12	**MJF**	Textile dye	PSS	3.5 - 4	4	3 - 3.5	4
		DM Black 01	PSS	4.5	4 - 5	3 - 3.5	4 - 5

Table 15: Result of the color fastness testing to sweat according to ISO 105-E04

Both dyeing processes achieve better values with the alkaline perspiration tests than for the acidic tests. For both materials EOS PA 2200 and HP 3D HR PA 12, coloring with the pot dyeing process scores a staining mean value of 3.5 – 4 and 2.5 – 3, respectively. The color change comprises a grey scale value of 4 and 4 – 5 or 3 – 4 and 4, depending on the testing pH. In contrast, dyeing with the DDC process, great improvements could be observed. When tested with alkaline solutions, a staining mean value of 4.5 and a color deviation value of 4 – 5 was achieved. Testing with acidic solutions, the obtained staining mean value was 3 – 3.5. In this case, the color change showed a grey scale value of 4 – 5.

CONCLUSION

When it comes to the part properties examined in this paper, such as light and heat resistance, scratch resistance and color fastness the DeepDye Coloring (DDC) process is able to achieve better results in the different performed tests. Especially the light and heat resistance results showed that pot dyed parts fade quickly, compared to DDC. When it comes to color variety, pot dyeing reaches its limits as it is difficult to develop consistent colors with a process that is not a 100% reproducible process. For single pieces, prototypes or non-visible parts, which are not exposed to heat and light, pot dyeing is suitable. However, the manual process is not suitable for high-performance end-use parts.

The DDC process with the cartridge system provides a solution for a stable and reproducible dyeing process that is suitable for any 3D-printed end-use product.

All findings from this whitepaper with regard to the two dyeing processes examined in this paper are summarized on page 18.

AT A GLANCE

POT DYEING

- Hardly controllable, manual "trial & error" process
- No certified hardware available
- Manual cleaning of the pots required
- Strongly limited color options
- Colors fade quickly under UV light or heat
- Conventional textile dyes are not officially certified for 3D-printed plastics: no ISO certifications for biocompatibility (Cytotoxicity, Skin Irritation etc.) can be guaranteed
- Fields of application: suitable for single pieces or prototypes that do not require exact color accuracy

DEEPDYE COLORING (DDC)

- Industrial, traceable and fully automated "plug & play" process
- DM60 & Add-on solutions as certified hardware available
- Integrated and automated cleaning program for DM60 available
- Largest color variety on the market – from standardized color database to tailor-made recipes
- Special solutions for industries, e.g. Automotive[x] Colors with improved light and heat resistance
- Certified and proven colors for high-end manufacturing
- Can be used for any 3D-printed end-use product

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