Accelerated Weathering Test: Mechanical Properties

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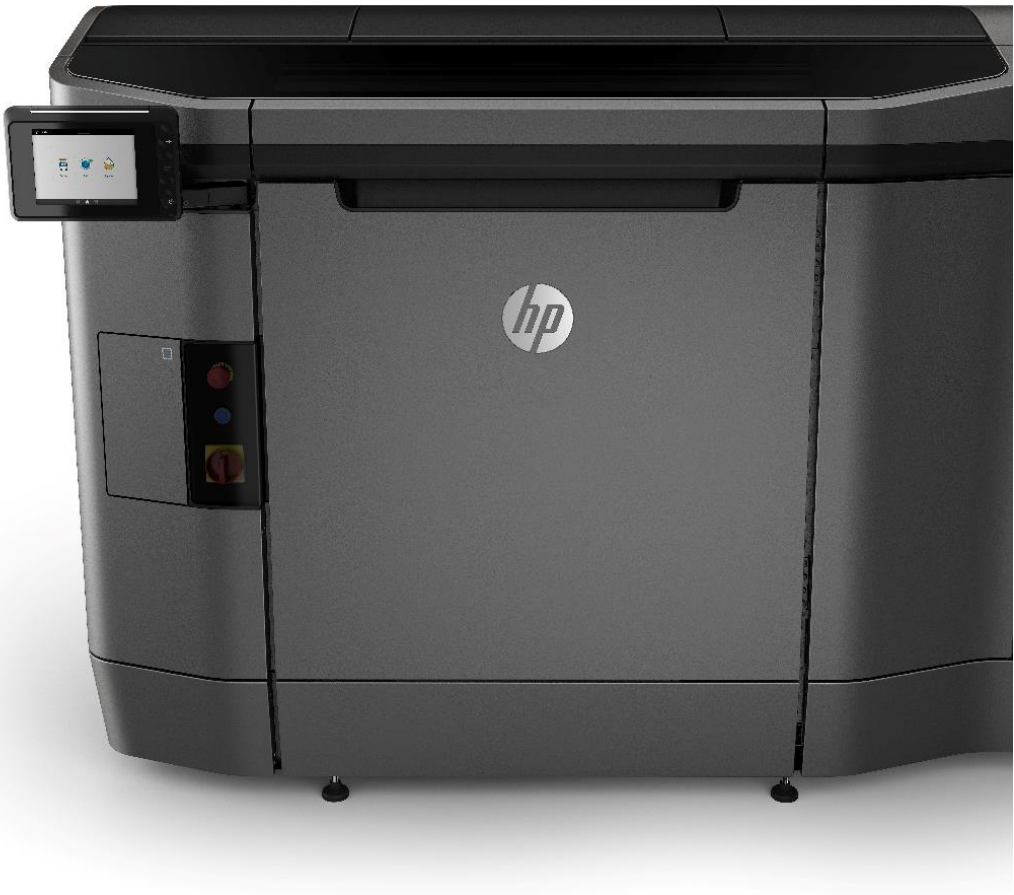

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Executive summary

The ability of a plastic material to resist deterioration of its mechanical and optical properties caused by exposure to light, heat, and water can be very important for many applications.

The purpose of this test is to characterize the Mechanical properties for outdoor durability under exposure to UV light and sprayed water. The MJF parts were printed with HP 3D Jet Fusion 4200 printer with HP 3D High Reusability PA12, PA12GB, and PA11 materials. No postprocess was done, just a bead blasting cleaning took place.

UV radiation present outdoors is known not only to cause fading/yellowing of polyamides, but also make their mechanical properties worse because of the oxidation and molecular weight decrease. MJF polyamide parts degrade as well and the rate of degradation is powder formulation dependent as it is sensitive to the antioxidant package present in the powder.

About the Test

In this 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.

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 spurring on fading using high intensity Xe-Arc lamps combined with water sprayed. Table 1 shows the cycle's characteristics used.

Program	Segment	Event	Time (min)	BPT (°C)	Air T (°C)	RH (%)	Irradiance (W/m2)	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	

Table 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.

Type 5 dogbones were placed into an Atlas Weatherometer, as can be seen in the figure 1 an exposed on one side only and removed from the machine at appropriate time intervals, detailed in the next table 2.

The total exposure time used was 1000 machine hours, according to the geographical situation and the climate of the area, this machine exposure time would be around 4 years at real weather exposure.

Figure 1 - Xe - Arc light source

After the experiment was complete, all the tensiles type V were conditioned at 23ºC and 50% RH for 24 hours. After this, a tensile test has been performed following the ASTM D638 standards to evaluate any change in the material mechanical behavior.

Test conditions summary have been summarized in Table 2.

Printing conditions plot	1st experiment
Printer	HP 3D Jet Fusion 4200
Materials tested	HP PA12 HP PA11 HP PA12 GB
Samples type	Dogbones type-V
Number of tensiles each pack	3 units
Exposure time (hours)	0 200 400 600 800 1000
Data analysis	Tensile strength Young Modulus Elongation at break

Table 2 - Summary of the experiment's design

Test Results

To determine the changes in the mechanical behavior a tensile test was performed, evaluating the tensile strength, the tensile modulus and the elongation at breakpoints of the samples.

In the next graphics it has been represented the evaluation of the materials during the test. A pack of three samples of each material come out of the UV exposure every 200 hours until the last measurement of 1000h at the weatherometer, after each subtraction, the tensile test was done.

The values are not shared but the evolution can be found percentual in relation with its baseline material.

Effect of UV exposure on elongation at break

As it can be seen, there is a clear embrittlement for the three materials in test. The kinetics can be interpreted as the induction period ending at 200-400 hours, after which the mechanical properties start to degrade.

The exact kinetics is different for all the materials tested- possibly because the antioxidant packages are different as well.

but it is from the 400 hours of exposure that the degradation is visible since the elongation decreases more drastically.

The evolution of PA11 is more gradual. On the contrary, the degradation of PA12 is the most abrupt.

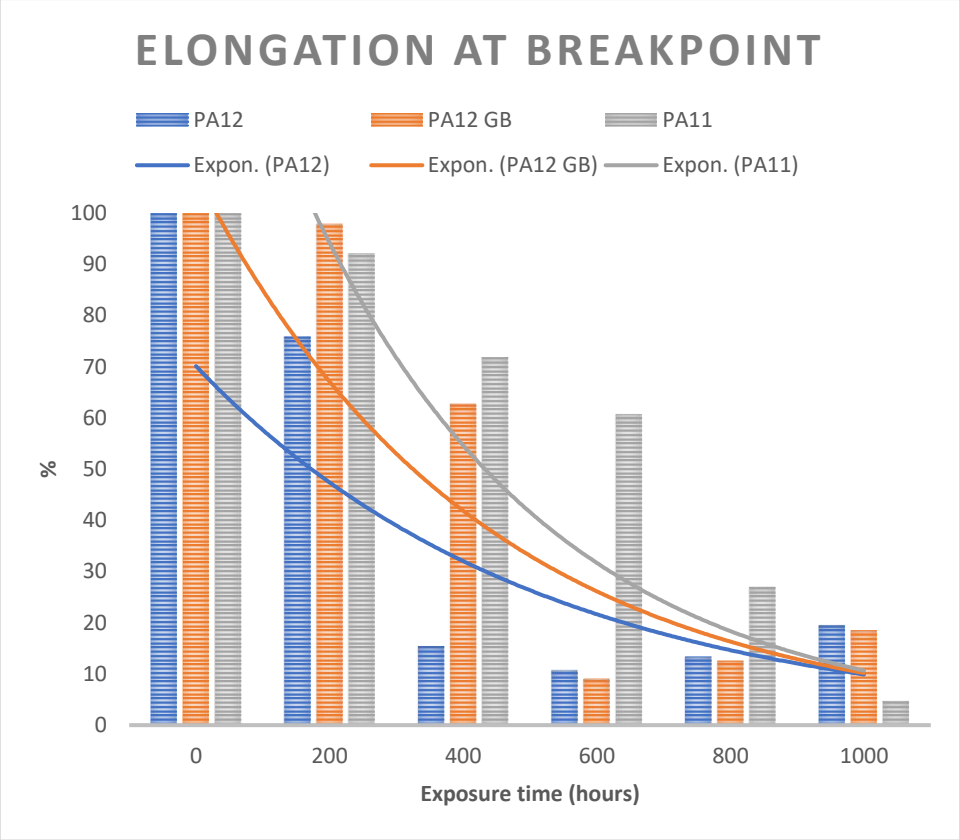

Chart 1 - Evolution of the elongation at breakpoints along the exposure time

Effect of UV exposure on strength

In Chart 2 can be seen the variation of the tensile strength with the exposure time.

As in the elongation at breakpoints, the degradation of PA12 is the most abrupt in comparison with PA12 GB and PA11. There is a degradation in strength with the time of exposure.

No induction period is seen for the glass bead filled material.

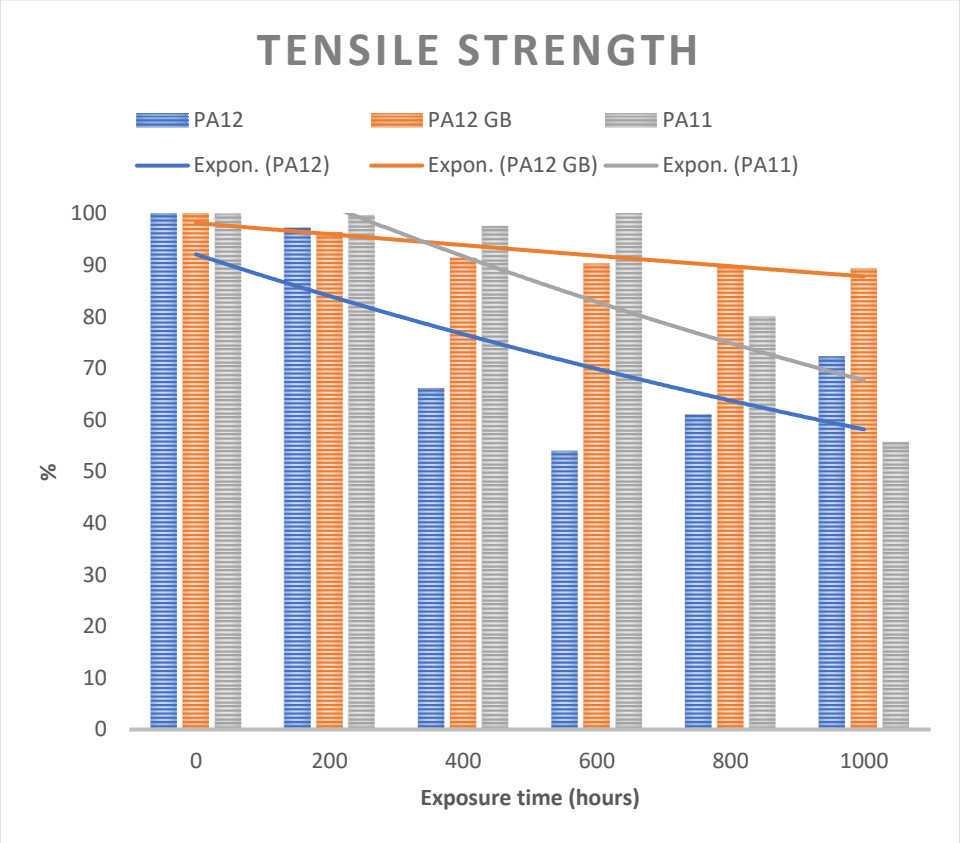

Chart 2 - Evolution of the tensile strength along the exposure time

Effect of UV exposure on Tensile Modulus

In

Chart 3 it can be seen the variation of the tensile modulus with the exposure time.

Some decrease in Young's modulus is observed for PA11.

Related PA12 the increase in Young's modulus in the middle of the experiment should be related to the variability of each pack of tensile type V more than the exposure impact. The final percentage is as at the beginning of the test and seems that this property is quite stable for this material.

Related the glass bead filled material seems to be the one which dominates the properties.

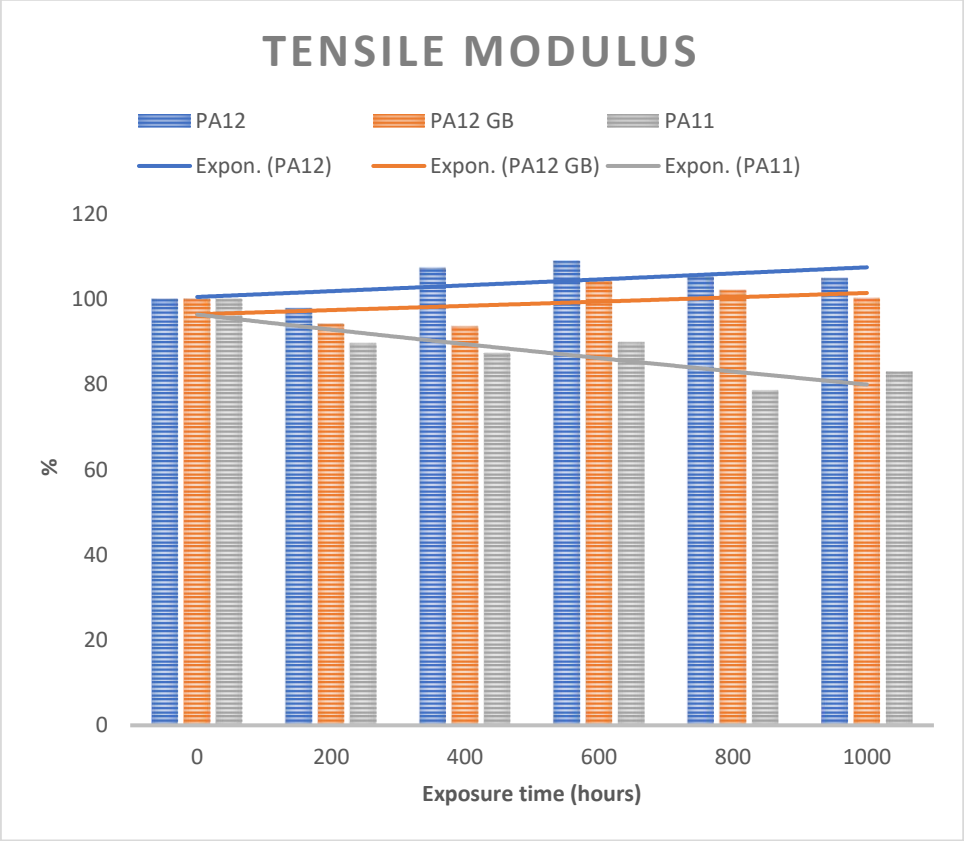

Chart 3 - Evolution of the tensile modulus along the exposure time

Conclusions

- A Mechanical degradation is observed in the parts after Temperature, water and UV exposure: the parts become brittle since elongation at break and tensile strength decreases in all cases. Tensile modulus also decreases in comparison its baseline except for the glass-filled parts that do not show this degradation although it happens for the other properties
- The kinetics with the induction period may indicate the effect of the sacrificial antioxidant package on the rate of the process: after the antioxidants are consumed, the parts start to degrade.
- Note also that these conclusions are driven by a limited statistic and there could also be the MJF material batch sensitivity, fusing recipe effects, etc.
- It is not clear if the light or temperature are the primary driving factor for the degradation; In the end, it does not matter as the test is intended to model the outdoor exposure that involves both light and heat.