Evaluation of the Degradation Process of Polyamide 12 Manufactured via Multi Jet Fusion: An FTIR Analysis

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This study investigated the effects of accelerated weathering on Polyamide 12 (PA12) manufactured by Multi Jet Fusion (MJF) technology, focusing on the chemical and structural changes of the material. The samples were exposed to UV-A radiation in an accelerated weathering chamber for 360, 720, and 1080 hours. To evaluate the degradation effect, characterization was performed by Fourier Transform Infrared Spectroscopy (FTIR), which revealed minor changes in the functional bands between 1500 cm^{-1} and 1300 cm^{-1}, indicative of photo-oxidation. Visual analysis, in turn, revealed no cracks or surface deformations. This study contributes to the understanding of the structural modifications of PA12 and its durability in extreme environments, which is essential for critical applications in the oil and gas sector, where resistance to aging is fundamental. Future research will continue to evaluate the impacts of prolonged exposures on the material's properties.
Keywords: Polyamide 12. MJF. Accelerated Weathering. FTIR.

Additive manufacturing, particularly through Multi Jet Fusion (MJF) technology, has become crucial for producing high-precision components in industries such as oil and gas [1]. PA12 is a widely used polymer in this process, distinguished by its properties of mechanical strength, thermal stability, and chemical resistance, which are crucial to ensuring the functionality and reliability of components manufactured in demanding environments [2]. MJF enables the efficient production of complex geometry parts, which are vital for manufacturing components such as valves and connectors that require high precision and must withstand extreme conditions [3].

Exposure to environmental factors, such as UV radiation, humidity, and thermal cycling, can lead to degradation in PA12, which affects its properties over time. These effects include photodegradation, hydrolysis, and thermal aging, which can compromise the structural integrity of components. Studies indicate that encapsulation can mitigate these effects, but improvements in the material itself are necessary to ensure greater durability and reliability [4]. Accelerated aging tests, which simulate extreme environmental conditions, are essential for better understanding the rate and nature of this degradation, providing crucial data for optimizing design and material properties [5].

This study aims to contribute to the oil and gas industry, where the durability and reliability of components are essential. Understanding how accelerated aging affects PA12 components manufactured by MJF may lead to the development of new materials and manufacturing processes that enhance resistance to environmental stressors. The results may also inspire the implementation of protective measures, promoting greater longevity and operational safety under extreme conditions [6].

Materials and Methods

The samples used in the study were printed in the Z orientation, with a 20° orientation and 7 mm spacing between each piece within the printing bed. Samples were produced with HP 3D High Reusability PA12, with a ratio of 80% reused powder and 20% virgin powder. Printing was performed on an HP Multi Jet Fusion 5210, following the manufacturer's recommendations.

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The printer had a build volume of 380 × 284 × 380 mm, a print speed of up to 5058 cm^3/h, a resolution of 1200 dpi, and a layer thickness of 0.08 mm.

The accelerated weathering test was conducted in a BASS UUV/2009 chamber, utilizing UV-A lamps with a 340 nm emission. The exposure cycle was continuous for 24 hours a day, totaling 1,080 hours of exposure. Samples were removed for analysis after 360, 720, and 1080 h. To minimize interference from external factors, the samples were stored in aluminum foil until they were tested. This conditioning aimed to prevent exposure to humidity, oxygen, and especially electromagnetic radiation, particularly visible and UV light, whose protection is fundamental after the accelerated weathering cycles with UV exposure, ensuring the preservation of sample properties for subsequent tests.

FTIR analyses were performed on a Thermo Scientific™ Nicolet iS10 FTIR, using an Attenuated Total Reflectance (ATR) accessory. The equipment, with a KBr beam splitter, covered the spectral range from 7800 cm^{-1} to 350 cm^{-1}, and analyses were carried out using OMNIC software.

Results and Discussion

For analyzing the behavior of Polyamide 12 samples subjected to accelerated weathering, FTIR characterization was employed. This technique plays a crucial role in identifying potential changes in the functional groups and chemical bonds of the polymer, thereby enabling a more detailed understanding of degradation, photo-oxidation, and material aging processes. The FTIR spectrum graph presented in Figure 1 shows the evolution of the characteristic bands of Polyamide 12 (PA12) after exposure to different periods of accelerated weathering. This behavior indicates changes in the chemical structure of the polymer, which are associated with degradation processes induced by aging conditions.

It is observed that the leading characteristic bands of PA12 remain throughout aging; however, small changes are noticeable, especially in the region between 1500 cm^{-1} and 1300 cm^{-1}. These changes suggest modifications in the chemical bonds of the polymer chain, possibly related to photo-oxidative degradation caused by UV radiation and thermal action [7].

Detailed studies on the effects of weathering in PA12 and other polymers demonstrate that prolonged exposure to UV radiation can lead to chemical changes in the material's structure, primarily due to the breaking of amide bonds and the formation of new functional groups, such as carbonyls. Furthermore, the intensification of specific bands in the region of 1650 cm^{-1} is often attributed to degradation of the material [7].

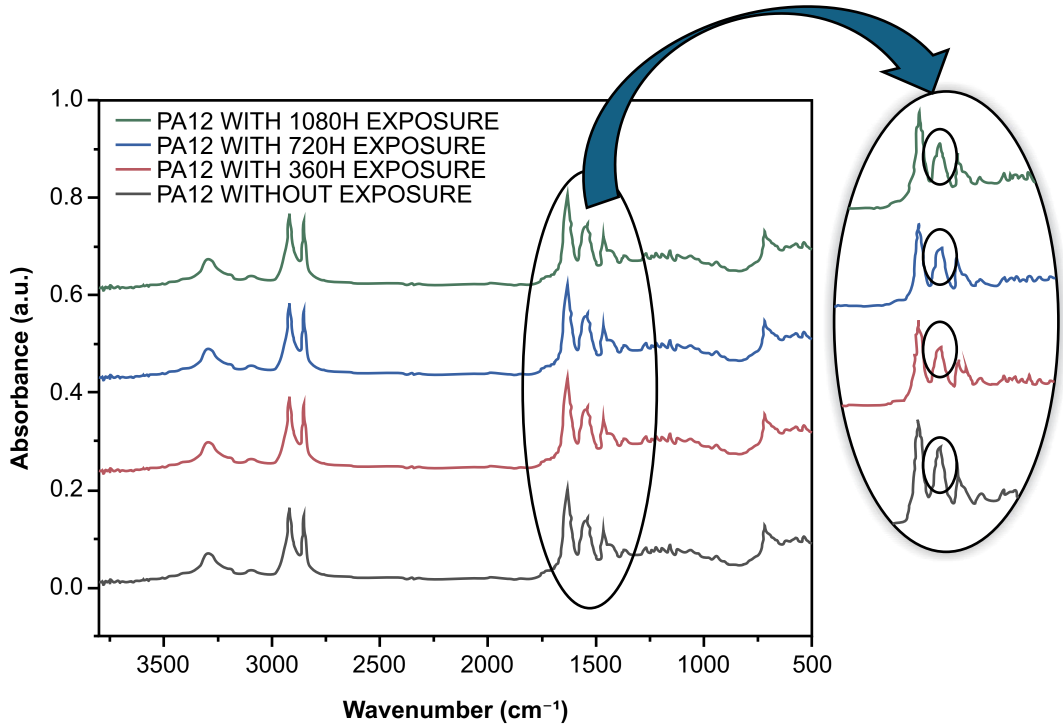
These results indicate that although PA12 maintains its overall chemical structure during aging, there is progressive degradation that can compromise its mechanical properties and long-term stability, a crucial factor for applications in the oil and gas sector. The use of stabilizing additives may be an interesting strategy to mitigate these effects and ensure greater durability of the material under severe operating conditions.

In visual analysis, no significant surface changes were observed in PA12 after accelerated weathering exposure. The absence of cracks, fissures, or apparent deformations suggests that although the material underwent aging processes, its surface morphology remained stable over the exposure period. This behavior may be related to PA12's intrinsic resistance to adverse environmental conditions such as UV radiation and humidity [8].

Conclusion

The results obtained so far indicate that PA12 exhibits structural and surface stability under the evaluated conditions, with minor changes in functional bands detected by FTIR and no visible cracks or deformations on the material's surface. However, due to the complexity of polymer degradation processes, such as photo-oxidation, and adverse environmental conditions, it is necessary to extend the exposure time in accelerated weathering to evaluate more deeply the degradation mechanisms involved. This research line aims to gain a deeper understanding

Figure 1. FTIR Spectrum – PA12.



of the potential chemical and physical changes in the material over time, particularly regarding the behavior of polymer chains and the formation of specific groups related to photo-oxidation. This deeper analysis will provide more robust data on the durability of the material and possible strategies to enhance its resistance in critical applications, such as the oil and gas sector.

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