# INFLUENCE OF COLD ACETONE VAPOR TREATMENT DURATION ON THE SHORE D HARDNESS OF ABS SAMPLES FABRICATED BY FDM

**Turiac Raul-Rusalin,** *Babeș-Bolyai University, Cluj-Napoca, ROMANIA*
**Korka Zoltan-Iosif* (corresponding author),** *Babeș-Bolyai University, Cluj-Napoca, ROMANIA*
**Cojocaru Vasile,** *Babeș-Bolyai University, Cluj-Napoca, ROMANIA*
**Magda Mihael,** *Babeș-Bolyai University, Cluj-Napoca, ROMANIA*

**ABSTRACT:** This paper investigates the influence of cold acetone vapor treatment on the surface hardness of ABS samples fabricated by the FDM method. The experimental procedure consists of exposing 3D-printed samples to cold acetone vapors at room temperature for time intervals ranging from 10 to 60 minutes, with a 10-minute increment. The main objective of the study is to evaluate how the exposure time to the treatment affects the mechanical performance, particularly the Shore D hardness, of the treated parts. This post-processing method is widely used to improve surface quality, but it also leads to changes in the mechanical properties. In this research, all samples were printed under identical FDM conditions to isolate the exposure time variable. After treatment, hardness measurements were performed according to standards, and the obtained data were analyzed comparatively. The results contribute to understanding the relationship between solvent–polymer interaction and the mechanical response of FDM parts treated with cold acetone vapors, offering useful insights for optimizing post-processing conditions.

**KEY WORDS:** FDM (fused deposition modeling), ABS (acrylonitrile butadiene styrene), cold acetone vapor treatment, post-processing, shore D hardness.

## 1. INTRODUCTION

3D printing, also known as Additive Manufacturing (AM), represents a modern method of producing components, with a significant impact on both industry and research. This technology enables the rapid transformation of a digital model into a physical object through the successive deposition of material layers. Owing to this layer-by-layer approach, 3D printing offers a high degree of design freedom, the possibility of component customization, and efficient material utilization, factors that contribute to redefining traditional manufacturing processes.

The Fused Deposition Modeling (FDM) technology is one of the most widespread and commonly used 3D printing methods, due to its flexibility, ease of use, wide range of printable materials, and low operating costs.

Like any technology, in addition to its numerous advantages, FDM also presents certain limitations, such as the large number of process parameters that directly influence the mechanical properties of the components produced by this method [1,2,3].

At present, one of the main challenges faced by the 3D printing industry in producing functional and durable parts capable of replacing those manufactured through traditional techniques lies in identifying efficient methods for reducing surface roughness. This roughness is caused by the so-called "stair-stepping" effect, resulting from the successive overlapping of material layers.

In this context, to enhance the surface quality of ABS parts, acetone vapor treatment is used, due to its high efficiency and low cost.
In previous research, we demonstrated the effectiveness of cold acetone vapor treatment on surface quality, achieving a reduction in roughness of up to 98.3% [4].
However, considering that parts produced by FDM technology are often intended for functional applications, where they are subjected to repeated mechanical stresses or contact loads, it becomes necessary to analyze how acetone vapor treatment influences the mechanical properties, particularly surface hardness, a key indicator of wear resistance and local deformation.
The specialized literature primarily refers to hot acetone vapor treatment, which leads to hardness improvements of up to 11.21% after 15 seconds of treatment [5] or even 14.05% after 10 seconds [6]. Other studies report increases of up to 10.36% after four treatment cycles of 13 seconds each [7] or up to 8.33% after five cycles of 8 seconds each [8]. However, some studies [9,10] do not indicate a significant improvement in hardness following the treatment. It has also been observed that prolonged exposure (over 15–20 seconds) to hot vapors leads to a decrease in part hardness [5,6,7].
Regarding acetone immersion treatment, the literature reports increase of less than 1% after 30 seconds of immersion [11], as well as decreases in hardness of up to 7.14% after 50 seconds [12].
In the current context, where the reviewed literature does not address the impact of cold acetone vapor treatment on the hardness of 3D printed parts, and considering that this type of treatment is less harmful and more cost-effective than other methods, the present study aims to analyze the influence of cold acetone vapor exposure time on the Shore D hardness of ABS samples manufactured using the FDM process.

## 2. METHODS AND MATERIALS

To examine the influence of cold acetone vapor treatment on the hardness of ABS parts, 21 parallelepiped specimens were fabricated, with dimensions shown in Figure 1.
This specimen format was selected to meet the requirements specified by ISO 868:2003 [13] and ASTM D2240–15 [14] standards, which state that samples intended for Shore D hardness testing must have a minimum thickness of 6 mm, a flat surface, measurements taken at least 12 mm from any sample edge, and a size that allows for at least five measurements with a minimum spacing of 6 mm between them.
The specimens were fabricated using a Creality Ender-3 V3 KE 3D printer, with black ABS+ filament produced by eSUN.
The printing parameters were kept constant for the entire batch of samples and are presented in Table 1.

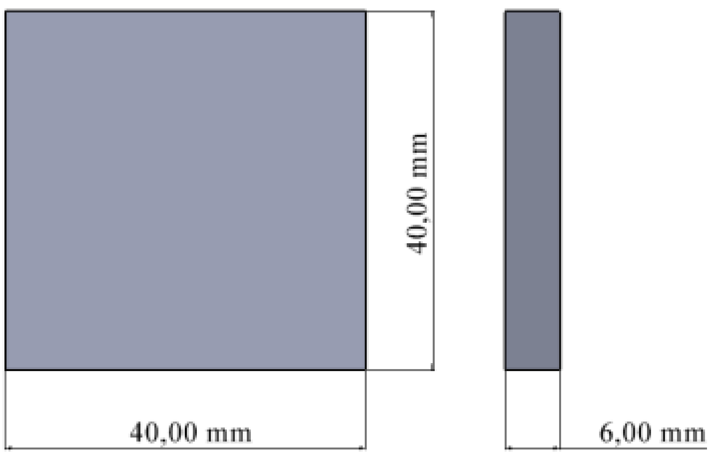

Figure 1. Test specimen

**Table 1.** Process parameters used for printing

| | |
|---|---|
| Material | ABS |
| Filament diameter | 1,75 mm |
| Nozzle diameter | 0,4 mm |
| Extruder temperature | 250 ℃ |
| Printing bed temperature | 100 ℃ |
| Layer thickness | 0,20 mm |
| Printing speed | 50 mm/s |
| Fan | Yes, at 50% of the maximum power |
| Orientation | YX |
| Raster angle, θ | 0°/90° |
| Infill density | 100 % |
| Number of contour lines | 2 |
| Build plate adhesion | brim type, 20.00 mm width, applied only on the outer contour |

For the application of the cold acetone vapor treatment, an experimental setup developed in the laboratory was used. It consists of a sealed chamber equipped with a fan designed to accelerate the smoothing process and ensure a uniform distribution of acetone vapors over the entire surface of the samples [10].

Figure 2 schematically illustrates the experimental setup, while Table 2 presents the details and parameters corresponding to the experimental configuration and the applied treatment process.

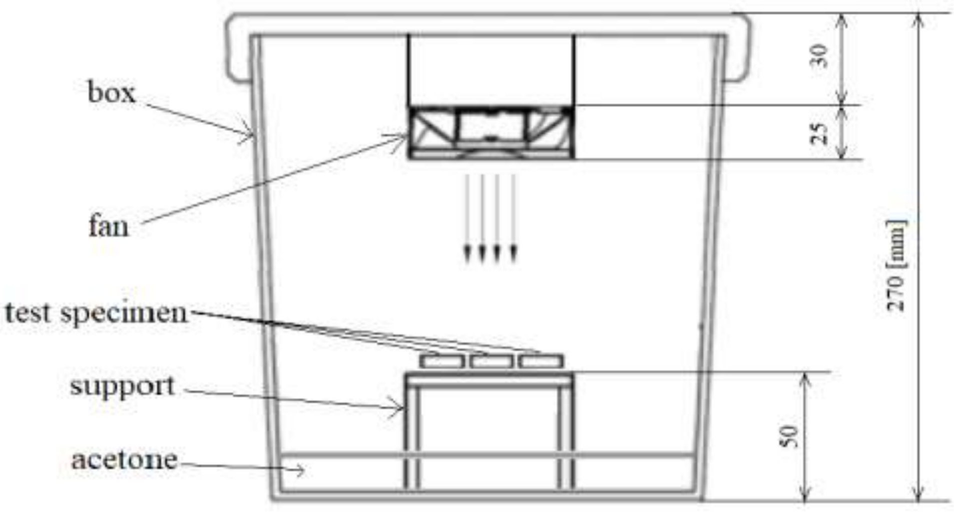


Figure 2. The experimental setup used for the application of the cold acetone vapor treatment

**Table 2**. Process parameters used for the surface smoothing process

| | |
|---|---|
| Dimensions of the chamber | L/l = 395 [mm]; h = 270 [mm]; Volume = 32 [l] |
| Fan | Gamemax GMX WFBK, 120 [mm], speed= 1100 [rpm], maximum air flow = 46,5 [CFM] |
| Ambient temperature | 23 ℃ |
| Acetone used | Fidea acetone puro (100% purity), volume: 0.5 l |

To specifically identify the influence of cold acetone vapor treatment on the ABS specimens, a process variable was introduced, namely the treatment duration. Thus, six distinct exposure times were used, ranging from 10 to 60 minutes, with an increment of 10 minutes between series. For comparison, an additional set of untreated samples was included as a reference. Each experimental set consisted of three identical specimens to minimize experimental errors and ensure the repeatability and accuracy of the results.

To prevent the release of acetone vapors that would have occurred due to repeated opening of the treatment chamber (every 10 minutes), each set of samples was treated individually. Throughout the entire experiment, the acetone volume of 0.5 liters was kept constant.

After the treatment, all seven series of samples were kept in a controlled atmosphere (23 °C ± 2 °C, 50% ± 5% RH), in accordance with ISO 291:2008 [15], to ensure the uniform stabilization of properties prior to hardness testing.

The Shore D hardness of the samples was determined using a type D durometer mounted on a Shore Durometer Test Stand, model TI-D, manufactured by SAUTER GmbH (Germany). The equipment is equipped with a controlled vertical pressure system, in accordance with ISO 868:2003 and ASTM D2240–15 standards, ensuring uniform force application on the sample surface.

For high accuracy, nine hardness measurements were performed for each specimen, and the graphical representations present the average value of these measurements.

## 3. EXPERIMENTAL RESULTS

To examine the influence of cold acetone vapor treatment duration on surface hardness, after performing the Shore D hardness measurements on the seven series of samples corresponding to exposure times ranging from 0 to 60 minutes, the obtained results were graphically represented.

Figure 3 shows the evolution of the individual hardness values for each specimen, along with error bars indicating the standard deviation. Analyzing the graph, it can be observed that the standard deviation values are relatively small, ranging from ±0.67% to ±1.42% (for the entire batch of 21 specimens), which indicates good test repeatability and, at the same time, the stability of the measurements performed.

Relatively small variations can be observed between the samples within the same set, demonstrating that the testing process was rigorously controlled. The minor deviations can be attributed to local surface irregularities generated by the 3D printing process, which involves the successive deposition of material both layer by layer and side by side. This characteristic may result in situations where the indenter penetrates between two layers rather than directly into a compact layer of material.

The graph highlights a clear decrease in hardness with increasing treatment time, with a maximum value of 76.89 Shore D recorded for the untreated sample (0.2) and a minimum value of 61.84 Shore D for the sample treated for 60 minutes (6.3), corresponding to an approximate decrease of 19.57% in hardness.

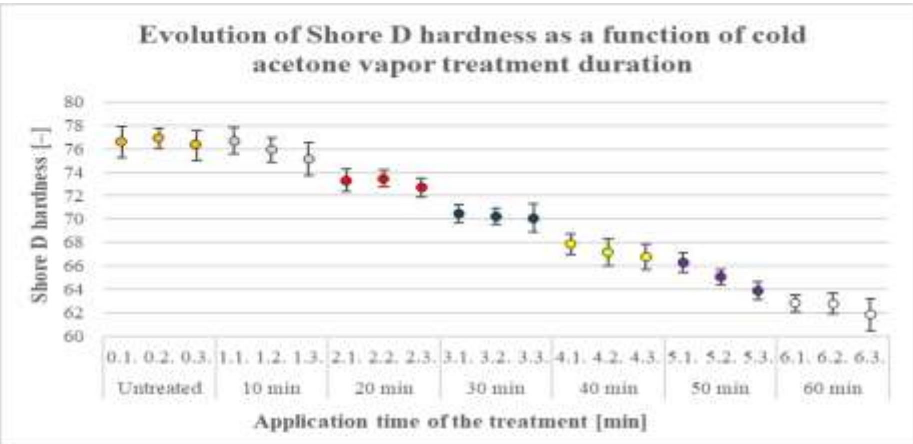


Figure 3. Evolution of Shore D hardness as a function of cold acetone vapor treatment duration

For a clearer view of the hardness reduction phenomenon as a function of the cold acetone vapor treatment duration, Figure 4 presents the average values obtained for each tested set of specimens.
The graph reveals a progressive decrease in hardness with increasing exposure time to acetone vapors. Analyzing the evolution of the average values, it can be observed that the maximum value obtained for the untreated sample set (76.6 Shore D) gradually decreased by up to 18.45%, reaching a minimum of 62.47 Shore D for the samples treated for 60 minutes.
This downward trend confirms the surface softening effect caused by the action of acetone vapors, which leads to the relaxation of the polymer chains in the outer layer of the ABS material, resulting in a gradual decrease in hardness.

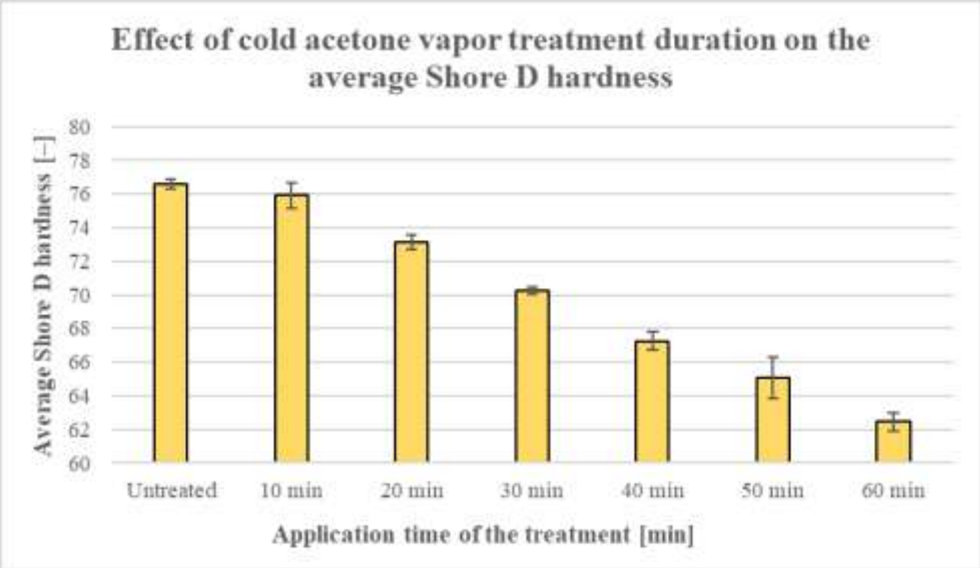

Figure 4. Effect of cold acetone vapor treatment duration on the average Shore D hardness

Correlated with previous research [4], in which variations in surface roughness and dimensional deviations were analyzed for the same treatment durations, an improvement in surface quality of up to 98.3% was observed after 30 minutes of treatment, accompanied by small dimensional deviations (L: −0.12%, l: −0.24%, h: +0.83%). Based on these results, it can be concluded that the most favorable compromise between surface quality and hardness loss is achieved at 30 minutes of treatment, when the surface exhibits high smoothness, while the hardness decreases by approximately 8.28% compared to the untreated sample.
Conversely, if the goal is to maintain a hardness value close to that of the untreated ABS material (with only a 0.9% decrease), the 10-minute treatment proves more advantageous, as it provides a 94.3% improvement in surface quality and minor dimensional deviations (L: −0.05%, l: −0.13%, h: +0.11%).

## 4. CONCLUSION

Based on the results obtained in this study, the following conclusions can be drawn:

- The cold acetone vapor treatment applied to ABS samples causes a significant decrease in Shore D hardness, proportional to the exposure duration.
- The maximum average hardness value was recorded for the untreated samples (76.6 Shore D), while the minimum value was obtained for the samples treated for 60 minutes (62.5 Shore D), corresponding to an approximate reduction of 18.45%.
- The standard deviations for the measurements performed on the same sample, ranging from ±0.67% to ±1.42%, confirm the repeatability and stability of the measurements, demonstrating proper control of the experimental process.

- The decrease in hardness is associated with the surface softening effect caused by the solvent action, which leads to the relaxation of the polymer chains in the ABS material.
- The results confirm that the treatment duration is a critical parameter in the cold acetone vapor smoothing process, directly influencing the surface mechanical properties of parts manufactured by FDM.

From the perspective of process optimization, it is recommended to select a compromise between surface smoothness, dimensional accuracy, and hardness retention by limiting the treatment time to moderate values (10–30 minutes).

As a future perspective, the authors intend to perform a microscopic analysis (optical and SEM) of the treated surfaces to observe the degree of acetone vapor penetration into the material and to correlate the morphological changes with the variations in hardness and roughness identified.

## REFERENCES


[1]Cojocaru, V., Frunzăverde, D., Micloșină, C.-O., Mărginean, G. The influence of the process parameters on the mechanical properties of PLA specimens produced by fused filament fabrication – a review. Polymers, 2022;

[2]Cojocaru, V., Turiac, R.-R., Frunzăverde, D., Trișcă, G., Băcescu, N., Mărginean, G. Effect of the printing scenario on the dimensional accuracy and the tensile strength of different colored PLA specimens produced by fused deposition modeling. Applied Sciences, 2024;

[3]Frunzăverde, D., Cojocaru, V., Băcescu, N., Ciubotariu, C.-R., Micloșină, C.-O., Turiac, R.-R., Mărginean, G. The influence of the layer height and the filament color on the dimensional accuracy and the tensile strength of FDM-printed PLA specimens. Polymers, 2023;

[4]Turiac, R.-R., Korka, Z.-I., Ardeljan, D. D. The use of cold acetone vapors to smooth the surface roughness of parts obtained by the FDM method from PLA and ABS. Annals of the "Constantin Brâncuși" University of Târgu Jiu, Engineering Series, No. 4, 2024;

[5]Singh, R., Singh, S., Singh, I. P. Effect of hot vapor smoothing process on surface hardness of fused deposition modeling parts. 3D Printing and Additive Manufacturing, 2016;

[6]Marciniak, D., Szewczykowski, P., Czyżewski, P., Sykutera, D., Bieliński, M. Effect of surface modification by acetone vaporization on the structure of 3D printed acrylonitrile-butadiene-styrene elements. Polimery, 2018;

[7]Kalyan, K., Singh, J., Phull, G. S., Soni, S., Singh, H., Kaur, G. Integration of FDM and vapor smoothing process: Analyzing properties of fabricated ABS replicas. Materials Today: Proceedings, 2018;

[8]Singh, J., Singh, M., Chawla, K. Shore hardness analysis of ABS based hip implants prepared by fused deposition modelling. Journal of Emerging Technologies and Innovative Research (JETIR), 2019;

[9]Singh, R., Singh, J., Singh, H. Investigations for improving the surface finish of FDM based ABS replicas by chemical vapor smoothing process: A case study. Assembly Automation, 2017;

[10] Tamasag, I., Amarandei, D., Besliu, I. Some insights on chemical treatment of 3D printed parts. Materiale Plastice, 2022;

[11] Gaekwad, S., Vikram, A. V., Sharath, C. N., Anupama, B. C. Morphological analysis of FDM parts subjected to surface treatment. Scientific Reports, 2025;

[12] Francis, V., Garg, S., Saxena, K. K., Jain, P. K., Lade, J., Kumar, D. Effect of chemical and heat treatment on 3D printed parts: nanoparticles embedment approach. Advances in Materials and Processing Technologies, 2022;

[13] ISO 868:2003 Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness);

[14] ASTM D2240–15 Standard Test Method for Rubber Property—Durometer Hardness;

[15] ISO 291:2008 Plastics — Standard atmospheres for conditioning and testing.