

STUDY OF MUTUAL ADHESION OF COATING SYSTEM AND POLYMER MATERIALS PRINTED BY FDM 3D PRINTING TECHNOLOGY

^{1,2}Jitka PODJUKLOVÁ, ²Jan VANĚK, ¹Jakub ŠEBESTA, ²Svatopluk SLOVÁK, ²Václav TVARŮŽKA

¹VŠTE, Faculty of Institute Technology and Business, Department of Mechanical Engineering, Ceske Budejovice, Czech Republic, EU, podjuklova@mail.vstecb.cz, jakub.sebesta0160@gmail.com,

²Department of Technical and Vocational Education, Faculty of Education, University of Ostrava, Czech Republic, EU, jitka.podjuklova@osu.cz, jan.vanek@osu.cz, svatopluk.slovak@osu.cz,
vaclav.tvaruzka@osu.cz

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Abstract

Polymer surface treatments are now a commonly used technology that finds application across many industries. Additive manufacturing, known as 3D printing, is currently one of the technologies that is used in the production of not only small but also large-size printed parts. Due to the nature and properties of printed parts, one of the necessities is to deal with their surface treatment, which is essential to ensure their durability and functionality. The paper discusses the results of the experimental tests of the mutual adhesion samples basic polymeric materials - filaments such as **PLA** - polylactic acid, **PETG** - polyethylene terephthalate glycol and **ASA** - acrylonitrile styrene acrylate as substrates materials under the coating system produced by FDM 3D printing / Prusa i3 MK3S+/ with two-component coating system LV AKZ 421 /manufacturer Synpo a.s. Pardubice / and which were experimentally evaluated and tested according to ČSN EN ISO 4624 / pull test / and ČSN EN ISO 2409 / cross-cut test / and to ČSN EN ISO 16 276. The best adhesion of the coating system was measured to the surface of the PLA filament.

Keywords: Additive manufacturing, surface treatment, adhesion testing, 3D printing, filament

1. INTRODUCTION

Surface treatment of plastics is now a commonly used technology that is used across many fields – for example, in the automotive industry, in the production of kitchen appliances, dishes and other everyday products. Materials used for FDM 3D printing have recently been the fastest developing sector of the 3D printing world. In the context of 3D printing, we call them "Filaments". The advantage is that polymers are at least partially etchable in most cases, which allows the application of a single-layer coating that disrupts the surface of the material and thus creates a strong bond between the polymer and the paint. This eliminates the need for the application of multiple layers to ensure adhesion. The issue of applying coatings to 3D printed parts lies mainly in the structure of the products. The printer stacks the individual layers on top of each other, creating larger or smaller ridges on the surface in one direction. These can trap grease, make it difficult to spread the paint or imprint their relief on the surface of the paint. The following experimental work was carried out to classify especially the adhesion of coating systems in the topic of FDM 3D printing.

1.1. EXPERIMENTAL MATERIAL

The two-component LV AKZ 421 coating system was chosen as the coating system, manufactured by SYNPO a.s. The coating system has been developed for painting plastics and is suitable for the chosen purpose. It offers adhesion to most manufactured plastics. Its basic color variant was chosen - white.

The filaments used - substrates under the coating system are listed in **Table 1**.

Table 1 Used filament

Filament	Producer	Color	Picture
ASA	C-Tech	TRAFFIC VWHITE RAL 9003	Figure 1, 4
PETG	Majkl3D	GREY	Figure 2, 5
PLA	eSun	RED SILK	Figure 3, 6
RED - A	bottom area	RED - B	top area
GRAY - A	top area	GRAY - B	bottom area
WHITE - A	top area	WHITE - B	bottom area

Total thickness of the individual filament samples before coating 2 mm and 4 mm. Pre-treatment of the surface of filament sample: Cold degreasing, solution of Simple Green Crystal – pH = 6.0. Application of the coating: Laboratory application using a ruler. Curing of the coating 24 hours in air, 3 hours at 50 °C, 240 hours in air. WFT (Wet Film Thickness) = 200 µm. DFT (Dry Film Thickness) = ø 110 µm.

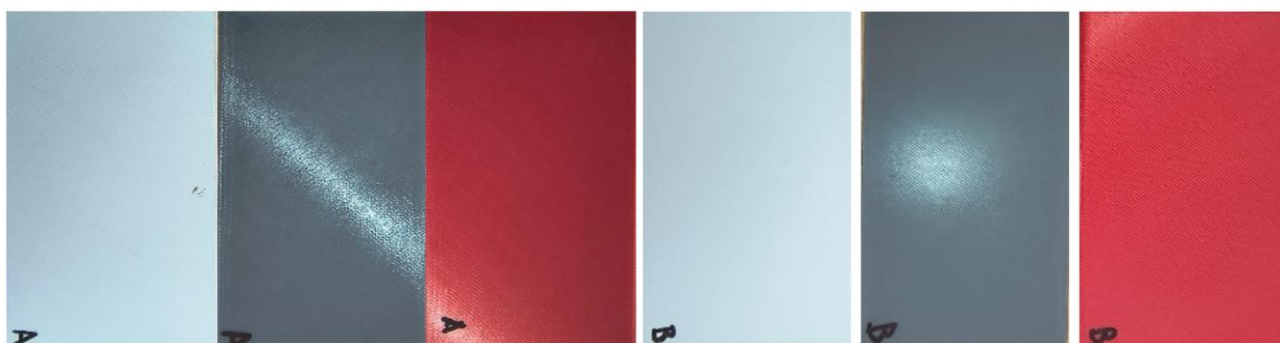


Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 1- 6: 1-ASA top area, 2-PETG bottom area, 3-PLA bottom area, 4-ASA bottom area, 5-PETG top area, 6- PLA top area

2. RESULTS AND DISCUSSION

2.1. OPTICAL MICROSCOPY

Optical microscopy of the surface of filament samples after degreasing. Keyence VHX digital microscope.

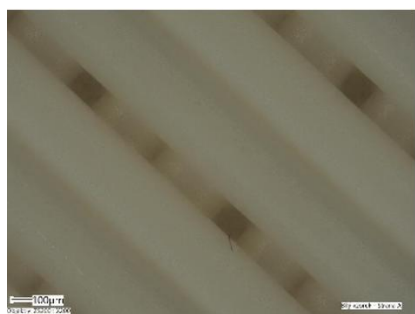


Figure 7 ASA - area A

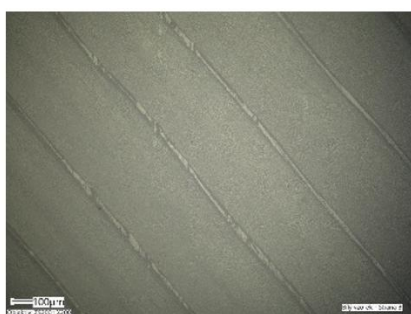


Figure 8 ASA - area B



Figure 9 PLA - area A



Figure 10 PLA - area B

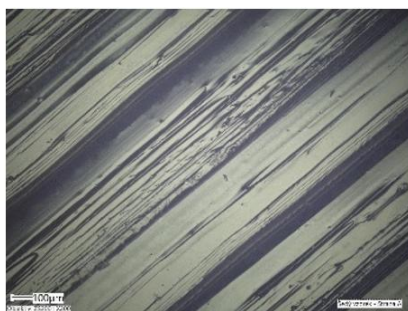


Figure11 PETG - area A



Figure 12 PETG - area B

Figure 7- 12: Optical microscopy of the surface of filament samples after degreasing. Keyence VHX digital microscope. Zoom 200 x

Experimental samples of all filaments after degreasing in Simple Green solution showed differences in the character of the relief of the surface of surface A compared to surface B. The surface was partially etched.

2.2. ADHESION OF THE COATING SYSTEM TO THE FILAMENTS USED

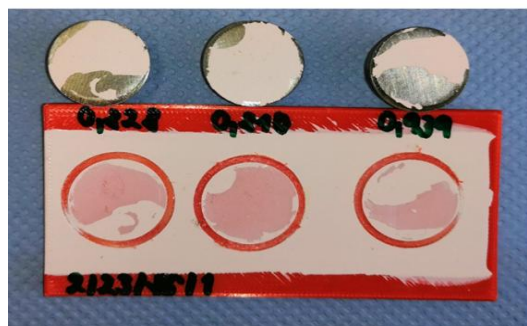
The adhesion of the coating system to the filaments has been evaluated according to the standards below. ČSN EN ISO 4624 / Pull - off test / and ČSN EN ISO 2409 / Cross-cut test / , ČSN EN ISO 16 276 – 1 and 2. [1, 2] For Pull-off test were used glue two-component epoxy Verobond 520 – 2608, curing time 48 hours.

The results are shown in the following ways: **Figure 13 - 18.**

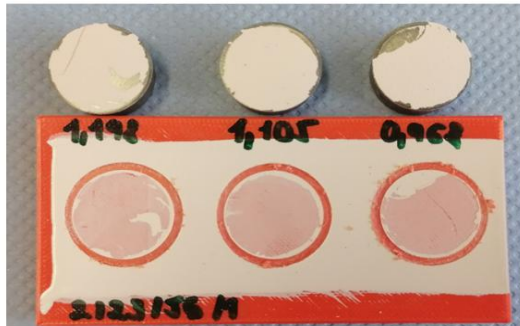
bottom



top



top



top

Figure 13 Pull – off test for PLA sample. Average breakaway force: 1.5 (± 0.3) MPa top area 90% B + 10% - /Y. Average breakaway force: 1.7 (± 0.2) MPa bottom area 50 % B + 50 % -/Y.

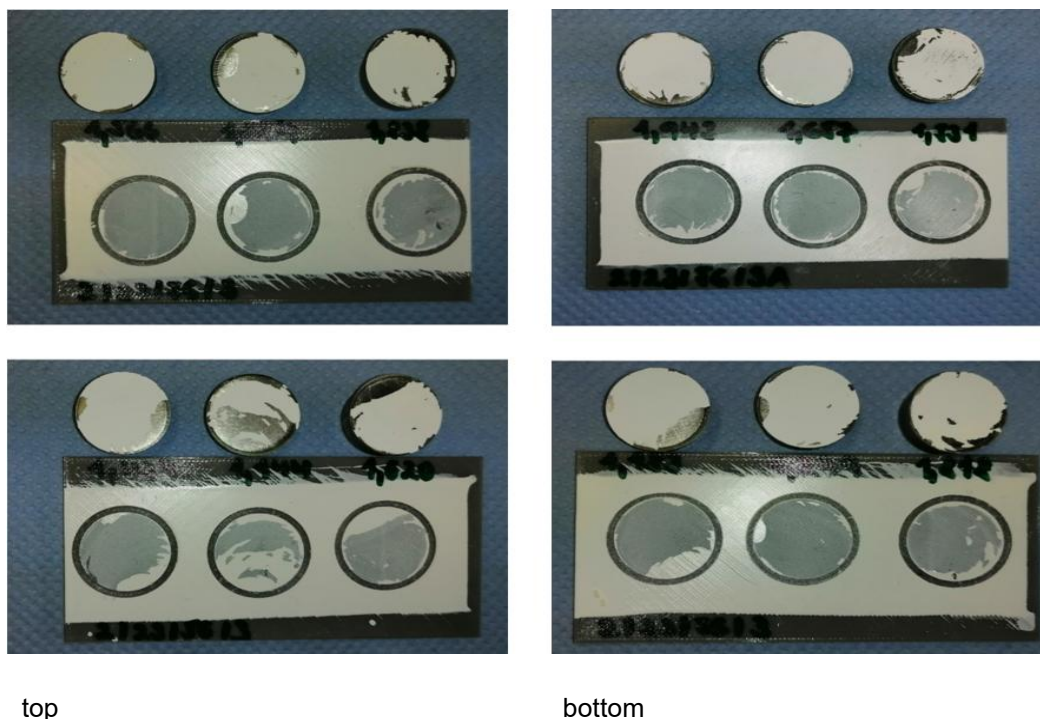


Figure 14 Pull – off test for PETG sample. Average breakaway force: 1 (± 0.1) MPa top area 90 % A/B + 10 % -/Y. Average breakaway force: 0.8 (± 0.1) MPa bottom area 80% A/B + 20% -/Y.

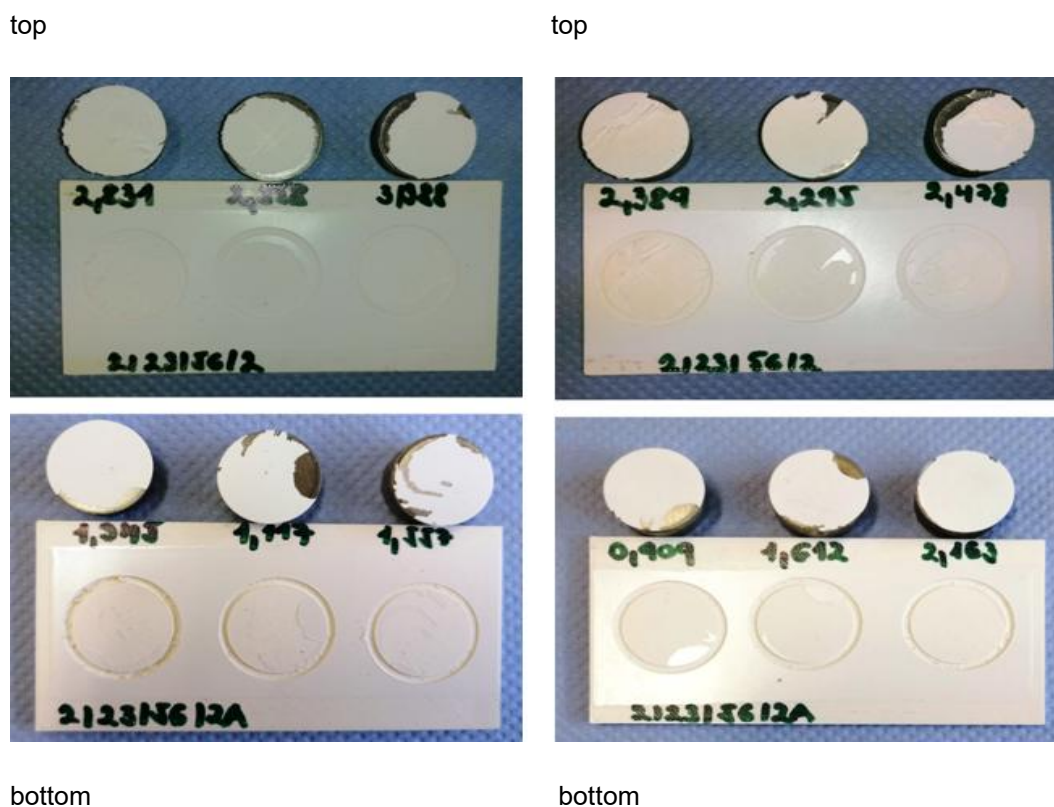
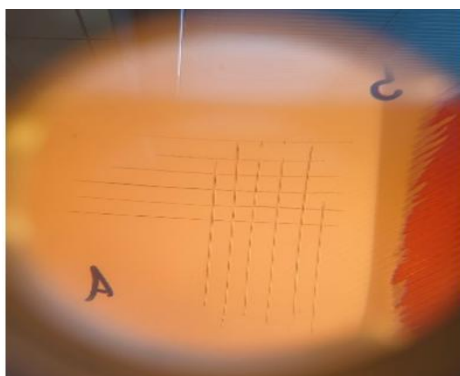


Figure 15 Pull – off test for ASA sample. Average breakaway force: 2,7 ($\pm 0,4$) MPa top area 90 % A/B + 10 % -/Y. Average breakaway force: 1.7 (± 0.2) MPa bottom area 80 % A/B + 20 % -/Y.



top area



bottom area

Figure 16 Cross-cut adhesion test of PLA sample: A top area classification 1, bottom area classification 0

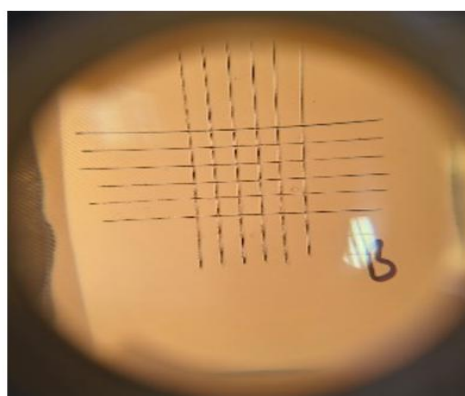
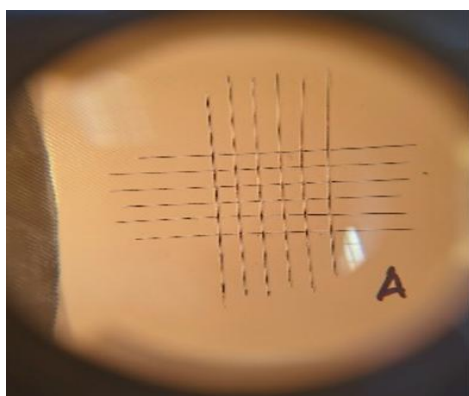


Figure 17 Cross-cut adhesion test of PETG sample: A top area classification 3, B bottom area classification 3

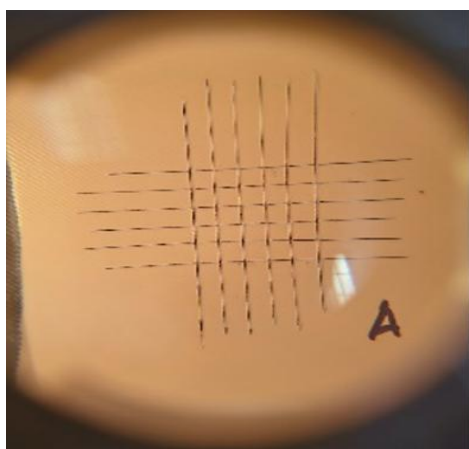


Figure 18 Cross-cut adhesion test for ASA sample: A top area classification 5, B bottom area classification 3

3. CONCLUSION

The results of the experimental tests showed low adhesion of the coating system to the filaments in the values of tear-off force from 0.8 to 2.7 MPa. The most suitable results were shown by the PLA filament, where the adhesion was broken only in the coating layer (B-cohesion failure in the coating layer). In the case of PETG and ASA filaments, there was a violation of adhesion, especially between the filament surface and the coating (A/B - adhesion failure between the filament surface and the coating).

The cross – cut adhesion test showed the most suitable results for PLA filament in the adhesion classification range 0 - 1. For PETG and ASA filaments the adhesion was in the range of adhesion classification 3 - 5.

Overall, the most suitable adhesion results were demonstrated between the coating system and the red PLA filament.

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