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Layer deposition strategies in FFF technology and their influence on tribological properties

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ABSTRACT

The work focuses on the tribological properties of materials that are not yet fully explored due to their manufacturing technologies. The work focuses on the fabrication of samples produced by Fused Filament Fabrication (FFF) technology and their subsequent testing for abrasive wear. In the second chapter, the thesis deals with an introduction to tribology and a description of all wear occurring on the surfaces of the materials. The aim of the experiment is to compare different coating strategies in FFF technology and their effect on abrasive wear at given process parameters and according to ASTM standardized tests, and then to compare and evaluate the different strategies.

Keywords *– surface, FFF, 3D, progressive method, PLA, friction*

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I. INTRODUCTION

As mentioned in the introduction, FFF technology is still one of the so-called "new" technologies. The first use can be registered as early as 1980 under the name Rapid Prototyping (RP). The name Rapid Prototyping is associated with the main use of 3D printing, which meant and still means the rapid production of various prototypes for the shape or design idea of a product or the production of a machine component capable of bearing a certain load. Among the first 3D printing technologies is the SLA (stereolithography) technology patented by Charles Hull in 1983. Of course, new technologies were created along with new ones when SLS (SelectiveLaserSintering) was created in 1987. It was not until 1989 that the FusedFilamentFabrication (FFF) method was patented for the first time by Scott Crump. The FFF method has become the most widely used method in 3D printers as it is an "OpenSource" technology [1-4].

Already in the 1990s, a revolutionary situation in the world economy began when the struggle of companies for consumer goods began. The main priority for companies was to have equipment capable of producing as many units as possible at the lowest possible cost. With development and various innovations came the use of office volume printing printers [5-8].

The ever newer refinement of 3D printing in the early 21st Century began to divide into two industries. Until now, this method has been used for prototyping but the second industry is focused on the precise and accurate 3D printing of objects for various industries such as aerospace, automotive, medical or artistic jewelry. These are mainly very expensive systems exclusively for high quality and complex systems. The former industry is 3D printers belonging to the group of office printers with a simpler user interface and lower price. Additive technology is also among the new and modern trends in the production of various models and prototypes. By additive manufacturing we can imagine the creation of a model in layers by sintering powders, molten plastic, etc... .A huge advantage is that with this technology we can produce parts of different external and internal shapes, which brings us many advantages [9-12]:

- Creating a complex model at once,
- Reducing production time and saving costs,
- Increasing reliability ,
- Preventing failures and errors.

Materials used for RP production [9-12]:

- photopolymers,
- thermoplastics,
- metal powders,

- special paper and many others.

Despite the great advances in additive manufacturing in recent years, there is still a gap between methods differing in speed, accuracy, material and cost. The difference is mainly between sophisticated printers and between home printers [12-14].

II. CHARACTERISTICS OF OUR SYSTEM FOR ABRASION MEASUREMENT

Testing of the samples was carried out in the university laboratory at the Institute of Process and Materials Engineering on ASTM G65-16 test equipment. As mentioned in the explanation of abrasive wear so in this case it is a three point wear which means that we added free particles (abrasive) to the two friction materials as free moving (gravity movement).

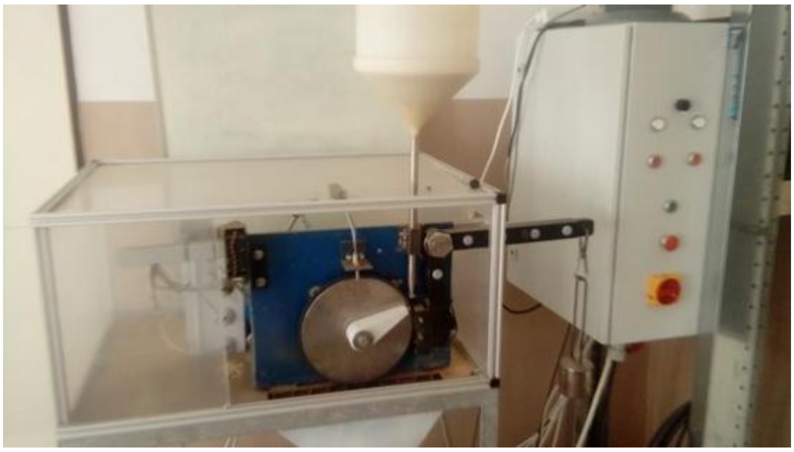

Fig. 1 ASTM G65-16 sample testing equipment

When testing the samples, all data was stored and recorded on a PC using the sensors stored on the device. The data we recorded were:

- Friction force
- Load
- Temperature
- Speed
- Path length

Fig. 2 Garnet 80

Table 1 Parameters of abrasion process

Sample dimension (mm)	70x20x6
Abrasives	Garnet $Fe_3Al_2(SiO_4)_3$
Speed (rpm)	200
Wheel diameter (mm)	229

Load (N)	25
Speed (m/s)	2,5
Distance (m)	278

For the PLA material, only three types of samples (Fig.3) were printed due to unsatisfactory 3D printer conditions. That is, only samples with an area parallel to the wear surface were printed. The samples printed by the COLIDO DIY printer are of types 1, 2, 4.

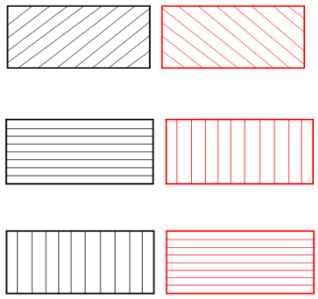

Fig. 3 Strategies used No.1, No.2, No.4

Table 2 Sample weights before the experiment

	1	2	3
M*	10,2383	9,9711	9,8710
M**	10,4320	9,5684	9,7582
M**	10,2617	9,3722	9,7515
Average (g)	**10,3107**	**9,6372**	**9,7936**

III. MEASUREMENT OF GLOSSY SURFACES

The thesis deals with the issue of abrasive wear for materials used in FFF (FusedFilamentFabrication) technology. In this case we focused on PLA material. Nowadays, the use of FFF technology is growing at a tremendous pace at the level of companies or amateur printers for home use, but it is still a young technology. You can still hear somewhere about this technology under the name FDM (Fused Deposition Modeling) which is actually the same thing. The first chapter describes what 3D printing is and the ways in which any model or prototype can be printed. In my thesis I am dealing with FFF technology and this is one of the possibilities of 3D printing. The next issue is tribology, which deals with the state and processes in natural and artificial tribological systems. It is about the interaction of surfaces and consequently the wear of the less compliant material. Since tribology is a broad term and includes many modes of wear so the work is more specifically focused on abrasive wear. The goal was to fabricate the parts 3D printers and test them on ASTM G65 standardized test equipment. Then evaluating the experiment and writing up the results in graphical form with a comparison between the different strategies.

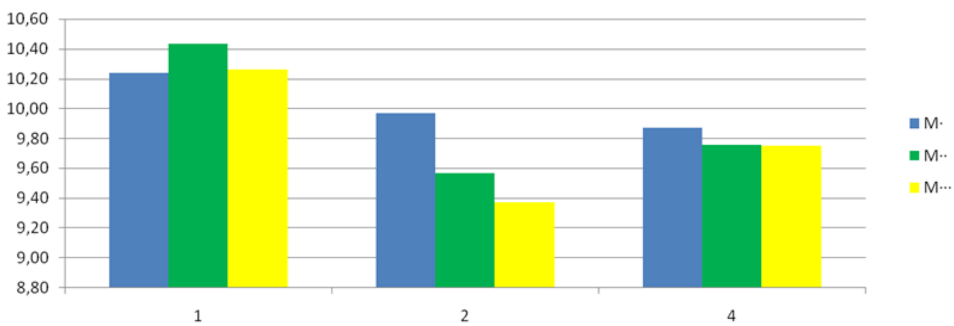

Fig. 4 Graphical representation of the mass after the experiment for each sample

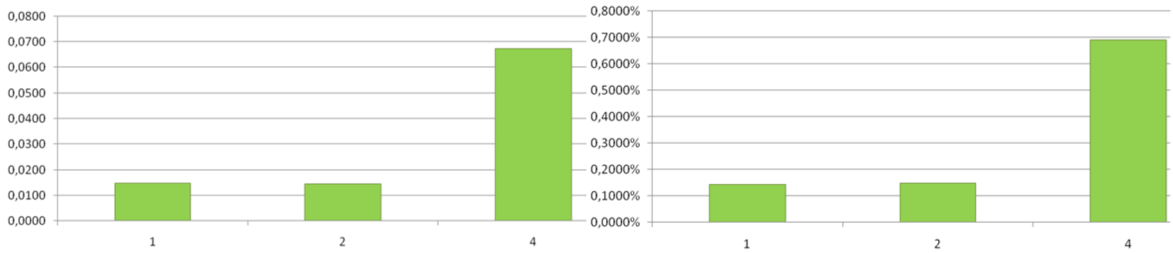

Fig. 5 Graphical representation of average weight loss (g) left, Graphical representation of average weight loss (%) right

When comparing weight loss in percentages and grams and using the same numerical scale, we notice slight differences. With strategy 4, we see a huge jump from the previous two strategies.

Comparison of Strategy 1, 2 and 1, 4

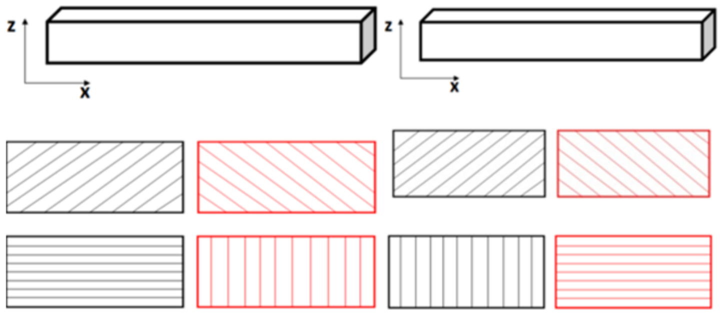

Fig. 6 Strategies 1 and 2 used (left), Strategies 1 and 4 used (right)

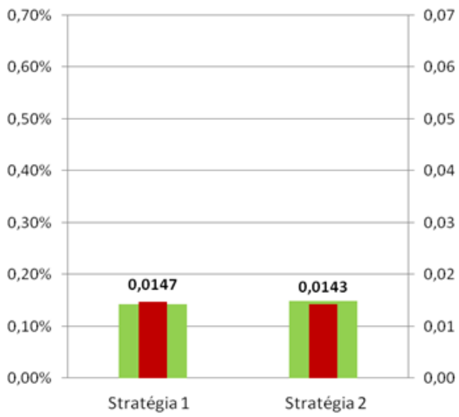

Fig. 7 Graphical representation of weight loss in (g) and (%) for strategy 1 and 2

From the result we can read better conditions for abrasive wear for strategy 1 even though they are almost the same numbers. The reason for choosing the first strategy is the lower percentage ratio to the initial weight.

Comparison of strategy 1 and 4 (sample 1-4)

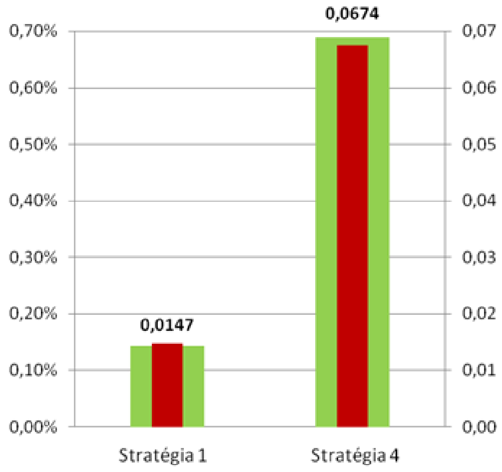

Fig. 8 Graphical representation of weight loss in (g) and (%) for strategies 1 and 4

For the PLA material, the high wear is clearly visible from the beginning of the experiment with strategy 4 and, on the contrary, the best properties with strategy 1.

Evaluation of strategies 2 and 4 (sample 2-4)

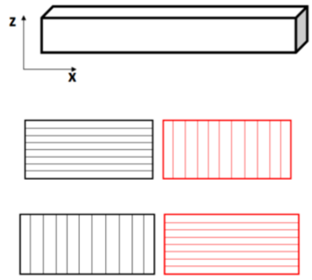

Fig. 9 Graphical representation of weight loss in (g) and

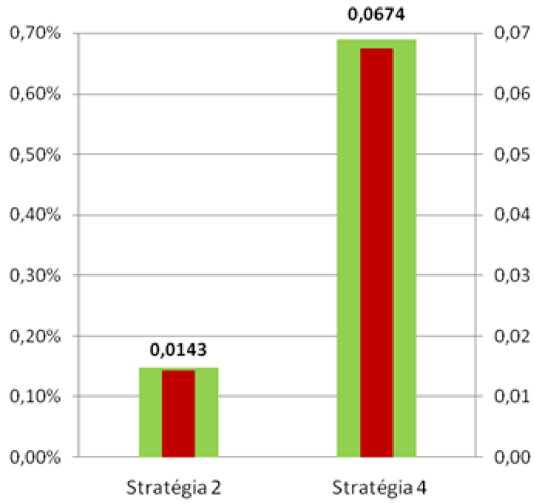

Fig. 10 Graphical representation of weight loss in (g) and (%) for strategies 2 and 4

IV. Conclusion

The aim of the experimental task was to investigate the effect of abrasive wear for different strategies. The results led us to different comparisons and properties of different coating strategies using FFF technology.

From the printing technology where the sample was with the longest edge dimension parallel to the X-axis, we concluded that the most advantageous strategy for PLA is No. 2. This strategy was similar to strategy 4 where the results were almost on the same level and therefore we can define them as strategies with the same properties towards wear.

Fibers deposited at an angle 45° and individual layers that alternate are the most resistant to abrasive wear of our strategies. In contrast, strategy 4, which was slightly worse than strategy 1, is unsatisfactory for the PLA material according to the test results because of the high values of weight loss expressed as a percentage. From all these results and graphical comparisons, they prove that the coating strategies in FFF technology have a great influence on the abrasive wear.

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