WP T2 – INNOVATION ON TEXTILE WASTE MANAGEMENT

ACTIVITY A.T2.3 PILOT CASES

D.T2.3.4 PILOT CASES FEASIBILITY STUDY

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ENTeR – Expert Network on Textile Recycling

ENTeR works in five central European countries that are involved in the textile business, to promote innovative solutions for waste management that will result in a circular economy approach to making textiles.

The project will help to accelerate collaboration among the involved textile territories, promoting a joint offer of innovative services by the main local research centres and business associations ("virtual centre"), involving also public stakeholders in defining a strategic agenda and related action plan, in order to link and drive the circular economy consideration and strategic actions.

The approach of the proposal and the cooperation between the partners is oriented to the management and optimization of waste, in a Life Cycle Design (or Ecodesign) perspective.

CONTENT

1. Pilot case description – aim and scope

Thanks to the seven pilot-projects, the international partnership under the ENTeR project launched an overview and analysis of production processes and the use of secondary raw materials in order to contribute indirectly to the reduction of industrial waste for more efficient production.The study, which is the ENTeR 8 pilot, has been named “3D Printing in the Textile Industry”, and undoubtedly covers all the priority areas addressed by the project and not only seeks to summarise interesting research results, but also has successfully involved several local actors in this interesting and new experiment. It gave others the opportunity to learn about the latest and state-of-the-art techniques, and the samples produced by 3D printers printed on textiles were the first in the region to test, form an opinion, and thus help the professional progress of the ENTeR project and the knowledge of the consortium.

The further aim of the PBN was to examine how the project can be even more successful and innovative.3D printing is now well known and widely popular, even in a home environment suitable for prototype or small series production. The ordinary, though hand-held device capable of producing 3D print fibres from scrapped plastic granules in practice, 3D printing from various plastic materials is widespread, nowadays it is no longer a curiosum if metal-printed, high-precision and extremely varied geometry components are produced in different parts of the industry, which of course, in addition to prototype testing, can be used even in operating conditions.The speed of the technological development of 3D printing is exceptional, and the achievements achieved in this area over the last decade or even in the last few years are remarkable. In the eyes of many analysts, it is no longer a question of whether 3D printing will be the future in several industrial areas where material processing is being dealt with, but when the “throne of current technologies” will take place. Of course, we're not here yet and it’s a long way to go. In the case of serial production, 3D printing is higher than for example CNC.In many cases, however, this technology is more cost-effective than industrial counterparts. A good example of this is small series of plastic printing. Depending on geometry, printing thousands of copies may prove cheaper than making a injection mould.It is also a major advantage that, unlike conventional machining technologies, a relatively small amount of waste is generated by additive manufacturing technologies and that there are already different ideas and existing experimental solutions for the use and recycling of this small amount of waste in 3D printing.Furthermore, as 3D printing is now widely available, a huge user and developer community has developed, whose members are constantly sharing their experiences and suggestions in the online space. In addition to the forum discussions, a number of websites have been developed on which models created by others can be accessed, available or, in many cases, downloaded free of charge. And this can give a big boost to a beginner in the field of 3D printing. The above trend provides room for recycling of plastics on a new stage.3D printing in housing for non-industrial purposes can also be a clear area for recycled plastics. A more thorough discussion of this issue and the examination of its textile aspects motivated our activities within the framework of the ENTeR project.

In our study of the literature available to us, we concluded that the mechanical properties of the products produced from plastics suitable for 3D printing are already well known, and these parameters have already been compared with those of injection moulded samples with the same materials. However, no studies have been found to determine how the mechanical properties of each type of plastic are modified if they contain to some extent recycled raw materials. This appears to be less relevant to the manufacturer’s eyes, since, for example, when injection moulding increases the amount of regranulate in the process, the optical properties of the manufactured product deteriorate. On the other hand, 3D printing technology – especially when used at home – tolerates minor beauty defects and lower values in mechanical parameters, since 3D printed products do not usually face high mechanical stresses and increased aesthetic expectations. That's why this area is so promising in plastic recycling, and many creative and useful long-term tools can be made from shredded old parts. During our studies, we made 504 test samples on the 3 3D printers available in am-LAB, of which 216 were tested in Charpy impact tests, 216 in a tensile test and 72 3 point bending tests in the mechanical laboratory (ELTE SEK) of the University Centre of ELTE Savaria. The hardness of 3D printed samples against breaking on a Zwick/Roell HIT 5P standard Charpy percussion with a 5 J hammer, while the elastic modulus, bending modulus, and tensile strength values were tested using a Zwick/Roell Z100 tensile machine. The geometry of the 3D printed test bodies was performed in accordance with MSZ EN ISO 179-1/1eA for impact tests, MSZ EN ISO 20753: 2014 for tensile tests, and 3-point bending tests in the case of MSZ EN ISO 178A. The test bodies were manufactured with 3 FDM type 3D printers made from 3 different materials. We have chosen the PLA (polylactic acid), which is common in print 3D.Although this plastic can be obtained from a renewable raw material (maize starch), it is not a self-degradable plastic, which, contrary to popular belief, would require special conditions, bacteria, which are not available at most waste sites. The PLA raw materials tested are made of plastics that do not contain recycled plastics (originals), partly (up to 90 %) recycled plastics and 100 % recycled plastic.

Testing of different 3D printers was justified by different printer geometry and manufacturer-specific Slicer programs converting 3D files to printable G-code series.

The test bodies were prepared at different printing layer thicknesses, infill percentages, printing temperatures and the raw material dried or used without drying.

At the end of themechanical tests, the surprising and initial hypothesis was partially refuted, that with the increase in the amount of recycled plastic, the 3D printed samples do not always produce worse results than the original, factory filaments. It was shown that the choice of the 3D printer could have a serious impact on the mechanical parameters, but we also found significant differences depending on the print parameters tested. As a conclusion, it can be concluded that it is justified to use filaments made of recycled plastic in print 3D. Neither its mechanical properties nor the optical appearance of the printed torso nor the cost of the raw material showed any outstanding differences compared to the test bodies made of factory filament. Ordinary 3D prints in our opinion can make these raw materials absolutely applicable. After verifying that recycled plastics can be used in 3D prints, we have made an attempt to ironing 3D printed logos from 100 % recycled PLA material to textiles and to test those items in real life.

As an ANNEX 1, the entire study has been provided.

2. Recycling of textile waste in the pilot case company – state of art

In the framework of the study, we tried to find ways to use 3D printing and recycled plastics in the textile industry in everyday life. We have looked for methods that have more raison d'être than the full 3D printed plastic garments described above, but still take advantage of the opportunities and freedom offered by technology.

The basic idea was to base 3D prints made of recycled filament on T-shirts and then to test T-shirts in active use. We wanted to involve two communities to test the results, where we could reasonably assume that the clothes to be tested would be affected and stressed in such a way that we could safely draw conclusions at the end of the experiment as to the durability, vulnerability and applicability of the T-shirts and attached logos; to this end, a kindergarten and a fitness group were selected as test subjects.

Our initial assumption was that, on the basis of the process described below, the pattern of T-shirts would be more rigid than the pattern or images of traditional textiles, but since we printed the logos in one layer, it was expected that they would be flexible enough to avoid breakage during use.

Basic conditions

We have chosen the Szombathely Progym Fitness for the training room. For the staff involved by the sports association, we purchased a black cotton T-shirt because the manager had specifically requested that the logo be printed in white, except for the red Y letters, so the black T-shirt appeared to be the most appropriate choice. A total of 25 has a non-uniform material composition for testing. According to the manufacturer's recommendation on the labels, all T-shirts should be washed at 30 degrees. For the white letters of the logos, 90 % recycled plastic fibres of the type rPLA manufactured by Filamentive, with a diameter of 2,85 mm, and for the red letters, filaments of 1,75 mm with a PLA base and manufactured by Extreme Builder were used. Another test group was a class in the Margaréta Óvoda Szombathely, where children are aged 3 to 7 years. On the T-shirts to be worn at a carnival ceremony in kindergartens, the logo was designed to be a margarette sample, but for technical reasons we finally printed and raided a butterfly. For this purpose, 25 cotton-shirts were purchased in white for the group.

As in the past, we received the vector logo, but we encountered such an error that it contained too many small details, which the printer might not have been able to print and, if so, the way in which the many small details were produced on the T-shirts would have been problematic. The solution was found to be appropriate to print another emblem on the subject. Our testers went to the Butterfly group within the kindergartens, so we selected and downloaded a ready Butterfly model file from the web pages, which can certainly be printed using our tools.

Testing

The training room testers also worn the test T-shirts for one week in several jobs and during the exercise of a wide range of forms of movement. We have been a trainer, receptioner, but also a tester wearing the T-shirt during his own training, so it cannot be said that the test pieces have been subjected to the same uniform load, which can be seen from the various results. For practical reasons, testing included the testing of washing, which meant a uniform single washing at 30 degrees for the test tips in the training room.

As small children continue to play in kindergartens, they are mobile and they were unaware of the sensitivity of the shirt on their T-shirts, they could be vulnerable, so they could not be expected to be vigilant to preserve their integrity and used the T-shirts for several days not only during but also outside the carnival. As a result, we believe that we have achieved life-threatening results with regard to thedurability of plastic emblems and we would probably see the same in an equally short period of everyday use.

3. Feasibility study

The main advantage of the method described above is that it is possible to apply completely individual samples onto a cloth.If someone has a 3D printer at home, there is no obstacle to repeating the process at home, but it is also true for companies that they can make more multifaceted use of their 3D printers by implementing similar ideas. This gives workplaces the opportunity to experiment themselves with logos, but equally to kindergartens, schools, sports events, celebrations and individual occasions, this can be done locally, simply with the help of a 3D printer and ironer, not only for clothes, but also for caps, shoes, bags and similar accessories. Another important factor is that the help of 3D printing can produce completely unique solutions even in a sufficiently small number of copies.

The results of the testing were very varied. As the use was not uniform, the results were not the same, but this was not necessarily the aim. Fundamentally, the aim is to test the permanence of the prints and their ability to slide.

The injuries and defects on the logos can be divided into three groups: the first case when a T-shirt took place, but it is assumed that no active work was carried out, as it returned to the original situation. In the second group, the letters of the logos were folded and matured in that state. In the third case, the plastic parts were fragmented or some pieces fell from the clothes. Typically, according to the reports of the test leagues, the attached logos have been damaged, not during motion, but during washing.

As we worked on the two test printings with similar basic materials in terms of composition, we expected the same defects that occurred in the fitness room. Typically, the logos ont he shirts are crushed, damaged, sometimes they even got hardened or some party fall off from the shirts. There are also logos in good condition, which appear to be undamaged, but we have found this to be a presumably humane treatment rather than ironing on the basic material. According to the parents, damage to the logos is typically caused not by wear, but by washing with the washing machine and then drying with the tumble drier. The ironing has not resulted in any visible damage or change to the logo.

In summary, it can be concluded that the underlying concept is feasible and viable in practice, but further studies would be needed to determine how profitable it is possible to use this 3D printing with recycled plastic filament in the textile industry.

The examinations we carried out did not specify the quality of all T-shirts, the tensileness of the T-shirts during ironing, we did not set a uniform time and temperature for ironing, washing, all of which could influence the results of the tests, and we did not continuously monitor the events with T-shirts during the tests, so we could not subsequently determine the actual impact of each injury or lesion, if it was caused by it. This is not necessarily a problem when looking at the basic question, as the above conditions, which are not fully harmonised, have led to the conclusion that it is worthwhile to reflect further on the initial idea. The clarification of these factors may be more relevant in the event of a possible further development of the process or in the context of a more precise implementation and evaluation of the tests. It would be necessary to optimise the parameters in a more precise and comparable way, in several variants, in order to be able to carry out logoing of the best quality, but despite these shortcomings, we see a perspective on the use of the technology in this regard.

A 3D printer has a multifunctional tool, such as a device used in the textile industry, but it is not expected to be a printer as it is not a target device, and it enables us to make ourselves creatively without the acquisition of a separate device or without the involvement of a third party. In addition, the method provides an opportunity to renew, update old things, rethink and recycle clothes, especially if we work with recycled materials, as we did during the project experiment.

A way forward and development could be to use flexible manifold at a later stage, which is likely to create a more convenient and lasting solution. A recycled version of the material is not yet available, so we have not tried to do so yet, but instead, following the example of the Israeli designer previously described, we have printed interesting structures and thin patterns at the experimental level of the material that are not basically flexible, but have a flexible effect. We have seen that the idea is viable and really works, so further experimentation using such structures in the textile sector may be interesting at a later stage.

The statement that 3D printing has brought a huge change to the life of both ordinary average users and industrial operators is no longer only to be treated as a talking marketing haul, but as a general fact. A very large number of people, who are open to engineering and have practical veins, buy 3D printers for home use ‘for domestic purposes’.The cheap availability of technology has opened up the opportunity for modern creation for those willing to acquire 3D modelling knowledge and to invest time in increasing their own digitalisation knowledge. It is of course necessary to point out here that relatively cheaply available FDM and SLA printers, which could be safely used in both office and7 home settings, would have been much less widely distributed or in a limited form without the possibilities of open source “slicer” or CAD software.

Fortunately, the reorientation of education and the opportunities offered by the internet facilitate the acquisition of 3D design software management and the efficient use of 3D printing. There is a very large community behind the forums dealing with the topic, as well as the most popular video-sharing channels for “vloggers” operating their own channels, who are interested in answering the professional questions raised in the comments, providing advice on how to start, how to choose software and how to correct and correct any errors.

This is a great help, as the choice between slicer, CAD and husk modelling software, which can be used partly or entirely free of charge, is now also widely available. Each software is strong in a slightly different function, is more focused on other areas and it is worthwhile for the user to know the group of software that is best adapted to his own application, which, moreover, should be used in a process during 3D printing. For this reason, there is a need for more target software to be known and practiced in addition to technical knowledge.

Filaments with different levels of recycled plastic have been tested and compared in the FDM technology of 3D printing. In total, 504 samples were mechanically tested. A Charp impact test of 216 samples, a tensile test of 216 samples and a bending test of 72 samples of 3 points were carried out. Summarising the results and experience of mechanical measurements and examining the distributions of the measured data graphically according to several criteria and presentation methods, the following relationships can be derived:

The nominal longitudinal dimensions of the samples could be returned with the smallest defect on the products manufactured on the Czech 3D printer Prusa i2 MK3. Here, the measured values are scattered around the nominal, drawing value.

The Dutch printer Ultimaker 3 Extended was able to return the nominal longitudinal dimensions of the samples with the highest degree of precision depending on the selection of the individual raw materials. Here, however, the measured values are not scattered around nominal values, so it is recommended to fine-tune the printing parameters.

The Z-directional height of the samples was also best produced around the nominal design value by the Czech printer Prusa i3 MK2.

The slicer programs of the three FDM type 3D printers have printed samples of different weights for different alignment possibilities. The samples produced on the Dutch printer Ultimaker 3 Extended were the least weight samples in distribution, while the samples produced on printer Prusa i3 MK2 were the samples produced on the highest weight in total.

The effect of statistically significant differences in mass distributions is not reflected in the suction to impact, but in the tensile strength and elastic modulus values. The samples manufactured on the Ultimaker 3 Extended printer were the weakest, while Prusa i3 MK2 was the strongest samples against the tractive loads. This may of course have been influenced by other settings of printers (print speeds, material recycling settings, etc.) in addition to the weights of the samples.

The measured and derived mechanical parameters of samples of the type Extreme Builder 1000 manufactured on the Dutch industrial FDM printer provided the lowest standard deviation, i.e. this printer was capable of producing the most reproducible mechanical parameters.

In line with our initial expectations, increasing the thickness of the printing layers has on average reduced the values of the measured mechanical parameters, but on several occasions this is dependent on raw materials and printers.

In line with initial expectations, we obtained stronger samples on average (positive correlation) by increasing internal filling (infill), but this is also dependent on material and printer selection in detail.

Contrary to initial expectations, no increase in the mechanical parameters with a slight increase in the printing temperature (zero correlation) has been observed, but an in-situ maximum of the measured mechanical parameters has been observed at 200 °C over the temperature range considered.

Contrary to initial expectations, the drying of raw materials (filaments) did not lead to any significant improvement in mechanical parameters.

Contrary to initial expectations, recycled plastics did not fulfil weaker mechanical parameters compared to 'original' plastics that do not contain recycled plastic. Although the image is mixed, for certain parameters where one and the other material were found to be stronger, for several settings, samples manufactured from fibre containing recycled plastic showed better mechanical parameters. Thus, the use of recycled plastics is a reality. Neither did they behave worse during 3D printing, nor did we see in their mechanical behaviour that they fell short of the original filaments recommended by the manufacturers, which in principle did not contain recycled plastic.

However, the fact that mechanical tests have given such a variety of results, that one substance and the other substance have acted better, unfortunately the reasons for this have not been revealed in the context of the present research. However, we see an interesting opportunity that the issues raised here could be identified in the case of a larger number of studies, where a specific description of these links would be targeted.