WP T2 – INNOVATION ON TEXTILE WASTE MANAGEMENT

ACTIVITY A.T2.3 PILOT CASES

D.T2.3.3 PILOT CASES TECHNICAL REPORT

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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 theseven 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 available 3D printers 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 tested 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 the mechanical 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.

2. Mapping of the market available technologies for waste pre-treatment in partner region

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.

After creating the 3D printable code that can be implemented by the available 3D printer, the actual 3D printing, the "creation", can start. The fact that "creation" should be emphasised, as technology is therefore popular and spreading rapidly in everyday and industrial practice. Using this method, we are able to create a wide variety of geometry without hands, to an extent that depends on the device and its method, but in a relatively well-reproducible way, which can even be of practical significance. This is inspiring for many, as we can replace old, broken parts, rethink existing objects without having to discard them, or obtain super-expensive after-market or second-hand spare parts. However, this is a general problem in the "plastic world" around us. If something breaks, it is most often worthwhile to replace it together. This is extremely wasteful and environmentally burdensome, and its message is not very positive for the next generations: If something is not good, take a new one!

Fortunately, it seems, that 3D printing offers a meaningful opportunity to reshape this message: If something is not good, rethink and do better!

This is both a much more acceptable message from the point of view of protecting the environment and a more pleasant approach to the digitalisation development of countries. Indeed, anyone creatively making 3D printing not only generates value, not only saves the environment as illustrated above, but also acquires a wealth of software. He learns about various file formats, which are widely used in industrial practice, learns to find out about the world of forums, filters technical information, generates 3D objects, produces technical designs at a basic level, and learns different modelling concepts. In addition, it will build up a useful practical and technical experience, as the 3D printer is also a machine, its components will be destroyed and aged even when used properly. These need to be known, they need to be protected against specific defects, they need to avoid negative effects, they need to learn about the importance of preventive maintenance and, in case of a defect, they need to know where and how a spare part corresponding to our data sheet should be allocated to our device. This learning process can start and continue with results already in the secondary school age, and the long-term impact of this knowledge can be assumed to be significant for generations later entering the labour market. It is no coincidence that a large number of educational establishments already have 3D printers and promote this technology in Hungary.

If this technology with good prospects is suitable for reducing unwarranted consumption and reducing the plastic burden on the environment, consideration should be given to whether it could also be applied to actual recycling. Several solutions already exist for the printing, regranulation and recycling of 3D printed materials.These tools have so far been deployed on an even narrower scale, but there is an increasing number of producers who target the recycling of 3D printed materials with their devices, or even promote the production of recycled filament made from conventional PET bottles.Fortunately, social media have repeatedly helped to raise awareness of environmental damage and the severity of the plastic burden, which can help to launch a number of counter-measures at governmental or even EU level. One example is the Print Your City project, where, for example, in Thessaloniki, Greece, they are already capable of producing 3D printed displays outdoors from PP and PE, which is a great opportunity to produce individually designed, stored outdoors, durable, hot (bad thermal conductor), aesthetic and practical landmarks, not least as part of the circular economy concept.

Summary of the testing part

We have exposed 3D printed samples to three different types of mechanical test in order to compare them depending on the settings in which they were printed, the material from which they were printed and the available FDM type 3D printer:

- Charpy's impact test
- Tensile test
- 3 point crushing test

The mechanical tests were carried out in the mechanical laboratory of the University Centre of Savaria (ELTE SEK Szombathely) of Eötvös Lóránd University. The test impactors are designed in accordance with MSZ EN ISO 179-1/1eA for the Charpy impact test, MSZ EN ISO 20753: 2014 for the tensile test and MSZ EN ISO 178A for the bending test. The appropriate standard proposals have been selected in accordance with the recommendations of the Technical Institute of the University, so that the results obtained can be reproduced by anyone in the future after the use of the test samples described in the relevant standards and the precise follow-up of the test settings. This is important for the conduct of possible future investigations or for the subsequent review and verification of the results. The Charpy impact test is one of the most common, standardised methods to characterise the absorption (specific impact) of the test substances, i.e. how much energy is sinked in the test body before breaking, so the test characterises the "suction" of the substance. The more energy is needed to break it, the more 'suction' it is. This method is highly suitable for testing 3D printed samples (and usually of any kind of solids) against rigid fractures. However, the method is only suitable for comparative testing and ranking of samples, and there is no theoretical derivation of the measured values from the other strength properties of the substance [64].

The test has been carried out in a temperature-independent manner (at room temperature in the laboratory, ~ 25 °C) on a standard Charpy @-@ 5P impactor with a @-@ 5J @-@ os. The principle of measurement is very simple and is therefore also widely used. A standard weight ("hammer") of the shape and weight is raised into the upper fixation end position of the device and released from it on the perimeter intersects to the opposite side of the impactor with the "V-shaped" incision. Thus, if the sample is properly placed, the impactor will always break at the V-shape. As the hammer unfolds the impactor, the kinetic energy will be lost and the swinged mass will not rise to the same height as its initial position when moving on the circle. The decrease in the kinetic energy suffered by the excision of the impactor can therefore be deduced from the angle of swing of the hammer, which is at the same time equal to the energy absorption of the sample material. This has been calculated with precision by the software of the device, as energy losses due to the bearing of the hammer axle, air drag, marginal vibration losses, etc. should also be corrected for the sake of overall precision (these correction factors should be known to the manufacturer and applied in software). An analogue outline of Zwick/Roell HIT 5P Charpy impact tester (ELTE SEK, Szombathely) and its theoretical operation. The diverted hammer slashes the impactor in the lower position and then the maximum climb height on the opposite side can be used to determine the kinetic energy absorbed by the sample ($E = mg(h-h')$) (66)

The tensile and bending tests were located in the same laboratory as the dynamic impact test and irreversible mechanical tests were carried out at the same room temperature (~25 °C). Both test types were carried out on the same Zwick/Roell Z100 device at a bending and break speed of 10 mm/min. For the two types of measurement, we have replaced the corresponding grips and tools. The device disassemblyses the samples taken with the aid of breaking jaws moved by threaded stalks in an extremely robust, betonal jacket. The apparatus disassemblyses samples of a shape fixed in the appropriate standard, which, in addition to plastic, may be of metal, ceramic, etc., so that the breaking of plastic samples on such a device is an easy task.

The plastic samples we examined have been shown to be extremely rigid and therefore they had to be captured with due care so as not to harm them. Similarly, to the execution of Charpy's impact tests, the samples were placed on precise buffers. These single-axle tensile tests are easily reproducible and the resulting specific material characteristics (e.g. elongation at break, initial tensile elastic modulus, flow tension, tensile and tensile strength, etc.) can also be used in the calculation of strength when designing components with more sophisticated geometry. Short elongations can also be seen on tensile strength curves, with only a very low incidence of plastic deformation. Where we have experienced slightly higher elongations, neither can we attribute them to the properties of the plastic material itself (i.e. it is not due to the fact that it is made from recycled or non-recycled material), but rather to the disintegration of the printed 3D structure.