УДК 677.074
DOI 10.30857/2706-5898.2020.3.2

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ТЕХНОЛОГІЯ 3D-ДРУКУ В ТЕКСТИЛЬНІЙ ТА МОДНІЙ ІНДУСТРІЯХ

Однією з найбільш значущих технологій четвертої промислової революції є 3D-друк. Надзвичайна річ у застосуванні технології тривимірного друку полягає в тому, що її можна використовувати для створення різноманітних предметів, адаптованих до власних потреб. У індустрії моди існує потреба в індивідуальних захисних засобах. У даній роботі представлена можливість застосування нових технологій, таких як 3D-моделювання захисних елементів, які можна зробити за допомогою 3D-принтерів.
3D-моделювання та адитивні технології (3D-друк) можуть бути використані при розробці захисного робочого одягу. Для виготовлення потрібен лише цифровий файл із 3D-моделлю та правильно обраний матеріал. В даному дослідженні використано термопластичний поліуретан. Зразки конструкції були побудовані та змодельовані за допомогою програмного забезпечення Rhinoceros. Зразки можуть бути інтегровані в предмет одягу для відтворення форми тіла та забезпечення необхідного захисту.
Мета роботи. *Робота спрямована на вивчення можливості застосування 3D-друку з використанням термопластичного поліуретану для розробки захисного спорядження.*
Наукова новизна. *У індустрії моди тривимірний (3D) друк використовувався дизайнерами та інженерами для створення для створення різноманітних речей, починаючи від аксесуарів і закінчуючи одягом. Дана робота одна з небагатьох, в якій доведено можливість його застосування в засобах індивідуального захисту.*
Практичне значення. *Адитивна технологія та 3D-друк є предметом інтенсивних досліджень та розробок (методи, матеріали, нові техніки, сфери застосування тощо), що продовжено в даному дослідженні з використанням термопластичного поліуретану. Розроблено зразки матеріалів, які можуть бути застосовані у захисному одязі.*
Ключові слова: *індустрія моди, аддитивне виробництво, 3D-друк, дизайн, захисне обладнання, термопластичний поліуретан.*

3D PRINTING TECHNOLOGY IN TEXTILE AND FASHION INDUSTRY

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The extraordinary thing about the application of 3D printing technology is that it can be used to create accessible items customized to personal needs. In the fashion industry, there is a need for individualized protective equipment. The possibility of applying new technologies such as 3D modelling of protective elements that can be made by using 3D printers is presented in this paper.
3D modelling and additive technologies (3D printing) can be used in the development of protective work clothing. The fabrication process only requires the digital file with the 3D model and the right material - we chose to use thermoplastic polyurethane (TPU).
The design samples were constructed and modelled using a software program called Rhinoceros. The samples can be integrated into the clothing item, in order to follow the body shape and to provide the necessary protection.
Purpose. *This paper aims to explore the applicability of 3D printing materials using thermoplastic polyurethane (TPU) for the development of protective gear.*
Scientific novelty. *In the fashion industry, three-dimensional (3D) printing has been used by designers and engineers to create everything from accessories to clothing, but only a few studies have investigated its applicability in personal protective equipment.*

Practical value. *One of the most significant technologies of the fourth industrial revolution is 3D printing. Additive manufacturing and 3D printing are the subject of intensive research and development (methods, materials, new techniques, application areas, etc.). The purpose of this study is to develop 3D printing samples and study conditions related to TPU.*

Keywords: *fashion industry, additive manufacturing, 3D printing, design, protective equipment, thermoplastic polyurethane.*

This study attempts to develop design samples, using a FDM desktop 3D printer of the type widely used in many different industries. In total, three types of materials designs were developed.

This study is meaningful in terms of developing shield protectors, examining the limitations, and suggesting methods by which to improve and enhance technology of 3D printing for the protective equipment.

The additive manufacturing is used in various manufacturing fields (healthcare, construction, mechanical, retail, defense, pharma, automotive industry, aerospace, smart manufacturing). Adding materials to create an object is called as "additive manufacturing" and 3D printing is an additive technique [1], [2]. This technique allows a creation of a three-dimensional physical object by laying down layers of materials from a digital computer model [1], [2], [3].

In the solid type 3D printers (Fused-Deposition Modelling (FDM)), thermoplastic materials (polymer wire or filaments) are melted down by heating. Then, the melted polymer is passed through nozzle and laminated [2], [4]. Objects are created in layers on a descending platform.

When modeling with the end goal of fabricating an ergonomic and effective shield protector, from both manufacturing and print strength points of view, one must take into consideration aspects such as print orientation, overhang, infill and other technical aspects that are directly tied to the printer technology and materials used [5]

All 3D printing materials have their own distinctive features. There are necessary factors like texture, durability, resistance, cost, etc. that need to be considered in 3D printing. Researchers in this field have keen interest in new materials suitable for 3D printing applications. Although a large number of plastic/polymer constituents are available for additive manufacturing [5]. New molding materials are continuously being developed but can largely be categorized as polyamide, polylactic acid (PLA), thermoplastic polyurethane (TPU), metal, ceramic, wood, and composite materials.[6]

For this paper, different materials were compared by the strength, flexibility and durability of the filament. We chose polyurethane because is a flexible and abrasion resistant thermoplastic and is resistant to many chemicals, see Table 1. TPU material also has a higher abrasion resistance and a higher resistance to oils and greases [6].

Table 1 – **Specifications for TPU material**

Specifications for TPU material	Dimensional accuracy	Strength	Flexibility	Durability	Material costs
Features	High	High	Very high	High	Medium
Resistance	Heat resistance	Chemical resistance	Flame retardant	Water resistance	Abrasion resistance
Temperatures	Melting -	Nozzle 220-250°C	Heated bed up to 60 °C	Print temperature ± 210-230 °C	Melting temperature ± 220 ± 10°C

Methodology.

First step was using the Rhinoceros and Grasshopper software for modeling. The Rhino for Windows interfaces (Fig.1) uses NURBS, for all curves and surface geometry. Non-Uniform Rational B-Splines, are mathematical representations of 3-D geometry. The program requires basic education or training.

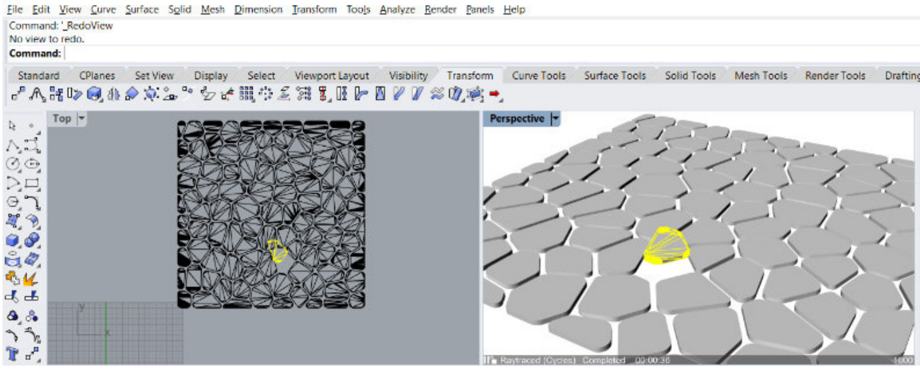

Fig. 1. **First design in Rhinoceros 6.0 software**

Samples were modeled using the Rhinoceros 6.0 software (Robert McNeel & Associates, Seattle, WA, USA).

In the next step, we converted the 3D models to compatible files with 3D printers by generating the G-code using 3D printing software -Ultimaker Cura (Fig.2). We tested layer height, infill density, infill pattern and print speed. The designs were printed at a temperature of 215 °C, using a flexible thermoplastic polyurethane (TPU). We gave careful consideration to the requirements of manufacturing and prototyping that are involved when using 3d printing technologies, such as print orientation, overhang management for minimal support usage, etc. [5]

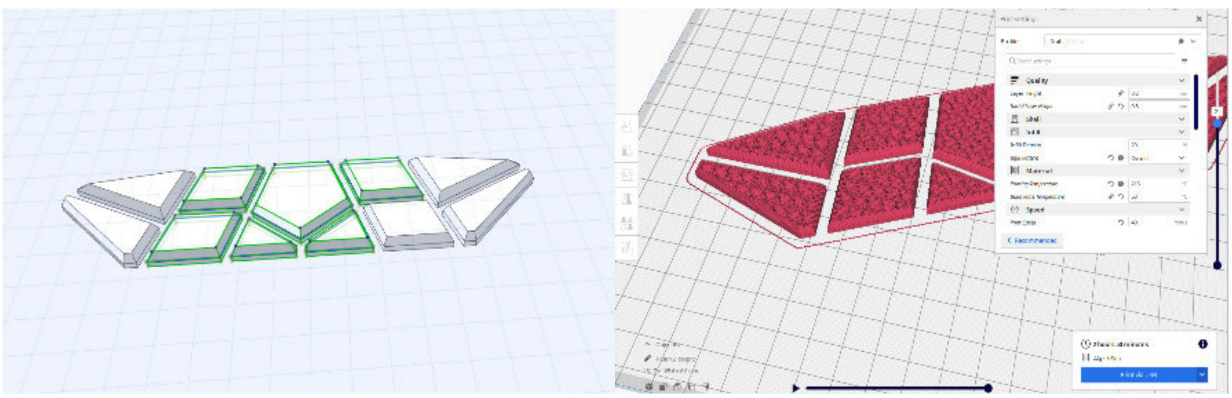

Fig. 2. **Model nr.2 in Ultimaker Cura**

The models were built around making a flexible but shock absorbing protective pad basis, combining 3-D printing technology and a support material (PE mesh or knitted cotton fabric) that tied the individual shielding subsegments together. This allows for more flexibility and range of motion in potential protective clothing where this method would be eventually applied.

The increased range of motion directly linked to the form of the shielding elements, their distance apart and the overall form of the inlay. The infill is geometrically generated so that it provides adequate support when faced with mid-range impact force, even at low infill density values such as 15-20%. It provides geometric stability for the Z axis – throughout the thickness of the shielding pad.[7]

Research results

Further testing is necessary. This study suggests that design surfaces, the samples produced (Fig.3-5.), can be used in development of further application such as protectors. The choice of material is crucial in this undertaking because the goal is to make items that are easy to manufacture and reproduce with inexpensive 3-D printing technology and materials.

Because TPU material is flexible and elastic, it makes it very sensitive to fast movements such as retractions. Therefore, to successful 3D print, it was crucial to optimize the retraction settings to limit the movements. Recent studies have shown that TPU is a suitable material for protective equipment due to its physical proprieties and ease of use and print, relative to other flexible materials. We ended up using a 20% infill value for an optimal elasticity/strength of print ratio. [7]

Fig. 3 **Sample model nr.2**

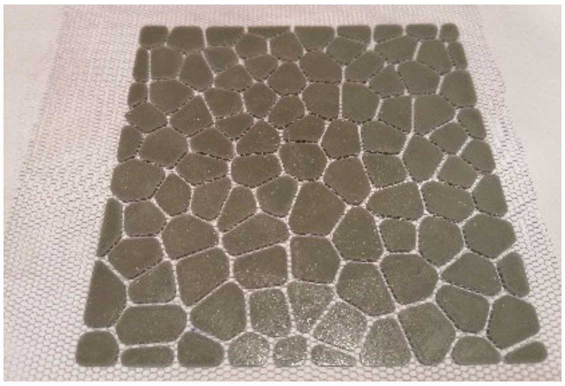

Fig. 4. **Sample model nr.1**

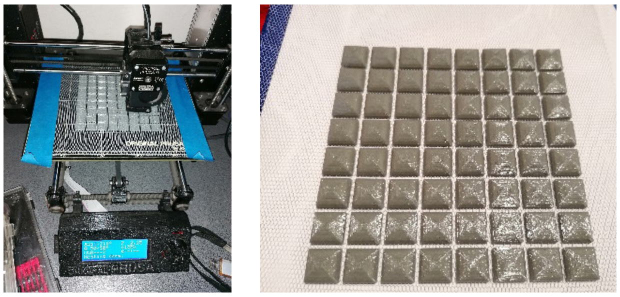

Fig. 5. **Printing Model nr.3**

The unique capabilities of additive manufacturing enable new opportunities for improvements in product performance such as protective pads. The flexibility of TPU is excellent, but this also depends on the 3D printing software settings. When we used a low level of infill, the 3D printed design was more flexible. This makes it possible to create objects that are more elastic or more rigid.

When it comes to 3D printing, TPU filament requires the transfer of a larger amount of energy. This research was conducted to examine the use of 3D printing and to analyze manufacturing process of three different designs using a FDM type desktop 3D printer of the type most commonly available.

Conclusion.

NURBS modelling can be used to create the virtual model for shielding pad elements, from concept to manufacturing stages.

Out of the many materials that can be used in 3-D printing, TPU shows the most potential, having great parameters optimal for protective equipment. We have chosen this material to fabricate different flexible shielding prototypes for further testing in the future.

This research aims to examine the applicability of 3D design and printing on a larger scale, using composite techniques combining 3D printing thermoplastics along with fabrics. Further testing is needed in order to develop acceptable protective pads, but the design and manufacturing principles stand.

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