How to cite this article:

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Title of article: „Techniki przemysłowe na Wydziale Wzornictwa ASP w Warszawie – nauczanie z wykorzystaniem druku 3D" ("Industrial technologies at Faculty of Design, Academy of Fine Art in Warsaw – teaching with 3D printing")

Mechanik, Vol. 91, No. 1 (2018): pages 50–52

DOI: https://doi.org/10.17814/mechanik.2018.1.10

Industrial technologies at Faculty of Design, Academy of Fine Art in Warsaw – teaching with 3D printing

Techniki przemysłowe na Wydziale Wzornictwa ASP w Warszawie – nauczanie z wykorzystaniem druku 3D

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The teaching of industrial technologies at the Faculty of Design, Academy of Fine Arts in Warsaw, Poland was described. The using of additive manufacturing for the prototyping of various products, including foundry models and core boxes for the preparation of sand molds, was shown.

KEYWORDS: 3D printing, additive manufacturing, casting, teaching

Although the Academy of Fine Arts in Warsaw is a strictly artistic university, the Faculty of Design is unique, because it combines visual arts and cultural knowledge with technical sciences, architecture, ergonomics, materials science, knowledge about the economy and many others [1]. Originally, the Faculty of Design of the Academy of Fine Arts in Warsaw was called the Faculty of Industrial Design. It was created in 1977 after the division of the then Art Design Department into two separate units.

Currently, the Faculty of Design has two fields of study: "Product design and visual communication" (first and second cycle) and "Designing fashion" (first cycle studies) [3]. In the first of these courses, up to 30 students are admitted annually, who in the study plan [3], apart from artistic subjects (painting, sculpture, art history), also have a group of design subjects and the science of technical issues. Of course, design studios which, for the first and the second year of studies are compulsory, and from the third year students can choose them themselves. The study plan also includes specialist subjects, i.e. "Presentation drawing" for the first year and "The basics of ergonomics" and "History of design" on the second year. The group of technical subjects consists of "Modeling" and "Technology and construction". On the first year, students learn the rules of machine technical drawing (projections, dimensioning, etc.). Basic information about industrial technologies (machining, plastic and casting) is also taught. In addition, students learn the most important functions of solid modeling and the generation of flat documentation in the 3D CAD system. The scope of knowledge provided to students in the second year as part of the subject "Technologies and constructions" is the thematic development of material from the first year, but the classes are conducted in a different way. They are rather in the form of design exercises from selected manufacturing techniques, and the scope of knowledge includes, among others, publications [4–8].

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Course program

Currently implemented program of the subject "Technologies and constructions II" consists of a series of lectures, a set of computer exercises and three technological projects. Lectures on industrial technologies and construction materials as well as exercises from the 3D CAD system precede the so-called large technological projects that each student performs independently. Three topics have been implemented in recent years:

- elements forming the injection mold for thermoplastics, e.g. a water jug, a soap dish;
- an element made of edge-curved sheet metal, e.g. a letterbox, a napkin holder, a shelf for spices;
- sand casting in aluminum alloy for which models and core boxes are made using incremental technology; usually they are node elements of furniture or tubular spatial structures, e.g. for stores or exhibitions.

The practical design process consists of the selection of a real product for modernization and the determination of utility, material, design and technological assumptions for it. Each time, a review of similar products available on the market and handwritten sketches of a minimum of three versions of the modernized product are carried out (Figures 1, 5 and 8). After selecting one of the versions, the student performs a solid model in the 3D CAD system and prepares simplified flat technical documentation with dimensions (figs. 2, 6, 9). Students do not perform strength calculations of modernized products.

Project No. 1 – plastic molding

The aim of the thermoplastic product design is to learn injection molding technology. Each student, apart from the 3D CAD model of the compact (fig. 2a) and 2D documentation (fig. 2b), shapes the cavity (fig. 3a). With its help, it performs the analysis of the opening of forming elements in the 3D CAD system (fig. 3c) and checks the inclinations (fig. 3b) and the thickness of the molded walls. Some of the products are produced in the form of prototypes using 3D printing with FDM/FFF incremental technology [4] from PLA polymer (fig. 4). Figs. 1–4 present the design of the molding on the example of the egg stand by the student Olga Darwaj.

Project No. 2 – sheet metal bent edge

The purpose of another technological project is to teach metal sheet metalworking (the recommended material is aluminum sheet, e.g. PA11 with a thickness of 1 mm). In particular, students learn about bending on press brakes using segment tools. The sheets are laser cut and bent on the machine in the departmental model. On the basis of his conceptual sketches (fig. 5), each student prepares a 3D model (fig. 6) of a composite sheet in a dedicated 3D CAD system module. In addition, material waste is analyzed and flat product documentation is generated (fig. 6) and its cutting. On this basis, DXF files are created for tool rooms for programming laser cutting. After consulting the lecturers, all students files are sent to several tool rooms to evaluate the material needed and the cutting service.

After receiving the plates, the students themselves (after training) perform bending on the machines available in the departmental model (fig. 7). Polymer elements are made of some sheet metal products using 3D printing – e.g. wall connectors, stiffening elements or protecting the user from sharp edges of the sheet.

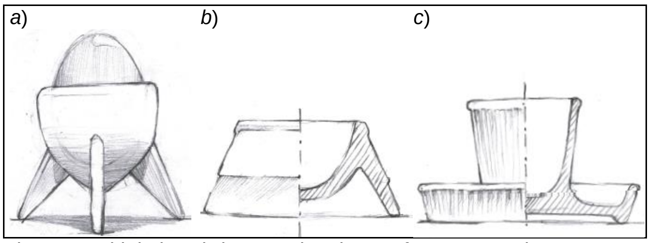

Fig. 1. Initial hand-drawn sketches of conceptual egg trays (O. Darwaj); the sketch (*c*) was chosen for further stages of shaping.

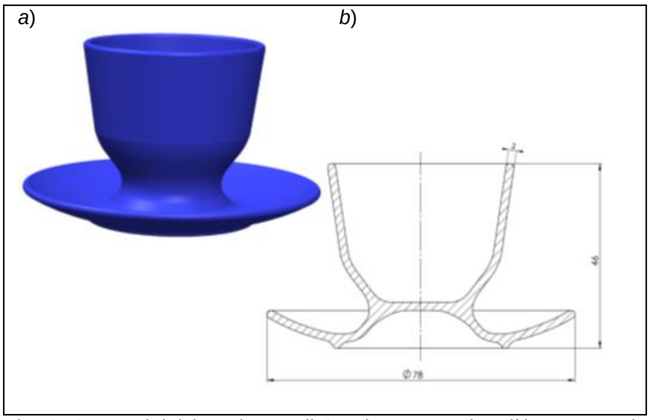

Fig. 2. 3D model (*a*) and overall 2D documentation (*b*) egg stands (O. Darwaj)

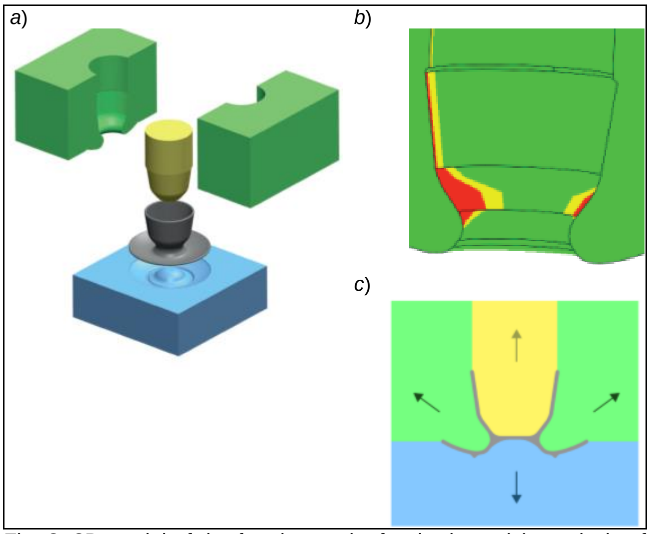

Fig. 3. 3D model of the forming cavity for the base (*a*), analysis of the inclination of forming elements showing the potential problem when opening the halves of the punches (*b*) and analysis of the directions of opening the forming elements in cross-section (*c*) (O. Darwaj)

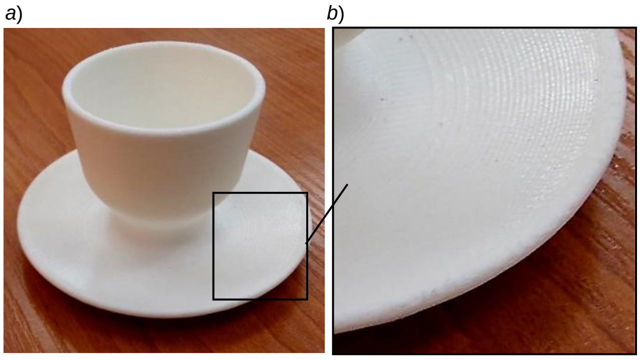

Fig. 4. Prototype of the egg stand made with 3D printing using the FDM method from PLA (*a*) and the visible stepped effect (*b*) (O. Darwaj)

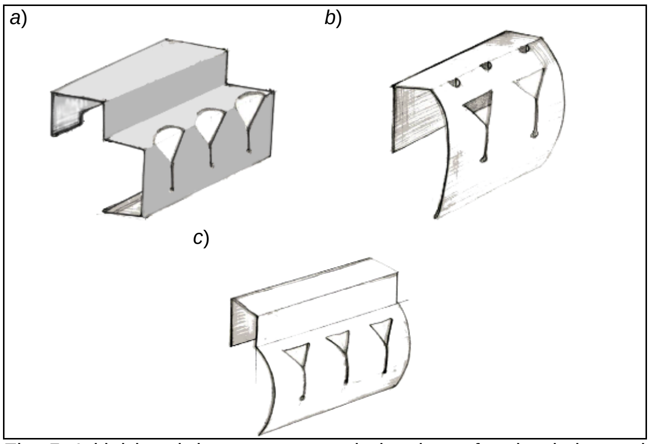

Fig. 5. Initial hand-drawn conceptual sketches of a tin cloth towel hanger, mounted on the door of a kitchen cupboard (A. Jankowska); the sketch was selected for further stages (*a*)

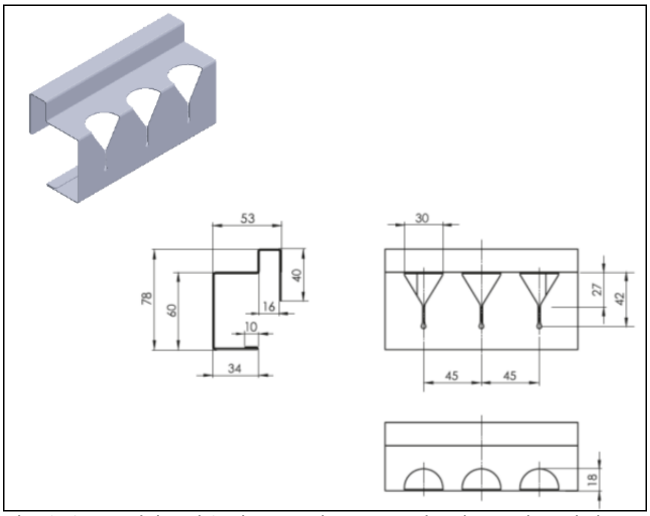

Fig. 6. 3D model and 2D hanger documentation (A. Jankowska)

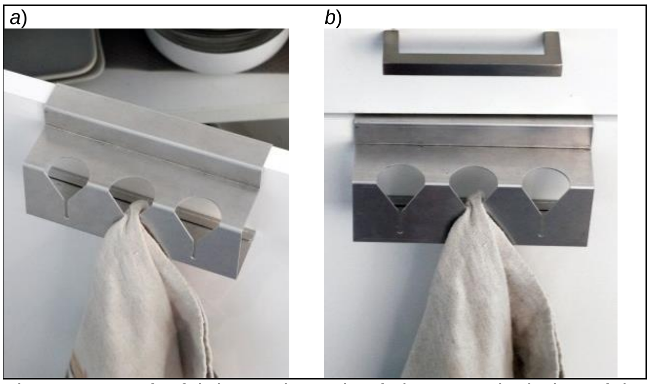

Fig. 7. Hanger for fabric towels made of sheet metal: *a*) view of the fastening on the door of the kitchen cabinet, *b*) the drawer over the cabinet's door is not blocked (A. Jankowska)

Project No. 3 – sand casting in aluminum

The aim of the third technological project is to learn the technology of gravity casting of metal alloys in sand forms [8]. As part of this exercise, students also learn incremental technologies that are used to produce foundry models and possibly core boxes. As casting objects, students usually choose different types of nodal elements (e.g. for furniture, shop shelves, exhibition structures, clothes hangers) and small architecture (e.g. bus stops) or specific products (e.g. ashtray, nutcracker or a knife for paper). They can be single- or multi-part products, but only the main element is enough to complete the item – by casting.

In the 3D CAD system, a student develops a solid 3D model of the product, on the basis of which he molds the casting, casting model, and if needed – core boxes. In addition, the student prepares 2D product documentation and assembly documentation, showing where the element is mounted (fig. 9). After the correct 3D CAD files have been checked by the student, the student generates STL files for 3D printing. The vast majority of facilities are manufactured using the FDM/FFF incremental technology [4]. Students usually use the services of the 3D Prints Laboratory of the Design Department, which has five MakerBot machines (of various types).

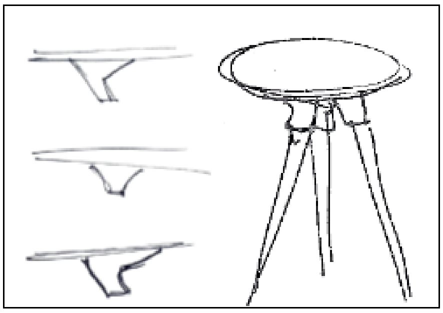

Fig. 8. Initial sketches of the leg connector to the stool (N. Gil)

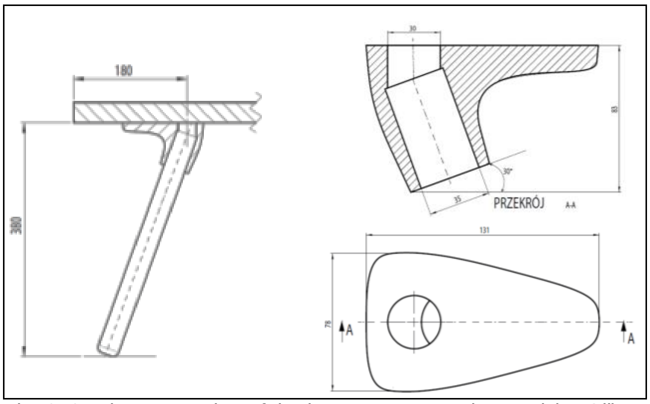

Fig. 9. 2D documentation of the leg connector to the stool (N. Gil)

Using 3D CAM software for 3D printers, students develop guidelines for the production of foundry models and core boxes, i.e. they orient the STL model to the machine working table and determine the height of the layers and the degree of interior filling. Due to this knowledge, how to reduce the generation of support structures and what the quality of the surface will probably be able to make. They also assess the degree of wear of the model material and the time of the 3D printing process. After receiving the printouts, students usually improve the smoothness of the walls by means of putty and varnishing (fig. 10a), so that molding sand is less sticky to them. In addition, the fitting of holes for positioning parts of casting models and core boxes (fig. 10b) requires improvement. Then, in the outer foundry, sand molds are made and metal elements are cast, which students usually still mechanically process in the departmental model (fig. 11). Such a process was presented on the example of a project by a student, Natalia Gil, who developed a new shape of the leg connector to the stool.

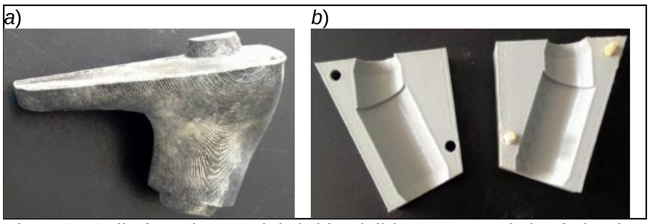

Fig. 10. Split foundry model (with visible core marks) of the leg connector to the stool, made with 3D print from PLA (a); core box made with 3D printing (b) (N. Gil)

Fig. 11. Cast aluminum connector for stool legs (N. Gil)

Conclusions

Previous, several-year effects of the science of industrial technologies at the Faculty of Design are very positive, and the use of 3D printing makes them more attractive. 3D printing is also used in other studios, including in "Laboratory of Fundamentals of Design III" [9], run by J. Surawski and D. Głąb, and in the studios of D. Zieliński and B. Mejor. Results of their activities were presented, among others, during the 2nd Scientific Conference "Rapid Prototyping" on September 21–23, 2016 in Pruszków and as part of the scientific seminar during "3D Printing Days" at STOM in Kielce on March 28–29, 2017.

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Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland