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Technology infusion of intellectual 3D printers-based prototyping of products into learning process

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Abstract. The article considers the prospects for the technologies of intellectual design and prototyping applying 3D printers. It presents basic technologies of 3D printing, currently developed and released for construction. The experience of educational activities in the University to train students for the Academic Competitions on three-dimensional modeling and prototyping is described in the present article. Requirements for the prototyping implementation are given, allowing obtaining a positive effect from the technology infusion released for construction. The results of activities to train students for the Academic Competition are stated. It is established that the proposed approaches to the training of students have led to the highest score in the national contest in Novosibirsk when performing tasks for prototyping a stand for a cell phone and manufacturing the product on a 3D printer at the SLS technology, selective laser sintering. The conclusions about the possibilities and prospects of development of this direction in the industry in the entire country are drawn.

1. Introduction

The model of an innovative development of the Russian Federation economy, adopted by the Russian leadership as the only possible one to reduce the technological gap with Western countries, involves the introduction of new approaches in the educational process so as to train personnel of higher qualification. Modern trends in industries, related to the quality of products facing competitive market, and the increase in the rate of implementation of the stages of the technological chain "project–sample–product", indicate the need for maximum automation of design processes and manufacture. One way to significantly increase productivity is the infusion of intellectual technologies of three-dimensional modeling and further prototyping products using 3D printing technology.

Prototyping is a quick "draft-quality" implementation of basic functionality to analyze the product operation in general. After the prototyping phase, it is obligatory to proceed with the steps of the product structure revision, optimization of the shape and physical-mechanical characteristics, development, implementation, and testing of the final product. The stage of prototyping, according to many experts, is the most difficult and responsible when developing products. At the stage of prototyping, a working system is created with little effort where one can see a detailed picture of the object organization to reflect its full functionality. As the technologies of three dimensional modeling and manufacture of prototypes got their mass-market in the engineering industry, instrument making and many other areas, it is necessary to provide conditions to qualify specialists in this sphere according to the most modern and effective educational programs [1-3]. This will allow graduate engineers to take a leading position in knowledge-intensive market where niches are still not occupied.

However, it should be noted that competition is rapidly increasing.

Companies, engaged in the production of finished products, are concerned about prototyping and 3D design; for them this is the real way to reduce the risks, and improve the quality of the product. To obtain a positive result from the prototyping implementation, it should satisfy the following requirements:

1. It should automate standard solutions and routine operations, freeing up time to design, develop ideas and implement innovations.
2. It should allow creating interactive, detail prototypes accessible to all participants of the project with the ability to make quick changes.
3. It should ensure the growth of production efficiency and cost reduction in the production of finished products.
4. It should help innovative companies win the battle for the championship entering the market.

Experience to apply various software systems and 3D printers has shown that with the use of 3D prototyping it is possible to test future products for compliance with geometric shapes, sizes, functionality and colors (and even strength properties [4, 5]) prior to full production. Multi-stage optimization of models allows performing product development based on ergonomics and high functionality of objects and mechanisms. The use of 3D printing can accelerate the design process of a new product. Prototyping is used in experimental, single and small batch production. Chinese colleagues have already suggested equipment for industrial 3D printing of skeletons of low-rise buildings out of special plastic, that is filled in the future with different eco-friendly fillers. There is no doubt that speed enhancing and accuracy of printing, the extension of the equipment range will help introduce the technology in a large-scale batch production. However, it certainly requires a broad scientific research for technology development.

2. Methods

Let us consider the generally accepted (both in production and training) stages of product modeling in the software environment of AutoCAD or Compass 3D.

1. Laser stereolithography – layer-by-layer buildup of three-dimensional objects from liquid photopolymer resin that hardens under the action of the laser beam.
2. Selective laser sintering – a high power laser is used to sinter small particles of plastic, ceramic, glass, flour, or metal into a three-dimensional structure.
3. Electron beam melting – additive manufacturing method that is similar to selective laser sintering (SLS), but applying the beam of high energy electrons instead of laser.
4. Fused deposition modeling [6] – 3D printing technology, the object is constructed due to molten plastic.
5. Method of laminating – layer-by-layer formation of the object by interplay adhesion of material cut with a knife or laser.
6. Poly Jet [7] – 3D printers release a jet of liquid photopolymer, which forms layers on the build tray that are instantly fixed by ultraviolet radiation.
7. Layered distribution of the adhesive substance on the gypsum powder – powder production method similar to SLS, but instead of sintering or melting of powder, it utilizes adhesive substance (glue), which is added to the powder.
8. Drop on demand jet – construction of highly accurate models with a completely smooth surface due to the mechanically moving head.
9. 3D printing [8] with paper sheets sizing is an emerging technology that allows printing items from ordinary A4 paper. The incisor of carbide steel cuts each layer of the future model from a sheet of paper. Then the layers are glued with ordinary office water-based glue.
10. Contour crafting – this construction technology, the device for printing similar to a gantry crane [9]. Instead of a multi-ton hook, the device has a spraying concrete mix head with integrated pneumatic formers surfaces. Instantly solidifying concrete is applied layer by layer on the base of the house.

As scientific progress continues to move forward, this list of 3D printing technologies is rapidly updated.

Considering the experience and achievements of the authors of this paper, one should mention that the authors have assembled a team of talented students and conducted intensive training of prototyping skills [10]. Since the basic knowledge of 3D modeling (using software packages AutoCAD, Compass), as well as descriptive geometry and engineering drawing were obtained by students in Tyumen state oil and gas university, it was decided to enhance training to acquire new special skills.

At the beginning of April 2015, the Novosibirsk state technical University held the all-Russian student competition with international participation on the basis of Department of engineering graphics. PROTOTYPSTER company actively participated in the Academic Competition, the company offered 3D printing online service. 14 teams participated, including one team from our University consisting of 3 people. In the category "Prototyping" the contestants create a prototype for the proposed task, and perform 3D model in compliance with the requirements of 3D printing. After reviewing the results, the best three works were executed on a 3D printer in the Academic town of Novosibirsk in the center of a prototyping company PROTOTYPSTER and later given to the winners.

3. Results and Discussion

In the course of preparation to the Academic Competition, various products were executed having a complex geometry, the details of which have different kinematic pairs with the rotational and translational motions. The following objects were constructed: a bicycle and a tricycle, a scooter, and a tank (Figures 1-3). Items such as wheels, a steering control wheel, pedal-wheel drive bike, tank tracks, etc. were elaborated.

One of the important results of academic competitions is recommendations of the expert panel, consisting of representatives of different universities and administration of Tyumen and the Tyumen region, to increase the number of directions in computer programs on Computer Graphics in order to attract students of not only engineering specialties, but also design students. According to the task received at the Academic Competition, it was necessary to design and execute the 3D model prototype of a universal stand for a cell phone. The stand should be adjustable for different phone sizes and have two angular positions.

Figure 1. 3D- scooter model.

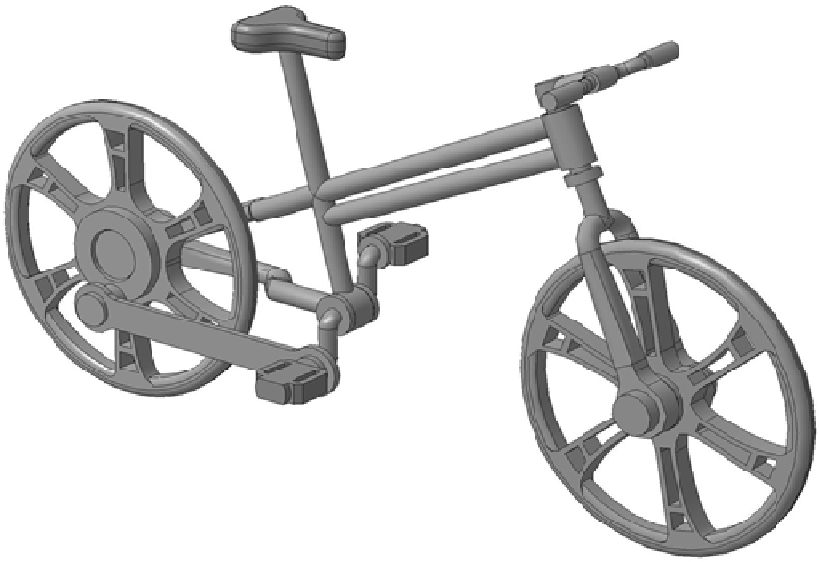

Figure 2. 3D-bicycle model.

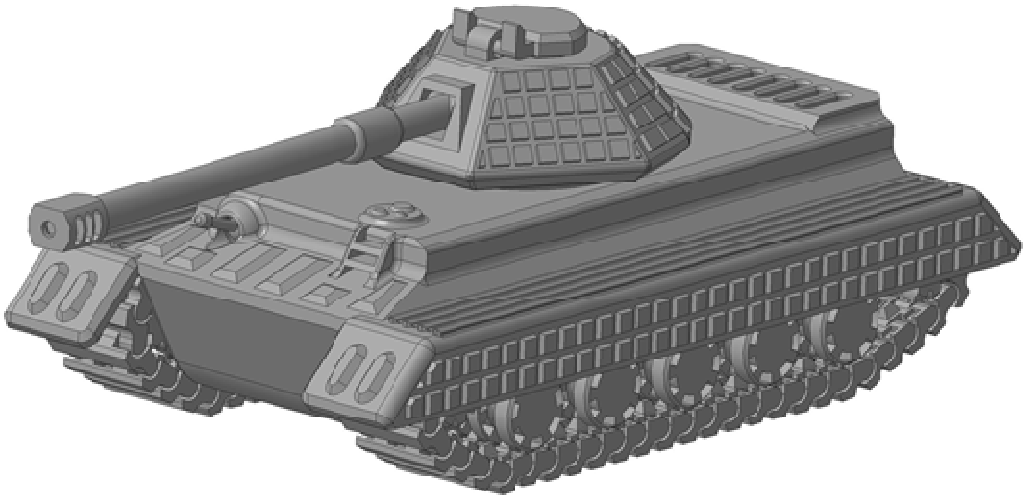

Figure 3. 3D-tank model.

The design of the stand should have symbols of Novosibirsk. Specified dimensions of the model should be 150 mm, the minimum size of a model element should be not less than 0.8 mm, the minimum clearance between the mating parts and moving elements – less than 0.5 mm. The amount of the material used should not exceed 120 cm^3. The performance evaluation was based on:

- compliance with the instructions and the prototype;
- modeling and in-depth development of the elements;
- design of the product.

Since the task was given for the first time in the Academic Competition, it raised a lot of technical issues. But the team of TSOGU competed in the “Modeling of Assembly units” and completed the task at the highest level. The model of the phone stand, developed in the software package Solid Edge, that is shown in Figure 4, received the highest scores of the jury. Years of experience and motivation the get the highest result have allowed us to take the first place in the Competition.

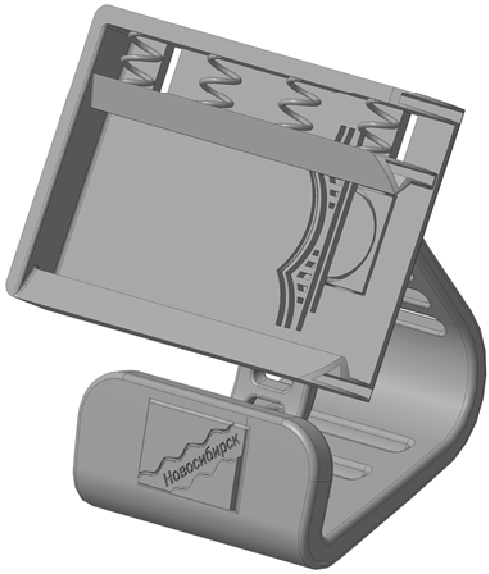

Figure 4. 3D-cell phone stand model.

In accordance with the terms of the contest, the authors were given an opportunity to print the developed model of a phone stand on a 3D printer of PROTOTYPSTER company that is implementing SLS technology – selective laser sintering (Figure 5).

Figure 5. A photo of a 3D printer-designed (SLS technology) cell-phone stand, developed in program SolidEdge.

4. Conclusion

Obtained experience in the field of 3D modeling and prototyping allows us to conclude that this trend is very perspective for further development and requires maximum inclusion of scientific organizations. It is established that the highest rate of development of 3D technologies, involvement in

the actual production obliges us to take part in the "race". There is no need to prove that prototyping based on 3D computer models is a critical technology, an integral part of future military and civil industries.

Therefore, the key challenge for the coming years is to reduce the technological gap in this area comparing to Western countries and start development of the branch based on the existing technologies.

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