REVIEW PROTOTYPING TECHNOLOGIES AT COMPLEX DESIGN

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While working on a new project, especially at the stage of designing the complex, difficult to detect a variety of errors and shortcomings, using only the display screen. Having a real physical model of the future product can detect and eliminate various errors, correct way to continue the design process. A prototype of the product can be used as a conceptual model for visualization and analysis of the structure; It allows designers to perform revision and spend some functional tests; Master can serve – as a model for the manufacture of tooling. The prototype may be used for marketing purposes or in determining the manufacturing cost.

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Test models reduce the costs of design and pre-production due to possible errors in the early stages. Also, physical models designed products enhance communication and mutual understanding between designers and customers, reducing the time to market the product.

The traditional way of producing physical models of future products – making them easily from processed materials by hand or on conventional machine tools. Spent on manufacturing model from several weeks to several months, which results in increased costs for new product development and delays the timing of issuance of new products.

Rapid Prototyping

Rapid Prototyping (Rapid Prototyping – RP) – is a new technology, is actively developing in the design and production industry. It provides the opportunity to receive physical parts and models without instrumental of their production, by converting data coming from the CAD-systems, and receive drawings and designs in 3D-representation, just by pressing the button. Upon completion of the work on CAD-workstation at the idea or project, you can give the command "Print", and within a few hours or days, depending on the size, get a physical model of the product.

Compared with other methods (making patterns from foam, wood, wax by hand or on CNC machines) that existed until the mid 80s, the emergence of rapid prototyping systems has been a revolution in technology. Instead of waiting for the physical model over several weeks, designers can receive them within a few days or hours.

Currently on the market there are different systems RP-producing patterns on various technologies and various materials. However, all the systems for rapid prototyping, available today, are working on a similar, layer by layer to the principle of building a physical model, which is as follows:

- reading the three-dimensional geometry of the 3D CAD-systems in STL format (usually solid-state model, or a model with a closed surface contours). All solid modeling CAD-systems can produce STL files;
- partitioning a three-dimensional model cross-sections (layers) using a special program that comes with the equipment, or used as a supplement;
- building sections parts layer by layer from the bottom upwards, until until a physical prototype model.

The layers are arranged from bottom up, one over the other, physically linked together. Building a prototype continues as long as data is received on sections CAD-model. RP-operation of some systems based on photopolymerizable – chemical process in which a liquid resin (polymer) is converted into a solid polymer by exposure to ultraviolet radiation or it visible spectrum radiation.

Other RP-systems operate using thermal processes for the construction of physical models. This technology, in which the thermoplastic material is pressed out of the injection heads, forming layers, the sequence which constitutes the physical body; technology sintering powder materials under the influence of thermal processes; "Bonding" sheet materials.

Variety rapid prototyping processes corresponds to the number of manufacturers. Consider the basic technology of quick product prototypes.

1. Stereolithography

Stereolithography is the first and most common method of prototyping, largely due to a sufficiently low value of the prototype. The principle of the method consists in stratified

cured liquid photopolymer laser beam scanning system guided. The elevator is in the container with the liquid photopolymer composition, and then curing the next layer is shifted down in steps of 0,025–0,3 mm. It uses solid enough, but the delicate translucent material, which is subject to warping under the influence of atmospheric moisture. The material is easily processed, glued and painted. Quality surfaces without finishing good.

2. Mask stereolithography

Faster version of this technology was developed by Cubital Inc. It is called "stereolithography Mask" (Solid Ground Curing or SGC). The working material used is the same photopolymer directly illuminates only its entire surface with a UV lamp through a photomask. Photomask for each layer is printed on the glass. It uses the technology resembles the laser printing. It is obvious that this method gives a significant performance gain by simultaneously blowing out the entire polymer layer instead of pointwise scanning.

3. Laser sintering of powder materials

Technology SLS (Selective Laser Sintering – laser sintering of powder materials).

The SLS technology as a working material used powdered plastic, metal or ceramic, similar properties to structural grades. At the surface a thin layer of powder which is then sintered by a laser beam, forming a solid mass that corresponds to the cross section and a 3D-model defining part geometry. SLS is the only technology that can be used for the manufacture of metal parts and shaping plastic and metal casting. Prototypes of plastics have good mechanical properties can be used to create full-featured products.

4. Layered imposition of-the Molten polymer filaments

FDM technology (Fused Deposition Modeling – layering imposition of molten polymer filament).

Yarn used in ABS, polycarbonate or wax. The properties of the plastics are very close to structural grades. Thermoplastic modeling material is squeezed out through the head at a controlled temperature, heating it to a semi-liquid state. The head gets very thin layers of material on a fixed base with the highest accuracy. Subsequent layers lie on previous, harden and connected to each other. The technology is used for single samples of products in terms of functionality close to the serial, as well as for the production of cast models for metal casting.

5. The technology jet modeling

Different varieties of this patented technology called: MJM (Multi-Jet Modeling) – 3D Systems; PolyJet (photopolymer jetting) – Objet Geometries; DODJet (Drop-On-Demand-Jet) – Solidscape. All technologies have their own characteristics, but operate on the same principle. The head, comprising two nozzles 96 and causes the model to the plane supporting material layer. After application of the layer, it may be carried out photopolymerization and mechanical alignment. As the support material is generally used wax, and as a model – a wide variety of materials that are very close to the properties of engineering thermoplastics. This method allows to obtain a transparent and colored prototypes with different mechanical properties – of soft, rubbery to hard, similar plastics.

6. Powder bonding technology

Used starch-cellulose powder and liquid water-based adhesive, which comes from the ink jet head and binds the powder particles forming the circuit pattern. After constructing the excess powder is removed. To increase the strength of the model, the available voids may be filled with liquid wax. Such technologies allow not only to create 3D-objects of arbitrary shape, but also to paint them.

7. Bonding of the waterline cross sections, laser cut from sheet material

Technology LOM (Laminated Object Manufacturing – laminating sheet materials). prototype Layers are created by laminating a paper sheet. Circuit laser cut layers and the surface, which must then be removed, cut into small squares laser. After removing the parts, finely chopped excess material can be easily removed. The structure of the prototype is similar to wood, afraid of water.

What a fantastic opportunity opens up rapid prototyping. Touch it, created a computer model of a few hours. Besides, we get an exact copy of our computer 3D model. Moreover and in any scale.

For if we do not come up on the computer, you can get it in a few hours.

What is the scope for creativity is open to sculptors, 3d modelers, advertisers, and many business people who can see this technology is a huge business potential.

The main advantages of rapid prototyping technology is:

- reduction of the duration of the technical preparation of production of new products in 2–4 times;

● reduction of production costs, especially in small batch or unit production by –3 times;

● a significant increase in production flexibility;

● improving the competitiveness of production;

● through the use of computer technology, integration with CAD systems.

This technology is a real boon for companies that are engaged in artistic casting of metals or plastics. Sculpture studio, advertising agencies, engineers, students of art schools. How the technology will expand the capabilities in areas such as:

Casting of liquid marble, gypsum, plastics into flexible molds. Manufacture of interior and park sculptures, bas-reliefs, columns, fireplaces, souvenir and premium products.

But the trouble is that the equipment for rapid prototyping costs a lot of money. And many here are not relative concept. The price range of 20 thousand. up to a million green.

It is clear that spending so much money can afford not everyone. In prototyping needs have almost everyone who is engaged in business or industry.

It is necessary to mention one more pitfalls.

Cost of production of prototypes ranges from 1 to $ 5 per 1 cu. cm. In order to better orient imagine any object, the size of 10×10×10 cm. And a prototype will be released in price from 500 to 5000 $, depending on the equipment used for the manufacture of the prototype. Not surprisingly, the rapid prototyping services are used by very few people.

The multi-jet modeling with help of 3D-printers

Classic RP-system of the first generations have a number of drawbacks. This is primarily a very high cost (up to a million dollars depending on configuration), the complexity of the operation, special requirements for premises and operator skill. If we draw an analogy with the development of computer technology as a whole, these systems are similar to the first computer – a huge, highly complex and expensive work which could only highly skilled programmers. It is not surprising that the mass distribution of rapid prototyping technology received only with the appearance on the market a new class of devices – three-dimensional (3D) printers. This class of systems is deprived of many of the shortcomings of their predecessors – 3D printers are designed to work in a typical office environment, easy to use, automatically prepare a file to build and do not require post-processing complex models after printing. The increasing popularity of rapid prototyping technology is linked with the appearance on the market in the past five years, 3D printers. 3D printers have played a role in the spread of rapid prototyping technologies similar to the role of personal computers in the spread of digital technology in our lives. According to the given data we can conclude that on a global scale rapid prototyping technology is already widely recognized. You can talk about the growth of the popularity of these technologies in Russia, but so far our country lags behind the industrialized countries of Western Europe, USA and Japan.

All of the above systems have a working principle, laser-like three-dimensional printing, but there is also a “blast” three-dimensional printing. The simplest of these technologies – modeling of diffusion-coated (Fused Deposition Modeling or FDM).

1. Simulation of diffusion-coated

Based on this technology were developed in 1988 by Scott Crump, a manufacturer of equipment for the FDM was the company Stratasys.

The main advantage of such systems is controlled by two coordinate heating head. The idea is very simple – the liquid thermoplastic material is extruded from the head of the printer, and then put a thin layer. Material is fed from the reel in a wire diameter of 1,25 mm. The wire head is heated and melted at a temperature above the curing at 10C. The liquid substance hardens very quickly. Thanks to two-coordinate the movement of the head material is placed in a uniform layer. The width of the diffusion layer ranges from 0,22 to 2,5 mm depending on the material deposition rate, nozzle size and head positioning accuracy. After application of a single layer platform is lowered by the amount of 0,03 to 0,7 mm. It is important to control the process by a computer, such as when milling. FDM technology allows with sufficient accuracy (minimum thickness – 0,12 mm) to produce fully ready to use parts quite large (up to 600×600×500 mm).

2. Multi-phase jet solidification

Conventional 3D-printers do not provide high accuracy and strength of the finished prototype, but the mechanical properties of such models is sufficient to render the developed product.

Stuttgart and Bremen institutes have developed a technology multiphase jet solidification. In this technology, a mixture of fibers and

powder is deposited on the surface with a nozzle managed. The mixture is heated to a printer 70–100 S compartment temperature depending on the properties of the working material. As a material used powders used for injection molding. At this temperature, the mixture becomes uniform in density and is capable of passing through the nozzle. It is important to provide a low surface tension material for forming without shrinkage. Subsequently, the prototypes are being finalized with the help of technology, reminiscent of metal injection molding. Sintering material and obtain a new molecular rugged grid.

Currently, this technology is used in of 3D printers Actua 2100 the company 3D Systems. Material prepared the prototype looks like a solid wax. The thickness of the overlay layer is 0,0015 inch (0,04 mm) with a resolution of 300 dpi. The installation cost of about 65 thousand. dollars.

There is another technology of "inkjet" already using powdered materials. It was developed at the Massachusetts Institute of Technology, as the first and main manufacturer of the equipment was the company Z Corporation. Its 3D printers are relatively inexpensive and work much faster than the above devices. The technological process is as follows: a special ink jet head is sprayed onto the powdered adhesive material. As used conventional gypsum powder or starch. The "spattered" powder glued locations, and generates a model. Printing as in the previous cases, is layered, and excess powder is shaken off in the end. However, there is a significant difference – the printer can use a liquid adhesive with the addition of dyes and pigment print color model. The color printer from Z Corporation fitted with four ink jet heads – basic adhesive colors so that the resulting model can reproduce not only the shape but also in color (i.e., texture) of the virtual prototype. However, the plaster model obtained is not very strong, but once they can be used as molds for casting. Detailing the resulting object – very high.

3. The use of three-dimensional models for rapid prototyping

Currently, there are different trends and approaches to the implementation of rapid prototyping technologies. As used materials can be divided into methods for applying liquid (photopolymers, electrolytes, water), powders (sintering homogeneous or two-component compositions), solid materials (plastics, waxes, metals), the sheet material (laminated paper, plastic), gases. Some of the methods is in the stage of research development part has a commercial application.

Rapid prototyping is a very wide range of applications, however, the main ones include:

- visualization;
- check collection units and mechanisms;
- production of small batches of preparation methods for rapid tooling.

Visualization still stands on one of the first locations in a number of areas due to the use of prototypes product model representation clarity, on the one hand, and the lack of need for hardware – the other.

Often there is a need to conduct market research and demonstration of the product to the customer or at the exhibition before its serial production, in order to assess the potential customer demand and to decide whether to promote this product to the market.

If necessary, make changes in product design material and time costs are minimal in comparison with the need to rework tooling, manufacturing of which takes, as a rule, more than one month.

Another very important factor is the ability to verify the quality of assembly units and mechanisms, assessment of the convenience and reliability of fixing parts. The three-dimensional model created in the CAD-system, does not give a complete idea of how tough the fixation parts in an assembly unit. Prototypes of the same, being the analogue final manufactured products, allows to analyze the characteristics of their design and quickly identify possible shortcomings.

Simulation of mechanisms to assess their functional qualities – is another area of application of rapid prototyping. This applies to both new products and upgraded to a change in one or more parts in the assembly.

Emerging in the recent downward trend in batches of manufactured products, increasing their structural complexity and reduce delivery times cause the rapid spread of technology training equipment (Rapid Tooling), which include vacuum casting in silicone molds; metal-casting mold; metal casting by lost wax, obtained by casting in silicone mold technology, and other methods. These technologies are inextricably linked with the technology of rapid prototyping and are their logical continuation in the chain of design – design – prototype – parts – finished product.

Rapid prototyping is becoming more common and is becoming an integral part of the preparatory process for the production of new products. In industrialized countries, a number of firms in this step is optional and

transition from product design to the development of technology is impossible without the prototype.

Research in the field of rapid prototyping are in full swing. For example, a group of scientists from the University of California is developing a three-dimensional printing technology, which would allow both to create and shape and content of the object. By content is meant here e-filling, i.e., The printer prints a mobile phone plastic housing and also type in the body all the electronics. Even today, there are ways to print plastic semiconductor devices and their connecting wires. It remains only to combine these methods with the technology of 3D printers, and is ready to a revolutionary breakthrough in modern production.

Another example – the development of the University of Missouri, allow using inkjets display unique biological organ harvesting is printed. As an ink used with the specified type of cell clumps. Instead, the paper advocates a special bio-gel, which fixes the position of the cell clusters in space. Printing is done in several layers. The result is a volume of the cell structure which, in principle, any organ can mimic (after sprouting cells gel dissolves, so that is possible to obtain hollow structures). Of course, the full body of the seal is to be transplanted seems too challenging, but the work in this direction is underway.

Rapid prototyping plays an important role in the technical preparation of the new machine tool products. Using the layout tools or separate units in the process of construction engineering and discussion at technical meetings became the norm. This estimated design and layout decisions, simulates the movement of individual units, and so on. D.

According to the principle of work all rapid prototyping system can be divided into two broad classes: the actual RP-systems-and 3D printers.

Currently on the market as a whole, including the Russian market is represented by most of the leading companies – developers, like the classic big RP-systems and of 3D-printers. In spite of the general principle of work – building a three-dimensional model of the two-dimensional planar layers of different systems are markedly different from each other techniques of construction of each layer. And it defines the scope of the equipment. In my opinion, from a practical point of view there are two main parameters that characterize any system for rapid prototyping – a thick layer of construction and materials with which the machine operates. It is the thickness of the layer determines the quality of the construction of the final model, and model material properties determine the applicability of the prototype.

References

1. URL: http://www.comprice.ru/articles/detail.php?ID=41410.

2. URL: http://www.foliplast.ru/tech/6.

3. URL: http://www.vzrt.ru/rp_tec.php.

4. Gavariev R.V., Savin I.A., Savina A.I. To a question of forecasting of firmness of foundry equipment // Modern technics and technologies. – 2015. – № 6.

5. Savin I.A., Kaumov A.F. Mathematical model to predict resource of press form with protective covering // International Journal Of Applied And Fundamental Research. – 2015. – № 2.

6. Rezakov A.P. Application of the 3D press in machine-building production // Actual problems of science in student's researches: collection of works V of the All-Russian scientific and practical conference. AF KNITU-KAI. – Almetyevsk. – 2015 p.