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Use of PolyJet technology in manufacture of new product

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Analysis and modelling

ABSTRACT

Purpose: The paper presents an approach to rapid manufacture of new product by PolyJet technology.
Design/methodology/approach: Resolution, accuracy, speed and materials are basic factors of rapid prototyping, which mutually exclude themselves on most devices. PolyJet procedure is a technology, which successfully simultaneously solves some of these problems.
Findings: The manufacture of product by PolyJet technology has proved to be a good approach. All advantages offered by that technology have been applied and all requirements of the new product have been satisfied. By testing on the first prototype the adequacy of the product shape has been established and the prototype has been suitably adapted. As the data on the product shape are in the computerized form, the changes on the product are made simply.
Research limitations/implications: Regrettably, the models from rapid prototyping do not allow major loadings and exposure to exacting conditions, since the materials used are in the development stage and are gradually gaining strength and toughness. Our product is not exposed to major mechanical loadings; therefore the process as such is adequate.
Practical implications: By this technology very sophisticated and complicated products can be made. It assures the manufacture of nested structures and mechanisms already assembled. The price is influenced only by the product size. The shape complexity is not important at all.
Originality/value: : In case of a small quantity of products, not exposed to major mechanical loadings, the models made by PolyJet process are usable also as final products.
Keywords: Rapid prototyping; PolyJet technology; 3D CAD model; New product

1. Introduction

In the 21st century, the market requirements changed very much. One of the principal reasons for that is the market globalization and saturation. Thus, now the products must be adapted to buyers. The products must be offered in several versions and adapted to the target population. Now, products different for women and men, or children and adult, for business use or entertainment are appearing. In addition, the service life of products is shorter and shorter. On the other hand, the products are geometrically as well as functionally more and more complex, whereas the manufacturing times must be as short as possible [1].

With the appearance of highly capable computers at favourable price, the development environment has completely changed. 3D CAD modelling has become a foundation [2]. Although a lot can be done with the model in virtual environment, it is still always appropriate to have physical model for the development. That was reached fastest possible by rapid prototyping. Today, the rapid prototyping is no longer used only as visualization means. The model made by rapid prototyping can be used also in different tests. It can also be used as the master for the manufacture of tool models. In some cases, the model from rapid prototyping can be used as final product [3]. Such case was discussed in our paper. The paper describes how by rapid prototyping the product meeting all our functional requirements can be made within a very short time. A very small number of mutually differing products are in question. Therefore conventional method of manufacture of such product has proved to be considerably cheaper and taking a considerably longer time than the rapid prototyping method. Let us mention in addition that our product, i.e., the digital altimeter housing, only protects the PCB (printed circuit board) and the sensors against environment, it is of proper design and serves to fix all necessary components into a whole without being exposed to major loadings. Regrettably, the models from rapid prototyping do not allow major loadings and exposure to demanding circumstances, since the materials used for rapid prototyping are only being developed and are gaining higher strength and toughness [4].

2. Rapid prototyping

Rapid prototyping is a process introduced some years ago as an important aid for shortening the time from the idea to marketing of the product, with simultaneous reduction of the costs of development and improvement of quality of final products [5]. The basic idea of the product is the fastest possible manufacture of the real prototype on the basis of the CAD model, usually without interference of machining processes. The resulting prototypes have a high geometrical accuracy, whereas the mechanical properties of materials, of which they are made, usually do not satisfy the requirements of the final product. Therefore, such prototypes are intended particularly for [6]:

- presentations of final products
- visualization of design concepts
- shape analyses and conformity analyses
- making tool die impressions and casting moulds[7]
- simple functional tests

Today, many rapid prototyping technologies are available, using a great variety of processes and adequate materials. The used materials range from paper and various polymers to metallic powders. The number of different technologies increases from day to day; some of the most widespread ones are pointed out herebelow. One of the first technologies to appear was stereolithography (SLA) developed by 3D Systems and today most wide spread [8]. Another popular process is the LOM (Laminated object manufacturing) developed by the company Helisys Inc. Further very popular processes are the FDM (Fused Deposition Modeling) owned by the company Stratasys and SLS (Selective Laser Sintering) developed by DTM (today owned by 3D Systems) [9]. There are still many other processes, however, currently the leading rapid prototyping technologies are the Stereo lithography (SLA), the Selective Laser Sintering (SLS) and the so-called PolyJet process, the result of the Israeli company Objet Geometries [10].

Resolution, accuracy, speed and materials are the basic factors of rapid prototyping, which mutually exclude themselves in most devices. Usually, the systems with high accuracy are very slow or they have a very narrow choice of materials; on the other hand, rapid procedures give very rough results. The PolyJet procedure is a technology successfully solving some at these problems simultaneously [11].

3. Rapid prototyping with PolyJet process

The PolyJet is one of the most recent rapid prototyping processes appearing on the market. This process is the result of the relatively young Israeli company Objet Geometries. As far as its functionality is concerned the PolyJet process can be grouped into the processes of three dimensional printing. It is a kind of hybrid between selective hardening and drop deposition.

The most important component is the printing head as used on large, industrial printers for printing advertising bills. Instead of ink the printing head applies the liquid compound of reactive monomers and oligomers polymerizing due to ultraviolet light. The device prints two-dimensional bit maps (individual layers); the motion of maps into the third direction is effected by the tray.

The Laboratory for intelligent manufacturing systems is equipped with the most up-to-date printer, EDEN 330 on which the prototypes of the test deices were made.

The thickness of layer on this device is 16μm so that this process can be ranked among the most accurate processes and the device can be considered as on of the fastest devices for rapid prototyping; in addition, the price is favourable [12]. As was said, the process of application of the individual layers is completely identical to the process offered by the so-called inkjet printers, except that here the process is much simpler since practically only two-colour bit maps are printed. Each individual layer represents the cross-section of the model with added supporting material. Thus, the cross-section is a bit map where the section plane of the model and supports is located. In fact, the printer applies the model material to the plane of the model ink and the supporting material to the plane of the supporting ink. The application of the material to the tray is effected by the piezo-electric printing head injecting onto the metallic tray which, after injection of each layer, moves downwards for one layer thickness; then the process is repeated with the next layer. On application, each layer applied polymerizes due to ultra-violet light coming from two UV light bulbs fixed to either end of the printing head [13].

Thus, the product is ready for immediate use and does not require any subsequent treatment, except removal of the supporting material. The latter can be removed by means of a high pressure pump and water. The small layer thickness (16 μm) ensures the manufacture of models with very smooth surface and small details. Therefore, subsequent treatment is not necessary, while the finished products can be sand blasted, polished, ground with emery, painted or treated otherwise. The products are usable as master patterns for making silicone moulds [14], for vacuum casting in silicone moulds and, if special combustion chambers are used, also for casting processes with lost core.

3.1. Materials

At present, the company Objet Geometries offers two kinds of materials for the PolyJet process. One of them is the FullCure 510 which is of translucent yellow colour and can be used on the device QuadraTempo. On the same device it is possible to use also the FullCure 555 which is a material of the same type, except that it is grey and non-transparent. A newer material is the

FullCure 700 which can be used only on the device EDEN 330. This is a transparent material having slightly better mechanical properties than the above mentioned material. In particular the toughness and the tensile strength are higher (Table 1).

Table 1.
Mechanical properties of material FullCure 700

Property	Standard	Value
Tensile Strength	D-638	42.3 MPa
Elongation at Break	D-638	15-25 %
Modulus of Elasticity	D-638	2000 MPa
Flexural Strength	D790	70.6 MPa
Flexural Modulus	D790	1978 MPa
Impact Strength (Notched Izod)	D256	25-38 J/m
Heat Distortion Temperature	D648	43°C at 1820 Kpa 46°C at 455 KPa
Compression Strength	D695	69.4 MPa

4. Manufacture of altimeter by PolyJet process

4.1. Basics

The altimeter is a device indicating how fast the flying device soars or descends. In our case, digital altimeter is in question into which additional functions have been incorporated and which we called Alti-variometer. Basically, it measures the value of air pressure. From that value, it is possible to calculate the height by considering some parameters influencing physical properties of air. With altitude, the pressure drops almost linearly, whereas up to 3000 m altitude it drops even completely linearly.

By measuring the air pressure, the device is capable to calculate the current altitude as much as up to 5000 m. In addition, if pressure is measured in short enough time intervals, it is possible to calculate the speed of altitude changing (variometer). For good enough responsiveness of the device, those intervals must be rather short; it means that the measuring system must be quick. The calculated values are indicated on the LCD display, which is of segmental type because of limited available power (battery powered) and consumes little power. In addition to the abovementioned measurements, also the temperature, which is frequently an important data, is measured. In addition, a digital compass functioning on the principle of measuring the earth's magnetic field is incorporated. A foil keyboard sets parameters with five keys. Data storing into memory is possible with the Alti-variometer. The data (altitude) are stored each 10 seconds; this supposes about 20 hours of data. If the time of storing is longer, storing is stopped. The incorporated stopwatch can be activated manually or automatically in case of fast change of altitude-ž

The Alti-variometer indicates: speed of soaring and descending (m/s), air pressure (mBar), absolute altitude (m), relative altitude (in relation to a certain point; m), air temperature (ambient temperature; °C), angle to north (0° - 360°), time (stop watch; s, min). Through connector, the device can be connected to computer into which the data can be copied by special program drawing the flight altitude histogram.

4.2. Request

The design concept of the housing must meet the functional and construction requirements. When making the housing of this instrument we paid attention to placing of the air pressure sensor. To ensure accuracy of measurements, it must not be affected by the direct air shock. At this point the housing must be closed as tightly as possible, therefore the place of installation of the sensor must be accommodated in a special chamber so that it will not be affected by air strikes which would have a disturbing influence on the measurement. In the same time, it must allow equalization of air pressure with the environment. Further, the device contains also the temperature sensor that was installed into the housing so that airflow is as great as possible in order to reach the shortest possible response time of the sensor. To prevent this from affecting the air pressure sensor, the ingress of air into the housing itself had to be obviated. The segmental LCD display with keyboard was so installed that it is exposed as little as possible to possible mechanical damages in case of the device falling into the ground. Special attention was devoted to installation of the digital compass, which is very sensitive to the vicinity of metallic parts. Its position in the housing is determined on the basis of measurements. The sensor allows the metal objects to be 3 cm close to it. Position of the piezoelectric loudspeaker, often hindering the sensor operation, is also very delicate. The place of its installation must be distant form all sensors as much as possible. It emits the sound signals through a special opening on the housing.

4.3. Manufacture

The structure was made by program package SolidWorks2006 so that subsequent correction and adaptations were possible. Such product requires precise placing of the individual components, but it is proper also to take the costs, exactingness and the period of manufacture into account. A good compromise was offered by the technology of 3D printing as one of rapid prototyping technologies according to which the product was made. 3D models in stereo lithographic format (STL file) were used as the basis for printing. During the export from SolidWorks 2006 into the STL file the proper size of triangles must be set so that the made surface is flawless. In the graphic environment attention is paid to optimal setting of the model on the working tray.

Then the STL file is imported into the specific purpose control program determining the delivery time and the consumption of the bonding agent for full parts and the supporting material for hollow model parts on the basis of the model volume and position. The mass and the time frame serve for the financial estimate. Automatic determination of supports and layering of the model in vertical direction (Z axis) follow. Afterwards, individual layers (bit maps) are sent to the printer which takes them over and deposits them successively into the tray.

When the product has been printed by the machine, the product is ready for immediate use and does not require any subsequent treatment, except removal of supporting material. The supporting material looks like "marmalade", although it is not sweet and sticky … It can be removed by means of a high pressure pump and water. The supporting material is simply "washed away" by water jet under the pressure of about 40 bar. The water jet pressure mainly depends on the model to be cleaned. Models with thin walls and very small details were cleaned with lower pressure, while more robust models were cleaned with higher pressure so that the time of cleaning was shortened [15].

The first prototype enabled us to test correctness of the product design concept. Corrections of the design concept proved to be necessary, because of mutual disturbing of sensors and changes to chamber of the air pressure sensor. Then the 3D CAD model adjusted to new requirements was recorded and tested. The tests showed that the product, i.e. the altimeter housing, made by PolyJet process met all functional and structural requirements and was suitable for use.

5. Conclusions

The manufacture of the alti-variometer housing by the PolyJet rapid prototyping process has proved to be a good approach since all requirements could be fulfilled. The number of products in question with rather complicated shape is small. Let us point out that only the product size influences the price of rapid manufacture of the prototype. The shape complication is completely unimportant. Due to great number of requirements on the housing, the technology of rapid prototyping by PolyJet process has enabled us to establish adequacy of the housing by testing and to adapt it properly. As in case of rapid prototyping the data on the product shape have the form of a 3D CAD model, the modifications on the product are simple to execute.

Taking into consideration the experience in rapid manufacture of prototype models, their applicability and the responses of users, we assume that the PolyJet technology for manufacture of prototype models is adequate with respect to shape as well as dimension requirements. The advantages are obvious particularly in case of exacting shapes which would be difficultly manufactured by conventional processes or the price would be too high and the time of manufacture too long. In cases only a few products not exposed to high mechanical loadings are needed, the models made by PolyJet process are undoubtedly a good solution. The applicability of this technology will be still enhanced with a wider choice of materials already announced.

Such product requires precise placing of the individual components

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