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APPLICATION OF RAPID PROTOTYPING TECHNIQUE IN MANUFACTURING A CONTROL SYSTEM

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Abstract: *Rapid prototyping represents a new technique of building sample parts, prototypes, in order to improve manufacturing, to test, to evaluate or, just to check on the market. This paper presents a 3D printing rapid prototyping technology applied to an important component – elastic gear sector – of the control system As result of rapid prototyping, several problems that do have negative influence were detected. Thus, the required corrections were made and a proper device could be obtained.*

Key words: *rapid prototyping, ink-jet printing, Z Printer, elastic gear, control system.*

1. INTRODUCTION

Rapid Manufacturing, RM, represents [1] a broad term including the use of Rapid Prototyping, Rapid Tooling and Layer Manufacturing Technologies in order to shorten the design and production cycle of a product.

When a new product is designed, many times a prototype of it – or of some components, is important to be obtained. This prototype enables the checking and evaluation of expected product's characteristics and, so, changes in design could be done, before the real product be manufactured.

Rapid Prototyping, RP, can be defined [2] as a group of techniques used to quickly fabricate a scale model of a part or assembly, using three-dimensional CAD (computer aided design) data. In other words, Rapid Prototyping is [3] the automatic construction of physical objects, using solid freeform fabrication (SFF – the process that produces three-dimensional shapes from additive formation steps).

There are several Rapid Prototyping techniques, such as [1, 2, 4]:

- Stereolithography, SLA – a layer manufacturing technology, in which the layers are formed by using a laser to cure the surface of photo sensitive polymer resin into the desired shape;
- Selective Laser Sintering, SLS – a layer manufacturing technology in which the layers are formed by using a laser to bond the surface of a bed of powder material in the desired shape;
- Shape Deposition Manufacturing, SDM – a layer manufacturing technology in which the layers are deposited and shaped by CNC, with temporary materials also deposited to support layers with overhanging, undercut and separated features;
- Laminated Object Manufacturing, LOM – a layer manufacturing technology in which a part is fabricated by assembling and bonding layers of material cut to the desired shape;
- Ink Jet (3D) Printing, – a layer manufacturing technology by printing successive layers on top of the previous, to build up a three-dimensional object.

No matter what the Rapid Prototyping technique is, the methodology follows the steps [2, 3]:

- a CAD model is constructed then, converted to STL format (that approximates the shape of a part or assembly using triangular facets);
- the RP machine processes the STL file by creating sliced layers of the model;
- the first layer of the physical model is created then, it is lowered by the thickness of the next layer and, so, the process is repeated until completion of the whole model;
- the model and any supports are removed and the, its' surfaces are cleaned, dried and finished.

Based on the above presented aspects, this paper *presents the Rapid Prototyping technique applied to a completely new designed control system's components.*

2. RAPID PROTOTYPING EXPERIMENTS

The Rapid Prototyping technique used was the Three Dimensional, 3D, Printing, meaning [1, 4] layers of fine powder (plaster, corn starch or resins) are selectively bonding by "printing" a "liquid (binder)" from the inkjet print-head, in the shape of each cross-section, as determined by the CAD file.

The experiments were carried on a ZPrinter 310 Plus [5] – whose picture is presented in Fig. 1.

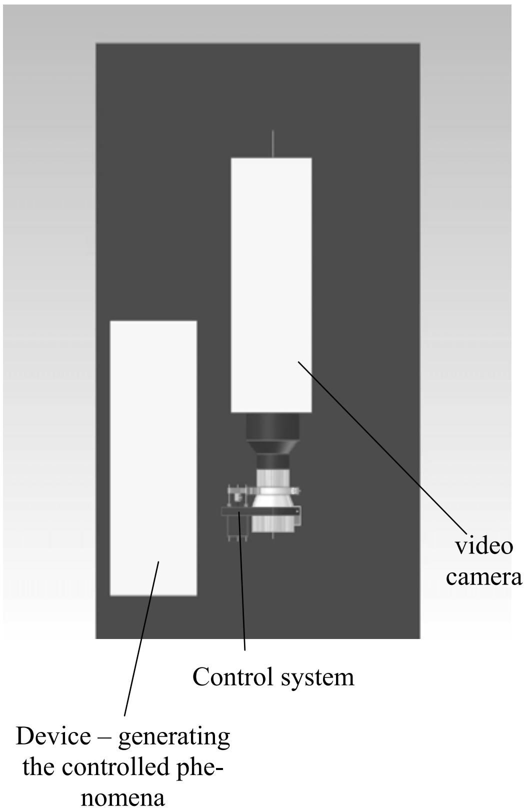
Fig. 1. ZPrinter 310 Plus.

The materials used – for creating the prototypes were:

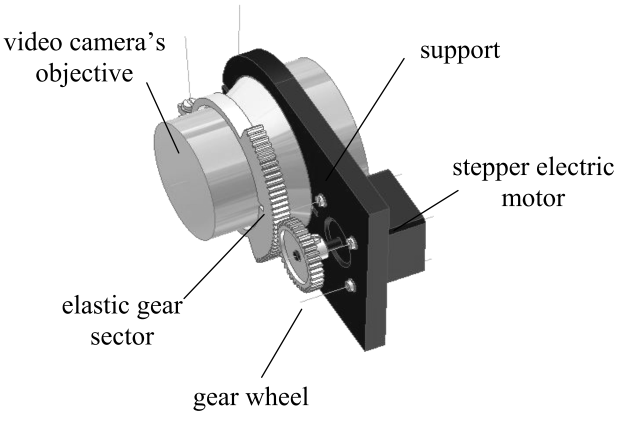
- ZP 131 POWDER (the material to be bond by printing);
- Zb 60 – binder solution and Z-Max – a high strength epoxy (the materials used for making the obtained prototype hard enough – to be handled).

The new designed control system, as well as its' assembly device are shown in Figs. 2a and 2b.

It is worth to be mentioned that this system should be used for remote automatic rotation of an ultra rapid video camera's objective. The whole device could be successfully used for optical measurements, such as quality control, combustion analysis, etc.

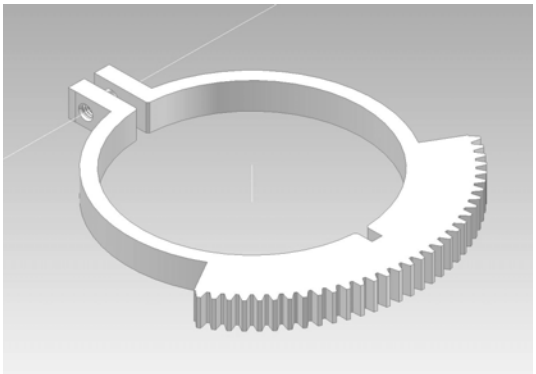


a. equipment including the control system

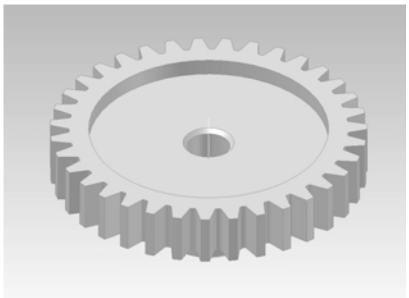


b. control system's components

Fig. 2. The control system and its' assembly device.



a. elastic gear sector



b. gear wheel

Fig. 3. Drawing of the parts to be prototyped.

The Rapid Prototyping technique was used for obtaining the models of elastic gear sector and gear wheel.

It was those elements chosen for prototyping because it is expensive to manufacture them, and if, after that, one discovers mistakes and errors in the gearing, then it is not good, at all. Their CAD drawings are presented in Fig. 3 (a and b).

The software being used is ZPrint one – specific to ZPrinter machine. It enables preliminary calculi –based on the models' CAD drawing – of important parameters, such as (see Fig. 4):

- models' height (the highest point to be "duild"): 15 mm;
- layer thickness (to be build: 0.1016 mm;
- number of layers: 147;
- estimated build time: 25 minutes;
- estimated binder usage: 10,6 ml;
- total volume of models: 19.47 cm3
- total surface area: 131.51 cm^2.

All the above mentioned parameters are very useful for economical aspects – that is it can be precisely determined the costs of prototype's manufacturing.

The software, also, provides information on what is going on while the rapid prototyping process (Fig. 5), meaning:

- current and target temperature into the enclosure;
- if the required process parameters are within limits;
- how long it took for the process to be over;
- what quantity of the binder was, really, used;
- the time until the prototype can be removed.

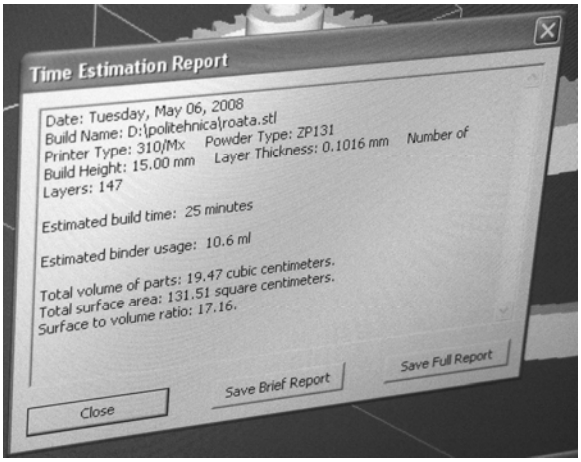


Fig. 4. Estimated parameters of RP process.

Fig. 5. Real parameters of RP process.

Once the input parameters settled, the Rapid Prototyping process of the two considered elements started.

Images taken point out the important aspects of this process – developing into the ZPrinter machine – meaning first stage of the prototyping. So, the following are relevant:

- starting moment of prototype building (Fig. 6);
- intermediate moment of prototype building (Fig. 7 a, b);
- end of prototype building and models' extraction (Figs. 8a and 8b).

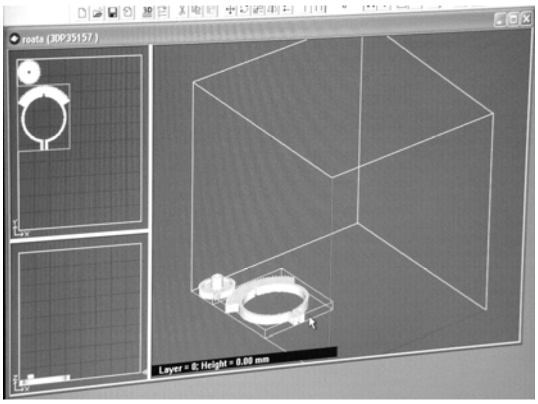
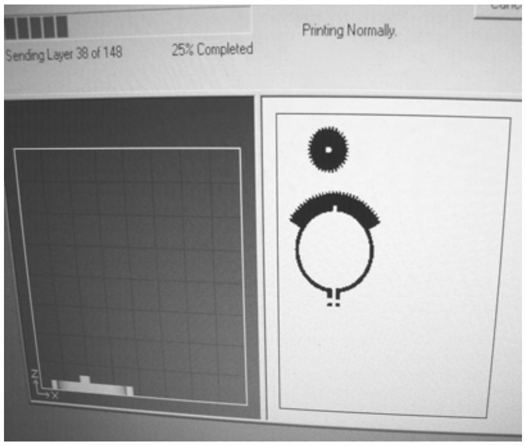
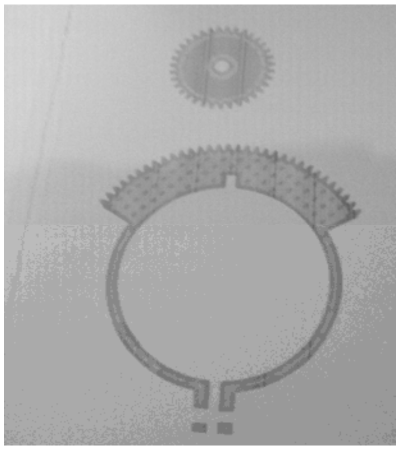


Fig. 6. Starting moment of RP process.

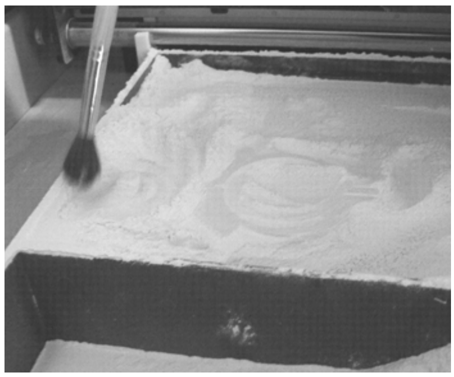


a. computer screen image – while RP process



b. enclosure image – while RP process

Fig. 7. Intermediate moment of RP process.



a.

b.

Fig. 8. End of RP process – models' extraction.

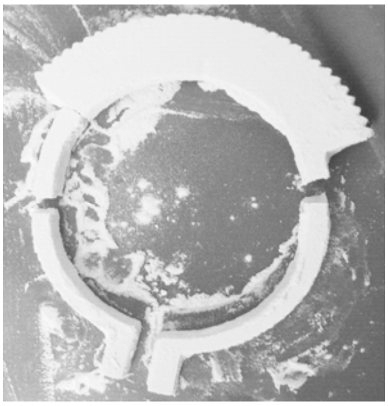


Fig. 9. Torn out model.

Observation: As the first models were prototyped on the ZPrinter machine whose print-head was worn out, the elastic gear sector torn out when extracted – as shown in Fig. 9. So, all the prototyping process had to be carried on again.

3. RESULTS AND DISCUSSION

Once the ink-jet printing process is over, and the models extracted from the ZPrinter machine, it is necessary to submit them to compressed air cleaning – for removing the powder. This operation is carried on into an adjacent equipment – provided with, both, a compressor and a vacuum cleaner.

After that, the models were introduced into an oven – whose temperature was about (70 … 80)°C – so that they could dry and harden (but remain, still fragile).

After taken out of the oven, the prototypes had to be impregnated with a strengthening resin (a mixture of binder solution and high strength epoxy) so that they can become hard parts. This is necessary for enabling the prototypes testing and checking and, even, if necessary, their machining - turning, drilling or milling.

An image taking while impregnating the models is presented in Figs. 10a and 10b).

So, once the prototypes ready it could be checked the way the assembly worked.

One good aspect was that the gearing was okay, meaning that the gear wheel and the elastic gear sector rotated the same angle and there was not too high clearance between their teeth. An image of both parts, while coupling is presented in Figs. 11.

a b

Fig. 10. Resin impregnating of the models.

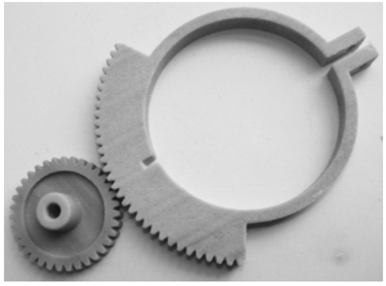


Fig. 11. Rapid prototyped parts – in gearing.

Another aspect that could be noticed, not as good, this time, was that the elastic gear sector did not fit the video camera's objective. That was:

- if the sector was tighten on the objective (so as not to be slippery) then, the last mentioned, did not rotate, any more;
- if the sector was large enough on the objective then, when changing the rotation direction, it was a free rotation (for a few angles) of the sector, without the objective's rotation, so it was not good.

So the required changes in elastic gear sector have been done and the control system could work properly.

4. CONCLUSIONS

Rapid Prototyping has proven to be a successful technique for testing and evaluating parts performances. The ink-jet printing of obtaining prototypes is a fast, versatile and simple one, functional test parts being obtained quickly and inexpensively. The control system's parts chosen for Rapid Prototyping were modeled and thus, their prototypes were able to manufactured. Some good and, also, bad aspects of control system's design could be pointed out and appropriate measures to be taken.

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