Emphasizing the advantage of 3d printing technology in packaging design development and production in local industries

Dr. Rania F. Mohamed*
Dr. Abeer S. Mahmoud**
***&**Assistant professors**
Department of printing, publishing, and packaging
Faculty of Applied Arts - Helwan University

ABSTRACT

Three-dimensional printing technologies are used to build parts of the product or the first model in the form of layers. There are a wide variety of available materials offering transparent, colored, opaque, flexible, rigid, high temperature and high toughness properties.

Digital Materials are composite materials created by simultaneously jetting two different materials. The two are combined in specific concentrations and structures to provide unique mechanical properties and to provide a closer look, touch and function of the desired end-product.

These materials are designed to answer the visual and verification requirements of designers and engineers in every industry.

This research includes an experimental study to produce a package sample using different 3D printing machines. Also an analytical descriptive study of using 3d printing in Egyptian market was carried out.

The study has identified that there is a wide range of 3d printing options (machines & materials) that meet different packaging field needs, and Egyptian packaging market can take benefit from 3d printing technology in various applications.

Keywords:
3d Printing, rapid prototype, packaging

INTRODUCTION

The term Printing is associated with two dimensions products and decoration techniques, whether on paper or fabric or even printed images, in order to associate the printing expression with one of the methods of formation as the workers in graphic design field are not used to it. The three dimensions printing is established by some international companies to achieve rapid and flexible production of parts of the prototype, as well as the final parts of the product which comes directly from the design on the computer assisted design program (AutoCAD) .

Since 2003 there has been large growth in 3D printers. Additionally, the cost of 3D printers has declined, This technology has been used in jewelry, footwear, industrial design, architecture, engineering and construction (AEC), automotive, aerospace, dental and medical industries, education, GIS, civil engineers, etc.

Packaging design is an increasingly important aspect of consumer decision making. It’s not just the plethora of other products competing for attention on the shelves and in advertisement, as environmental issues become a larger part of consumer decision making, the products need to appear to contribute less toward a vast array of problems that packaging creates. Therefore, it is crucial for the product to get itself noticed. Good packaging design is hard to be right and can be costly if poorly done.[2-6-7]

Hence, most of the known Egyptian packaging firms are not familiar with the latest developments in this field and are not aware of the advantage of 3d printing in packaging design, which causes a major problem that requires investigation.

The main Objective of the current study, therefore has been to Encourage industries to take advantages of 3d printing technology and use it in packaging design and production in Egyptian packaging fields.

Background:

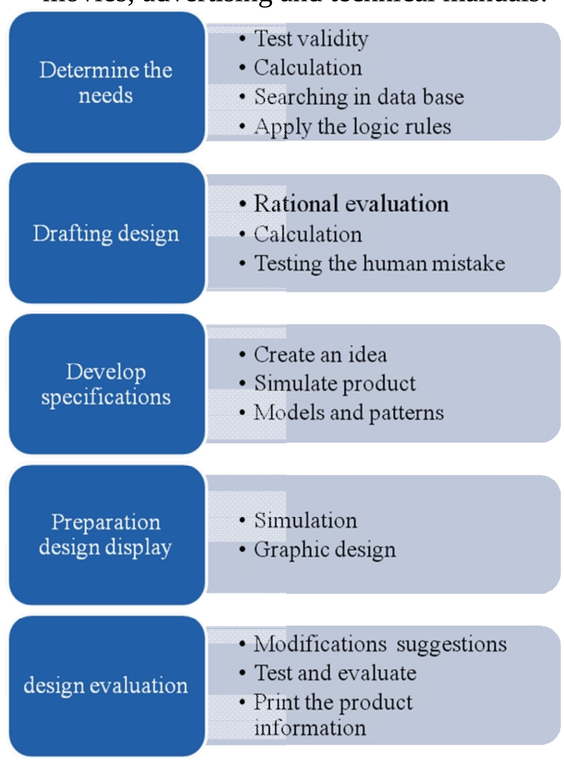
1- Packaging design

Package design and development are often thought of as an integral part of the new product development process. Alternatively, development of a package can be a separate process, but must be linked closely with the product to be packaged. Package design starts with the identification of all the requirements: structural design, marketing, shelf life, quality assurance, logistics, legal, regulatory, graphic design, end-use, environmental, etc. The design criteria, performance (specified by package testing), completion time targets, resources, and cost constraints need to be established and agreed upon. Package design processes often employ rapid prototyping, computer-aided design, computer-aided manufacturing and document automation. The design process need to find many relations between package parts which need special operation and procedures which made the computer necessary in most of the situation .The complex nature of package structure design included using function and aesthetic values considerations. And the techniques which are related with production process and the final user of the product make the use of computers the best solution in the structural design of the packaging. [5-10]

2- Computer-aided design

Computer-aided design (**CAD**) is also known as **computer-aided design and drafting** (**CADD**). It is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. Computer-aided design and drafting (CADD) software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes.

Computer-aided design (CAD) may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.4] Currently, CAD is important because of estimation studying various activities as real time industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals.



The role of computer in package design

The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.[2] The design of geometric models for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD).[11]

3- 3D printing processes: [2-6-4-11]

Three-dimensional printing technology are used to build parts of the product or the first model in the form of layers, where the required part are painted with the help of AutoCAD, and then the design is divided to the computerized drawing (Algorithm Draw) so that it contains all the information and drawing details of each layer.

Each layer are built by distributing or puffing powder raw material (powder) above the surface of another layer of powder which was prepared as a base, and is configured or built-layered technology similar to that used in ink jet printing and this technical used binders for the raw material to associate the particles in order to form the basic powder layer pressed by the compressor in order to install it and then the compressor rises to the next layer which will be spread it and then the particles get joined by the binders.

And it is repeated to build layer upon layer until the complete formation of the desired part. The droplets are spurt on demand by nozzle to distribute quantities of binders whether separate or continuous are deposited above the layer of powder, whether materials are ceramic, metal or polymer, which will turn into a thin sector for the required form and repeat the blowing of the raw materials and binders successively and consecutively until we get the final form.

3-1 Methods of 3D printing

A large number of competing technologies are available to do 3D printing. Their main differences are found in the way layers are built to create parts. Some methods use melting or softening material to produce the layers. Each method has its advantages and drawbacks, and consequently some companies offer a choice between powder and polymer as the material from which the object emerges.[15] Generally, the main considerations are speed, cost of the printed prototype, cost of 3D printer, choice and cost of materials and colour capabilities.[11]

* One method of 3D printing consists of an **inkjet printing system.** The printer creates the model one layer at a time by spreading a layer of powder (plaster, or resins) and inkjet printing a binder in the cross-section of that layer. This process is repeated until every layer is printed. This technology is the only one that allows for the printing of full colour prototypes. This method also allows overhangs. It is also recognized as the fastest method.

* **In Digital Light Processing (DLP),** a case of liquid polymer is exposed to light from a DLP projector under safelight conditions. The exposed liquid polymer hardens. The build plate then moves down in small increments and the liquid polymer is again exposed to light. This process is repeated until the model is built. The liquid polymer is then drained from the vat, leaving the solid model. The builder Ultra is an example of a DLP rapid prototyping system.

* **Fused Deposition Modeling**, a technology [15] that is used in traditional rapid prototyping which uses a nozzle to deposit molten polymer onto a support structure, layer by layer.

* Another approach is selective fusing of print media in a granular bed. In this variation, the un-fused media serves to support overhangs and thin walls in the part being produced, reducing the need for auxiliary temporary supports for the work piece. Typically a laser is used to sinter the media and form the solid. Examples of this are selective laser sintering and **direct metal laser sintering (DMLS)** using metals.

*** Selective laser sintering (SLS) and fused deposition modeling (FDM)**, In the case of lamination systems, thin layers are cut to shape and joined together. But, others lay liquid materials that are cured with different technologies.

* Finally, ultra-small features may be made by the **3D micro fabrication technique of 2-photon photo polymerization**. In this approach, the desired 3D object is traced out in a block of gel by a focused laser. The gel is treated to a solid only in the places where the laser was focused, due to the nonlinear nature of photo excitation, and then the remaining gel is washed away. Feature sizes fewer than 100 nm are easily produced, as well as complex structures such as moving and interlocked parts.3]

Resolution of layer thickness and X-Y resolution is given in dpi. Typical layer thickness is around 100 micrometers (0.1 mm), while X-Y resolution is comparable to that of laser printers. The particles (3D dots) are around 50 to 100 micrometers (0.05-0.1 mm) in diameter.

3-2 - 3D Printer Benefits:

3-2-1- The Fastest Print Speed

- Output multiple models in hours, not days
- Build multiple models at the same time
- Support an entire engineering department or classroom with ease

3-2-2 **Uniquely Multicolor**

- Produce realistic color models without paint
- evaluate Better look, touch , and style of product designs
- 3D print text labels, logos, design comments, or images directly onto models
- Multiple print heads provide the best range of accurate and consistent colors
- Full 24-bit color, just like a 2D printer. Produce millions of distinct colors.
- High-definition 3D printing produces models with complex geometries and small, detailed features
- 3D print the most intricate detail, such as a thin wall on a mechanical prototype or a railing on an architectural model

3-2-3- **Lowest Operating Cost**

- One-fifth the cost of other technologies
- Unused materials are recycled for the next build, eliminating waste

3-2-4- Others

- Suitable for visualizing during the conceptual stages of engineering design through early-stage functional testing.
- No toxic chemicals like those required in stereo lithography
- Minimal post printing finish work is needed
- One needs only to use the printer itself to blow off surrounding powder after printing process.
- Bonded powder prints can be further strengthened by wax or thermo set polymer impregnation.
- FDM parts can be strengthened by adding another metal into the part.
- Use in Any Standard Office or School Environment

3-3 3D Printing Materials and Its Benefits

There are a wide variety of available materials offering transparent, colored, opaque, flexible, rigid, high temperature and high toughness properties. These materials are designed to answer the visual and verification requirements of designers and engineers in every industry. In 2006, research began into 3D rapid prototyping machines, creating printed ceramic art objects. It has led to the invention of ceramic powders and binder systems that enable clay material to be printed from a computer model and then fired for the first time.[9]

3-3-1 Types of Digital Materials:

Digital Materials are composite materials created by simultaneously jetting two different materials. The two are combined in specific concentrations and structures to provide unique mechanical properties and to provide a closer look, touch and function of the desired end-product.

- Simulate rubber – Print a whole range of different Shore A values including Shore 27, 40, 50, 60, 70, 85 and 95, to simulate various elastomers/ elastic and rubber products.
- Simulate toughness – Print various rigid materials ranging from standard plastics to the toughness and temperature resistance of ABS or engineering-plastics.
- Create shades and patterns – Print various shades of rigid opaque materials and mix transparent and rigid opaque materials to create dots, grids and patterns.

- Simulate Standard Plastics – Transparent Ideal for:

• Form and fit testing of clear or see-through parts

• Glass, eye-wear, lighting covers and light-cases

- Visualization of liquid flow
- Color dying
- Medical applications
- Artistic and exhibition modeling

- Simulate Standard Plastics – Rigid & Opaque Ideal for:

- Wide range of fit and form testing
- Moving parts and assembled parts
- Exhibition and sales & marketing models
- Assembly of electronic components
- Silicon molding

Simulate Standard Plastics – Polypropylene: Ideal for:

• Reusable containers and packaging
• Flexible, snap-fit applications and living hinges
• Toys, battery cases, laboratory equipment, loudspeakers and automotive components

Simulate Engineering Plastics – High Temperature: Ideal for:

• Form, fit and thermal functional testing of static parts
• High-definition parts requiring excellent surface quality
• displaying modeling under strong lighting conditions
• Post-processing including painting, gluing, or metallization processes
• Models in transit
• Taps, pipes and household appliances
• Hot air and hot water testing

Simulate Engineering Plastics – ABS: Ideal for:

• Functional prototypes
• Snap-fit parts for high or low temperature usage
• Electrical parts, casings, mobile telephone casings
• Engine parts and covers

3-3-2 Material Specifications Determining: Materials specifications in most cases are determined by the following properties:

- Tensile strength
- Compressive set
- Elongation at break
- Tensile Tear resistance
- Shore Hardness
- Polymerized density

METHODOLOGY

An experimental study was carried out to compare package samples produced by different 3D printing machines. Also an analytical descriptive investigation of using 3d printing in Egyptian market to reveal obstacles preventing an extensive use was done.

1- Experimental study of different 3D printing machines:

Authors used the following types of machines to produce a mono color package (samples in figure 3):

1- Cube 3D printing machine (Cubify 3D systems) (figure 2-a):

Cube® 3D Printer tech specs:

Weight & dimensions
Cube® dimensions 26 x 26 x 34 cm
Cube® weight: 4.3 kg

Requirements: Cube Software (supplied with the Cube)
Wired: USB stick, to transfer print files (supplied with the Cube)

Print properties
Technology: Plastic Jet Printing (PJP)
Print jets: Single Jet
Maximum creaiton size 14 x 14 x 14 cm
Material: PLA plastic and ABS plastic or Tough Recyclable or Compostable Plastic
Layer thickness: 0.2 mm or 200 microns
Supports: Fully Automated, easy to peel off
Cartridge: 1 Cartridge prints 13 to 14 mid-sized creations

2- Dimension 768 3D printing machine (EOS manufacturing solution): (figure 2-b)

Technical Data

Build Envelope	203 mm x 203 mm x 305 mm
Layer thickness (material-dependent)	0.245 mm or 0.33

Modeling Material: ABS plastic in standard white, blue, yellow, black, red, green or steel gray colors. Custom colors available.

Support material	Soluble or breakaway
Material Cartridges:	One auto-load cartridge with 922 cu. cm.(56.3 cu. in.) ABS material. One auto-load cartridge with 922 cu. cm. (56.3 cu. in.) support material.

Workstation Compatibility:	Windows XP/Windows Vista

3- ZPrinter-450 (figure 2-c)

Resolution	300 x 450 dpi
Minimum Feature Size	0.15mm
Color	180,000 colors
Vertical Build Speed	(23 mm/hour)
Build Size	(203 x 254 x 203 mm)
Material	High performance composite
Layer Thickness	(0.09 – 0.1 mm)
Number of Jets	604
Number of Print Heads	2
Workstation Compatibility	Windows® 7, Windows Vista®
powder type	zp130
Build speed:	2-4 layers per minute

2- Description analysis study of using 3d printing in Egyptian market

2-1Determining the prevalence of 3d printing technologies in Egyptian packaging fields.

<u>Note that</u>: This questionnaire does not take in account some printers especially those bought from china because it is so wide and unlimited market.
Authors use the statistical program SPSS in analyzing data.

Questionnaire 1
Questionnaire target group: machines and accessories agents.
Questionnaire object: determining the prevalence of 3d printing technologies in Egyptian packaging market.
Questionnaire results:

- *90 % salesmen* know about 3D printing.
- Only 10% of % salesmen have experience with 3D printing.
- Only the industrial design dep. in faculty of Applied Arts takes advantages of 3d printing.

2-2 Determining suggested applications in packaging fields (design- and production)

Questionnaire2
Questionnaire target group: companies working in packaging design and production.
Questionnaire object: determining the willingness to use 3d printing in local packaging industry
Questionnaire results:

- 80 % of packaging companies develop their package.
- 90% of them develop their package outside Egypt
- 100% of packaging companies used AutoCAD program to develop their package
- 10% of designers know about the 3d printing technology and use it in developing their packages
- 75% of the designers after seeing the sample believe that they can develop their own package using 3d printing and send the sample to production.

RESULTS& DISCUSSION

There are many machines and a lot of materials used in the field of 3D printing. Each machine use one or many material according to the type of machine.

Mono color machines produce a mono color product, but machines contain Multiple print heads provide the best range of accurate and consistent colors.

There are variety in plastic materials can be used in packaging fields.

There is a range of finishing options to meet different needs, from resin for ultra-strong functional prototypes to water for creating concept models quickly, safely, and very affordably.

The material and the finishing process affect the quality and the durability of the final product.

Egyptian market did not benefit from the 3d printing as possible. In the academic fields only the industrial design branch in faculty of applied arts had taken advantage from 3d printing.

The packaging fields in Egypt contain many fields which can take advantage from 3d printing as:

- Plastic packages
- Plastic rolls
- Plastic rolls used in thermoforming
- Thermoforming packages
- Duplex printing houses
- Aerosols containers
- Sheet iron drums
- Soft drink drums
- Metal lids
- Tin packages used in paint and food industries
- Aluminum foil packages
- Ointments and creams aluminum tubes
- Local manufacturing machines

CONCLUSION

1 3D printing technologies can produce a wide range of packages specification, thus producing a package sample simulate the real package with specific specifications depends on selecting each of machine and material.

2 All salesmen know about 3D printing but no one has any experience with it.

3 Only the educational institutes buy the technology (only the industrial design dept. in faculty of Applied)

4 3D printing in developing packaging design success in producing the package sample..

5 In spite of packaging companies develop their packages designs, packaging designers don't use 3d printing in local packaging market.

6 Egyptian packaging designers can develop their own package using 3d printing and send the sample to production.

Therefore, it is recommended that - 3D printing Use in the field of packaging design and of packages development is to be intensified

3D printing should be consciously utilized in the field of packages samples production. Also the use of 3D in packaging concerned educational institutions should be designed with care.

REFERENCES:

1- Anon, 2011, Print me a Stradivarius Leader. The Economist.

2- Anon, 2010, "The World in 2008", Economist.

3- Balistreri, John, Summer-Fall 2008 "Creating Ceramic Art Using the Rapid Prototyping Process". *Studio volume* 36-issue (2).

4- CAGD, Farin, G, 2002, Handbook of Computer Aided Geometric Design, ELSEVIER SCIENCE B.V, Part:1 "A History of Curves and Surface" p:1:14.

5- Chee Kai Chua, Kah Fai Leong, 2003, *Rapid Prototyping*", Chu Sing Lim, World Scientific, p. 124.

6- 3D printers for 3d world, *3D Printers Australia Wikipedia, the free encyclopedia 10 February 2011 6:15*

7- Gerald Farin, 2002, Handbook of Computer Aided Geometric Design, ELSEVIER SCIENCE B.V, Part: 7 "*Curves and Surfaces for CAGD: A Practical Guide*", P: 165:192.

8- H. Pottmann, S. Brell-Cokca,, and J. Wallner, 2007, Discrete surfaces for architectural design, cited in Curves and Surface Design, Nashboro, pages = "213-234

9- Selke, S. " 2000, Plastics Packaging, Hanser. P: 425

10- Terry Wohlers, 3D Printing Goes Open-Source, Wohlers Associates, December 2009.

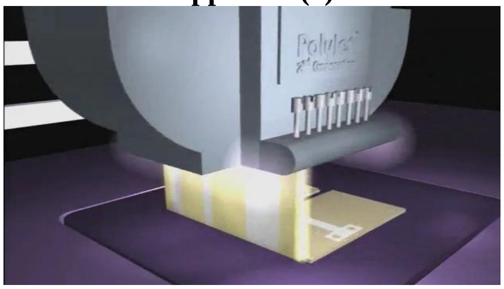
11- Vijay Dugga, 2000, CADD Primer, Mailmax Publishing.

12- http://www.eetimes.com/news/semi/showArticle.jhtml?articleID=198701422. Accessed on 2 October 2010 7:00.

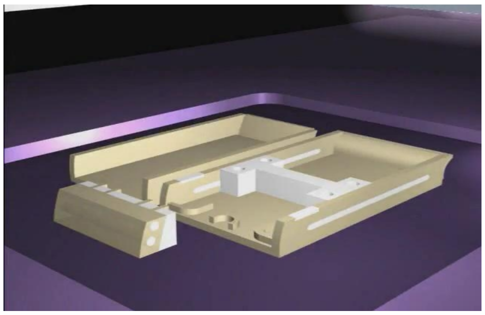
13- http://www.ptonline.com/articles/200408cu3.html. Accessed on 7 September 2010.

14- http://wohlersassociates.com/NovDec05TCT3dp.htm. Accessed on 10 December 2010.

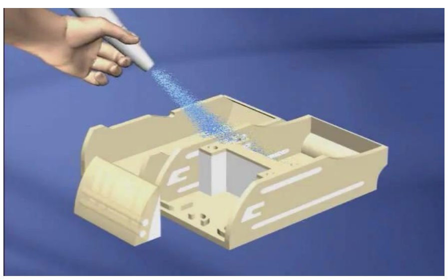
Appendix (1)



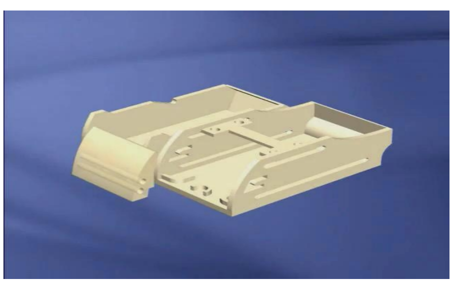
(Figure 1-a- THE MATERIAL DURING JETTING)



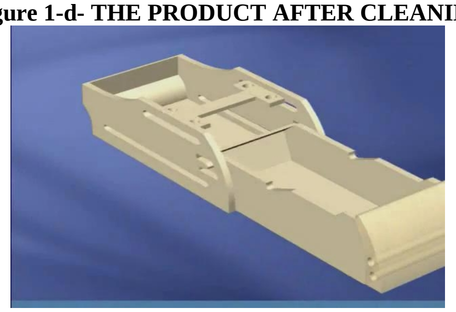
(Figure 1-b- THE PRODUCT AFTER PRINTED)



(Figure 1-C- REMOVE THE WASTE)



(Figure 1-d- THE PRODUCT AFTER CLEANING)



e- THE FINAL PRODUCT

(**Figure 1-f- Samples of colored packages printed by Z printer- powder** type **zp150**

Figure 1: An example of jet processes

(Figure 2- a) Cube 3D printing machine

(Figure 2-b) Dimention 3D printing machine

(Figure 2-c) Z- 450 3D printing machine

Figure 2: 3d printing machines

(Figure 3- a) Sample 1 package printed by Cube printer

(Figure 3-b) Sample2: printed by EOS printer

(Figure 3-c) Sample 3: package printed by Z printr

Figure 3: resulted sample