

The Revolution of Materials Used in 3D Printing Applications in Furniture and Interior Design	العنوان:
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The revolution of Materials used in 3D Printing applications in Furniture & Interior Design

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Abstract:

Innovation is a key factor to survive in today's competitive environment. Effects of innovation in consumer products that we use at every stage of our lives are clearly seen. While innovation releases more aesthetic, functional and smart/creative (innovative) goods to service for end users, it compels firms (that manufacture these goods) to technological development too. Non-industrial use of the 3D printing in interior design and furniture manufacturing can be stated as one of the latest innovative development. This handling can cause differentiation of everything from design to material. Convertibility potential to the end goods of everything based on design which starts and evolves in virtual environment can be shown as disruptive side of differentiation. In accordance with this potential, this study aims to make a detailed definition of three dimensional manufacturing, an evaluation of materials and methods used for interior design and furniture manufacturing by using this technology and their effects on the design within applied projects and create industry-specific awareness.

The research follows the descriptive & analysis methodology to describe and analyze the Materials used in 3D Printing applications in Furniture & Interior Design. Covering three of the crucial aspects of design: aesthetic form, ergonomic function, and structural soundness. Finally, the research displays the results and proposed recommendations.

Keywords:

Materials

3D printing

Furniture

interior Design

Furniture Production

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Introduction

"Transformation of inputs such as raw material, semi-finished material, machinery, labor, management and investment to the furniture or service outputs through transformation processes is called furniture production. Manufacturing is the production of furniture for merchandise. There are lots of manufacturing types that differ according to the production model and volume and product range. 3D printing is one of these production methods and nowadays getting more attention with "Do It Yourself" concept". (Murat Aydin, 2015)

3D printing – or Additive Manufacturing – is a group of manufacturing techniques defined as the process of joining materials layer upon layer to make objects from 3D-model data. It is a rapidly developing manufacturing technology which makes it possible to produce, repair or replace products everywhere.(A.J.M. van Wijk -2015)

"A product design is simply downloaded and then printed. One may copy, modify or personalize the product before it is printed. It will also be possible to make a 3D scan of something existing - and then print it. This will fundamentally change our world. We can create, design and manufacture

whatever we want, wherever we want. Additive Manufacturing will create a revolution in manufacturing; a paradigm change already called the third industrial revolution".(A.J.M. van Wijk - 2015)

In conventional production, there is movement of material between stations and also materials rotate around their own axis because of cutting, drilling, assembly and so on transactions. This cause waste and leeway. But in 3D production there is almost no wastage and leeway like in conventional systems due to decreased work stations. Furniture can be practically finished in a few stations; a computer for modeling and generating the production data, a 3D printer for manufacturing and finishing processes for surface quality.(Murat Aydin, 2015)

3D production may be the next step and the future of modern manufacturing and this idea is becoming significant with this projection. 3D manufacturing can also eliminate the classic formed furniture due to its production method. Thereby, this study aims to investigate how 3D manufacturing is used to produce furniture and interior design elements within applied projects, describe and analyze which materials and methods

used in 3D printing and their effects on the design in the field of interior design and furniture. Covering three of the crucial aspects of design: aesthetic form, ergonomic function, and structural soundness.

Problem:

1. What is the concept of 3D printing process in Furniture & Interior Design?
2. What are the advantages & disadvantages of 3D printing Furniture & Interior Design?
3. Which suitable materials and methods used for productions?
4. How can the materials and this smart technology affect on design?

Objectives:

The research describes and analyzes the materials used in modern and smart technology -3D printing- and their application and effects in the field of interior design and furniture

Importance:

1. Describing the technology of 3D printing.
2. Analyzing the effect of the materials and this smart technology on the design.
3. Describing the difference between a basic rapid prototyping machine and a 3D printer.
4. Mentioning the suitable 3D modeling software in 3D design.

Hypotheses:

Using 3D printing in interior design and furniture make design freedom, faster product development cycles, low costs for production. With no need for global logistics of both raw materials and products.

Methodology:

The research follows the, descriptive & analysis methodology to describe and analyze the Materials used in 3D Printing applications in Furniture & Interior Design.

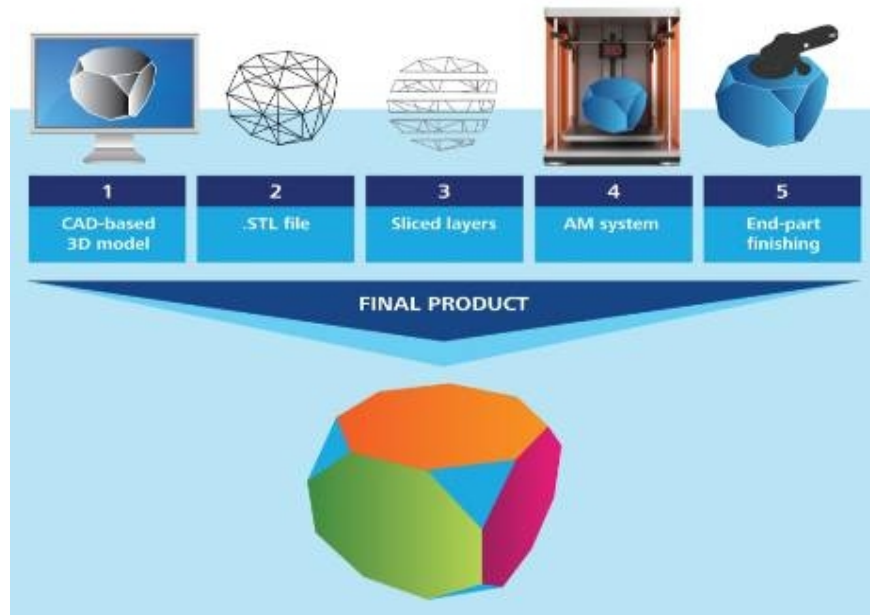


Figure (1) 3d printing process - Source: (Mark Cotteleer- 2014)

The concept of 3D printing Furniture and interior Design elements :

The concept of imagining an object and having it materialize in front of you has defined the term “futuristic” for a long time; however, the future is rapidly approaching. The introduction of 3D printing has just begun to transform the market behind the scenes, but three-dimensional manufacturing is on the cusp of a full-on breakthrough. Within the next few years, 3D printers will be more affordable and more widespread, and they will change the process of running a business forever. (Ad van Wijk- 2015)

3D printing is also known as additive manufacturing AM. It is a prototyping process whereby a real object is created from a 3D design.

The digital 3D-model is saved in STL format and then sent to a 3D printer. The 3D printer then prints the design layer by layer and forms a real object. <http://www.3ders.org/3d-printing-basics.html>

3D printing is not new. It was invented in the year 1984 by (Charles Hull), the design community has used the technique to create rapid prototypes and concept models. But advancements in technology now allow designers to use 3D printers to manufacture finished products, from lighting units to tables, chairs and interior design elements. (Satwik Kumar Roll -2015)

3D printing technologies (additive manufacturing AM process):

"The AM process traditionally begins with the

creation of a three-dimensional (3D) model through the use of computer-aided design (CAD) software. The CAD-based 3D model is typically saved as a standard tessellation language (.STL) file, which is a triangulated representation of the model. Software then slices the data file into individual layers, which are sent as instructions to the AM device. The AM device creates the object by adding layers of material, one on top of the other, until the physical object is created. Once the object is created, a variety of finishing activities may be required. Depending on the material used and the complexity of the product, some parts may

need secondary processing, which can include sanding, filing, polishing, curing, material fill, or painting." (Mark Cotteleer- 2014)

"There are several different 3D printing technologies. The main differences are how layers are built to create parts. SLS (selective laser sintering), FDM (fused deposition modeling) & SLA (stereo lithography) are the most widely used technologies for 3D printing. Generally, the main considerations are speed, cost of the printed prototype, cost of the 3D printer, choice and cost of materials and color capabilities." <http://www.3ders.org/3d-printing-basics.html>

Table (1) 3D printing technologies, advantages, disadvantages and materials used

Tech.	Description	3D process	Advantages	Disadvantages	Materials
FDM	Fused Deposition Modeling	Material jetting	Simple, cheap, is the most popular, strong parts, complex geometries	Low processing speed, precision and material density, difficult to form stalactite-like designs	Solid materials like thermoplastic filament or metal wire, ABS, PC, ULTEM
LOM	Laminated Object Manufacturing	Sheet lamination	Rapid prototyping technology	Less accurate, non-homogenous parts	foils such as paper (new or recycled), plastic foam, ceramic, metal powder impregnated materials.
DMLS	Direct Metal Laser Sintering	Powder bed fusion	Dense components, intricate geometries	Needs finishing, not suitable for large parts	Titanium, Aluminum, Nickel Alloy, Stainless Steel, Cobalt chrome, Maraging steel,
SLA	Stereo lithography Apparatus	Vat polymerization	Rapid manufacturing large tool	The materials are limited, more brittle. These printers are generally more expensive than FDM printers.	ABS-Like, PC-Like, PP-Like, High Heat Liquid materials
DLP	Digital light processing	Vat polymerization	Allows concurrent production, complex shapes and sized, high precision	Limited product thickness, limited range of materials	Liquid photopolymer
SLS	Selective Laser Sintering	Powder bed fusion	Strong structure, high heat and chemical resistant, high speed	Accuracy limited to powder particle size, rough surface finish	Paper, ceramic, composites, Nylon PA, Glass Filled, wood, Aluminum, Sandstone, steel
SLM	Selective Laser Melting	Directed energy deposition	Replacing welding processes, Lightweight and large parts.	High cost, support structures are required, need for post-processing activities to obtain smooth finish	Metal powder and metal alloys

Source :(Vincent Wang – 2015), (Mark Cotteleer- 2014)

3D modeling software suitable for 3D design:

Commercial software such as CAD software: AutoCAD , Pro Engineer, software packages Rhino, Maya,3ds max. and SolidWorks are all pretty good for designing 3D models. <https://i.materialise.com/blog/top-25-most-popular-3d-modeling-design-software-for-3d-printing/>

The difference between a basic rapid prototyping machine and a 3D printer:

"3D printers are the simple version of rapid prototyping machines. It is lowering cost and less capable. In general 3D printers are compact and smaller than RP machines. They use less energy and take less space. They are designed for low volume reproduction of real objects made of specific materials. Consequently 3D printers are easy to handle and cheap to maintain. Man can buy one of those DIY kits in the market and build up himself. It is cheaper than the professional rapid prototyping,.

- 3D printers are less accurate than rapid prototyping machines. Because of its simplicity the material choices are also limited." <http://www.3ders.org/3d-printing-basics.html>

Scanning Real Objects And Print Them:

"A lot of people wonder whether it is possible to 'simply scan and print' objects. It is possible, and there are a few companies that create dedicated 3D scanning equipment, such as Go!SCAN 3D.

However, the scanned models generally require a lot of tweaking before they can be used to print objects." (Whitney Hipolite – 2015)

The materials used to print 3D objects:

The materials available for 3D printing have come a long way since the early days of the technology. There is now a wide variety of different material types. Specific materials are now generally developed for specific platforms performing dedicated applications with material properties that more precisely suit the application.(Satwik Kumar Roll -2015)

However, there are now way too many proprietary materials from the many different 3D printer vendors to cover them here. Instead, these tables will look at the most popular types of material in a more generic way, includes properties, typical use, description and analyses of design model for each material.





Figure (2) :3D printing a model starting from a real decorative element 3D laser scan By (Nespoli) Source : (Whitney Hipolite – 2015)




Table (2) 3d printer materials, properties, typical use, description and analyses of design model.

Material	Acrylic
Properties	Acrylic Plastic is an acrylic-based photopolymer that comes in white, black and transparent.
Typical Use	It is recommended to use this material for smaller, detailed products that don't face high stress or heat. The level of detail for these products is high, but individual layers are more visible than in Strong & Flexible plastics. http://www.shapeways.com/materials/acrylic-plastic
Design model	<p>Figure (3) :The Picoroco wall Design: Ronald Rael, Virginia San Fratello, Seong Koo Lee Dimensions: 48"X48"X6"</p>
Description & analysis	<p>The Picoroco wall is a full-scale mockup using 3D Printing for the production of a free standing wall system. The design uses Picoroco Block, which can be aggregated to create a random surface pattern.</p> <p>The second side of the wall reveals the bumpy surface's underlying geometry—a series of interconnected pentagons, hexagons and quadrilateral shapes whose terminus is a circle.</p> <p>http://www.emergingobjects.com/project/picoroco-wall-in-blue/</p>


Technology	FDM (Fused Deposition Modeling)
Additional Information	Material is watertight ,not recyclable, Acrylic plastic is heatproof to 48°C / 118.4°F degrees. Higher temperatures may significantly change material properties.


Material	Cement	
Properties	It is a strong and rigid material that can be fiber reinforced, resulting in a 3D printed material stronger than standard concrete. Objects produced using cement polymer material are extremely light weight. The finish can be sand blasted, glossy or satin and in every case is semi-translucent. The material can also be machined, sanded or painted. http://www.emergingobjects.com/2013/09/27/concrete/	
Typical Use	Huge objects can be printed easily - or hundreds of small objects at the same time. Print parametric objects in concrete - each shape different.	
Design model	<p>Figure (4) Seat Slug Designed by Rael San Fratello Architects / Emerging Objects - 2012 Project Location: San Francisco, CA dimensions: 132" L x 42" W x 14"</p> 	<p>Figure (5) The Planter tiles Design: Virginia San Fratello & Ronald Rael - 2015</p> 
Description & analysis	<p>The Seat Slug is a bio-morphic interpretation of a bench. It is inspired by flabelina goddardi – the newest species of sea slugs discovered in California – and by the infinite tessalations of Japanese karakusa patterns. The seat slug blurs the lines between biology, technology and furniture and is a new twist on function and form. It is constructed of 230 unique rapid manufactured pieces and requires assembly. http://www.emergingobjects.com/project/seat-slug/</p>	<p>The Planter tiles are 3D printed cement hexagonal tiles that close pack together. The overall pattern is composed of 6 different tile patterns, 4 of which have the capacity to hold plant life. The petal motif on the tiles themselves ties together the planter tiles and non planter tiles through the use of a 3 dimensional graphic. The material process produces an uneven coloring which creates varying hues within the tile to create a rich material surface covering. http://www.emergingobjects.com/project/planter-tile-in-cement/</p>
Technology	LOM (Laminated Object Manufacturing)	
Additional Information	no epoxy or other binders ,high material strength ,cost effective ,fast production , no molds required , uv-resistant , fire-resistant http://www.gtecz-engineering.com/innovations/3d-printer-concrete/	

Material	Polyamide (powder)
Properties	Models are constructed from a white, very fine, granular powder. The result is a strong, somewhat flexible material that can take small impacts and resist some pressure while being bent. The surface has a sandy, granular look, and is slightly porous. https://i.materialise.com/3d-printing-materials/polyamide
Typical Use	Polyamide can be used for complex models, concept models, small series of



	<p>models (several copies of a model), lamps, and functional models. This technique allows the greatest freedom of design of all 3D printing techniques.</p>		
<p><i>Design model</i></p>	<p>Figure (6) The Picoroco Wall Design: Ronald Rael, Virginia San Fratello dimension of  5.75"X5.75"X5.75".</p>	<p><i>Figure (7) Precisely 3d-printed connection system</i> Designer-Möbel Komponente </p>	<p>Figure (8) Joining Furniture Panels: Designer: ollé gellért, 2015 </p>
<p><i>Description & analysis</i></p>	<p>A modular 3D printed building block for wall fabrication printed in PLA. Three different blocks are used in the construction of the wall—a 2, 3 and 4 hole block. Each block can be randomly rotated to create the variable pattern found in the wall.</p> <p>The transparency of the material creates different layers of visual porosity. Figures moving behind the wall are revealed within the cellular geometry of the blocks.</p> <p>The opposing side of the wall reveals the bumpy surface's underlying geometry—a series of interconnected pentagons, hexagons and quadrilateral shapes whose terminus is a circle. Each block is connect by 3D printed clips of the same material that bind the corners of each block together making the wall easy to assemble and disassemble.</p> <p>The variegated pattern allows for views to pass through in some areas of the wall, but not in others. The quality of light and shadow constantly changes across the surface with the passing of the day.</p> <p>http://www.emergingobjects.com/project/picoroco-wall-in-translucent-orange/</p> <p><i>Wood connectors, They can be easily printed by desktop 3D printers and this allows you to assembly preordered components such as simple wood with connector you printed. These connectors would make joinery skills unnecessary due to easy use but essential parts like table need to be shipped.</i> (Murat Aydin, 2015)</p> <p>3D-printed panel joints that may be used to join flat plywood or flexible panels into creative shelving or work-surface solutions. By creating unique sets of custom joints for a project, furniture designers are able to create contemporary pieces of furniture without any traditional fasteners or adhesives.</p> <p>The relatively small joints can be designed to position the panels at any required angle, and multiple copies of each component can be used as necessary to build a complete piece. This type of design lends itself to open-source furniture - if joints break or wear out over time, new parts can be printed from any machine, as long as the models are still available.</p> <p>Designs for these types of plastic joints may be also ultimately produced using injection molding for increased mechanical strength, however 3D-printed parts may suffice as-is for low-volume, lower-load bearing pieces of furniture.</p>		

		(Ollé gellért, 2015)
Technology	SLS (Selective Laser Sintering)	FDM
Additional Information	<ul style="list-style-type: none"> *Well-priced model, a maximum freedom of creation. *Polyamide models are not suited for outdoor use as they absorb moisture. *However, in some cases the material can be treated to make it watertight. *Models with large, flat surfaces or plates (< 25 cm). When such a model cools down, it can deform (warping). 	

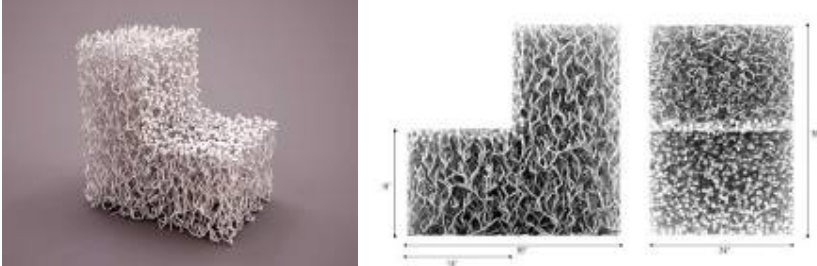
Material	Alumide (Metallic Plastic)	
Properties	Alumide models are constructed from a blend of gray aluminum powder and polyamide, a very fine granular powder. Alumide is a strong, somewhat rigid material that can take small impacts and resist some pressure while being bent. The surface has a sandy, granular look and is slightly porous.	
Typical Use	Alumide can be used for complex models, concept models, small series of models (several copies of a model), and functional models. It is suitable for models that need more stiffness than polyamide models or that require an aluminum look.	
Design model		<p>Figure (9) LINK is a DIY furniture system developed by Tamás Boldizsár from Hungary-2014</p> <p>http://diy3dprinting.blogspot.com/2014/08/link-furniture-system-with-3d-printed.html</p>
Description & analysis	It is made from three wood (plywood) parts and various 3d printed connectors which can give many different combinations of furniture pieces.	
Technology	SLS Selective Laser Sintering	
Additional Information	*Well-priced model, a maximum freedom of creation.	


Material	High Detail Resin	
Properties	Models made out of high detail resin are constructed from a photo polymeric liquid. High Detail Resin is ideal for small and/or very finely-detailed visual models. Although the functional use of this material is rather limited, the model will have a smooth surface. https://i.materialise.com/3d-printing-materials/high-detail-resin	
Typical Use	This material can be used for small, detailed parts and figures.	
Design model		<p>Figure (10) The Greeble Effect Designer : Urs Fries- 2014</p> <p>https://i.materialise.com/blog/the-6-geekiest-3d-prints-of-like-all-time/</p>
Description & analysis	“This model describes or deals with the Greeble effect. A Greeble adds something superfluous or redundant to a surface, but redundancy isn't always superfluous from an aesthetical point of view.”	
Technology	PolyJet prototyping technology	
Additional Information	*Support material is printed together with the model. It has to be removed and limits the freedom of design.	

*Post finishing a high detail model with paint is possible but leads to a possible loss of detail.
 Keep the natural model out of the direct sunlight to prevent discoloration Painting or varnishing the model will prevent or limit discoloration.



Material	Transparent Resin	
<p>Properties</p>	<p>Models made out of transparent resin are constructed from a hardened liquid. The material is strong, hard, stiff, water resistant by nature, and of course, transparent. Transparent resin is suited for models needing a good, smooth, quality surface with a transparent look. Therefore, it's ideal for demo models, accurate models and models with limited functionality. Freedom of design is limited because of the structure necessary to support the models during printing. https://i.materialise.com/3d-printing-materials/transparent-resin</p>	
<p>Typical Use</p>	<p>Transparent Resin can be used for models that need a transparent appearance or a nice smooth surface .</p>	
<p>Design model</p>	<p>Figure (11) C1 chair Design : Patrick Jouin –  (2005)</p>	<p>Figure (12) Satellite Lamp using 3D printing of recycled CD cases Design :Dirk Vander Kooij Dimension 22.8" H x 19.7" Depth http://www.loftmode rn.com/products/dir k-vander-kooij-satellite-lamp</p> 
<p>Description & analysis</p>	<p>The C1 chair is part of the SOLID collection of furniture consists of two chairs (C1 and C2), a table (T1) and a stool (S1). With SOLID, Patrick Jouin wanted to make us aware of stereolithography's great potential. SOLID is about inventing a process. First, exclusively focussing on the material. Second, the issue of how this material may then evolve and grow into the object. https://i.materialise.com/blog/5-amazing-full-sized-furniture-pieces-made-with-3d-printing/</p>	<p>The ruffled texture of the lamp modulates and diffuses the light revealing a warm glow that can increase or decrease in intensity. The beautiful object is made using ground-up recycled CD cases, which Dirk has melted into two concave shapes fitting neatly into one another. Three fluorescent lights are placed between the layers, each with a different temperature to emit various intensities of light. Two large knobs that work like a mixing tap control the light: one knob for warm and one for cold. Satellite Lamp is created out of recycled CD cases in order to explore the possibilities of 3D printing. The title "Endless" refers to an endless thread of synthetic material and infinite possibilities. He used an old industrial robot and reprogrammed it in such a way that it could "print" furniture. In a virtually perpetual movement the robot extrudes recycled refrigerator interiors into chairs or any other kind of furniture.</p>
<p>Technology</p>	<p>SLA (Stereo lithography Apparatus)</p>	
<p>Additional Information</p>	<p>*The transparency is not 100% water clear but lies between translucent and water clear.</p>	

	<p><i>*It is great when it comes down to surface quality. The surface is smooth and the stair-stepping look that is typical for 3D printing is reduced by sandpapering it.</i></p> <p><i>*Transparent resin models are painted with a shiny varnish to prevent discoloration from UV light. http://www.archello.com/en/project/3d-printed-models</i></p>
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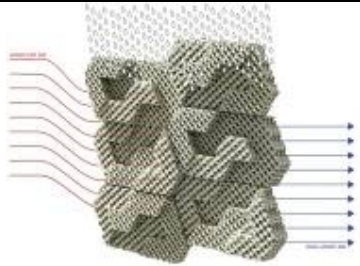

Material	ABS
Properties	It is very useful for functional applications because it matches 80% of the properties of the real injected production material. ABS models are very accurate and have an intermediate level of printed details. freedom for the design. The surface quality of the models is rougher compared to other materials.
Typical Use	<i>ABS can be used for full functional models. The material is UV resistant and comes closest to the material of real production models.</i>
Design model	<p>Figure (13)3D printed Bristle chair Design : Francis Bitonti-2014 (ZACHARY EDELSON -2015)</p> 
Description & analysis	Many tiny branches work together to form a rigid structural mass. The chair is developed algorithmically by reconstructing a cloud of independent floating points.
Technology	FDM (Fused Deposition Modeling)
Additional Information	<p><i>*Extra finishing steps are possible .</i></p> <p><i>*ABS is difficult to post-process because of the layering and the hard plastic.</i></p> <p><i>*The material is water permeable.</i></p> <p><i>*Since the support material is dissolvable, complex designs are possible.</i></p> <p><i>*The printing process is slow but a printed model requires less manual finishing.</i></p>


Material	Titanium
Properties	Models made in Titanium are printed in titanium powder that is sintered together by a laser to produce end-use metal parts that are as equally good as machined models. 3D printed Titanium (unpolished) doesn't look like the traditional shiny milled titanium. Instead it's a bit grayer and more matte with a slightly rougher and less defined surface. Models in Titanium are very strong, precise and can have feature size as small as 0.25 mm.
Typical Use	<i>Titanium can be used for full Functional parts, spare parts and jewelry.</i>
Design model	 <p><i>Figure (14) Ti-Join, Carbon fiber tubes + 3D Printed Titanium joints.</i> <i>Design: Peter Donders-2015</i> <i>source :(Peter Donders – 2015)</i></p>
Description & analysis	<i>The TI-JOIN is a hybrid chair, the result of an assembly of 3D Printed metal joints and carbon fiber tubes. Following the principles of lightweight design, the joints provide rigidity and structural strength with a minimal amount of material. 3D Printing is thus applied where it can be of most service, helping to reduce production costs and indirectly benefit the environment .</i>
Technology	DMLS (metal laser sintering).
Additional	<i>*It is the strongest material you can currently 3D print.</i>


Information	<p>*Titanium is also a high value material.</p> <p>*It's possible to make non-rectangular, organically shaped objects that are not able to be produced by any other process.</p> <p>*Any angles less steep than 35% will tend to be less attractive with this process.</p> <p>*The most ideal shape to make with this process is that of a “mesh with holes”. This makes it easy to design with this process and delivers the best results.</p>
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Material	Steel	
Properties	<p>Models made in Steel are printed in steel powder that is infused with bronze.</p> <p>Steel is the cheapest form of metal printing, very strong and suitable for very large objects. https://i.materialise.com/3d-printing-materials/steel</p>	
Typical Use	<p>Steel is typically used for full functional parts, spare parts and accessories.</p>	
Design model	<p><i>Figure (15) 3D printed Reaction table</i> Francis Bitonti's collections: Integrating 3D printing into architectural design</p> 	<p><i>Figure (16) Dragon Bench</i> Dutch designer: Joris Laarman</p> 
Description & analysis	<p>The legs travel up and blend into the top making many small openings. The top of the table travels down each opening into the leg and then back out the bottom, the table is one complex infinite surface, outside becomes inside and inside becomes outside over and over across the top surface. It's a fabric of space. Reaction Table one of the first of it's kind to use metal 3D printing technology to build full-scale functional furniture.</p> <p>http://www.3ders.org/articles/20130106-francis-bitonti-collections-integrating-3d-printing-into-architectural-design.html</p>	<p>Small amounts of molten stainless steel are printed mid-air, enabling Laarman to draw intersecting lines in space, resulting in a collection that includes the three and a half metre long, two and a half metre wide Dragon bench: an asymmetrical, organic form outlined with the steel mesh.</p> <p>http://www.dezeen.com/2014/05/22/joris-laarman-lab-3d-printed-furniture/</p>
Technology	MX3D-Metal 3D-printing robot	

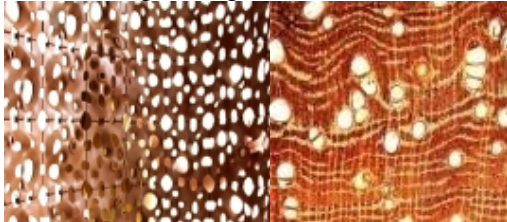

Material	Ceramics	
Properties	<p>Models made out of Ceramics are constructed from alumina silica ceramic powder and sealed with porcelain and silica. The glaze that is applied after printing is a lead free, non-toxic gloss. The material is heat resistant (up to 600°C), recyclable, and currently the only food safe 3D printing material. All of this makes it the perfect material for home decor stuff and table ware, especially when food and beverages get involved. http://www.materialise.com/blog/3d-printed-ceramics/</p>	
Typical Use	<p>Ceramics can be used for tiles, vases, art, and a whole lot more.</p>	
Design model	<p><i>Figure(17) Cool Brick</i> Design Team: Virginia San Fratello & Ronald Rael - 2015</p>	<p><i>Figure (18) INTERIOR STRUCTURES:</i> Architect: Brian Peters- 2015</p>

		
<p>Description & analysis</p>	<p>Inspired by the Muscatese Evaporative cooling window, which combines a wood screen, or mashrabiya, and a ceramic vessel filled with water, the “cool brick” masonry system is used to build walls that passively cool interiors in desert environments.</p> <p>Evaporative cooling airflow diagram Comprised of 3D printed porous ceramic bricks set in mortar, each brick absorbs water like a sponge and is designed as a three dimensional lattice that allows air to pass through the wall. As air moves through the 3D printed brick, the water that is held in the micro-pores of the ceramic evaporates, bringing cool air into an interior environment, lowering the temperature using the principle of evaporative cooling.</p> <p>http://www.emergingobjects.com/project/cool-brick/</p>	<p><u>A large 3D printer for making full-scale structures.</u> The designer adapted a desktop 3D printer to produce ceramic bricks to help build interior architectural structures with an aesthetic edge. “I’ve been working with desktop 3D printers for the past couple of years and wanted to transform the machine to build something on a larger, more architectural scale,” Peters said, using his skills gained on a 6-week residency at the <u>European Ceramic Work Centre</u> on a larger, architectural scale.</p> <p>(National design Academy–2015)</p>
<p>Technology</p>	<p>LOM (Laminated Object Manufacturing)</p>	
<p>Additional Information</p>	<p>*Ceramics can resist temperatures of up to 600° Celsius/1112° Fahrenheit.</p>	

Material	Brass	
<p>Properties</p>	<p>Brass is an alloy of copper and zinc. You probably know it from the many musical instruments that are made out of Brass because of its acoustic properties and ductility. It is used in a wide range of applications where people are looking for a more economical replacement for precious metals. Brass is plated to have that 18kt goldish look and can have the same level of detail as Silver and Gold.</p>	
<p>Typical Use</p>	<p>Brass can be typically used for detailed miniatures, sculptures, jewelry or preprint tests (e.g. to form-fit before ordering Gold or Silver). The material is perfect if you want your piece to bling as Gold but you don’t want to spend so much money.</p>	
<p>Design model</p>		<p>Figure(19) The "Mycelium Chair"- Designer: " Eric Klarenbeek " has used 3D printing common PLA plastic with brass http://www.ericklarenbeek.com/</p>
<p>Description & analysis</p>	<p>3D-printed chair using living fungus, which then grows inside the structure to give it strength</p>	
<p>Technology</p>	<p>The wax printing process is a type of Stereo lithography that uses a wax-like resin</p>	
<p>Additional Information</p>	<p>Structures such as a “ball within a ball” cannot be made with this process. Links of chains for example can also not be made with this process. Brass oxidates in a greenish way if not plated or varnished</p>	



Material	Bronze
Properties	Bronze is an alloy consisting primarily of copper. Bronze is an affordable material for printing models in metal, strong and used by mankind for ages already. A PU coating can be added and provides extra protection to tarnish.
Typical Use	Bronze can typically be used for detailed miniatures, furniture accessories, sculptures, jewelry or preprint tests (e.g. to form-fit before ordering Gold or Silver).
Design model	Figure (20, 21) Ventury's Organic Functional Sculpture 'Gaudi' – Bar Stools– Lounge Chair (Heidi Milkert- 2015) 
Description & analysis	<i>These pieces of furniture are designed based on an organic cellular pattern, and are cast in bronze. The design is based on the requirements of comfortable sitting and responds to load forces and ergonomic conditions. The chair – resulting from an all-embracing line of thought, from design to production, is an ideal field of application for 3D-printing-technology as it allows for an optimal material distribution.</i>
Technology	<i>The wax printing process is a type of Stereo lithography that uses a wax-like resin</i>
Additional Information	<i>Structures such as a “ball within a ball” cannot be made with this process. Links of chains for example can also not be made with this process. Bronze oxidates or tarnishes if not PU coated or varnished</i>

Material	Rubber-like
Properties	Models in Rubber-like are constructed from an off-white, very fine, granular powder. The result is a strong, high-flexible and durable material which is dyed black afterwards. The material is abrasive resistant, shows a limited level of detail, and has a sandy, granular look. The technical name of the material is TPU 92A-1. TPU 92A -1 is a Thermoplastic Polyurethane derived from a Shore A 92. The "1" stands for the fact that it is the first member of a family of materials, hopefully with many to follow.
Typical Use	Rubber-like can be used for haute couture, models that need shock absorption, gadgets, squeezeable models, and functional models.
Design model	 <p>Figure (22) 3d printed furniture modules. Designer : Stewart Allen- 2014 (Brian Krassenstein- 2014)</p>
Description & analysis	<i>Thingiverse user and 3D designer Stewart Allen has developed a modular Construction System that can be used to build sturdy and useable furnishing and shelving units. The parts can all be 3D printed on just about any home 3D printer and easily connected together into virtually any shape or configuration. The finished furniture pieces are strong enough to hold the weight of a person standing on them, and hold up to daily use.</i>
Technology	SLS

(Selective Laser Sintering)	
Material	Wood
<i>Properties</i>	Models in Wood are constructed from a brown, very fine, granular powder made from wood chips. The surface has a sandy, granular look, and is slightly porous. The strength of models printed in Wood is lower compared with other 3D printed materials; therefore, thicker walls are recommended.
<i>Typical Use</i>	Wood can be used for complex models which that don't need to be functional. The technique allows a lot of freedom in design. Typically, these are models you put on your desk or on a shelf, such as architectural scale models, figures, and awards. This technique allows a lot of freedom of design.
<i>Design model</i>	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Figure (23)The Sawdust Screen Design: Virginia San Fratello</p>  <p>http://www.emergingobjects.com/project/sawdust-screen/</p> </div> <div style="text-align: center;"> <p>Figure (24)The wood block 3D printed wood structures Design : Anthony Giannini,</p>  </div> </div>
<i>Description & analysis</i>	<p style="text-align: center;">http://www.emergingobjects.com/portfolio/</p> <p>The Sawdust Screen is fabricated from 3D printed walnut and the surface retains the layering effect from the additive manufacturing process, which simulates natural wood grain. The screen is comprised of individual 3D printed wood components which are affixed together to form a variably dimensional enclosure and surface. Pterocarpus santalinus. L Cross Section</p> <p>The Sawdust Screen is inspired by the vessels found in the microscopic analysis of wood anatomy in hardwoods. When viewed from the endgrain, vessels simply appear to be holes in the wood—what are commonly referred to as pores. In a live tree, vessels serve as the pipelines within the trunk, transporting sap within the tree.</p> <p style="text-align: center;"><i>The additive layer manufacturing of the Wood Block creates a grain similar to natural wood.</i></p> <p style="text-align: center;"><i>The wood material is composed of recycled agricultural waste.</i></p> <p>The texture and subtle translucency of the 3D printed wood material gives the material a warmth, texture and luminosity under certain lighting conditions. The Wood Block can be used as a curtain wall or as a customized masonry unit. The wood block is an example of 3D printed wood as a possible building material that can be mass-customized.</p>
<i>Technology</i>	SLS (Selective Laser Sintering)

Material	Sand	
<i>Properties</i>	Silica sand is one of the most common varieties of sand in the world and is derived from quartz crystals. It requires no changes at the foundry. Additionally, when used with furan binder, it is considered a “no bake” product, which means that printed silica sand molds and cores are immediately ready for casting.	
<i>Typical Use</i>	The Picoroco Block™ is a modular 3D printed building block for wall fabrication printed from sand. Each block is 12"X12"X12" and dimensional variability is possible using the 3D printing process.	
<i>Design model</i>	<p>Figure (25) Picoroco Block™ in Sand Design team: Ronald Rael,</p>	<p>Figure (26) Quake Column Design: Ronald Rael, Virginia San Fratello Dimensions: 6'-5"</p>



	<p>Virginia San Fratello, Seong Koo Lee Dimensions: 24"X24"X12"</p> 	 <p>tall</p>
<p>Description & analysis</p>	<p>The Picoroco Block™ is a modular 3D printed building block for wall fabrication printed from sand. Each block is 12"X12"X12" and dimensional variability is possible using the 3D printing process.</p>	<p>3D printing building components can create seismically resistant structures by using masonry principles that diffuse the force of an earthquake through the interlocking components of a wall. The <i>Quake Column</i> draws from traditional Incan ashlar techniques to explore this possibility Each block is numbered to designate its place in the construction sequence. Additionally, each block has a built in handle for easy lifting, control and placement of the massive (National design Academy– 2015)</p>
<p>Technology</p>	<p>SLS (Selective Laser Sintering)</p>	

The advantages of 3D printing Furniture & Interior Design elements:

1. Manufacture of Customized Products

With 3D printing technology, manufacturing stuff has become easier than never before. Now, anyone can manufacture any product they want, using nothing but a 3D printer, 3d software and the desired raw material. This has paved the way for customized products, as it allows you to create your own designs in 3D, and get them printed. (Mukulika Mukherjee – 2013)

2. Low Production Cost

You might think that the cost of 3D printing is very high, but the truth is that while the initial cost or cost of set-up is high, it is less when compared to labor costs and other costs involved in manufacturing the product in the conventional way. Add to this, the fact that the cost of manufacturing using 3D printing is the same for small-scale and mass production, and you have a winning technology at hand. (Deepak Nayak - 2016)

3. Elimination of Storage Costs

"Mass production gives rise to the problem of storage. Since small-scale production does not cost higher when using 3D printing technology, the

need for mass production is eliminated and along with it, the requirement and costs of storage are also done away with". (Mukulika Mukherjee – 2013)

4. Creation of Employment Opportunities

"With the use of 3D printing technology, furniture product designers can more easily and accurately evaluate each of these features before building production parts and in the end save time and money." (Christine Evans ,2015)

5. Less waste: (Deepak Nayak -2016)

Manufacturing metal and plastic objects in particular is usually a wasteful process with chunky parts and a lot of surplus material. For some aircraft makers, up to 90% of the material is being cut away and no longer useful. Making a similar object using additive manufacturing not only uses less energy but also reduces waste to a minimum. And sometimes, the finished 3D printed product can be up to 60% lighter compared to the machined part but still as sturdy according to the Economist. Significant cost savings can be achieved in this way and less waste also means a lower impact on the environment.

6. 3D Printed Fabrics:

Less waste compared to traditional manufacturing

methods is not only a cost saving feature of 3D printing but also a possible eco-friendly attribute. Add to this the multi-purpose characteristic of a 3D printer (can build different objects without the need of using specialised machines for each part) and their digital ecosystem (all 3D models are transmitted electronically so in theory they can be printed out where they are needed, minimising therefore transport costs) and you get a sustainable manufacturing process. Integrating additive manufacturing with more classic production methods – as is the case with 3D printed textiles in the clothing industry – adds another layer to the sustainability case. (Daniel Tamarjan – 2012)

7. New shapes and structures:

Traditional manufacturing methods rely on moulds and cutting technologies to produce a finite number of shapes and structures, with more complex hollow ones having to be created from several parts and assembled together. But 3D printing changes this altogether – the 3D printer's nozzle can build an infinite number of complex figures, being limited only by human imagination. This method gives them more durability and higher structural integrity (Deepak Nayak -2016)

8. New combinations of materials

Mixing different raw materials is not always possible with mass-manufacturing methods due to the sometimes high costs involved and to their physical & chemical properties that make them difficult to combine through traditional methods. 3D printing has removed many of these boundaries not only because of the initial dependency on plastic (being one of the few raw materials that melt at lower temperatures) but also because of a continuous innovation fed by enthusiasts believing that additive manufacturing's potential has not been reached yet. As a result, many companies now offer tens of different materials with different finishes giving the look and feel of metal, ceramics or glass with various strengths and temperature resistance. (Daniel Tamarjan – 2012)

9. Re-production of classical furniture:

.(Vanessa Palsenbarg -2014)

As mentioned before classical furniture can be re-production by scanning a real piece existing - and then print it, or even 3d printing furniture from flat design on paper .

A collection of furniture designed by the eighteenth century Italian architect Giovanni Battista Piranesi, who is most commonly known for his etchings of Roman sculptures and architecture, has been realized for the first time using 3D printing. These visionary artefacts have only ever existed as flat designs on paper. Now

they have been made real by Factum Arte in Madrid using the miracle of 3D printing.



figure (27) Chair designed by the eighteenth century Italian architect Giovanni Battista, The piece was created by Madrid-based design studio Factum Arte. (Vanessa Palsenbarg -2014)

Factum Arte consists of a team of artists, technicians and conservators dedicated to museum conservation and contemporary art. Over the past few years Factum Arte has worked with The Musée du Louvre, The British Museum, The Pergamon Museum etc carrying out a number of large scale projects. .(Vanessa Palsenbarg -2014) Each of these components—seat-adjusters, armrests, or lamp bases, for example—will have basic functional requirements. However, the distinguishing features for any particular furniture product will comprise the structural performance, ergonomic design, and aesthetic form. This is where the value of 3D printing comes into play for these design features.

The disadvantage of 3dprinting furniture and interior design elements:

1. Counterfeiting

"The biggest possible disadvantage of 3D printing is counterfeiting or production of "fake" stuff, and the copyright infringement issue arising due to it. This technology makes a manufacturer out of anyone who owns a 3D printer, and gets hold of the blueprint. Thus, it would be very difficult to trace the source of fake items, and copyright holders would have a hard time protecting their rights." (Mukulika Mukherjee – 2013)

2. Size Limitations

At present, 3D printers have limitations when it comes to size of the objects created. However, in the near future, we shall have printers that can even print architectural structures. (Mukulika Mukherjee – 2013)

3. Raw Material Limitations

Currently, 3D printing is viable for items made from a single raw material only. However, the technology of creating stuff using more than one material is being developed, and will soon be a reality.(Alexandru Pîrjan,– 2013

4- Need finishing(Mukulika Mukherjee – 2013)

Final product is not very fine and needs some

retouching before it can be used which adds few more steps and devices in completing the job.

The biggest drawback for the individual home user is still the high cost of 3D printer. Another drawback is that it takes hours or even days to print a 3D model (depending on the complexity and resolution of the model). Besides above, the professional 3D software and 3D model design is also in a high cost range.

The effect of using materials in 3d printing furniture: (Christine Evans ,2015)

There are many kinds of 3D printers in the world (right now). They can print practically anything, from small houses to cars, furniture to plane parts, or even very tiny parts used in several manufacturing.

Many modern functional furniture and interior design elements products are comprised of several smaller components that are assembled to produce the final product.

Initial parts or the whole piece of furniture can be modeled, printed, and immediately tested for ergonomic fit and function. One of the key strengths of 3D printing is the ability to cost-effectively produce multiple iterations of an idea in a short period of time. Having actual components on-hand quickly allows the designer to evaluate key aspects of ergonomic design, like the particular grip feel or viewing angles and then make rapid design optimizations.

This ability to interact with physical hardware early in the design process, rather than exclusively rely on models and drawings, empowers designers to make more confident decisions.

Materials should be considered when needing to create highly dimensionally accurate components with excellent surface finish and mechanical properties. For even higher quality prototypes or low-volume production runs, 3D models can be used to produce low-volume **RTV molds**.

Keep in mind the anisotropic nature of 3D printed components when evaluating their structural rigidity. The strength of a printed component will be greatest along the axis of the printed material.

(Christine Evans ,2015)

A Suggested projects

Project 1:Mashrabiya unit

The suggested design is about making a Mashrabiya unit (it's the Arabic term given to a type of projecting oriel window enclosed with kind of small pieces of carved wood latticework used in Islamic architecture) and producing it by using 3d printer .the Mashrabiya unit is created from a 3D max. Program design. The digital 3D-model is saved in STL format and then sent to a 3D printer. Then printed the design layer by layer and forms a real object.

It had been used Selective Laser Sintering technology in producing the unit with wood and polyamide materials,

The unit surface of wood material had a sandy, granular look, and was slightly porous, rough surface finish, constructed from a brown.

The strength of Mashrabiya unit printed in Wood is lower compared with the other 3D printed material; therefore, thicker walls are recommended.

The unit surface of polyamide material is constructed from a white (then painted), very fine. The result is a strong, somewhat flexible material that can take small impacts and resist some pressure while being bent. The surface has a sandy, granular look, and is slightly porous.

By creating unique sets of 3D-printed Mashrabiya units for a project, furniture designers are able to revive ancient pieces of Islamic furniture, or create contemporary pieces of furniture using these units without any traditional fasteners, joints or adhesives.

3D-printed Mashrabiya units can be used as a free standing wall system or a partition between interior spaces .

One of the major purposes of the Mashrabiya is privacy, an essential aspect of Arabic culture. A good view of the other side can be obtained by the occupants without being seen, preserving the private interior without depriving the occupants from a vista of the public outside.

It is said that traditional Mashrabiya costs a lot of time and finance to produce them. But with 3D-printed Mashrabiya units can save time, money and wastes.

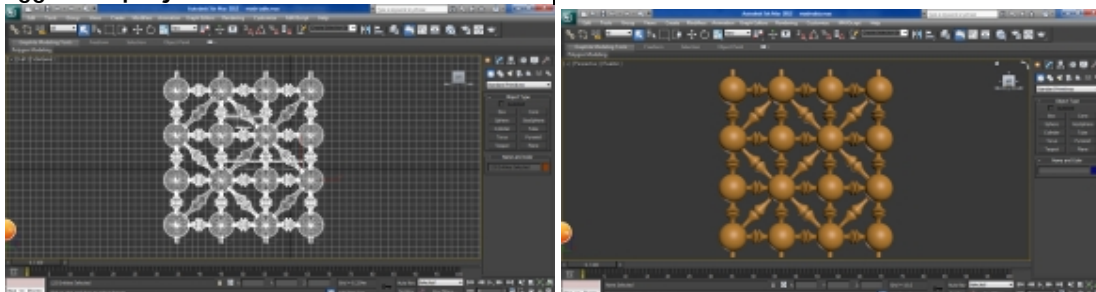


Figure (28) Mashrabiya units designed by 3ds max. program

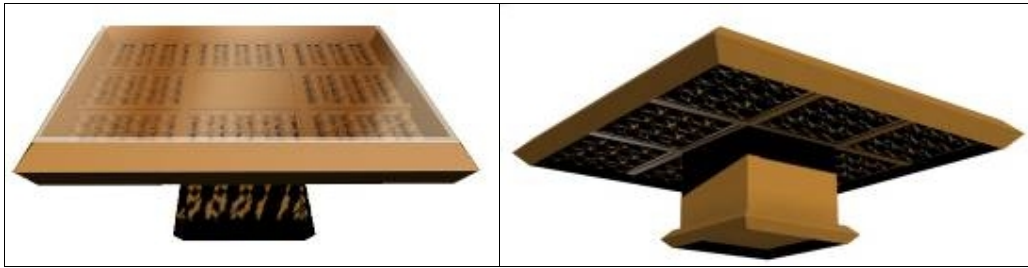


Figure (29) 3d printed table of wood using Mashrabiya units- the researcher design



Figure (30) 3d printed Mashrabiya units of polyamide used in partition between interior spaces - The researcher design



Figure (31, 32) Contemporary coffee tables using 3d printed Mashrabiya units- the researcher design



Figure (33) 3d printed Mashrabiya units in lighting units in interior design - the researcher design



Figure (34) 3d printed Mashrabiya units in doors design- the researcher design

Project 2: Contemporary egyptian chair:

It s consists of a group of simple geometric forms and lines compound together by harmony in lines, inspired from ancient egyptian cevelization in a Contemporary method ,alludes constancy in the chair base (the base shape insprisd from temples intrance) which carries svalte egyptian Obelisk that catch the sky and carry it jauntily. The base in plan has broken lines represent the Nile rever the symble of the bestwal.

Colors used in the design are complementry to express the desert nature of Egypt ,which rich with yellow sand and blue sky ,seas and Nile rever.

It s considered line direction ,arias, the relation of

negative and possitive in the form ,so the chair emerged as svalte sculpture piece.

It had used 3d printing tech. to produce this chair with wood as a one piece without joints or adhesives, so that it is free of opposes with chair legs, then it painted after preparing .

It s considered the human dimation (as a real standared of succses design)in the functional design side like human physiology,material technologies,texture and color.

Dimintions: Base hight 43 cm.-Back hight 107 cm.

Base front width 47 cm., back 37 cm., depth 43cm.

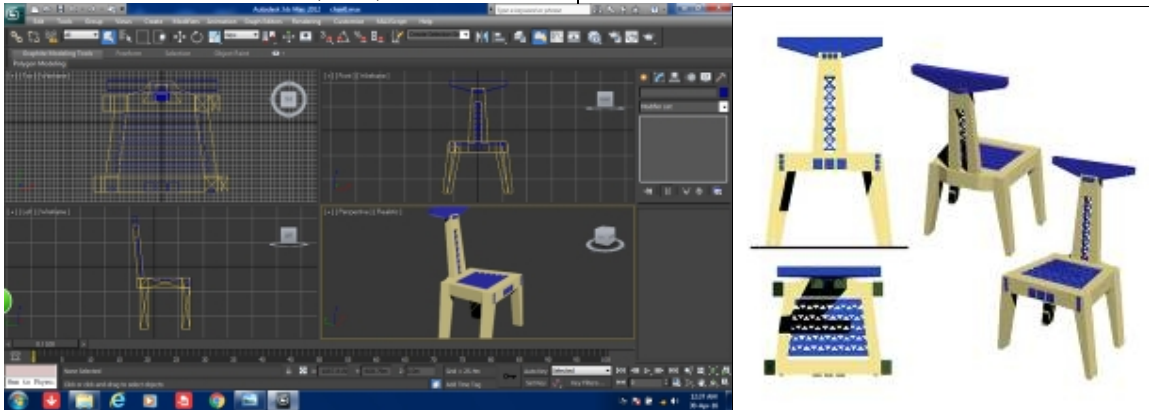


figure (35) 3ds max design of Contemporary egyptian chair -the researcher design

Project 3: Ring array box

It s a box use as a contemporary seat or small table . consists of intersecting number of cubes arraing in a ringing form around specific midpoint in different angles, which varrey to make different formations by a geometrical method. It s hard to make by traditional methods ,so it s designed to make by 3d printing tech., with polyamide

material, empty inside to be light, solid top to be usable .

The design seemed a harmony sculpture of parallel lines in vertical level up and down to achieve dynamic design .Graduated shadow underline the aesthetic structure to achieve balanced musical rhythm.

Dimintions: Base diamiter 45 cm., Hight 45 cm.

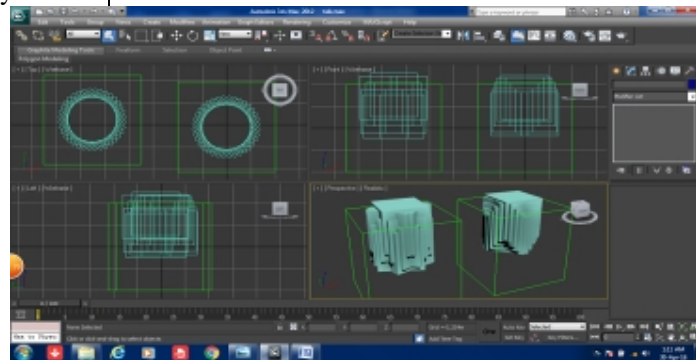


figure (36) 3ds max design of ring array box and model design

Project 4:Arabic letters table :

It is a table inspired from arabic letters with smooth methods certain the aesthetic of decorative form of arabic fonts. The table produced by 3d printing process of wood with varrieos effects and textures on the surface to certain another aesthetic dimation. The textures once imitate clays,

seawave or tangled arabic fonts on the surface.

The table produced from wood as one piece without joints . it s hard to make with traditional methods because of lines thickness, curves and textures which add a technological and artistic values.

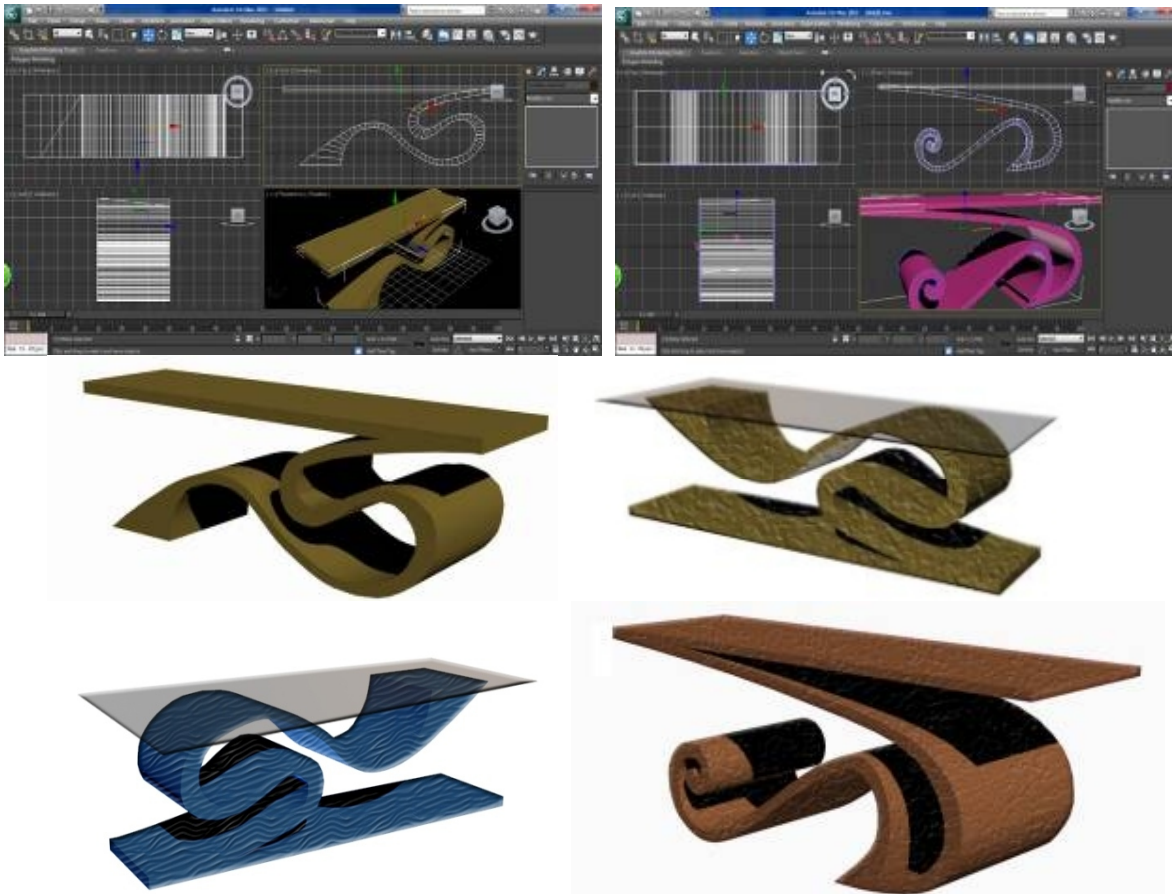


figure (37) 3ds max design of Contemporary of Arabic letter table and models design

Results :

1. 3D printers are less accurate than rapid prototyping machines. Because of its simplicity, the material choices are also limited.
2. There are material limitations in 3D manufacturing including physical, economic (cost of material and process), environmental and aesthetic (surface quality, color, transparency, texture and etc.) manner.
3. Usability of recycled or indigenous materials in interior design and furniture production by 3D printing is important for balancing sustainable production and consumption ratio. This is why there is almost no material wastage in 3D production.
4. Once the object is created by 3D printing, a variety of finishing activities may be required. Depending on the material used and the complexity of the product, some parts may need secondary processing, which can include sanding, filing, polishing, curing, material fill, or painting.
5. It could be impossible to manufacture products that have complex geometries using traditional process in a few steps. But 3D printing allows users to make products which have complex geometries.
6. About production speed, 3D production is relatively slow than mass production techniques and needs to be developed.
7. With 3D production methods, customization comes into prominence and by this means each piece of furniture could be printed distinctly.
8. 3D production can be assumed as the future of modern manufacturing system, but lots of traditional business such as after sales and craftsmanship would be affected positively (for example bringing design works into prominence) or negatively by the potential of it.
9. Furthermore, 3D printing continues to expand the realm of creative possibility by simply providing new methods for producing furniture.
10. Keep in mind that each type of 3D printing technology is limited to certain materials.
11. From the advantages of 3D printing Furniture & Interior Design elements as mentioned before that classical furniture can be reproduction by scanning a real piece existing - and then print it, or even 3d printing furniture from flat design on paper by using deferent

materials .

Discussion:

Lies the importance of these results and the suggested projects in the applied vision to solve the research problem to recognize the materials used in 3D printing technology , their applications in Furniture & Interior Design , how to choose the suitable material for the design by using this technology ,and how can the materials and this smart technology affect on design? by describing and analyzing the materials used in modern and smart technology -3D printing- and their application and effects in the field of interior design and furniture of many products to deferent designers all over the world . then putting a suggested projects:

1- The first project :

By creating unique sets of 3D-printed Mashrabiya units for a project, furniture designers are able to revive ancient pieces of Islamic furniture, or create contemporary pieces of furniture using these units without any traditional fasteners, joints or adhesives. With 3D-printed Mashrabiya units can save time, money and wastes. The strength of Mashrabiya unit printed in Wood is lower compared with the other 3D printed material; therefore, thicker walls are recommended. This means that some materials are suitable than others in the production process. Or we should make adjustments in the design to get positive results using a certain materials.

2- The second project:

It had used 3d printing tech. to produce a Contemporary egyptian chair with wood as a one piece without joints or adhesives, so that it is free of opposes with chair legs, then it painted after preparing . This means save time, money and wastes, but requires finishing activities; some parts need secondary processing, which can include sanding, filing, polishing, curing, material fill, and painting.

3- The third project:

It is a box designed to make by 3d printing tech. It could be difficult to manufacture the box that has complex geometries using traditional process in a few steps. But 3D printing allows the designer to make products which have complex geometries by using one material without joints or adhesives.

4- The fourth project:

It is a table produced by 3d printing process of wood with varrieos effects and textures on the surface to certain aesthetic dimention. The textures once imitate clays, seawave or tangled arabic fonts on the surface.The table produced from wood as one piece without joints . it s hard to make with traditional methods because of lines

thickness, curves and textures which add a technological and artistic values.

From above the research achave the Hypotheses that using 3D printing in interior design and furniture make design freedom, faster product development cycles, low costs for production. With no need for global logistics of both raw materials and products.

Recommendations :

1. Mechanical properties of materials should be analyzed before marketing the products.
2. You should carefully weigh the advantages and disadvantages of each of the materials before you settle for one. Think about what kind of objects you need to print, and what kind of applications they are required to fulfill.
3. The study recommend many researches in the field of improving the 3d printing technology about speed production , more materials and the technology of creating stuff using more than one material .

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