QUANTUM LEAP INNOVATIVE PROCESS FOR CASTING

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Abstract:

The purpose of the study is about the few of the techniques that we can use so that we can effectively utilize all resources in casting process and improve the quality of casting by reducing defects. The Techniques that we can use are

- ✓ 3D printing in casting
- ✓ Multiphysics CAE simulations in casting
- ✓ Value stream mapping for effective process planning
- ✓ Modular/Flexible molds for casting

We had done certain market analysis on casting and 3D printing to make sure that the ideas are feasible in this present market scenario

Keywords:

Casting, 3D printing, Multiphysics CAE, Modular mold, Flexible mold, Market Scenario, Slag

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BREAKTHROUGH INNOVATIVE PROCESS FOR CASTING

1. Introduction:
This Internship project is about Innovative process in casting for make in India. Casting is a 6000 years old manufacturing process and it is used until now to manufacture various parts/products, which we use in our daily life. In this Report, a major investigation was done on what is casting and which sector use that more often and a present market scenario of casting in India and some information about 3D printing in relevant to casting.

There will be a detailed information about all the four feasible ideas developed.

Business development:
Business development is the creation of long-term value for an organization from customers, markets, and relationships.

1.1.1 Long-Term Value

First, what do I mean by “long-term value?” In its simplest form, “value” is cash, money, the lifeblood of any business (but it can also be access, prestige, or anything else a company seeks in order to grow). In addition, there are plenty of ways to make a quick buck for you or your company. However, business development is not about get-rich-quick schemes and I-win-you-lose tactics that create value that has gone tomorrow as easily as it came today. It is about creating opportunities for that value to persist over the long-term, to keep the floodgates open so that value can flow indefinitely. Thinking about business development as a means to creating long-term value is the only true way to succeed in consistently growing an organization.

1.1.2 Customers

The “customers” portion of the definition may be slightly more obvious – customers pay the bills. They are the people who pay you for your products and services, and without them, you will not have any business to develop. However, not everyone is a natural customer for your business. Maybe your product does not have the features I am looking for. Maybe your product is perfect, but I do not even know your company sells it. On the other hand, maybe you are not reaching me because you are not knocking on my door.

1.1.3 Markets

That is because customers “live” in specific markets. One way to understand markets is by geography – if I only focus on selling in the U.S. but you reside in London, then you are currently unavailable to me as a customer as I do not currently reach the European market. But customers also “live” in markets that are defined by their demographics, lifestyles, and buying mindset. Identifying opportunities to reach new customers by entering into new markets is one important gateway to unlocking long-term value.

1.1.4 Ultimate aim of business development:

Figure 1: Portrait for Win-Win Situation

Image Source: www.salesresultsinc.com

A win-win situation, also called a win-win game or non-zero-sum game in game theory, is a situation by which cooperation, compromise, or group participation leads to all participants benefiting. The term can be applied to many aspects of daily living

2. Casting:

2.1 What is casting:

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a **casting**, which is ejected or broken out of the mold to complete the process.

2.2 Types of casting process:

Expendable Mold Casting Types

- ✓ Waste molding
- ✓ Sand casting
- ✓ Plaster mold castings
- ✓ Shell casting
- ✓ Investment casting

Non-expendable Mold Casting Types

- ✓ Die-casting
- ✓ Permanent mold casting
- ✓ Centrifugal casting
- ✓ Semi solid metal casting

2.3 Why casting is needed?

- ✓ To produce complex components with less costs
- ✓ Reducing purchase of machineries
- ✓ Parts can be prepared with accurate tolerance limits
- ✓ Auto manufacturing sectors is heavily dependent on casting from olden days itself

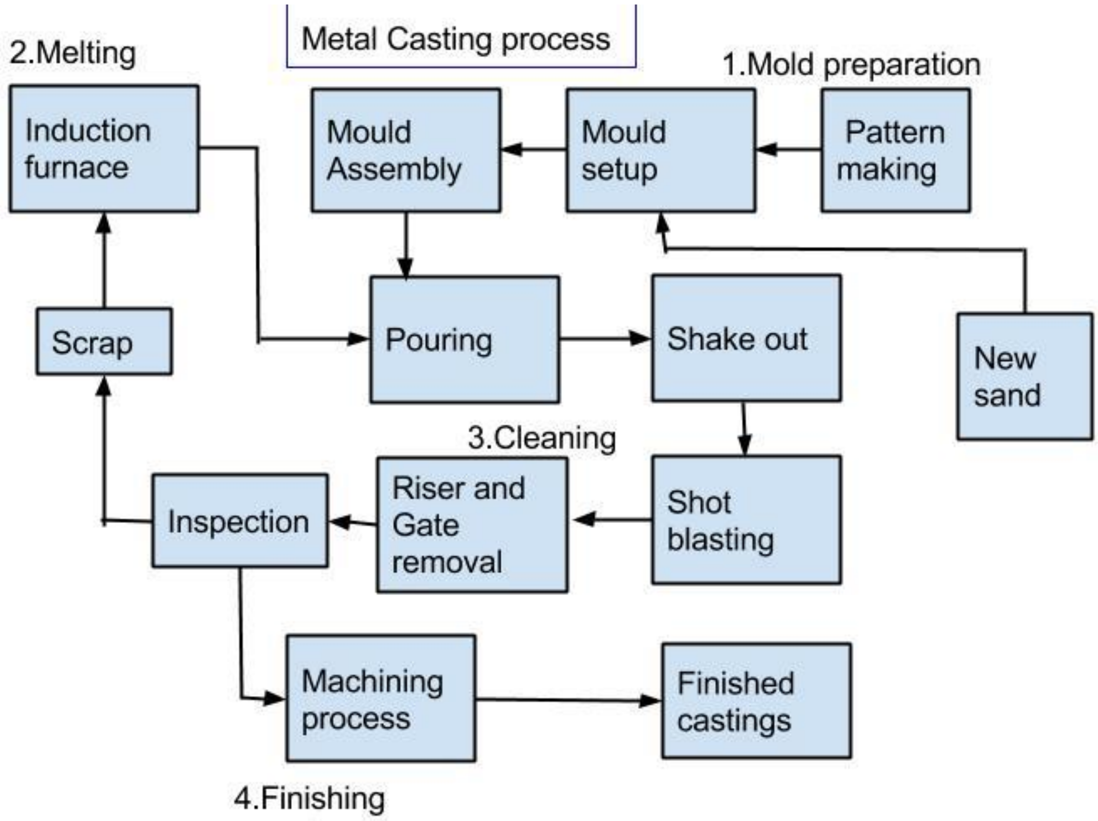


Figure 2: Steps for Metal casting process

2.4 How casting process can be done innovatively?

- ✓ Using Computer Simulations of casting and analysis
- ✓ Using 3D printed prototypes for molding
- ✓ Process planning
- ✓ Good design of prototypes using software

2.5 Market overview of casting in India:

2.5.1 The ups and down of foundry market in India:

Expected CAGR: 19.67 (2013-2018)

Some of the significant factors expected to impact foundry market for the next 4 years:

1. Increased need for infrastructure and power generation: (↑)

Power generation markets increase from 4 - 4.2% of total casting in 2013

8.5% of total casting is for sanitary casting requirements in 2013

2. High import duties on metal scrap :(↓)

Government duty – 2.5% import duty on scrap metal

Potential revenue loss of approximately 1.82 billion US dollars to metal casting manufacturers in India. (This increases their cost of operations)

3. Revival of manufacturing sector :(↑)

Strong demand from domestic and global markets

Ford – US $ 2 billion in India

Renault – Nissan – US $ 2.5 billion in India

4. High Power Requirements :(↓)

Rapid modernization, economic growth & industrialization in India resulted in huge demand on power grid & large power deficits

Industrial energy requirements of casting:

- ✓ Melting metals
- ✓ Mold making
- ✓ Core making

5. Industrialization and development in the emerging countries :(↑)

22.12% CAGR in of industrialization & development in APAC countries

Due to Euro zone crisis will drive the growth in domestic and export demand over the next few years

6. Increased Raw material costs :(↓)

Export taxes and import duties increases the cost of raw materials. It causes supplier to increase their prices. (Major hurdle for the forecast period)

2.5.2 Indian Foundry Industry at a Glance:

✓ Approx. Units :	4600
✓ Production:	9 Million MT PA
✓ Employment:	500,000 Directly 150,0000 indirect
✓ Major Clusters:	19
✓ Productivity Per unit :	1950 MT/PA
✓ Avg Productivity/Man/PA:	20
✓ Max Productivity /Man/PA:	90

2.5.3 Location of Major Clusters:

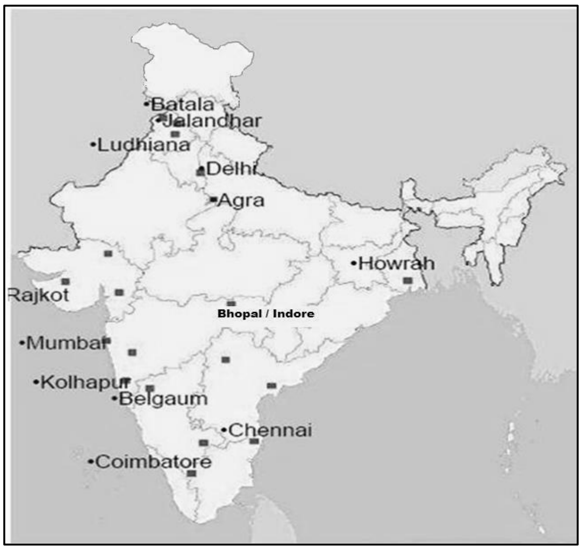


Figure 3: Major Casting Industries in India

There are approx. 4600 units in the country located in the areas marked in the map engaged in various types of metal castings

2.5.4 Product Mix:

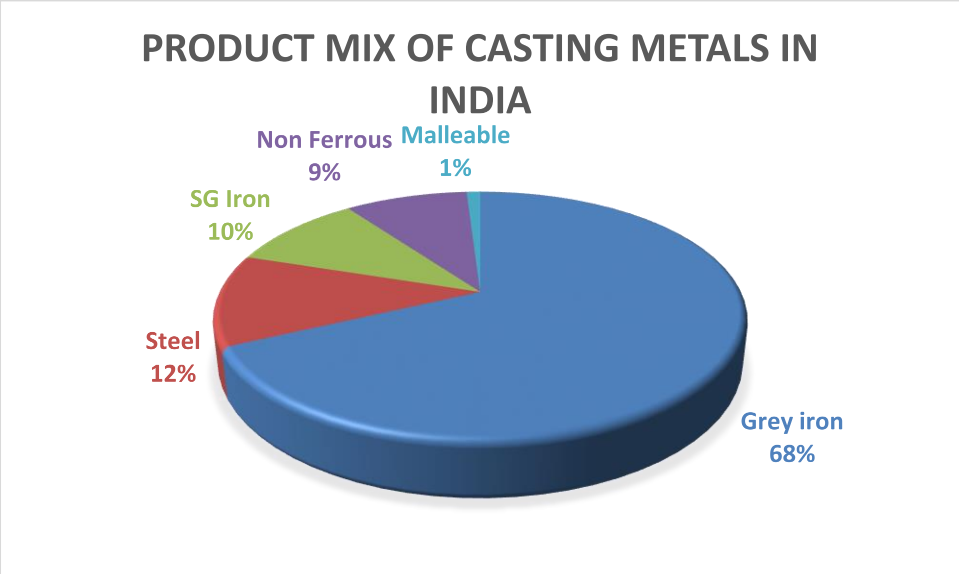


Figure 4: Types of Materials casted in India

2.5.5 Castings Production Trends in Million MT-India:

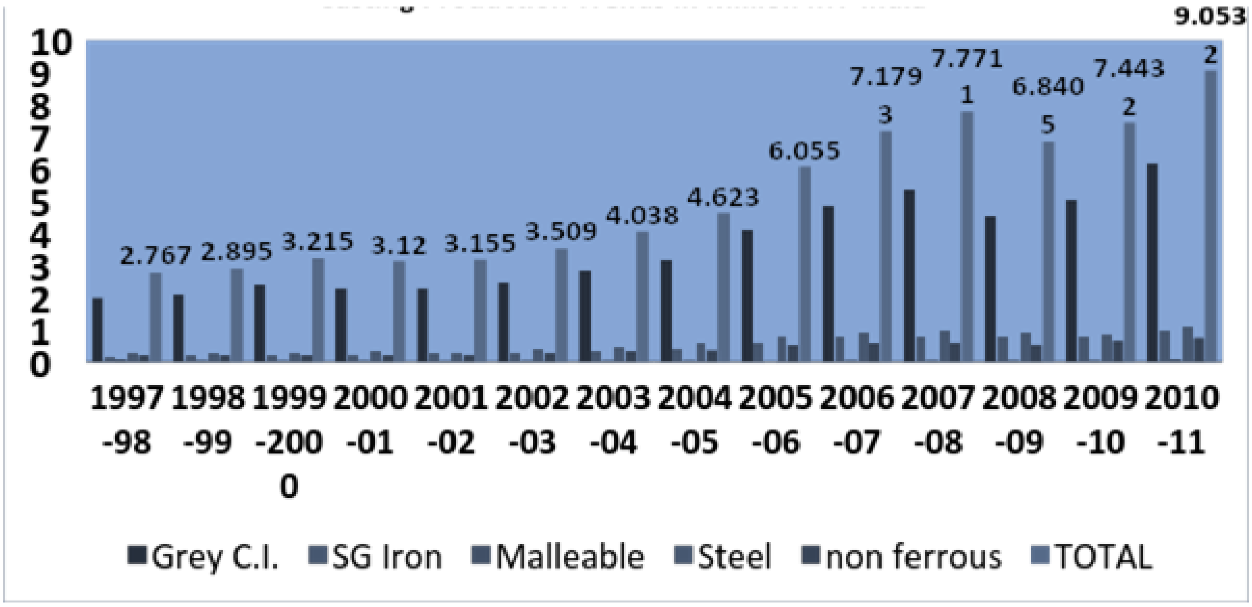


Figure 5: Current production Trends in Casting

2.5.6 Export Trends:

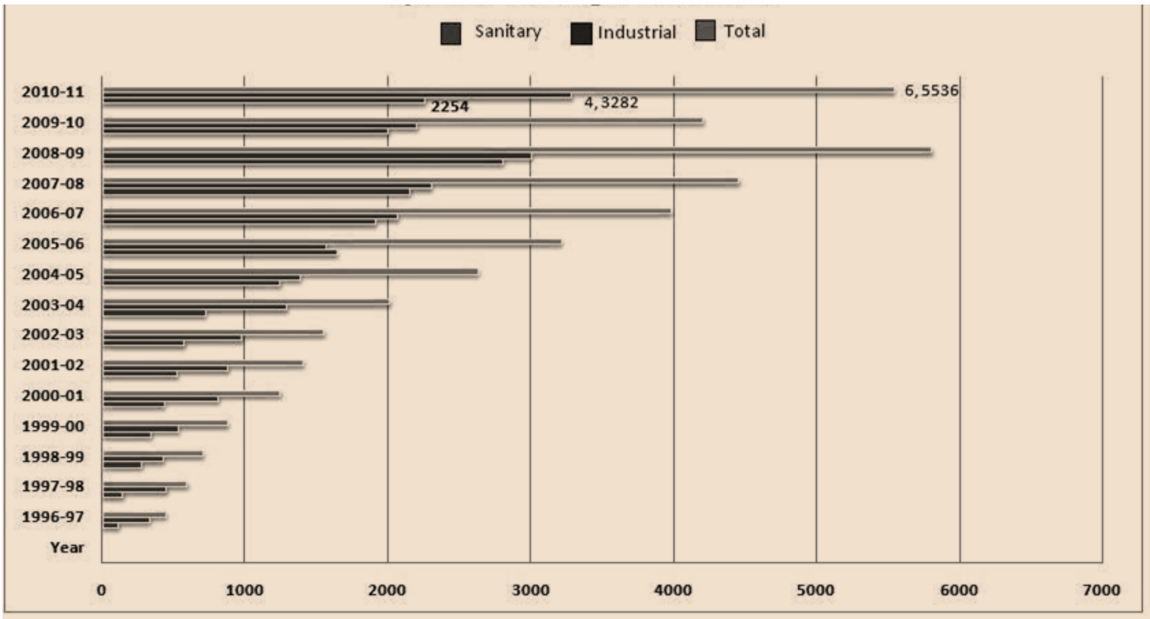


Figure 6: Export trends of Casting in India

2.5.7 Sector-wise Consumption of Castings:

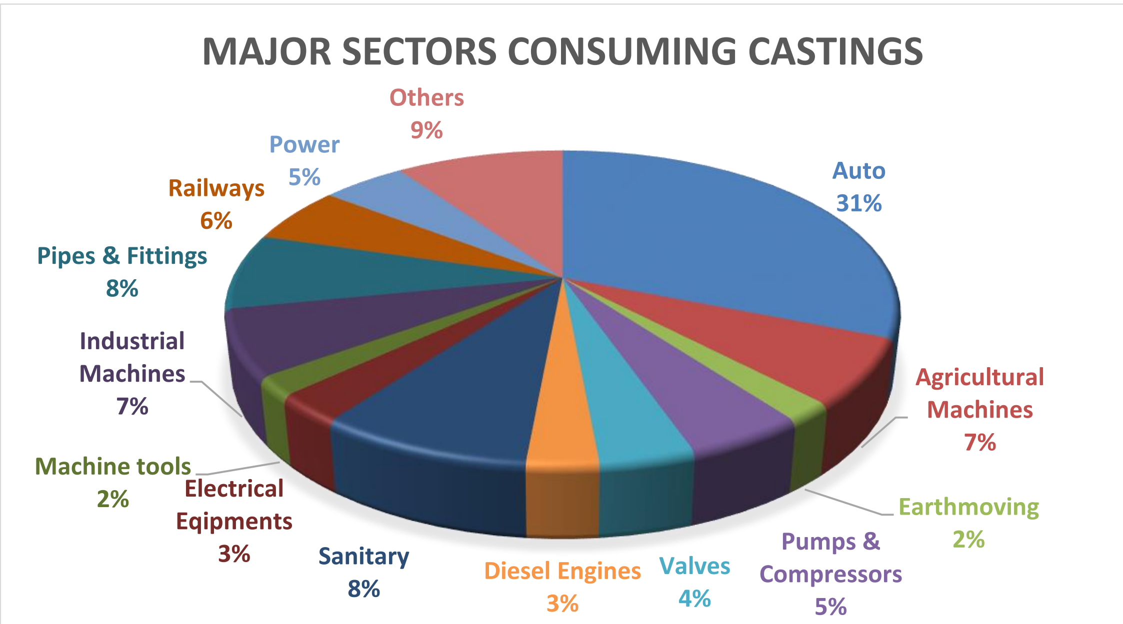


Figure 7: Major Sectors contributing to castings

2.5.8 Various Types of Castings Produced in India:

Figure 8: Types of castings produced in India

Above Images source: Status of Indian Foundry -Dr.H. sundaramurthy
http://www.slideshare.net/NFTN/status-of-indian-foundry-industry?related=1

2.5.9 Vision for Indian Foundry Industry:

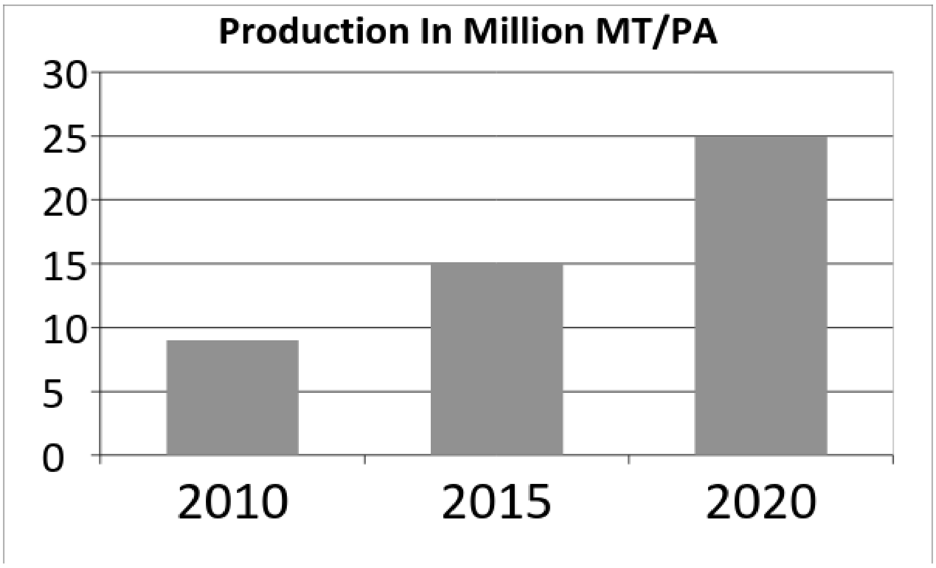


Figure 9: Production in Million MT/PA for the upcoming years

2.5.10 Major Constraints:

- ✓ Availability of skilled manpower
- ✓ Reliable power supply
- ✓ Raw Materials shortage forecast by some
- ✓ High cost of capital
- ✓ High cost of Energy

2.5.11 Top 5 casting producers in the world: (Table 1)

Country	Output (million tonnes)
China	33.5
USA	10.8
Russia	7.8
India	7
Germany	5.8

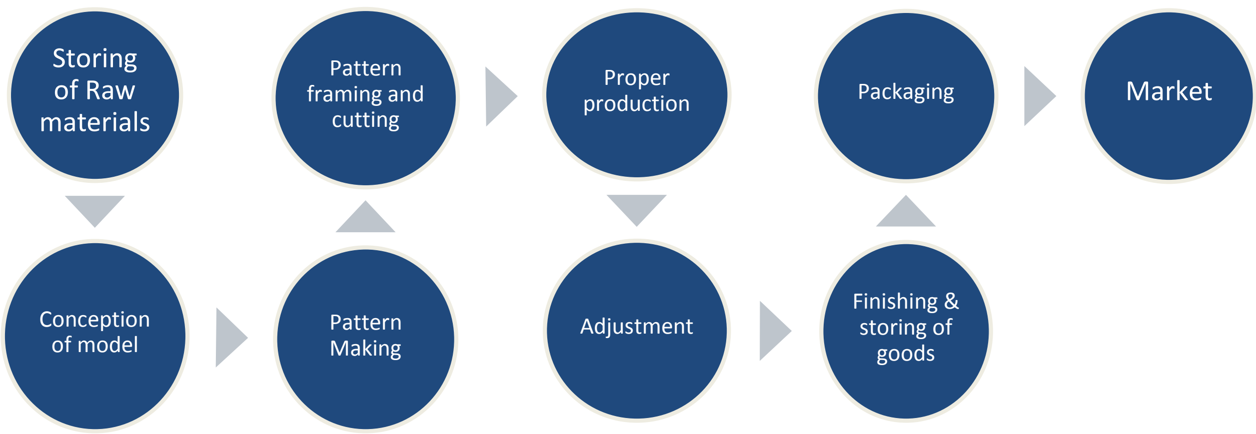
2.6 Industrial Value chain for casting:

Primary activities:

Inbound Logistics:

Acquiring raw materials from internal and external suppliers and storing it in a warehouse.

Operations:



Outbound Logistics:

Storing of finished products and distribute to custom exporter or to external logistics

Marketing/publicity/branding & Sales:

Wholesale dealer /supplier, Retailer

Service: support for customers

Customer service, Warranties and guarantees, easy return of products if there is defect

Support Activities:

- ✓ Firm infrastructure
- ✓ Human resource management
- ✓ Technology development
- ✓ Procurement

2.7 Parameters of Cost-Effective Metal Casting Design

Casting Properties

1. Fluidity
2. Solidification Shrinkage
    a. Type (eutectic, directional and equiaxed)
    b. Volume (small, medium, large)
3. Slag/Dross Formation Tendency
4. Pouring Temperature

Structural Properties

5. Section Modulus (stiffness of casting geometry)
6. Modulus of Elasticity (stiffness of alloy itself)

2.7.1. Fluidity

Fluid life more accurately defines the alloy's liquid characteristics than the term fluidity. Metal's fluidity one of the dynamic property, changing as the alloy is delivered from the ladle, etc. into a gating system and finally into the mold or cavity.

Fluid life affects the design characteristics of a casting such as

- ✓ Thickness Section
- ✓ The length of a thin section
- ✓ The cosmetic details Fineness
- ✓ The accuracy of alloy filling the mold ends.

2.7.2. Solidification Shrinkage

There are three distinct stages of shrinkage as molten metals solidify: liquid shrinkage, liquid-to-solid shrinkage and patternmaker's contraction.
Liquid shrinkage is the contraction of the liquid before solidification.
Liquid-to-solid shrinkage is the shrinkage of the metal as it transforms from the disconnected atoms and molecules into the structured blocks of solid metal.
Patternmaker's Contraction is the contraction that occurs after the metal has solidified and is cooled to ambient temperature

2.7.3. Slag/Dross Formation

Slag refers to high-temperature fluxing of refractory linings of furnaces and oxidation products from alloying. Dross typically refers to oxidation or reoxidation products in liquid metal from reaction with air during melting and can be associated with either high or low pouring temperature alloys. Some molten metal alloys generate more slag/dross than others generate and are more prone to contain small, round shaped nonmetallic inclusions trapped in the casting. Unless a specific application is exceedingly critical, a few small rounded inclusions will not affect casting structure significantly. In most commercial applications, nonmetallic inclusions are only a problem if they are encountered during machining

2.7.4. Pouring Temperature

The refractory characteristics will affect the choice of the molding process and design. When pouring temperature approaches a refractory limit, the heat transfer patterns of the casting geometry become important. Metal molds, such as those used in die-casting and permanent molding, have temperature limitations. Except for special thin designs, all alloys that have pouring temperatures above 2150 F (1180 C) are beyond the capability of metal molds. It is also important to recognize the difference between heat and temperature; temperature is the measure of heat concentration. Lower temperature alloys also can pose problems if heat is too concentrated in a small area—better geometry choices allow heat to disperse into the mold

2.7.5. Section Modulus

Playing with sketches before developing a solid model requires another way to evaluate stress and deflection. This "other way" is the essence of efficient structural evaluation of geometry in casting design. The equivalent of FEA for the design engineer's structural analysis is computerized "mold filling" and "solidification analysis" for the casting engineer; the basis for both is a solid model. The "other way" for the casting engineer is the manual calculation of gating, solidification patterns and riser sizes; these are established, relatively simple mathematical techniques used long before the advent of solid models.
This "other way" for the design engineer is not so simple. To take full advantage of engineering sketching/ print marking as a way to brainstorm geometry requires quickly evaluating stress and deflection at important cross sections in the sketches. The classic

formulas for bending stress, torsional stress and deflection are relatively simple. Each, however, contains the same parameter, Section Modulus, which is a function of shape and difficult to compute. Therefore, a quick, simple way to compute or estimate Section Modulus is needed so that we can move from sketch to improved sketch in our casting geometry brainstorming.

2.7.6. Modulus of Elasticity

The measure of a material's stiffness (without regard to material geometry) is known as the Modulus of Elasticity. Modulus of Elasticity varies widely among materials, and it varies significantly among metals; that is, some metals are considerably stiffer than others are. Modulus of Elasticity is an important parameter in structural design, and it is directly involved in the relationship between casting geometry and deflection. A larger Modulus of Elasticity means less Deflection. For example, a steel casting would deflect less than an aluminum casting of identical geometry simply because steel is stiffer than aluminum. Modulus of Elasticity is simply the elastic slope of the stress/strain diagram created.

3. 3D printing:

3-D printing—or additive manufacturing, as it is sometimes called—builds parts by depositing layers of metals, thermoplastics, and even ceramics in a design dictated by a computer file. The technology, which can create complex things that are difficult to manufacture traditionally, has been used to print highly customized products like hearing aids and parts for airplane engines.

3.1 Principles:

- ✓ Modeling
- ✓ Printing
- ✓ Finishing

3.2 Current 3D Printing Technologies

Stereo lithography - Stereo lithographic 3D printers (known as SLAs or stereo lithography apparatus) position a perforated platform just below the surface of a vat of liquid photo curable polymer. A UV laser beam then traces the first slice of an object on the surface of this liquid, causing a very thin layer of photopolymer to harden. The perforated platform is then lowered very slightly and another slice is traced out and hardened by the laser. Another slice is then created, and then another, until a complete object has been printed and can be removed from the vat of photopolymer, drained of excess liquid, and cured.

Fused deposition modelling - Here a hot thermoplastic is extruded from a temperature-controlled print head to produce robust objects to a high degree of accuracy.

Selective laser sintering (SLS) - This builds objects by using a laser to selectively fuse together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials.

Multi-jet modelling (MJM) - This again builds up objects from successive layers of powder, with an inkjet-like print head used to spray on a binder solution that glues only the required granules together.

The **VFlash** printer, manufactured by Canon, is low-cost 3D printer. It is known to build layers with a light-curable film. Unlike other printers, the VFlash builds its parts from the top down.

Desktop Factory is a startup launched by the Idea lab incubator in Pasadena, California.

Fab@home, an experimental project based at Cornell University, uses a syringe to deposit material in a manner similar to FDM. The inexpensive syringe makes it easy to experiment with different materials from glues to cake frosting.

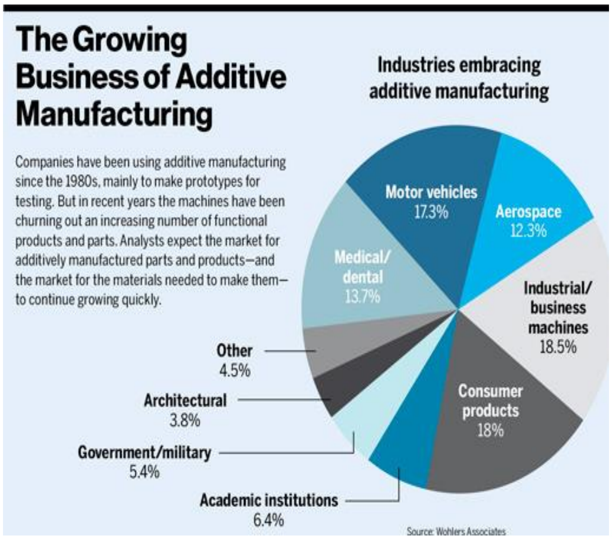
The **Nanofactory** 3D printing technologies are introduced that are related to the nanotechnologies.

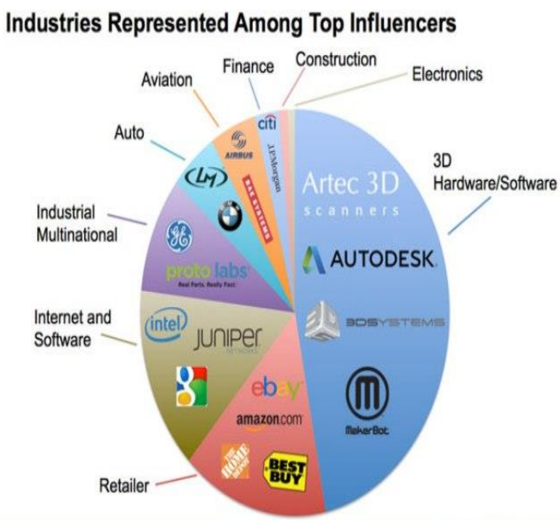
3.3 Types of processes: (Table 2)

Type	Technologies
Extrusion	Fused deposition modeling(FDM) or Fused Filament Fabrication (FFF)
	Robo casting
Wire	Electron Beam Freeform Fabrication (EBF)
Granular	Direct metal laser sintering(DMLS)
	Electron-beam melting (EBM)

	Selective laser melting (SLM)
	Selective heat sintering (SHS)
	Selective laser sintering (SLS)
Powder bed and inkjet head 3D printing	Plaster-based 3D printing (PP)
Laminated	Laminated object manufacturing (LOM)
Light polymerized	Stereo lithography (SLA)

3.4 Scope of 3D printing:





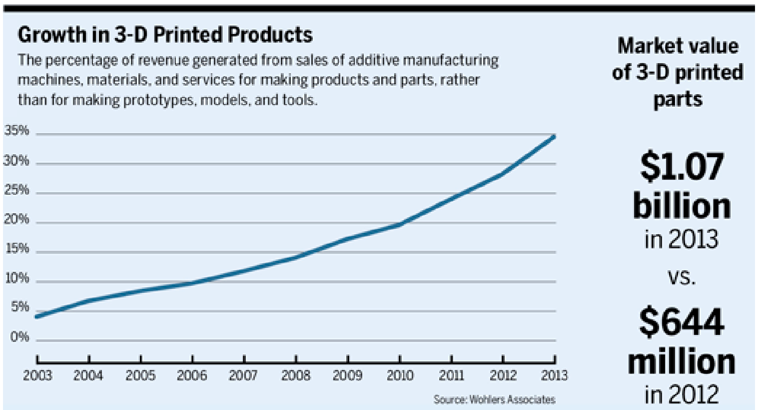


Figure 10: Market potential of 3D Printing

Image source: www.technologyreview.com, www.forbes.com

3.5 Major Players:

Shapeways is a New York based 3D printing marketplace and an on-demand provider of 3D printing services. Designers upload design files, and users can place orders with Shapeways to produce the 3D printed item for them. Shapeways offers a variety of materials, including metals, plastics, ceramics, etc.

3DLT is a platform for 3D printing as a service through which retailers offer 3D printable products online and in-store. Users of 3DLT design and upload 3D printable files and 3DLT works to print and sell these products.

Thingiverse offers free sharing of user-created digital designs for 3D printing. Makerbot (a subsidiary of Stratasys) owns the website. Numerous technical projects use Thingiverse as a repository for shared innovation and dissemination of source materials to the public.

My **MiniFactory** offers free sharing of 3D printable files too, but unlike the other platforms, My MiniFactory's content is fully curated, meaning that every downloadable object has previously been tested on 3D printers. The website is property of iMakr and also offers a free streaming service for 3D designers.

Threeding is an Eastern European startup that offers free and paid 3D printable content. The company launched its services in 2013 and it became popular among CAD designers and hobbyists with its simple design and interface. Significant parts of the 3D objects available at Threeding.com are digital copies of historical artifacts. Other sites have blossomed as market places for 3D printing such as Sculptteo.com and 3DPrintWise.com, which have a commercial flavor.

CGTrader started as the e-shop of computer graphics before transitioning into a more 3D printer friendly model marketplace. The company connects designers and buyers of 3D model designs, primarily focusing on 3D printing and computer graphics. Lithuanian venture capital fund Practica Capital invested in the company in early 2013 and Intel Capital invested further in 2014.

Ponoko sells laser cutting designs as well as 3D printing designs, with a greater focus on the laser cutting side. It gained noticeable media attention because of its unique business model, as one of the first manufacturers that uses distributed manufacturing and on-demand manufacturing.

I.Materialize offers a wide range of materials and especially finishes. It is the 3D printing marketplace of Belgian 3D printing company Materialize NV.

3.6 Customer requirements:

In **manufacturing** industry, they use 3D printing for

- ✓ Mass customization
- ✓ Distributed manufacturing
- ✓ Rapid manufacturing
- ✓ Rapid prototyping
- ✓ Research
- ✓ Food

INDUSTRIAL APPLICATIONS OF 3D printing:

- ✓ Apparel
- ✓ Automobiles
- ✓ Construction
- ✓ Electric motors and generators
- ✓ Firearms
- ✓ Medical
- ✓ Computers and robots
- ✓ Space

SOCIOCULTURAL APPLICATION OF 3D Printing:

- ✓ Art
- ✓ Communication
- ✓ Domestic use
- ✓ Education and research
- ✓ Environmental use

3.7 Global players of 3D printing:

- ✓ Stratasys
- ✓ Optomec
- ✓ Fabbster
- ✓ 3D systems
- ✓ Leap frog
- ✓ Flash forge

3.7.1 3D printing major players in India:

- ✓ Altem Technologies
- ✓ Imaginarium
- ✓ Brahma 3
- ✓ KCbots
- ✓ JGroup Robotics

3.7.2 3D printing opportunities:

3D printer market offers tremendous potential in the commercial segment such as

- ✓ Healthcare sector
- ✓ Architecture
- ✓ Educational
- ✓ Art & craft.
- ✓ Organ replacement
- ✓ Extent of customization
- ✓ Animation & gaming fashion
- ✓ Apparels customized footwear designs
- ✓ Interior decoration
- ✓ Furniture modeling
- ✓ Educational models
- ✓ Chocolate and Drug printing

3.8 3D printed products:

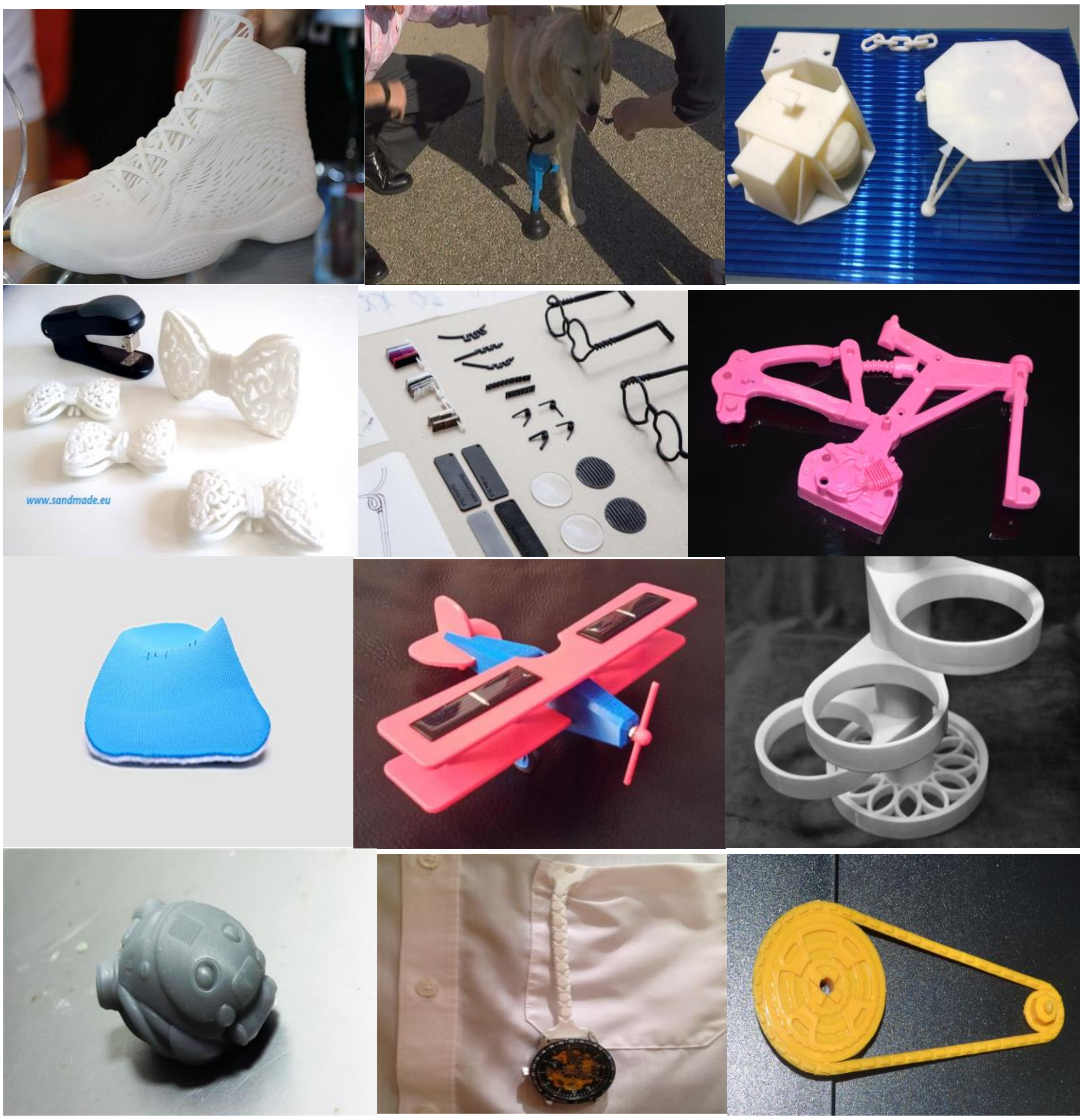


Figure 11: Various Areas Where 3D Printing can be used

Image source: [www.3ders.org, 3d.atoa.com](www.3ders.org)

4. New Concepts generated to improve quality of castings:

We had undergone a brainstorming session followed by research session to look for the ideas which are feasible and which process can highly improve the quality of castings at a low cost with the help of technologies

The Generated ideas are

- ✓ Effective process planning using value stream mapping
- ✓ Multiphysics CAE for casting
- ✓ 3D printing in casting
- ✓ Modular/Flexible mold for casting

4.1 Effective process planning in casting:
Effective process planning can be done using the technique called "**value stream mapping"**

Value stream mapping:
Special type of flow chart that uses symbols known as "**the language of Lean**" to depict and improve the flow of inventory

Purpose:
Provide optimum value to the customer through a complete value creation process with minimum waste in:

- ✓ –Design (concept to customer)
- ✓ –Build (order to delivery)
- ✓ –Sustain (in-use through life cycle to service)

Why value stream mapping?

- ✓ Many organizations pursuing "lean" conversions have realized that improvement events alone are not enough
- ✓ Improvement events create localized improvements, value stream mapping & analysis strengthens the gains by providing vision and plans that connect all improvement activities.
- ✓ Value stream mapping & analysis is a tool that allows you to see waste, and plan to eliminate it

Steps for value stream mapping:

- ✓ Step 1 -Select your sponsor and set expectations
- ✓ Step 2 -Select your team
- ✓ Step 3 -Select process to be mapped
- ✓ Step 4 -Collect data and produce current state map
- ✓ Step 5 -Critique Current state
- ✓ Step 6 -Map Future State
- ✓ Step 7 -Create Action Plan and deploy
- ✓ Step 8 -Measure benefits

Regarding cost:
Initial cost will be little higher due to paperwork done by experts, Afterward the cost will be minimum

4.2 Multiphysics CAE for casting:

- ✓ **Computer-aided engineering** (**CAE**) is the broad usage of computer software to aid in engineering analysis tasks. It includes Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Multibody dynamics (MBD), and optimization.
- ✓ **Multiphysics** treats simulations that involve multiple physical models or multiple simultaneous physical phenomena. For example, combining chemical kinetics and fluid mechanics or combining finite elements with molecular dynamics. Multiphysics typically involves solving coupled systems of partial differential equations.

Why multiphysics?

- ✓ Large number of real world problems requires Multiphysics simulation tool
- ✓ Need to solve integrated physics
- ✓ Ensure two way coupling

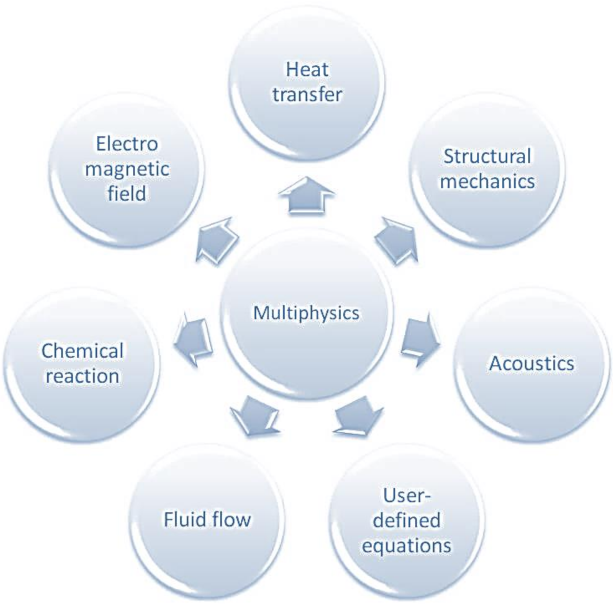


Figure 12: Various Streams of Multiphysics

Uses of Multiphysics Simulations:

- ✓ Consistency
- ✓ Compatibility
- ✓ Single database & memory map
- ✓ Accurate exchange
- ✓ Scalable parallel operations

Cost involved:

We should require a software specialist on solving multiphysics simulations so in addition to casting cost, there would be slight increase in administration cost

4.3 3D printing in casting:

3-D printing or additive manufacturing, as it is sometimes called—builds parts by depositing layers of metals, thermoplastics, and even ceramics in a design dictated by a computer file. The technology, which can create complex things that are difficult to manufacture traditionally, has been used to print highly customized products like hearing aids and parts for airplane engines

How does it work?

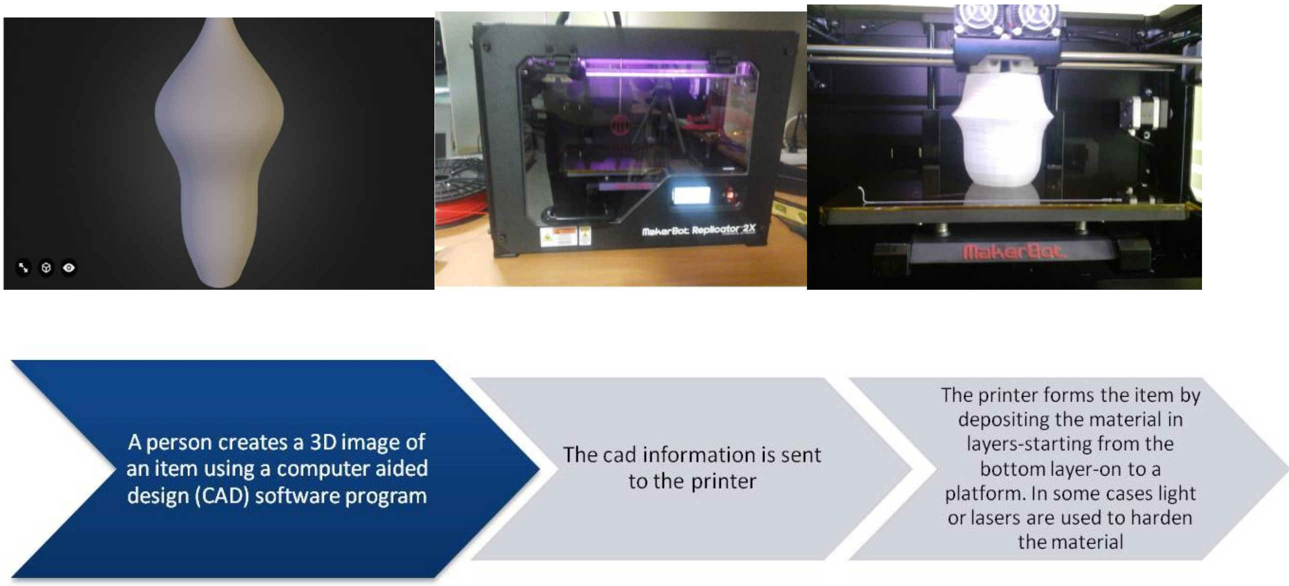


Figure 13: Three steps of 3D Printing

Limitation:

It is limited to making only certain parts but it is best suited for making small complicated products

Applications:

- ✓ Healthcare sector
- ✓ Architecture
- ✓ Educational
- ✓ Art & craft.
- ✓ Organ replacement
- ✓ Extent of customization
- ✓ Animation & gaming fashion
- ✓ Apparels customized footwear designs
- ✓ Interior decoration

- ✓ Furniture modeling
- ✓ Educational models
- ✓ Chocolate and Drug printing

Cost involved:

Only the Initial cost of 3D printing machine only is added with the casting process

4.4 Modular/Flexible mold for casting:

Modular approach to tooling provides for increased versatility and utilization of overmold tooling. In addition our standard mold base design allows the user to use mold inserts of many sizes, further decreasing costs so many companies incur in MUD base costs.
Modular Mold: constructed with standardized units or dimensions for flexibility and variety in use

Flexible mold: A coating mold made of flexible rubber or other elastomeric materials; used mainly for casting plastics.

Why Modular/Flexible mold?

- ✓ In order to reduce the production cost of casting
- ✓ Reduce mold rejection, sand rejection, etc.
- ✓ Recycling/Reusability of mold for making parts

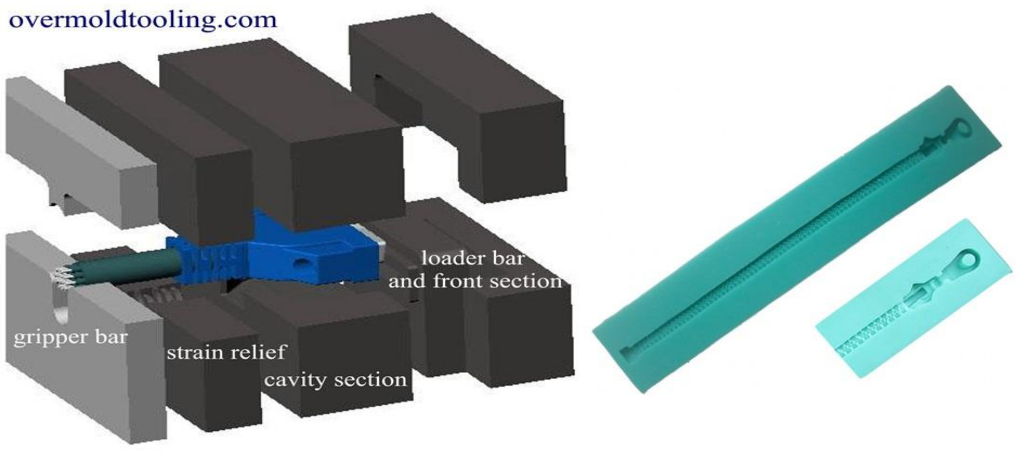


Figure 14: Modular and Flexible mold respectively
Image source:www.overmoldtooling.com

Cost involved:

In order to design the best modular mold/Flexible mold, so certain amount of cost should be given to that addition with the casting process

Appendix 1:

About company:

ATOA Scientific Technologies (ATOAST) is an Engineering simulations service provider. We provide advanced Computer Aided Engineering (CAE) simulation for material, product, process and system design. We leverage cutting edge research in computational mechanics, multiphysics modeling, material, system and application technology for providing innovative CAE simulation or engineering design solution to our clients.

We partner with our clients for, new product development, performance improvement and cost reduction through engineering simulations using state of the art software tools and methodology for virtual material, product, process and system design.

The core competency of the products will be always with the clients. We help our clients to accelerate the product development by leveraging ATOASTs virtual simulation and multiphysics engineering design core competency.

We provide engineering services for, Design, Analysis, Manufacturing, Support, Research and innovation for Material, Product, Process and System. Cost and Value engineering is also part of the services. We offer, simulation services in the following engineering domain,

- ✓ Structural Engineering
- ✓ Thermal Engineering
- ✓ Vibration and Dynamics
- ✓ Fatigue Life Prediction
- ✓ Crash Impact Analysis
- ✓ Computational Fluid Dynamics
- ✓ Acoustical, NVH Analysis
- ✓ Optical Ray Tracing
- ✓ Electromagnetics Analysis
- ✓ Chemical Reaction and Transport
- ✓ Biomedical and Bioengineering.
- ✓ Leverage us for CAE engineering Innovation

In order to benefit our clients ATOA has also ventured into 3D printing, Engineering Apps development, CAE Images

VISION

- ✓ The Business vision of ATOAST is to become a global leader for Multiphysics engineering Simulation solution provider for every successful product, process, material and system design for our clients.
- ✓ The technical vision of ATOAST is to proliferate multiphysics engineering simulations and material unity for innovative material, product, process and system design, by bridging Atom to Application.
- ✓ The social vision of ATOAST is to support economic empowerment of the society with a focus on sustainable technology solution development.

MISSION

- ✓ The business mission is to Provide high quality, cost effective, customer centric engineering services for virtual Innovative material, product, process and system development using state of the art tools and Technology.
- ✓ The technology mission is to devote 20% of our resources for Research and Innovation to develop breakthrough technology development for the benefit of our clients.
- ✓ The social mission is to redirect or invest 10% of our profit or resources for the benefit of society or sustainable social causes.

CODE OF HONOR:

- ✓ **COH 1:** Client First
- ✓ **COH 2:** Grow client and self by 100:20
- ✓ **COH 3:** Cultivate Technology Depth
- ✓ **COH 4:** Invent and Innovate for the field
- ✓ **COH 5:** Win Win

For More details about company visit:
apps.atoa.com - Android apps and IOS apps for engineering problems
3d.atoa.com - Official 3D printing Website of ATOA
ajf.atoa.com - ATOAST jyothi foundation
CAE.atoa.com - Where you can find the CAE images
Casting Cost estimation Tool:
https://docs.google.com/spreadsheets/d/1HiiEqBHt6ki3UtxnjbJiKgp8NJHSJX4npKlcKCQ0ANA/edit#gid=1100404221

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Useful sites:

http://www.valuebasedmanagement.net/methods
www.3ders.org/applications
www.forbes.com
www.technologyreview.com
www.overmoldtoolings.com
www.academia.edu
www.newscientist.com
www.stratyss.com