An Introduction to
Design for Manufacture (DFM)

and our core manufacturing processes:

- Plastic Molding
- Sheet Metal
- Rapid Prototyping/3D Printing
- Bar & Tube Fabrication
- Metal Casting
- Machining

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Understanding Manufacturing Cost of Consumer Products

– predominantly Sheet metal and Injection Molded Plastic

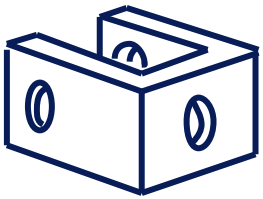
Look at retail prices…divide by 3!

Design for Manufacture (DFM) Overview

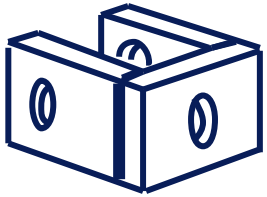
- **Product Development teams need to know cost early in design to do what-if analysis and explore alternative designs before expensive hard tooling decisions finalized**
- **aPriori's integrated CAD/DFM software utilizes 3D CAD's mathematical definition of the part/assembly to provide instant cost estimates as you create geometry.**
- **Necessary today due to high overseas competition and overseas sourcing opotunities**
- **Need to know early if cost targets are being met - redesign if necessary before its too late.**

Design for Manufacture (DFM) Example

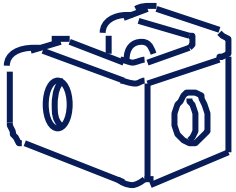
A simple fork end for Pneumatic Piston



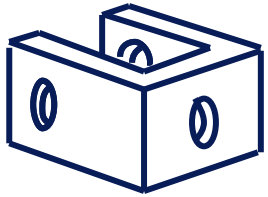
Machine from Solid



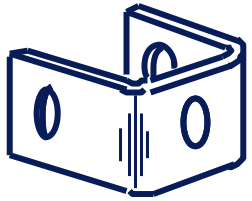
Welded Assembly



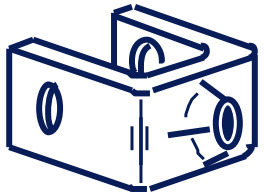
Casting



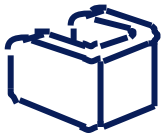
Stock Channel



Sheet Metal



Injection Mold



$95 **$75** **$55** **$25** **$1.20** **$0.30**

Piece-part costs

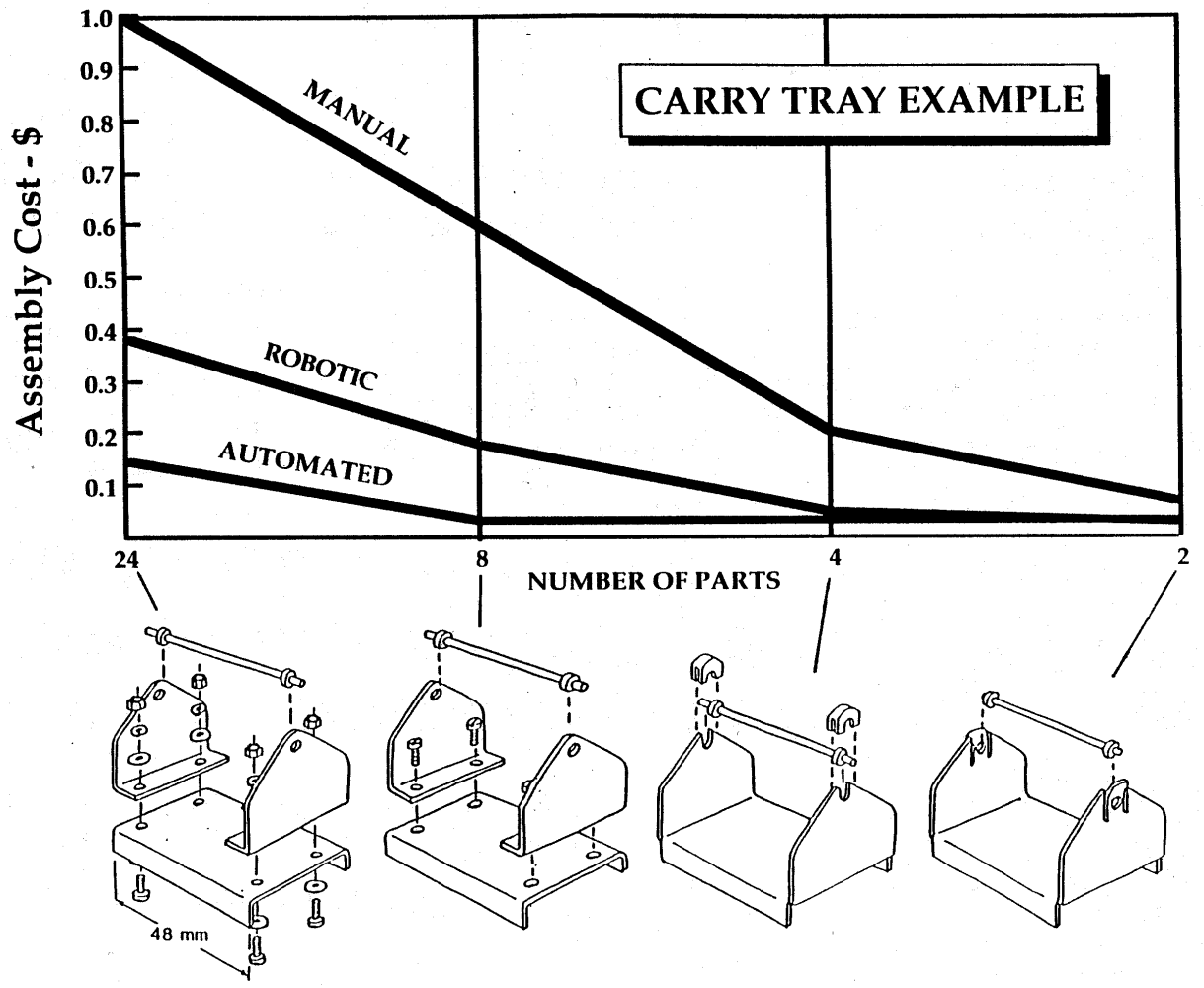
$10 **$100** **$400** **$8** **$5,000** **$60,000**

Tooling costs

Production Volume: Recurring Costs versus Non-Recurring Costs

Design for Assembly (DFA)

Fewer Parts generally means lower overall mfg.cost

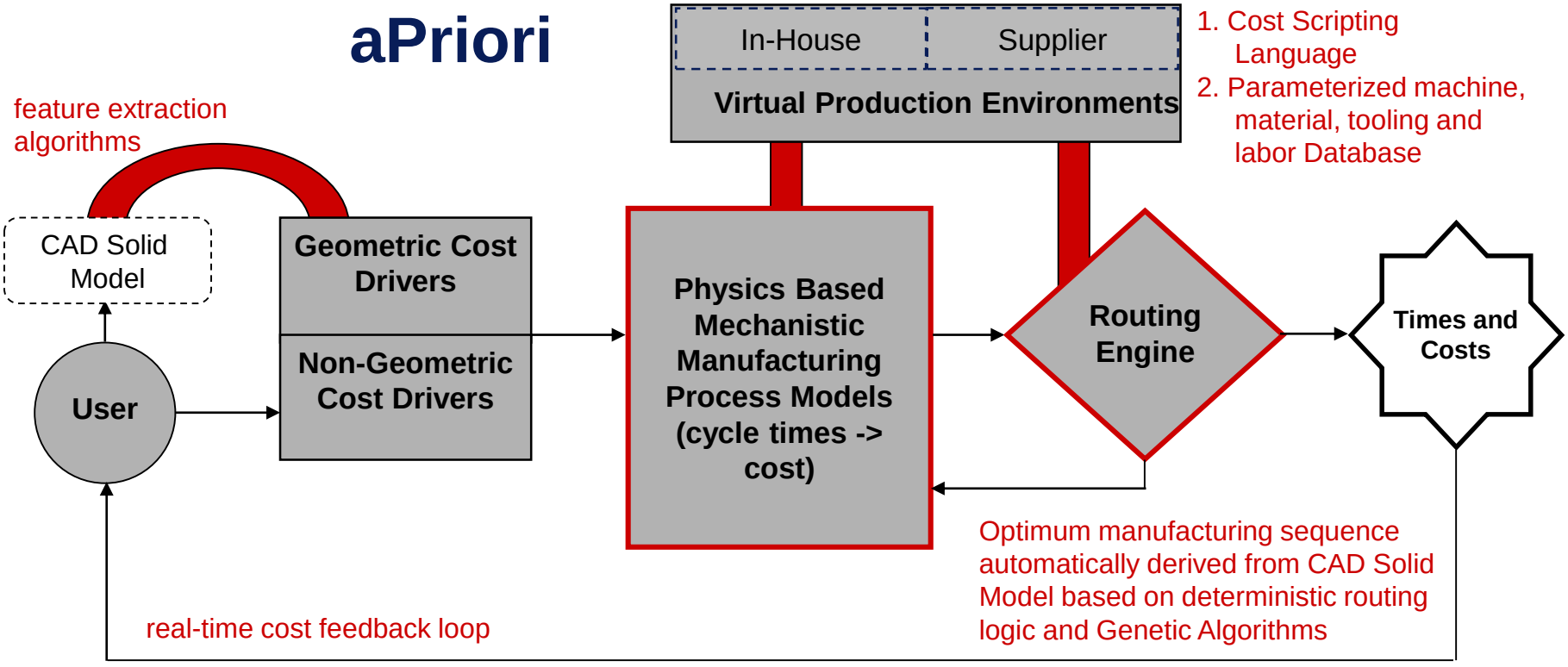


Number of Parts:	*24*	*8*	*4*	*2*
Assembly Time (s):	*100*	*38*	*10*	*3*

Feature Based Costing (FBC) Research

- **CAD-integrated feature recognition and extraction methodology to provide engineers with accurate real-time cost feedback during design.**

- **Industry/University Collaborative research project: Started in 1992 with UIUC / John Deere Collaboration - now commercialized www. aPriori.com***



** Philpott, M.L., "Integrated Real-Time Feature Based Costing (FBC)," U.S. Patent No. 7,065,420, June 20, 2006*

Cost Accounting

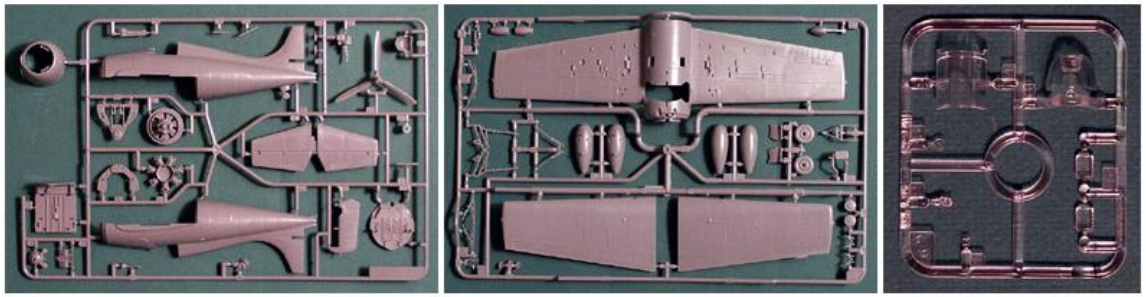
Insights and Cost Reduction Opportunities

Cost Statement - Calculated Results (one process, one part)

Direct Variable Costs:			
Material Cost	$1.22	=	Part Weight * Raw Material Cost Per Kg / Material Utilization
Labor Cost	$0.36	=	Labor Time * Labor Rate
Direct Overhead	$0.47	=	Cycle Time * Labor Rate* Overhead Rate
Subtotal	$6.00	=	Material Cost + Labor Cost + Direct Overhead
Expendable Tooling	$0.11	=	Expendable Tooling Cost
Set-up costs	$0.27	=	Set-upTime * LaborRate / (AnnualVolume * NumberOfParts / BatchesPerY
Additional Direct Costs	$0.00	=	Additional Direct Costs (none)
Other Direct Costs	$0.38	=	Expendable Tooling + Set-up Costs + Additional Direct Costs
Piece Part Cost	$6.38	=	Material Cost + Labor Cost + Direct Overhead + Other Direct Costs
Direct Fixed Costs:			
			AmortizationVolume = AnnualProductionVolume*NumberOfParts*ProductLife = 5,000
Direct Fixed Costs:			
Hard Tooling	$3.00	=	CapitalTooling / (AmortizationVolume)
Fixtures and Jigs	$0.00	=	CapitalFixtures&Jigs / (AmortizationVolume)
Programming Cost	$0.03	=	ProgrammingTime * LaborRate / (AmortizationVolume)
Amortized Investment	$3.03	=	Hard Tooling + Fixture and Jigs + Programming Cost
Total Cost	$9.42	=	Piece Part Cost + Amortized Investment

Plastic Molding

Injection Molding: Standard IM, Structural Foam Molding. Reaction Injection Molding (RIM)



KEY COST DRIVERS

- *Wall Thickness (typical: 1- 2mm)*
- *Undercuts - side Actions in the mold*
- *Number of cavities in the mold*

Roll over image to zoom in

Presto 02910 Salad Shooter Electric Slicer/Shredder

by Presto

4.5 out of 5 stars | 2,253 ratings | 247 answered questions

Amazon's Choice for "salad shooter electric"

List Price: ~~$49.99~~
Price: $35.91 prime FREE One-Day & FREE Returns
You Save: $14.08 (28%)

Get $70 off instantly: Pay $0.00 ~~$35.91~~ upon approval for the Amazon Prime Rewards Visa Card. No annual fee.

Package Quantity: **1**

Size: **NULL**

- Presto 02910 Salad Shooter
- One ingredient after another can be added without cleaning in between
- Shoots food right into a salad bowl, onto a pizza, or into soup
- Interchangeable slicing and shredding cones easily attach
- The product is from China.Wattage Output: 125 watts
- The fast and convenient way to slice or shred vegetables, fruits, and cheese for delicious salads, soups, pizzas, tacos, desserts and more.
- Grate chocolate, chop nuts, and make bread and cracker crumbs quickly and easily. Shoot ingredients right where you want, with no extra bowls to clean!

Show more

Compare with similar items

New & Used (72) from $19.52 prime FREE Shipping

Roll over image to zoom in






2 VIDEOS

The New York Times

COMPANY NEWS

COMPANY NEWS; PRESTO IS AWARDED $2.35 MILLION IN PATENT LAWSUIT

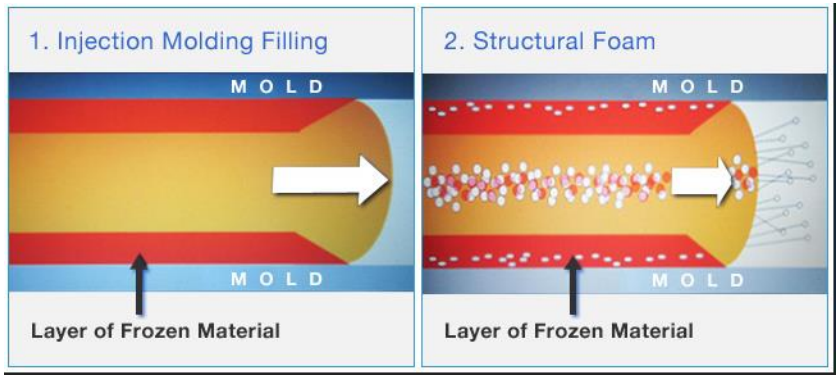
AP

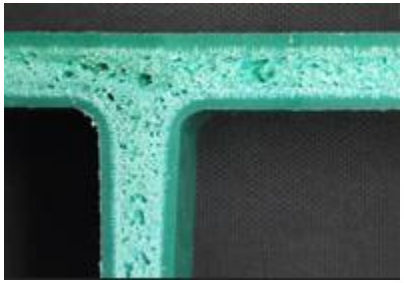
June 9, 1992

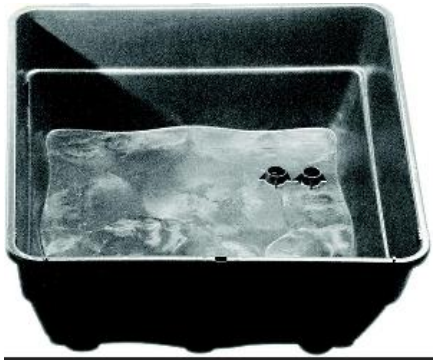
A Federal jury in Chicago has ordered the Black & Decker Corporation to pay $2.35 million to National Presto Industries for infringing Presto's Salad Shooter patent. Presto, based in Eau Claire, Wis., filed the lawsuit in 1989, contending that Black & Decker's Handy Slice 'N' Shred infringed the patent for Salad Shooter, an electric slicer and shredder, which is one of Presto's most popular products. In March, the jury said that Black & Decker infringed the patent, that Black & Decker's patent was invalid and that Presto was entitled to $2.35 million. Presto did not announce the award until Friday, after several Black & Decker motions were denied. A spokesman for Black & Decker, based in Towson, Md., said the company planned to appeal the ruling.

Structural Foam Molding

Thick parts => ¼ inch (6mm)







Blow Molding and Rotational Molding

Blow molding

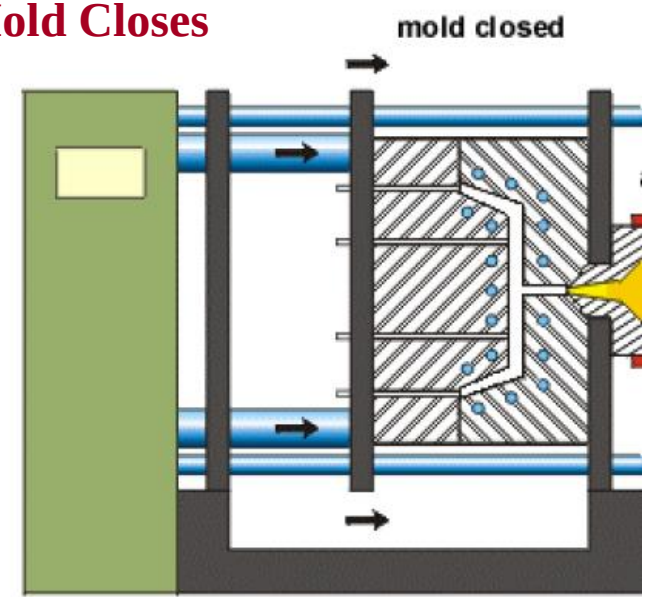
Bottles and small disposable containers

Rotational molding

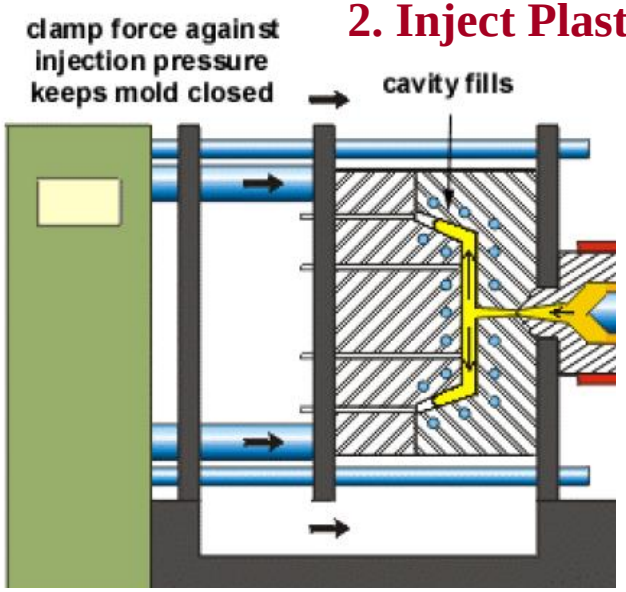
larger hollow shapes.

Injection Molding

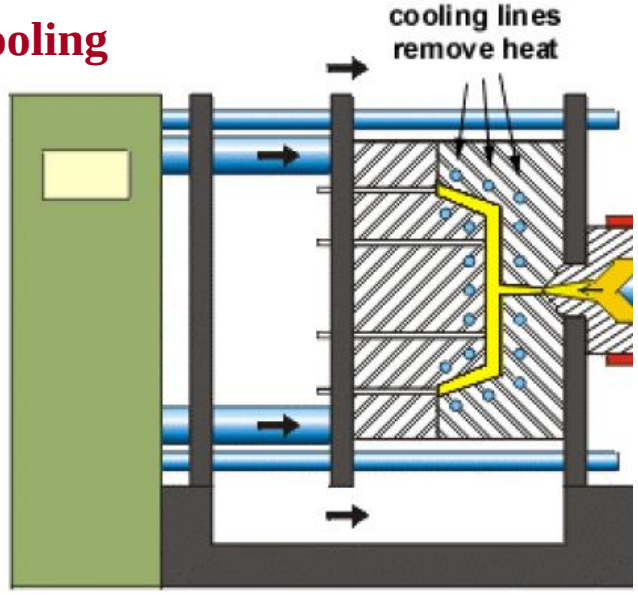
1. Mold Closes



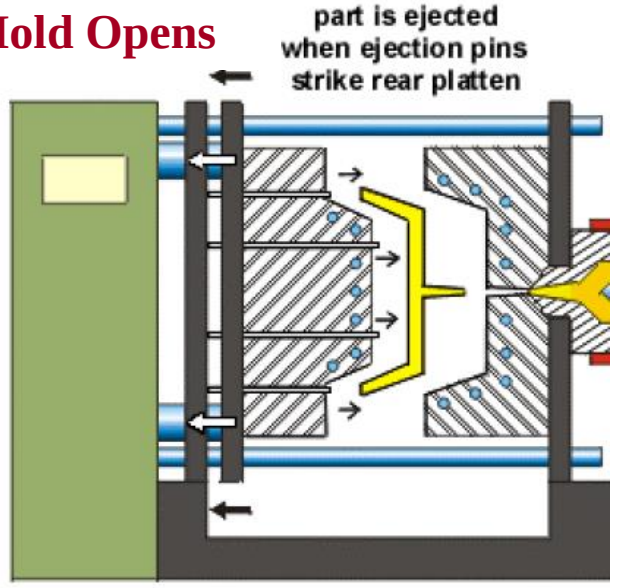
2. Inject Plastic



3. Cooling

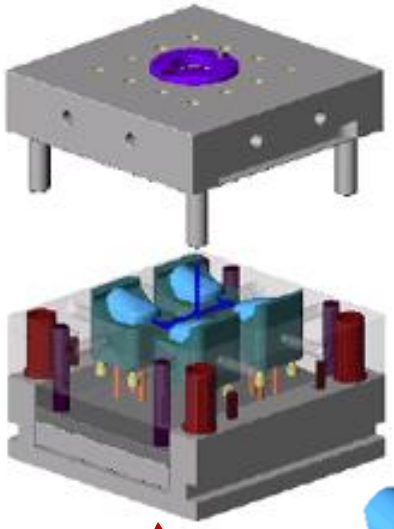


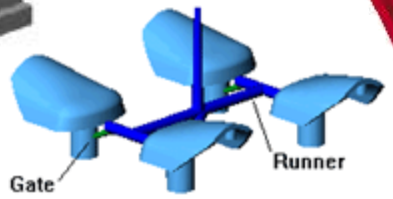
4. Mold Opens

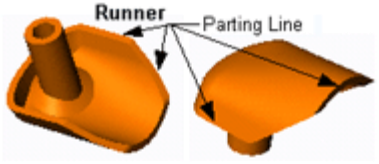


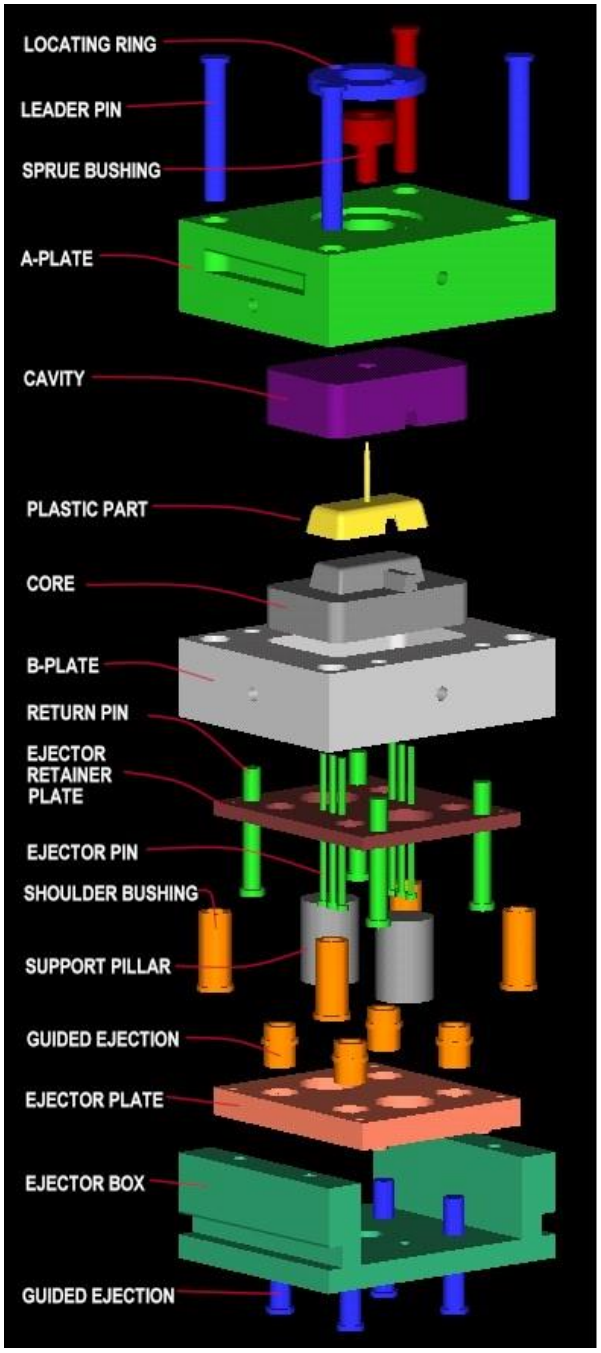
Labor Cost = (Mold Close time + Injection Time + Cooling Time + Mold Open time) * $/hr rate

The Mold
(Tooling)

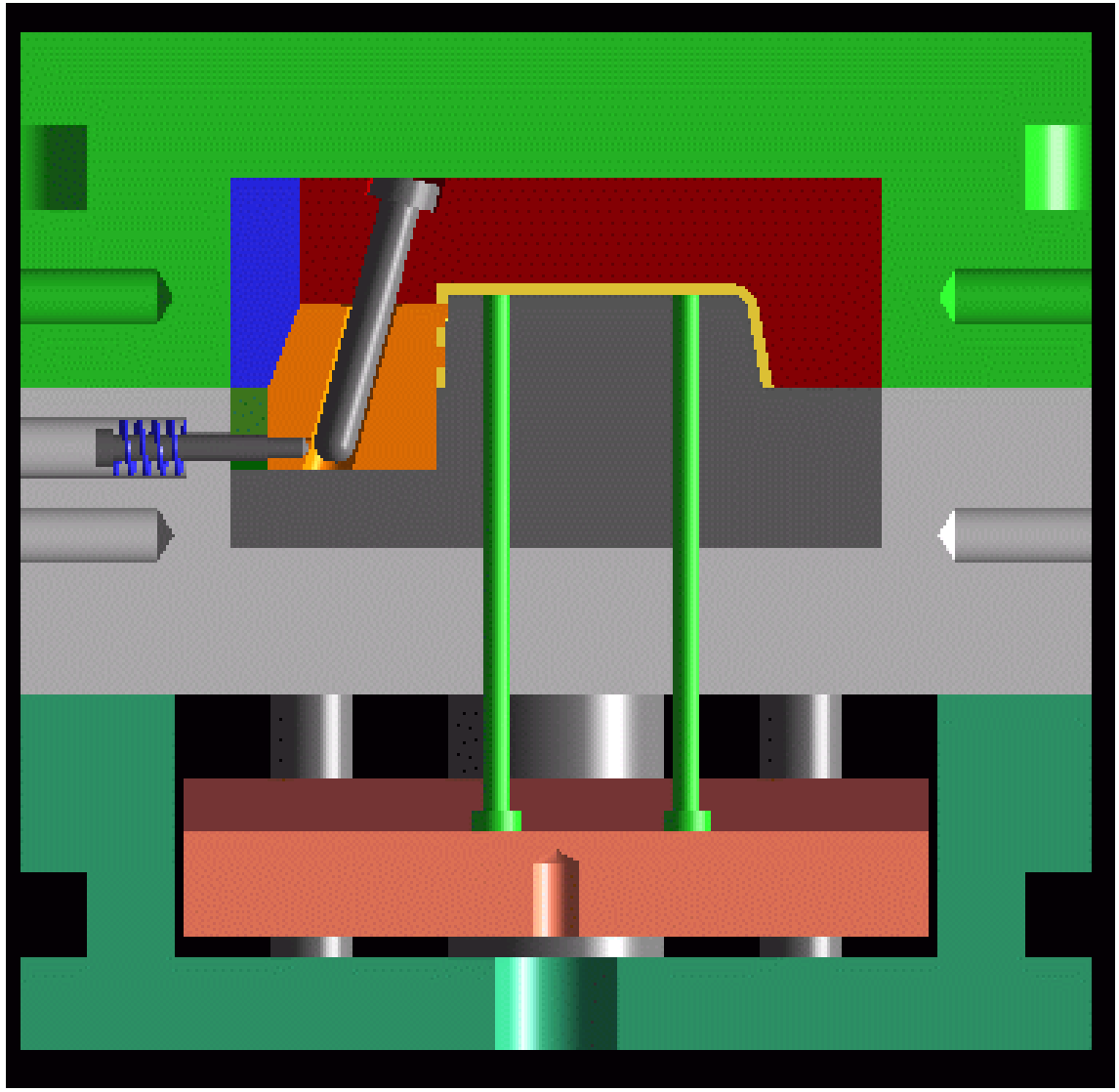




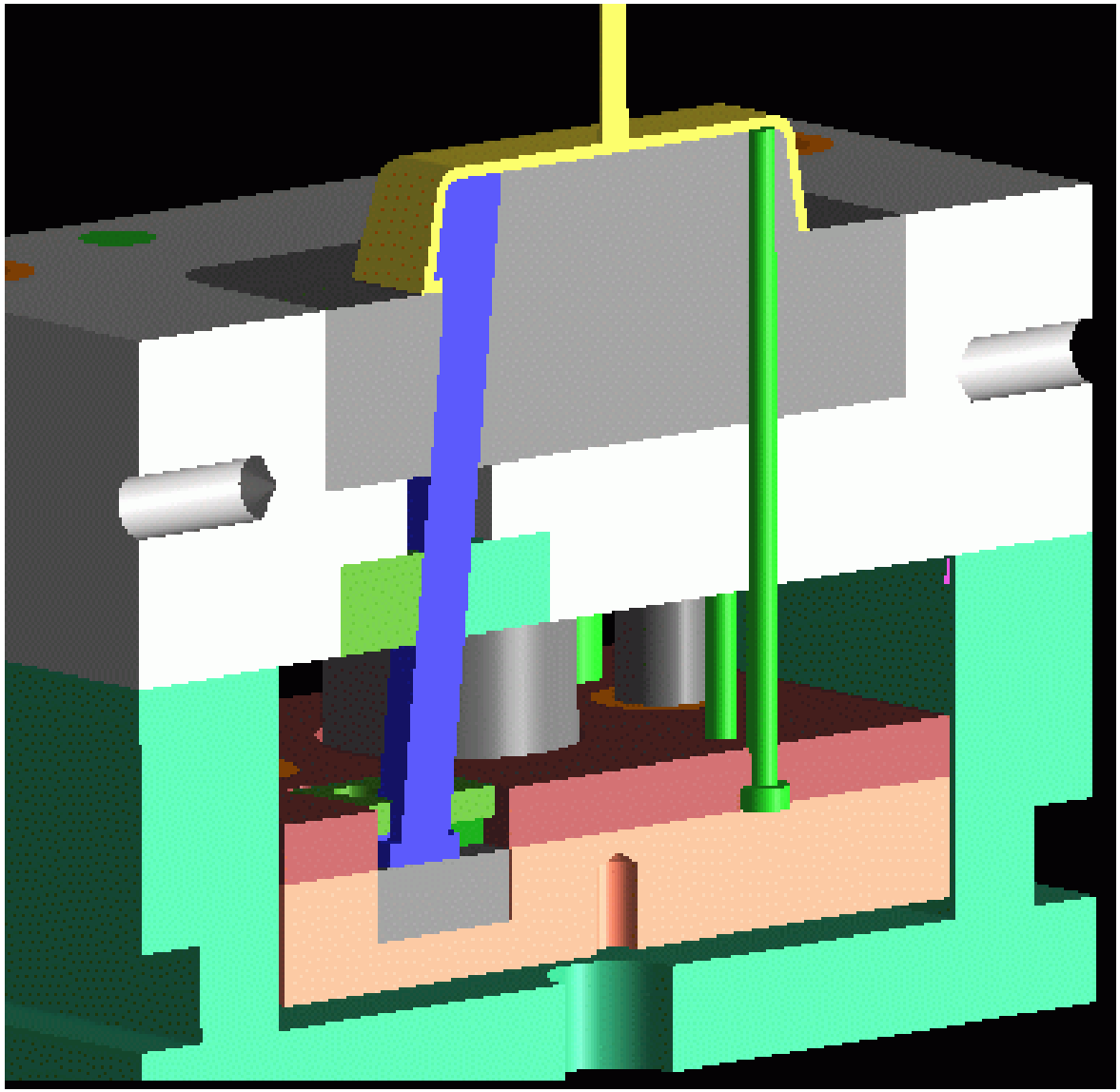




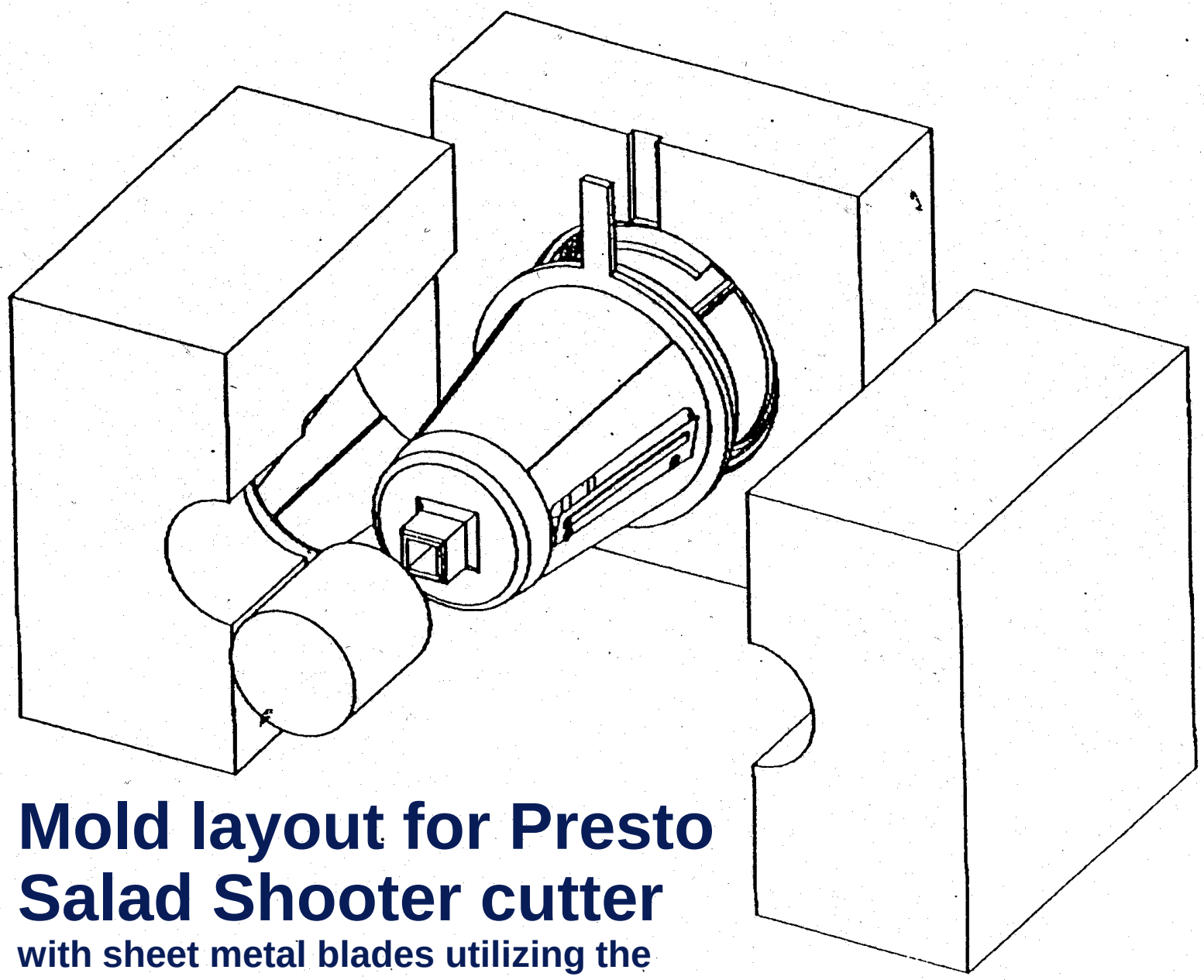
Tooling Cost = Cost to design and build this mold tool



Moving Side Cores or ‘Slides’



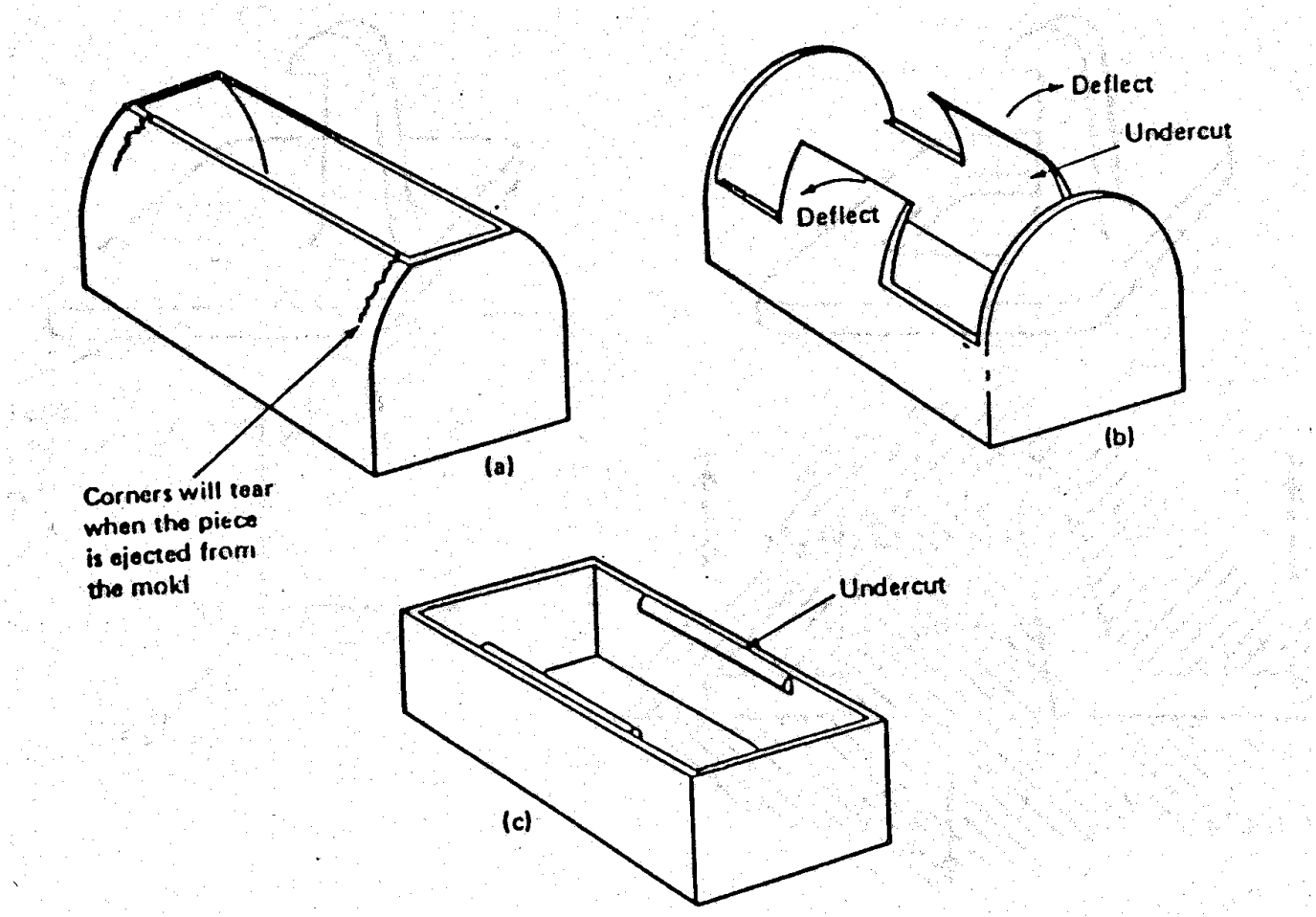
Moving Internal Cores or ‘Lifters’



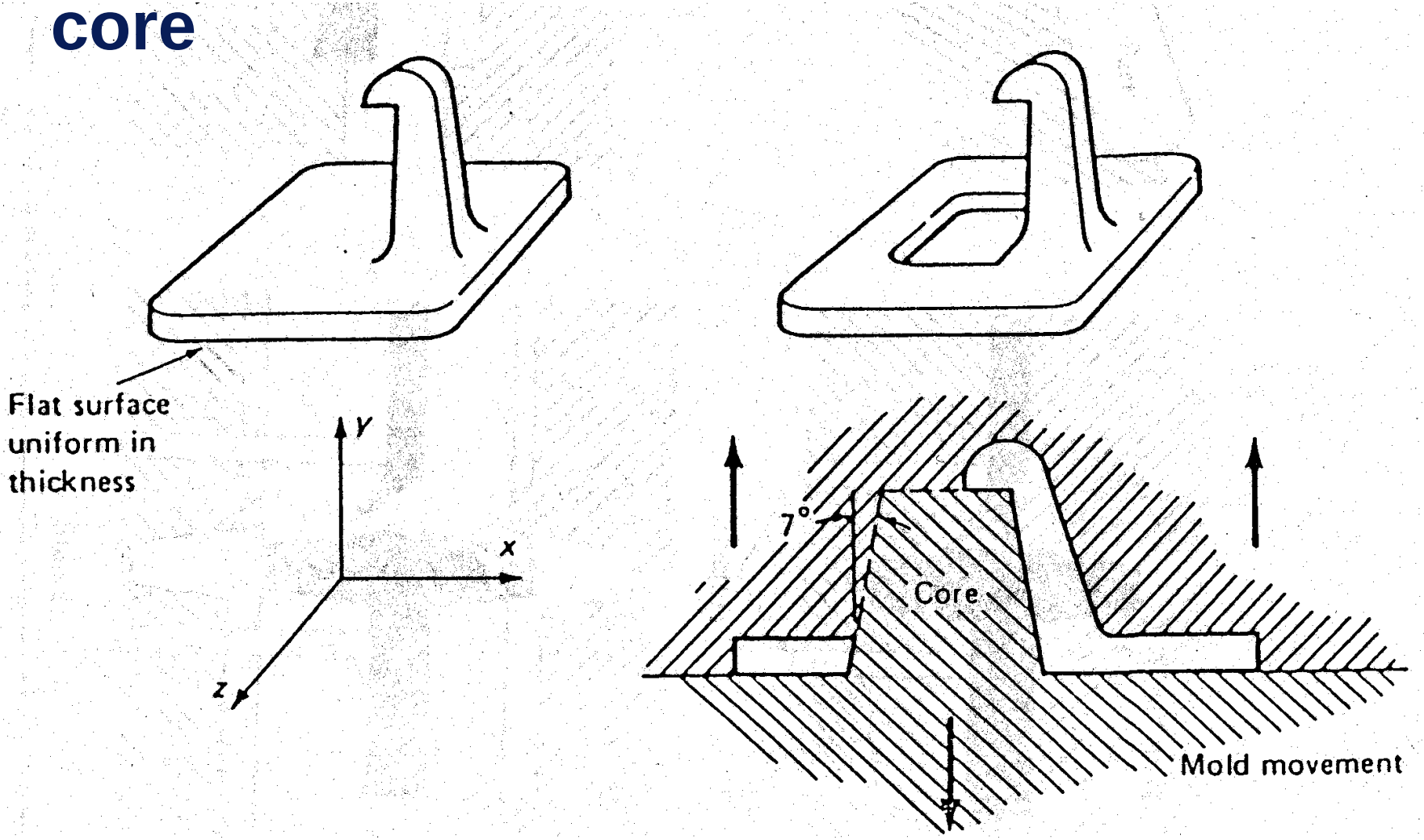
Mold layout for Presto Salad Shooter cutter

with sheet metal blades utilizing the "Insert Molding" process

Avoiding Moving Side Cores and Lifters (1) – allow feature to deflect as part is ejected from the mold



Avoiding Moving Side Cores and Lifters (2) – provide relief hole for core



Off-the Shelf Screw-on Hinges v. Molded-in hinges

Off-the-shelf screw-on hinges are rarely an economic in consumer products as not economic; too many parts. Long assembly times screwing fasteners in etc.

Molded-in hinges, snap fits, living hinges…more cost effective

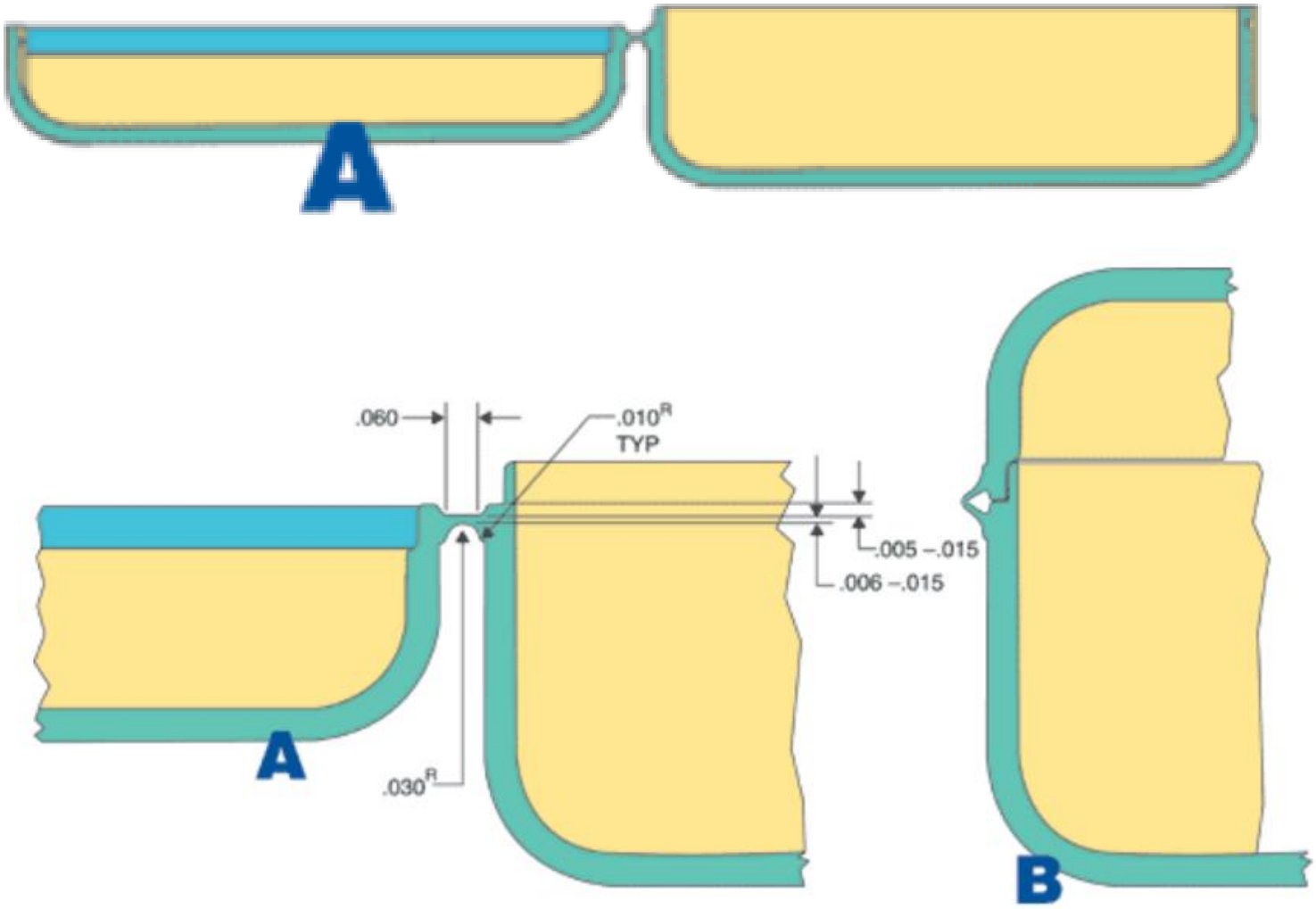
Molded-in Hinges

and Flexible Straps

Integral Hinges – not just in plastics!

Living Hinges

Single mold rather than two….limited to polypropylene for durable hinge life

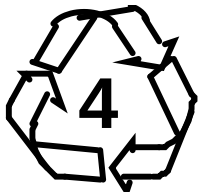


https://www.plasticstoday.com/materials/design-polypropylene-part-design-part-2-living-hinges/2085268932270

Common Thermoplastic Materials (1)

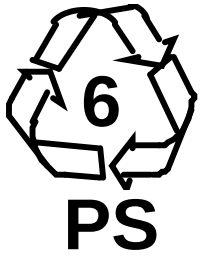
Polyethylene - HDPE & LDPE (1.2¢/cu. in)

Lightweight, easy to process, low cost material. Poor dimensional stability and heat resistance. Excellent chemical resistance and electrical properties.



Polypropylene (1.5¢/cu. in): Outstanding resistance to flex and stress cracking. Excellent chemical resistance and electrical properties., Good impact strength above 15^{o}F. Good thermal stability, light weight, low cost. Some grades can be electroplated.

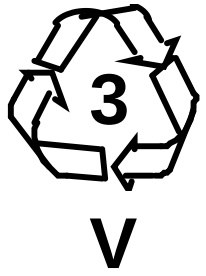
Polystyrene (1.7¢/cu. in): Low cost, easy to process, rigid, crystal-clear, brittle. Low moisture absorption, and heat resistance. Poor outdoor stability.



Resin Plastic Recycling Codes		
Resin Code	Technical Name	Typical Uses
	PETE, Polyethylene Terephthalate	soft drink bottles, deli trays, Mylar film, clear shampoo bottles, mouthwash bottles.
	HDPE, High-Density Polyethylene	Tupperware, milk jugs, dishwashing detergent containers, juice containers, opaque shampoo bottles, oven cleaner bottles, insecticide bottles, yogurt containers
	PVC, Polyvinyl Chloride	plumbing pipes, construction materials, vinyl records, opaque shampoo bottles,
	LDPE, Low-Density Polyethylene	grocery bags, dry cleaning bags, aquarium tubing.
	PP, Polypropylene	appliance parts, Tic Tac hinge lids, drinking glasses, mustard squeeze bottles, margarine containers, pudding containers
	PS, Polystyrene	styrofoam cups.
	Other plastics, including acrylic, polycarbonate, nylon, Kevlar, fiberglass.	compact discs, DVDs.

Common Thermoplastic Materials (2)

PVC (2.2¢/cu. in):
Rigid grades are hard, tough, and have excellent electrical properties, outdoor stability, and resistance to moisture and chemicals. Flexible grades are easier to process but have lower properties. Heat resistance is low, and low cost.

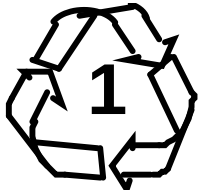


ABS (2.9¢/in3): Very Tough, hard, and rigid. Fair Chemical resistance. Low Water absorption and good dimensional stability. High abrasion resistance. Some grades are easily electroplated.

Acrylic (3.1¢/cu. in) Hard , glossy surface and high optical clarity. Fair Chemical resistance. Excellent resistance to outdoor weathering. Available in brilliant, transparent colors. Excellent electrical properties.

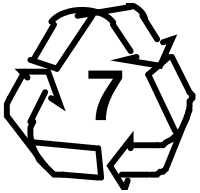
Common Thermoplastic Materials (3)

PETE (4.9¢/cu. in)



Crystal clear and hard. Used widely for shampoo bottles. Good moisture, and chemical resistance. Good dimensional stability.

Acetal (5.8¢/cu. in)



Very Strong, stiff, and low tendency to stress crack. High resistance to chemicals. Retains most properties when immersed in hot water. Exceptional dimensional stability. High abrasion resistance. Low coefficient of Friction.

Polyurethane (6.1¢/cu. in)

Tough, extremely abrasion and impact-resistant. Good electrical properties and chemical resistance. UV exposure causes brittleness, lower properties, and yellowing.

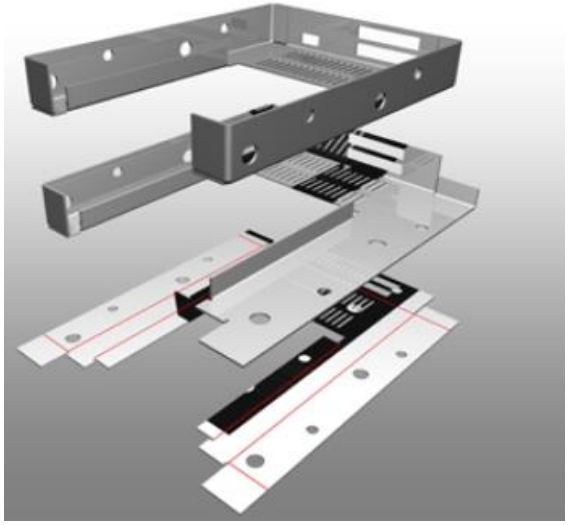
Common Thermoplastic Materials (4)

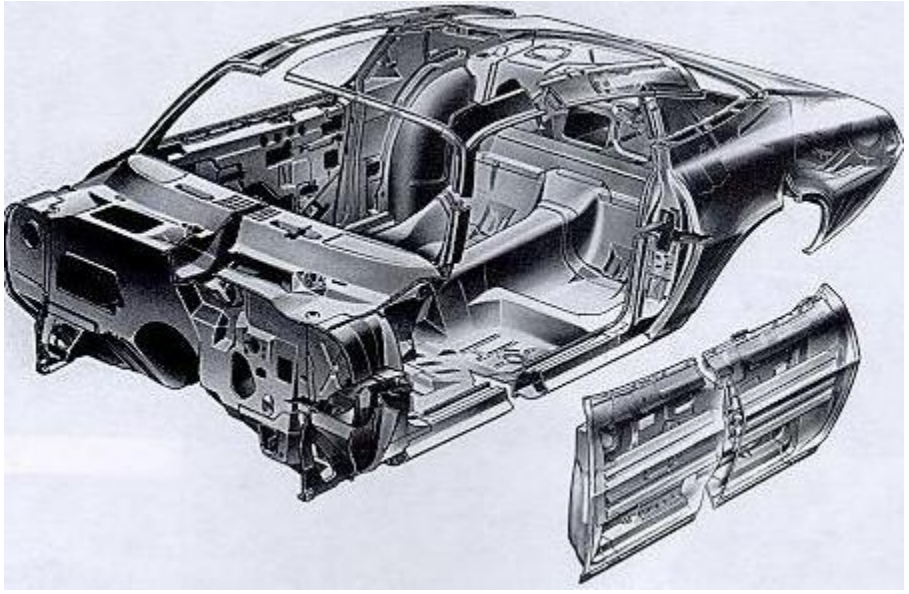
Nylon (6/6-5.9 ¢/cu. in;6/12 - 9.0 ¢/cu. in; +glass -16.3¢/cu. in): Family with outstanding toughness and wear resistance. Low Coefficient of Friction. Excellent chemical resistance and electrical properties. Hygroscopic; dimensional stability is poor. Some grades are electroplatable.

Polycarbonate (6.3 ¢/cu. in): Highest impact resistance of any rigid, transparent plastic. Excellent outdoor stability and resistance to creep under load. Fair chemical resistance. Some aromatic solvents cause stress cracking.

Fluoroplastics (30 - 65¢/cu. in): PTFE, FEP, PVDF etc. Family of high cost, low-to-moderate strength. Excellent chemical resistance. Low Friction. Outstanding stability at high temperatures.

Sheet Metal Process Group





Sheet Metal – Common Production Processes

Soft Tooling - general purpose programmable machines with low-cost expendable tooling

Typical Routings: (as in aPriori)

Sheet Stock ⇨ Laser cut ⇨ [Bend Brake]

Sheet Stock ⇨ Plasma cut ⇨ [Bend Brake]

Sheet Stock ⇨ Water Jet ⇨ [Bend Brake]

Sheet Stock ⇨ Turret Press ⇨ [Bend Brake]

Hard Tooling (aka Stamping) - Processes requiring custom made high-cost molds or die sets

Production Rate ↓

Sheet Stock ⇨ Standard Press

Sheet Stock ⇨ Stage Tooling (aka Tandem die)

Sheet Stock ⇨ Transfer Press — Large Stampings (eg car Body Panels)

Coil Stock ⇨ Progressive Die — Small Stampings

Laser Cuting

Bend Brake Process

‘Soft Tooling’ for straight bends – No Custom Tooling (ie no Hard Tooling)

Bend Brake (aka Press Brake)

Turret Press Process

‘Soft Tooling’ for straight bends – No Custom Tooling (ie no Hard Tooling)

Turret Press

Bend Brake – safety!

Sheet Metal – Common Production Processes

Soft Tooling - general purpose programmable machines with low-cost expendable tooling

Typical Routings: (as in aPriori)

Sheet Stock ⇨ Laser cut ⇨ [Bend Brake]

Sheet Stock ⇨ Plasma cut ⇨ [Bend Brake]

Sheet Stock ⇨ Oxy Fuel ⇨ [Bend Brake]

Sheet Stock ⇨ Turret Press ⇨ [Bend Brake]

Hard Tooling (aka Stamping) - Processes requiring custom made high-cost molds or die sets

Production Rate ↓

Sheet Stock ⇨ Standard Press

Sheet Stock ⇨ Stage Tooling (aka Tandem die)

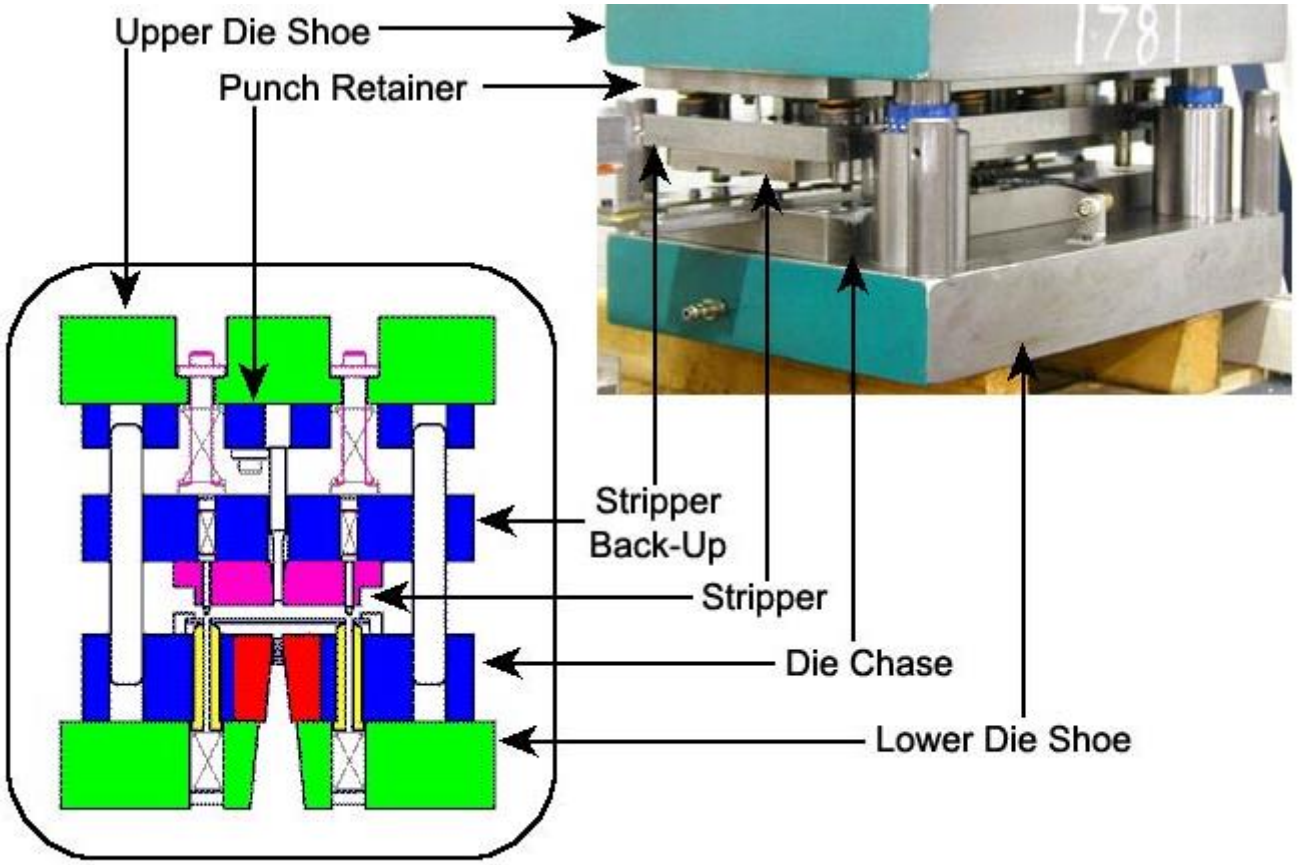
Sheet Stock ⇨ Transfer Press — Large Stampings (eg car Body Panels)

Coil Stock ⇨ Progressive Die — Small Stampings

Progressive Die – coil fed, automatic, high-speed single press with multiple stations; coil strip transfers the part

Hard Tooling

Sheet Metal - Progressive Die Set



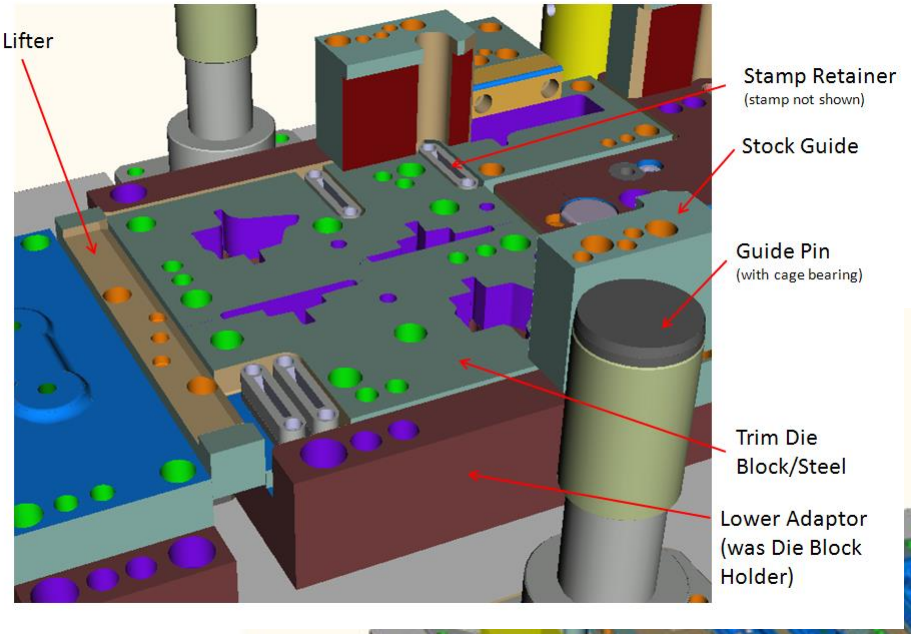
Progressive Die Tool – a tool custom designed and built to produce stamped metal parts at high speed on a Progressive Die Press (a reciprocating press)

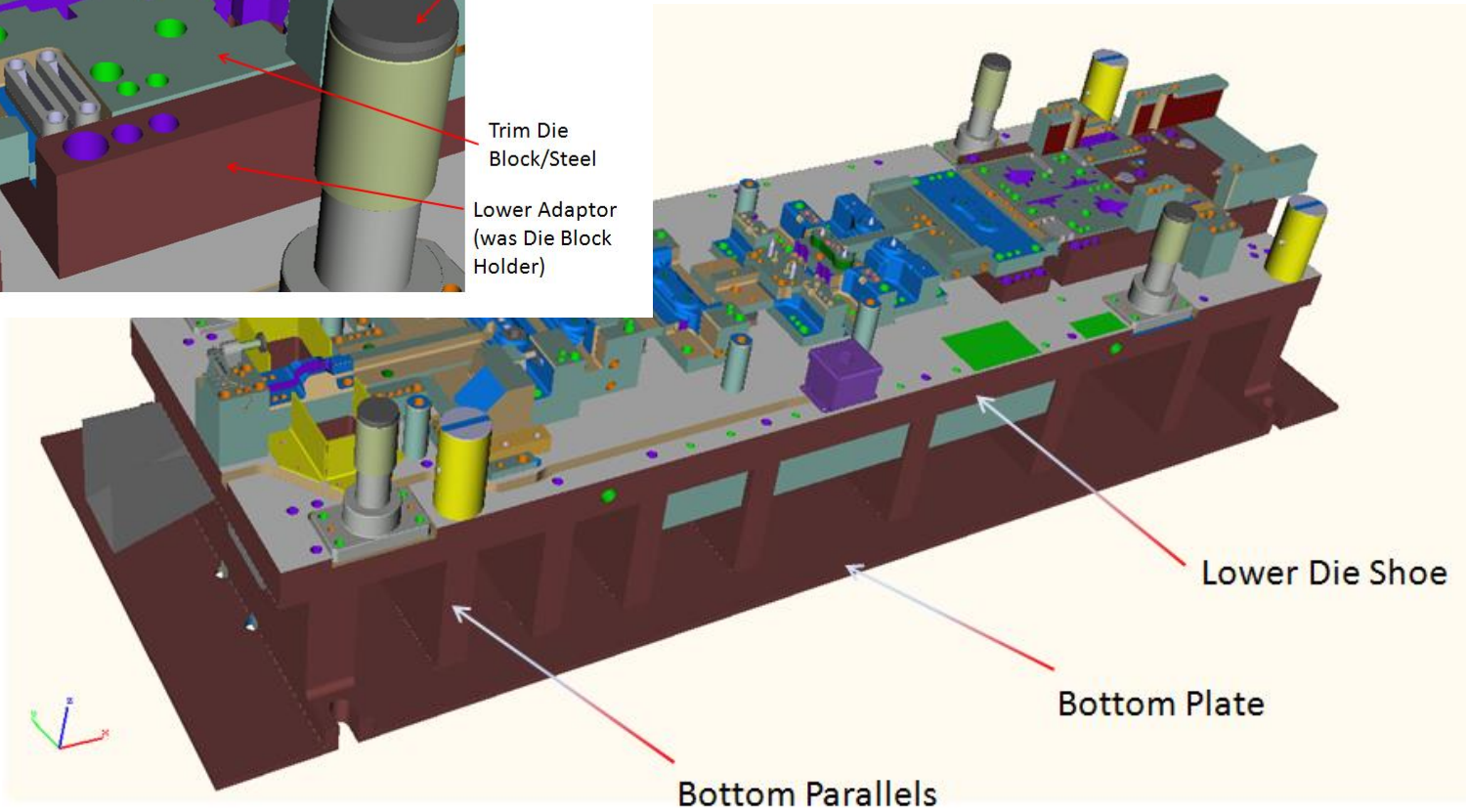
Progressive Die in Operation – 30 ppm

Progressive Die in Operation – 100 ppm

Used for Small High-Volume Stampings

Stamping Die
(i.e. Tooling)
Example





Standard Press - manual presses operated in batch mode, typically low-to-medium volume applications

Stage Tooling – manual presses organized in a production line with manual transfer of parts between presses (popular in low labor cost

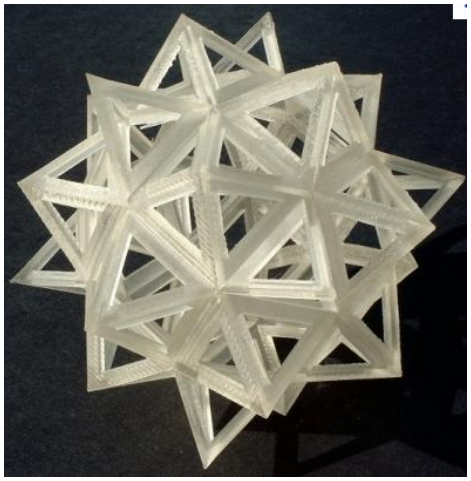
Manual Transfer inside a Press!

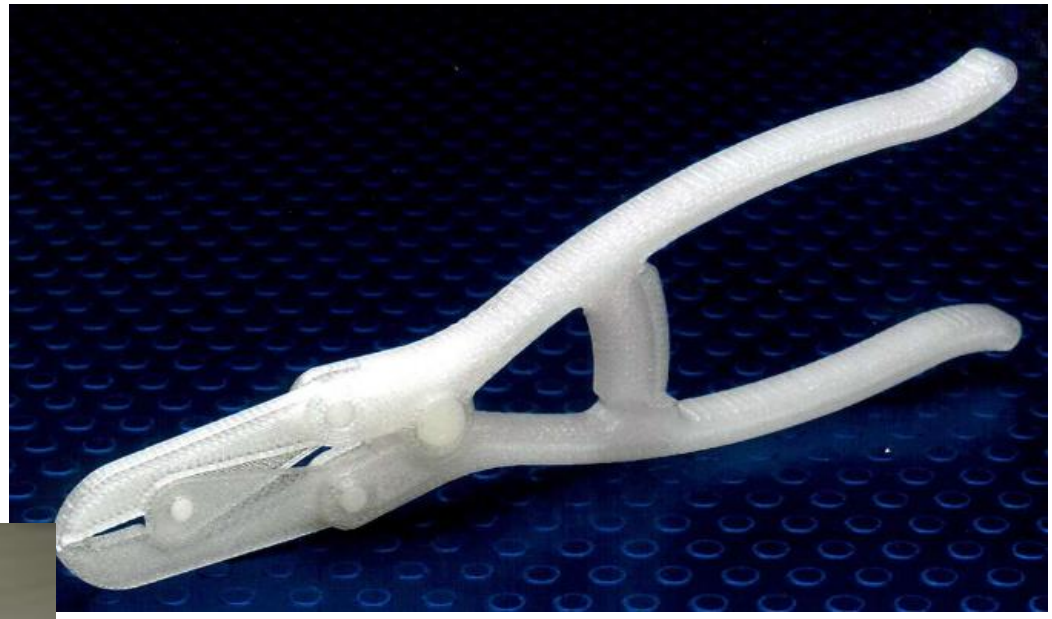
Tandem Die - manual or automatic presses organized in a production line
manual or robotic transfer of parts between presses (often a mix of manual or robotic)

Transfer Press – sheet fed, single press action with multiple dies attached to platen and transfer mechanism

Transfer Press in Operation

Used for Large High-Volume Stampings



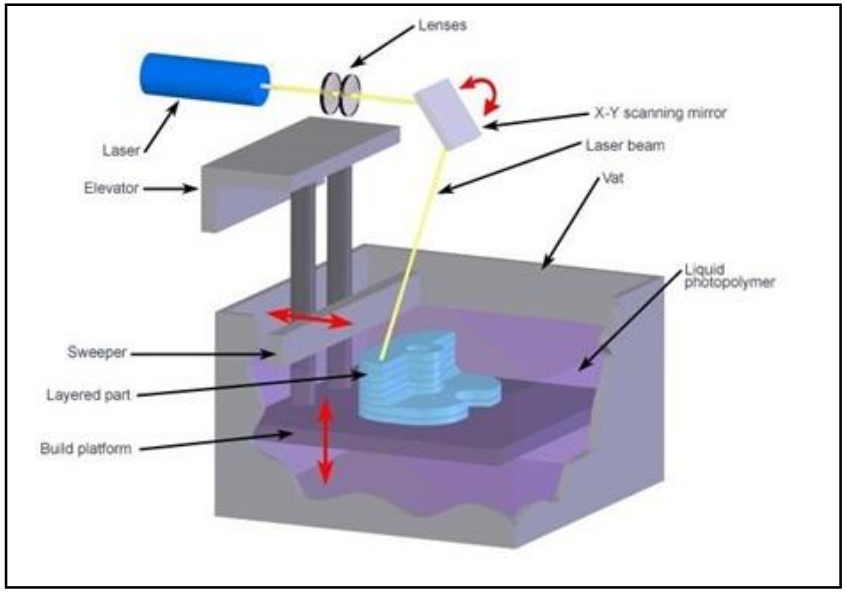


Rapid Prototyping Process Group

Rapid Prototyping Principles

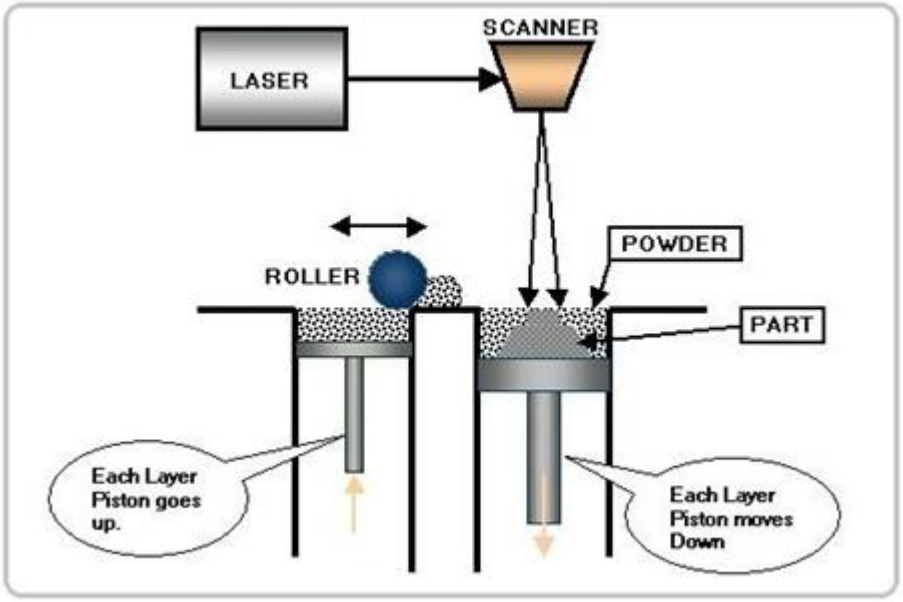
http://www.quickparts.com
MechSE Rapid Prototyping Lab

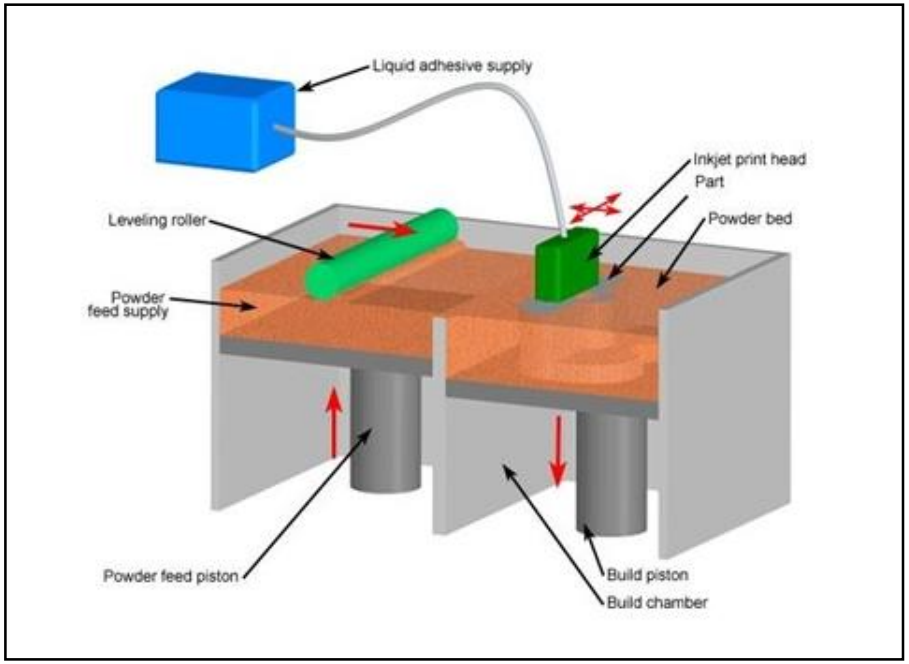
SLA



3D Printing

SLS





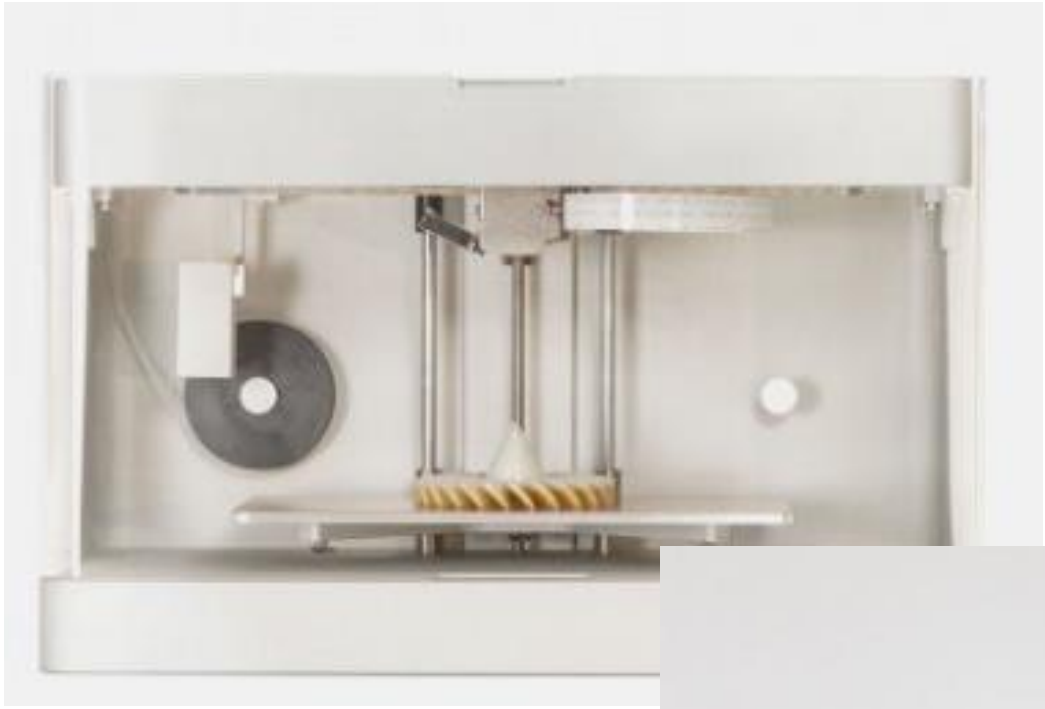
Rapid Prototyping Systems

- **StereoLithography (STL)**
- **Selective Laser Sintering (SLS)**
- **Fused Deposition Modeling (FDM)**
- **Polyjet - 3D Printer**
- **Composite 3D printer**
- **Direct Metal Laser Sintering (DMLS) – *on order***
- **Laminated Object Manufacturing**
- **Hot Plot**
- **Solid Ground Curing**
- **Light Sculpting**
- **Solid Creation System**
- **Solid Object Ultra-Violet Laser Plotting**
- **Computer Operated Laser Active Modeling**
- **Electro-Optical Systems - Stereos**

Rapid Prototyping at BMW

Cool video (click on pics)

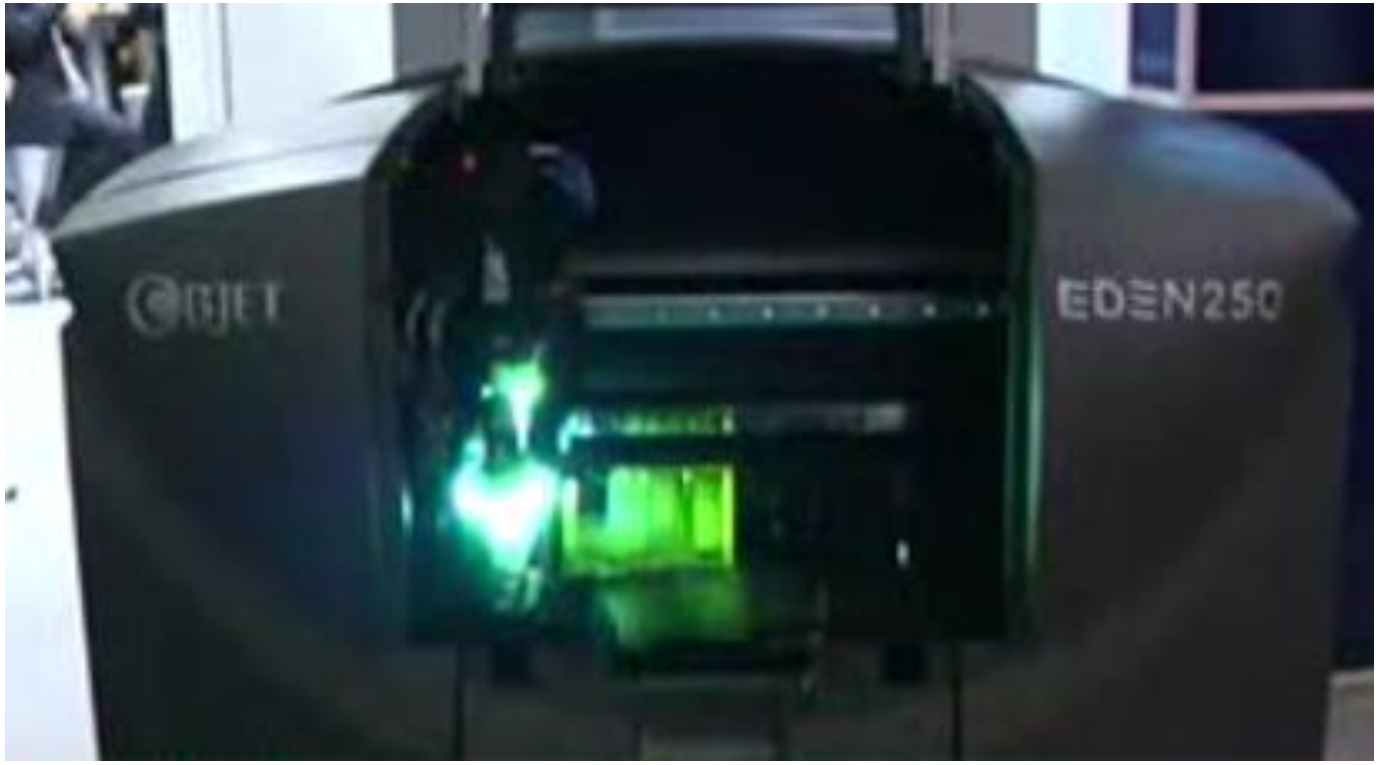
Rapid Prototyping
MechSE Ford Lab



Meet the Mark One: the world's first Carbon Fiber 3D printer ...

Stereo-Lithography Apparatus (SLA)

Polyjet Process



SLS - Sintered Laser System

EOS – Direct Metal Laser Sintering

3D Scanning &
FDM – Fused Deposition Modeling

STL Format: B-rep, solid object

- *An STL file is saved with the extension ".stl," case-insensitive.*
- *STL is a triangular facet based representation that approximates surface and solid entities only. Entities such as points, lines, curves, and attributes such as layer and color will be ignored during the output process*
- *An STL file consists of a list of facet data.*
- *Each facet is uniquely identified by a unit normal (a line perpendicular to the triangle and with a length of 1.0) and by three vertices (corners).*
- *The normal and each vertex are specified by three coordinates each, so there is a total of 12 numbers stored for each facet.*

```
BLOCK
 facet normal 0.000000e+00 -1.000000e+00 0.000000e+00
   outer loop
     vertex 0.000000e+00 0.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 0.000000e+00
     vertex 0.000000e+00 0.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 0.000000e+00 1.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 0.000000e+00
     vertex 0.000000e+00 0.000000e+00 0.000000e+00
     vertex 1.000000e+00 0.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal -1.000000e+00 0.000000e+00 0.000000e+00
   outer loop
     vertex 0.000000e+00 1.000000e+00 0.000000e+00
     vertex 0.000000e+00 0.000000e+00 -1.000000e+00
     vertex 0.000000e+00 0.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 0.000000e+00 1.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 0.000000e+00
     vertex 0.000000e+00 1.000000e+00 0.000000e+00
     vertex 0.000000e+00 0.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 -1.000000e+00 0.000000e+00
   outer loop
     vertex 0.000000e+00 0.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 1.000000e+00 0.000000e+00 0.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 0.000000e+00
     vertex 1.000000e+00 0.000000e+00 -1.000000e+00
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 endfacet
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   outer loop
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     vertex 1.000000e+00 0.000000e+00 0.000000e+00
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   endloop
 endfacet
 facet normal 0.000000e+00 0.000000e+00 -1.000000e+00
   outer loop
     vertex 0.000000e+00 1.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 -1.000000e+00
     vertex 0.000000e+00 0.000000e+00 -1.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 0.000000e+00 -1.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 -1.000000e+00
     vertex 1.000000e+00 0.000000e+00 -1.000000e+00
     vertex 0.000000e+00 1.000000e+00 -1.000000e+00
   endloop
 endfacet
 facet normal -1.000000e+00 0.000000e+00 0.000000e+00
   outer loop
     vertex 0.000000e+00 1.000000e+00 -1.000000e+00
     vertex 0.000000e+00 0.000000e+00 -1.000000e+00
     vertex 0.000000e+00 1.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 1.000000e+00 0.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 -1.000000e+00
     vertex 0.000000e+00 1.000000e+00 -1.000000e+00
     vertex 0.000000e+00 1.000000e+00 0.000000e+00
   endloop
 endfacet
 facet normal 0.000000e+00 1.000000e+00 0.000000e+00
   outer loop
     vertex 1.000000e+00 1.000000e+00 0.000000e+00
     vertex 1.000000e+00 1.000000e+00 -1.000000e+00
     vertex 0.000000e+00 1.000000e+00 0.000000e+00
   endloop
 endfacet
endsolid BLOCK
```
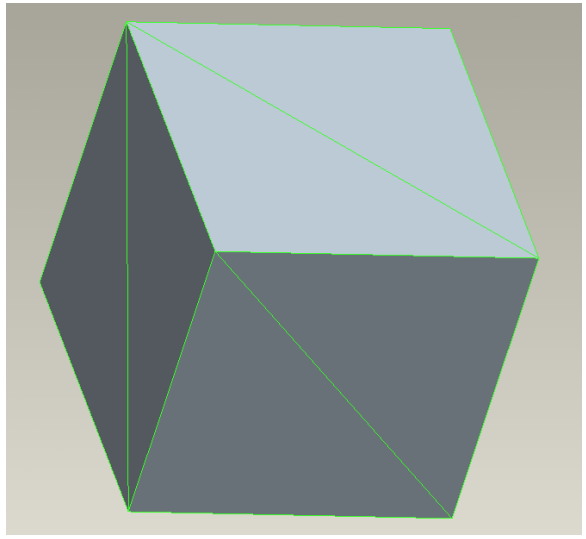
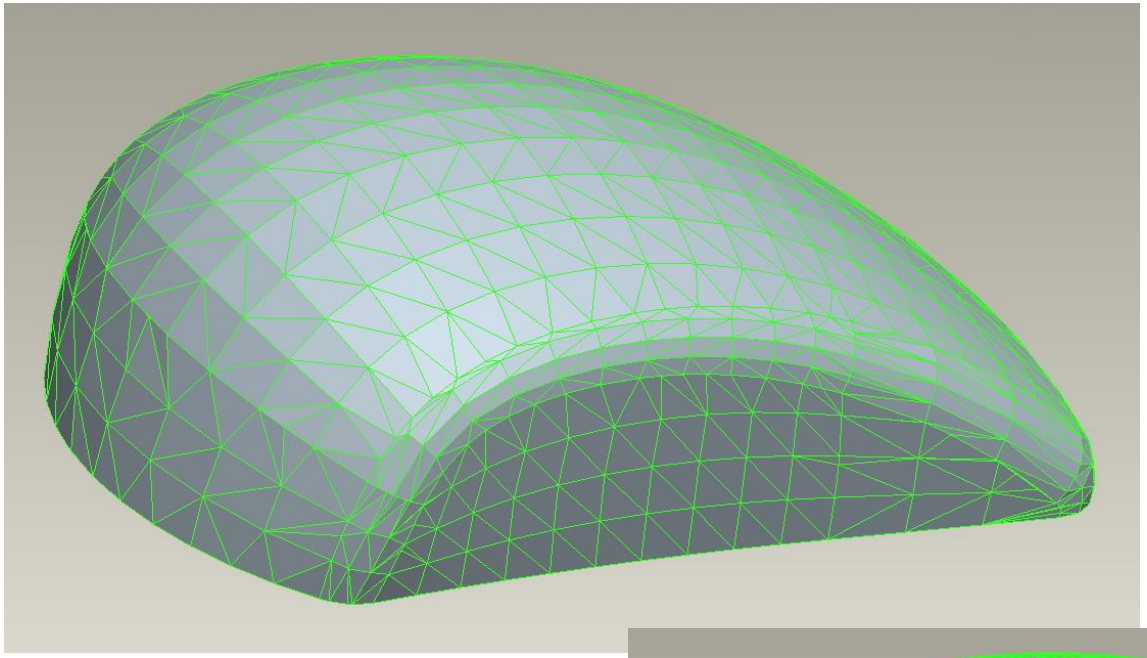
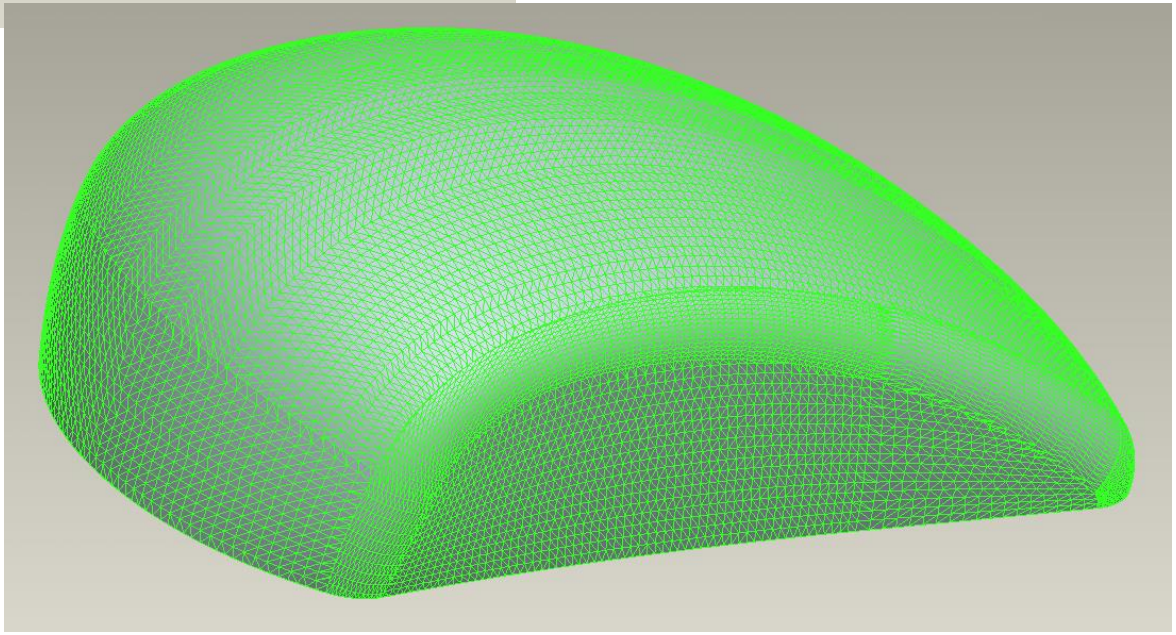



An Example STL File – Block.stl

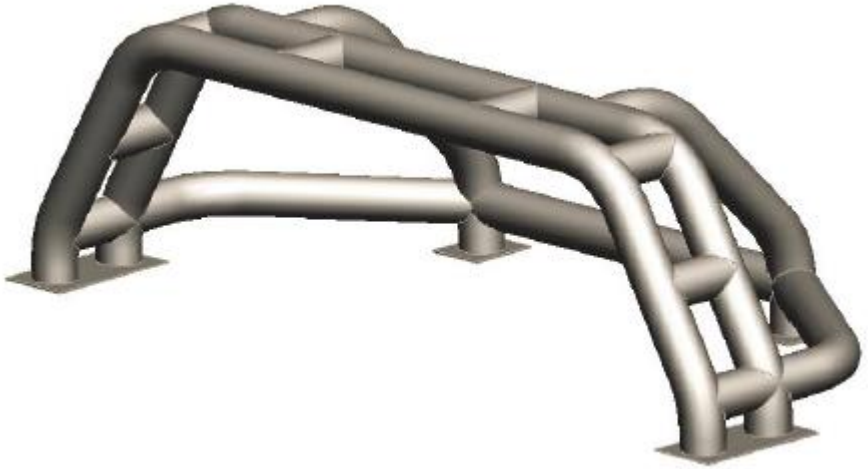


The density of triangle facets change according to the geometry



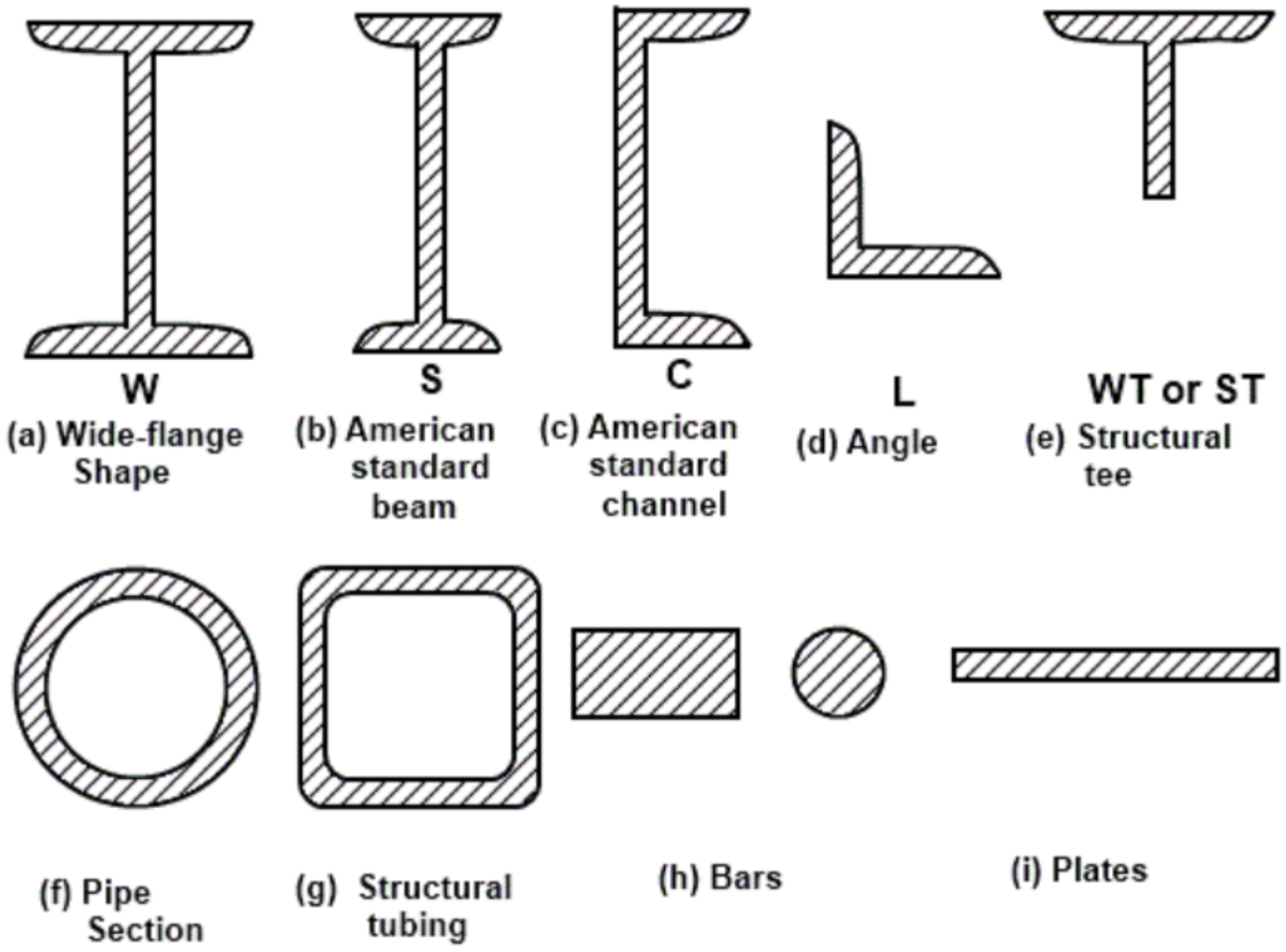
And it Changes with Chord Height affecting final surface resolution

Bar and Tube Process Group



Standard Structural Steel Shapes

Industry standard forms used in “Bar & Tube” process group



Tube/Bar Bending Processes

Bend Brake (aka Press Brake)

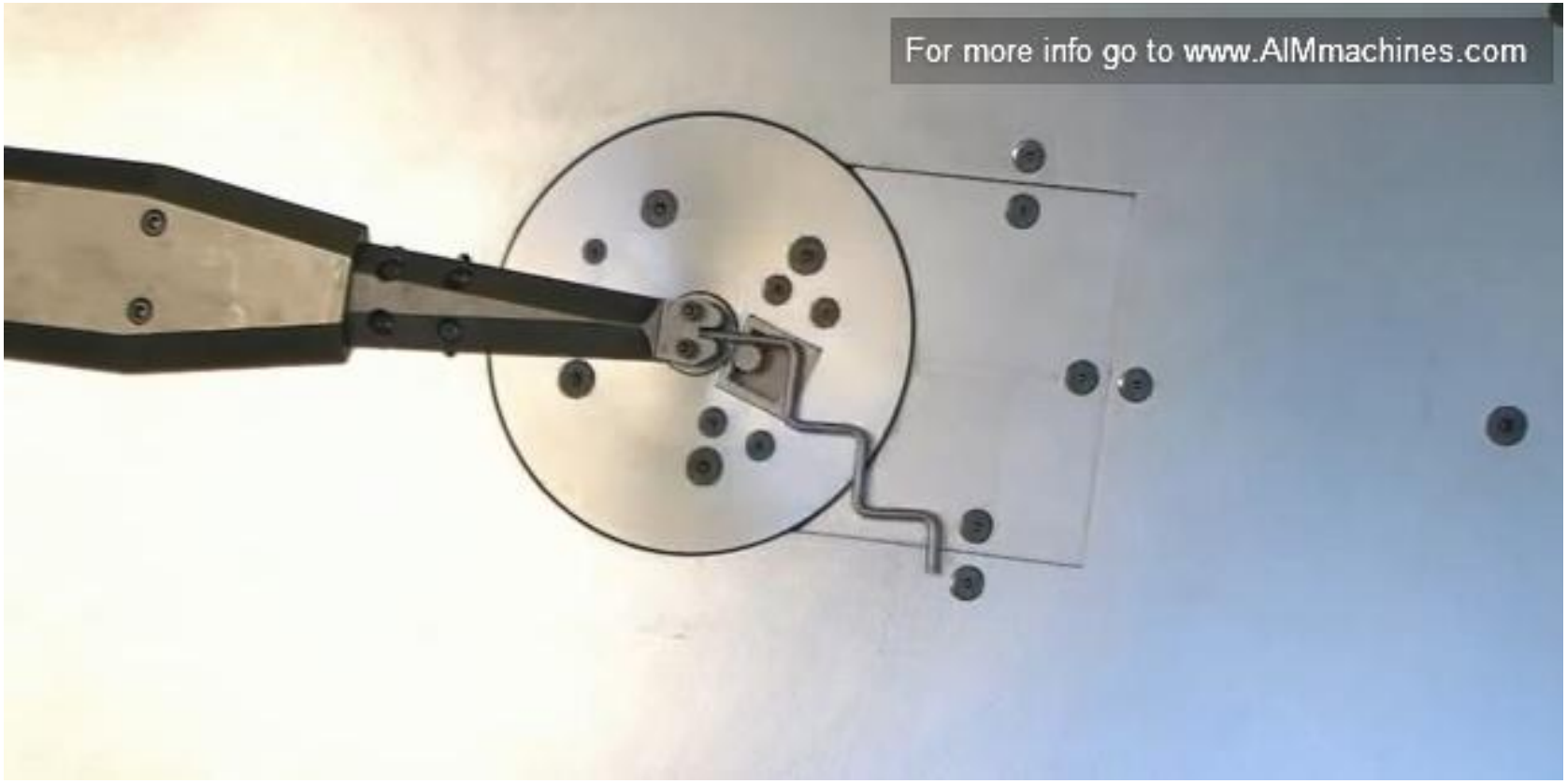
Not suitable for Tube, only solid bar forms

Rotary Draw Bending

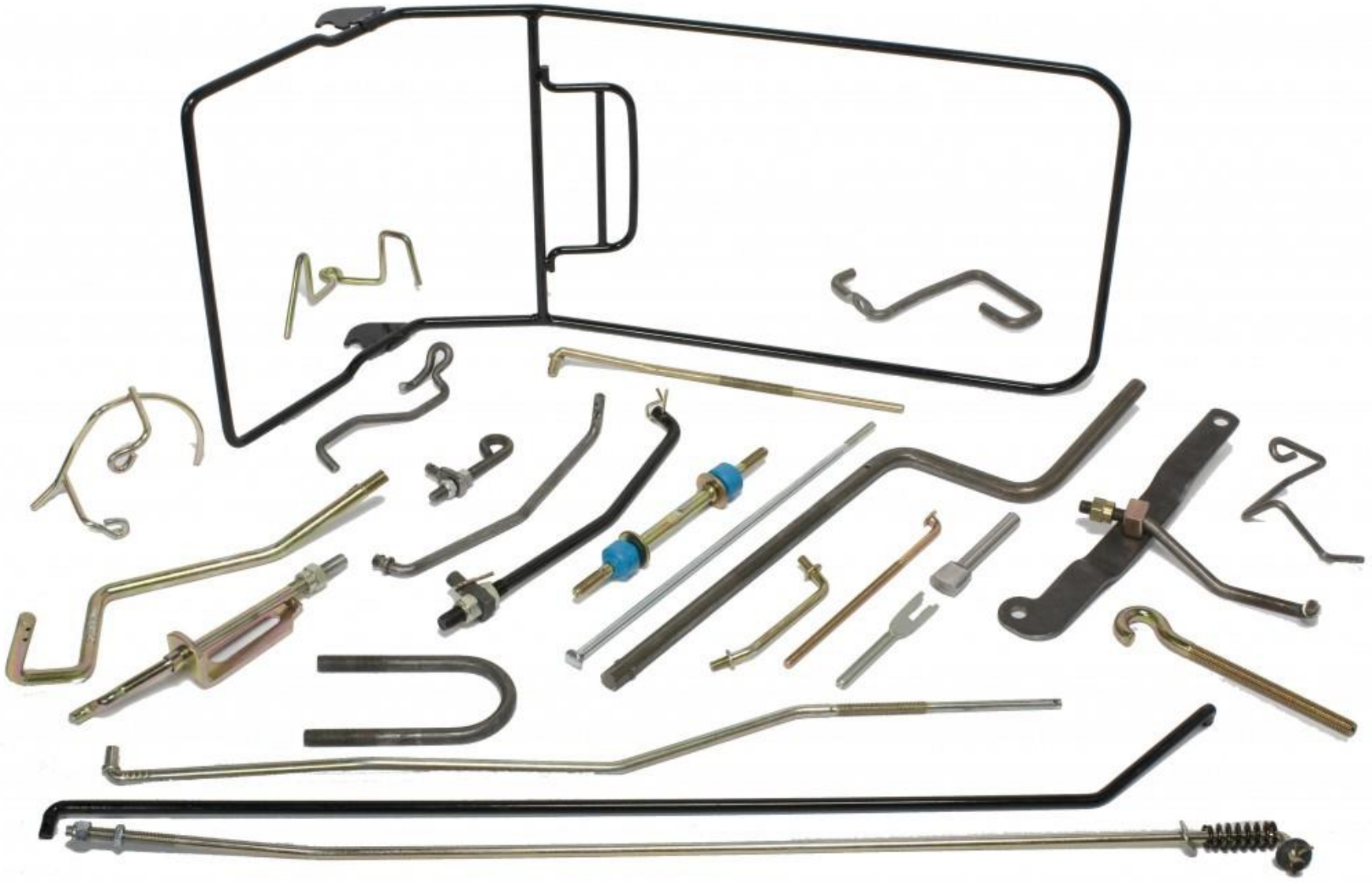
Rotary Draw Bending
with Mandrel

Reduces crushing of inner bend radius

High Speed Wire Forming

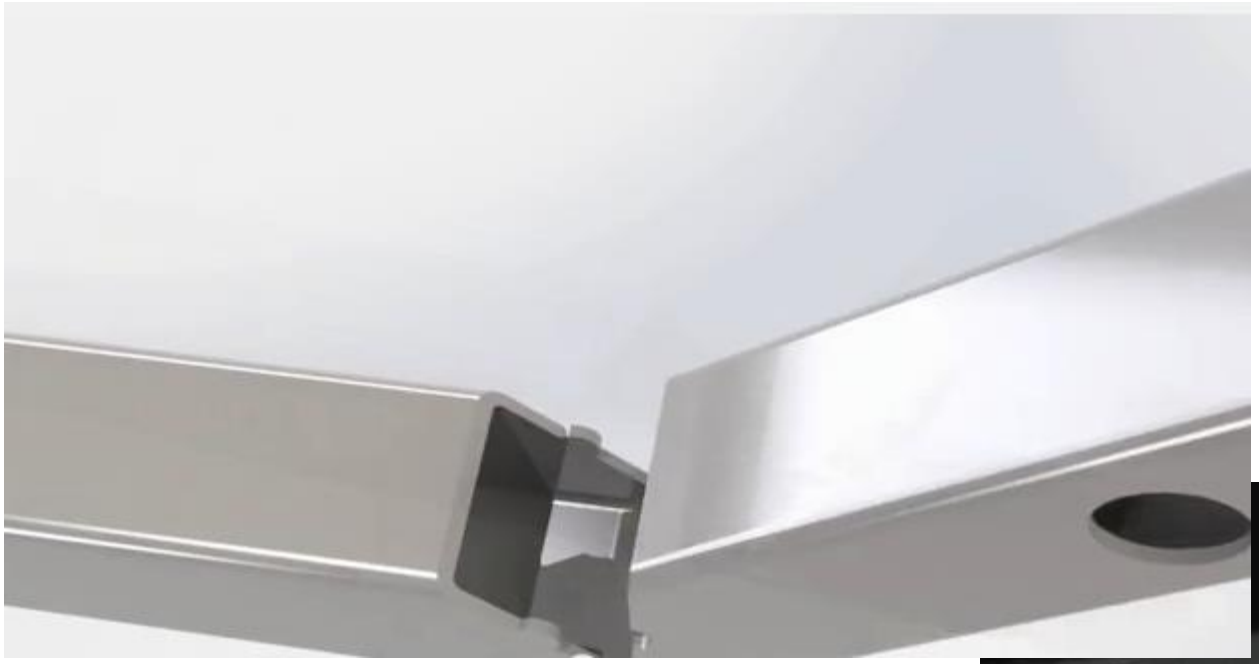


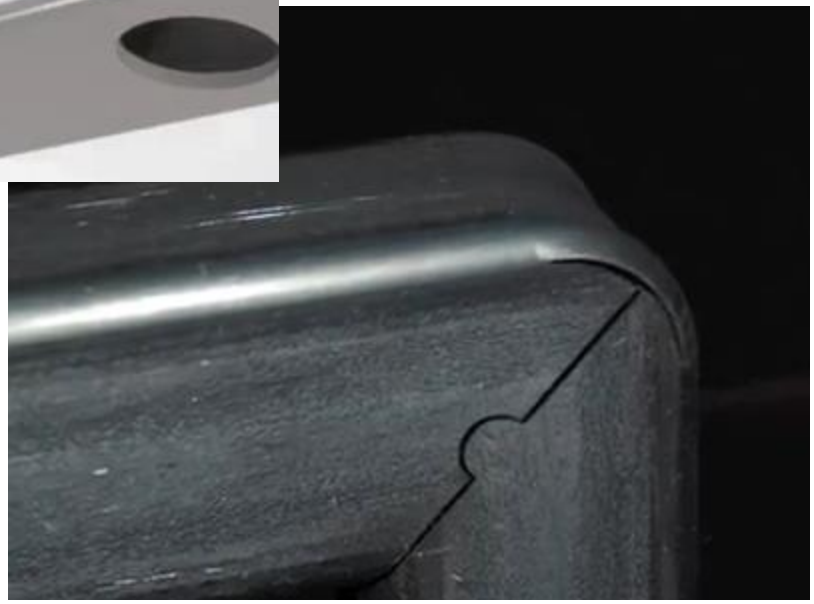
Wire Form Examples



Tube Laser Process

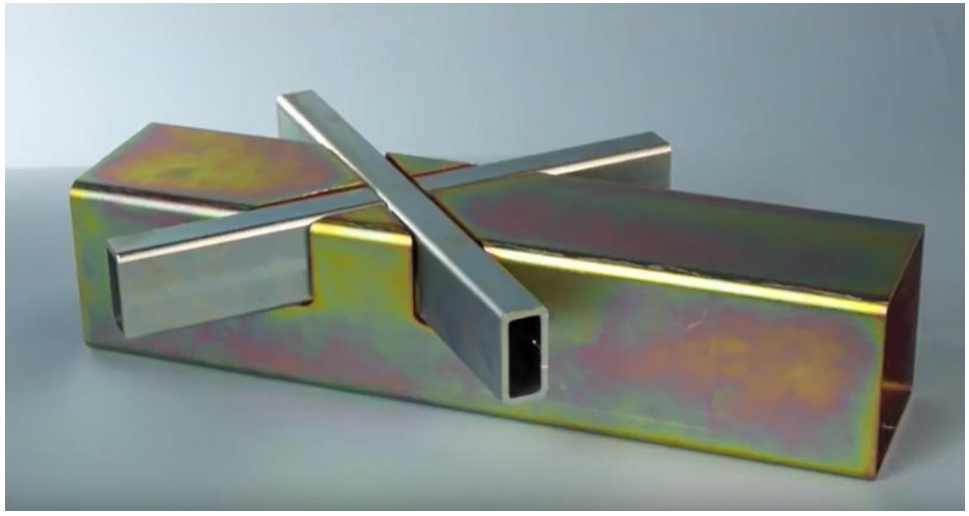
Rectangular/Square Tube
laser cut hand bending

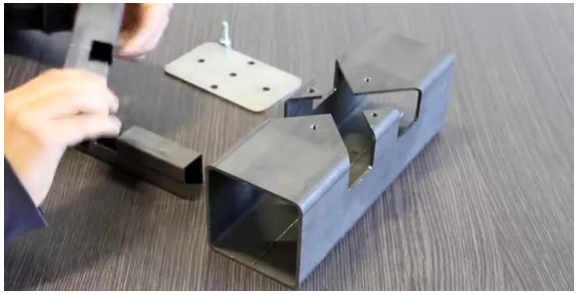


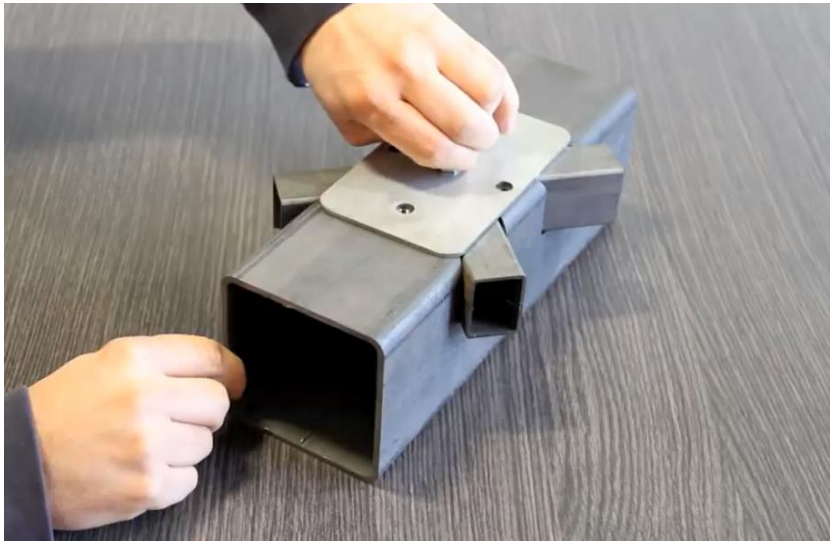


Rectangular/Square Tube

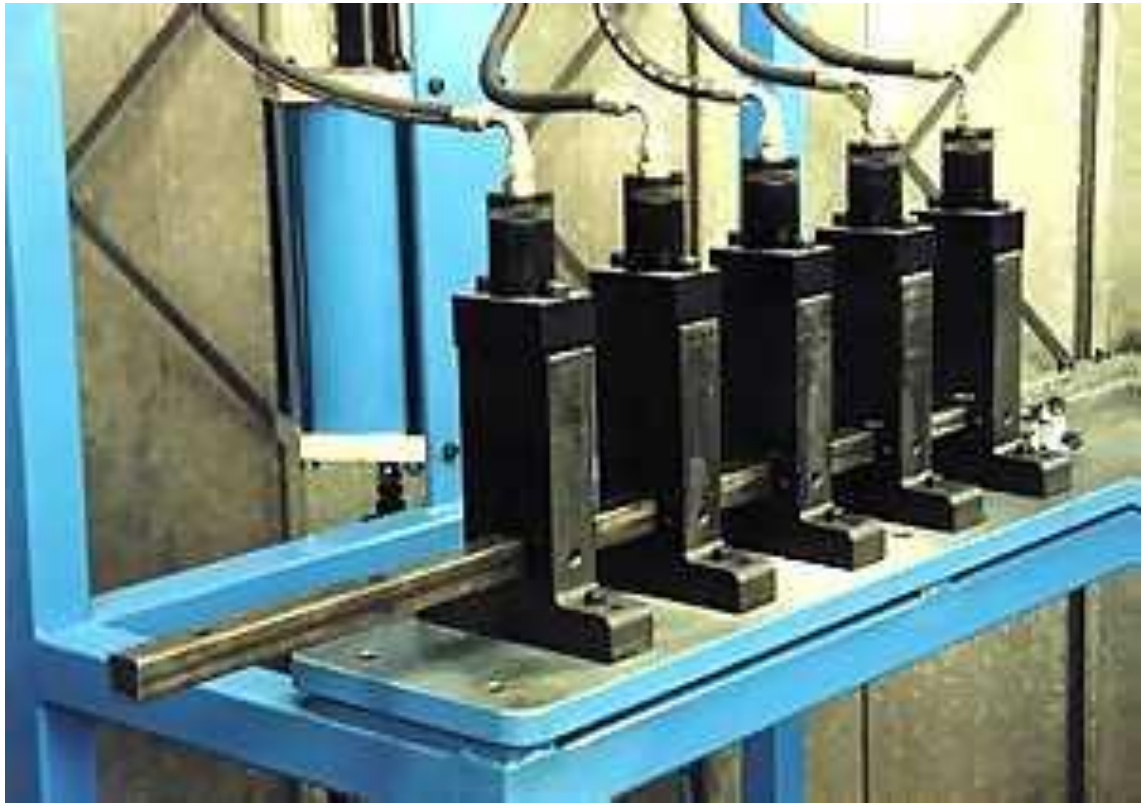
Laser Cut - Creative Weldless Connections







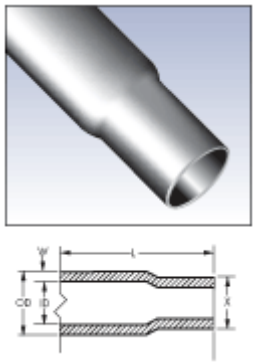
Punching Process
Tube Punching



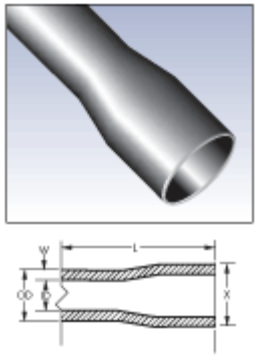
Punching Process
Bar Punching

End Forming Processes

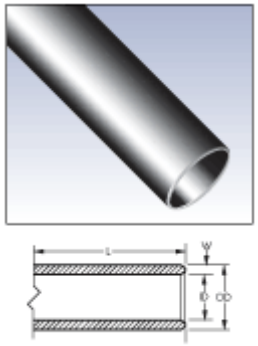
Reduction



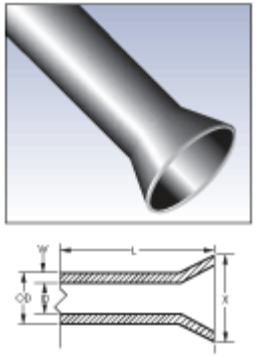
Expansion



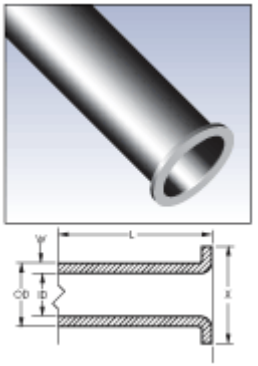
Chamfering



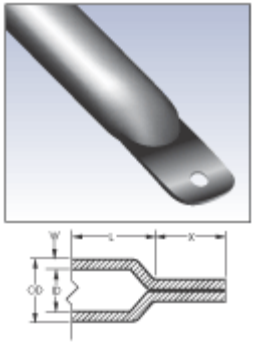
Flaring



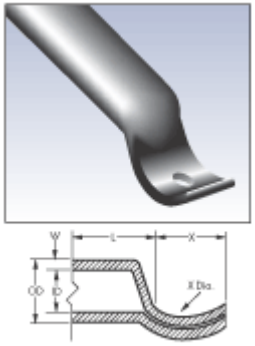
Flanging



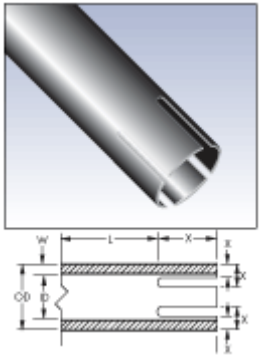
Flattening



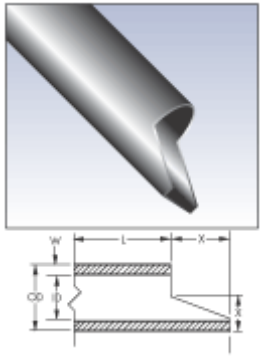
Forming



Slotting



Notching

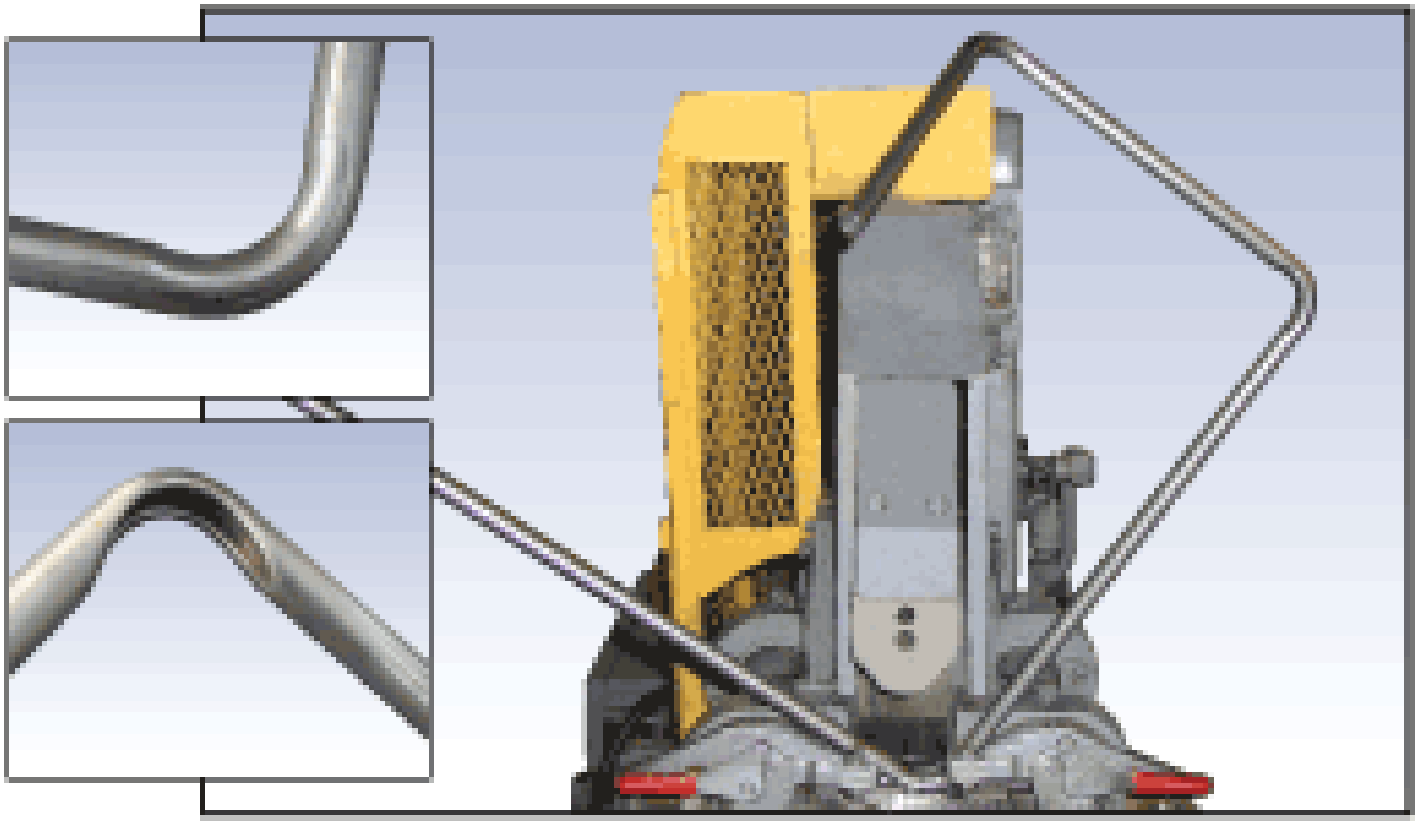


Circular Sawing Video

Multiple Parts - Bundling

Tube/Bar Bending Processes

Compression/Ram Bending



Primary Metal Casting Processes

1. **Die Casting**
2. **Sand Casting**
3. **Permanent Mold Casting**
4. **Investment Casting**

Die Casting

A non-ferrous metal is injected into a metal mold cavity under high pressure

- **Pressure is maintained during solidification, then mold is opened and part is removed, often by robotic manipulator**
- **Use of high pressure to force metal into die cavity achieves high production rates**

Die Casting Animation Video Clip

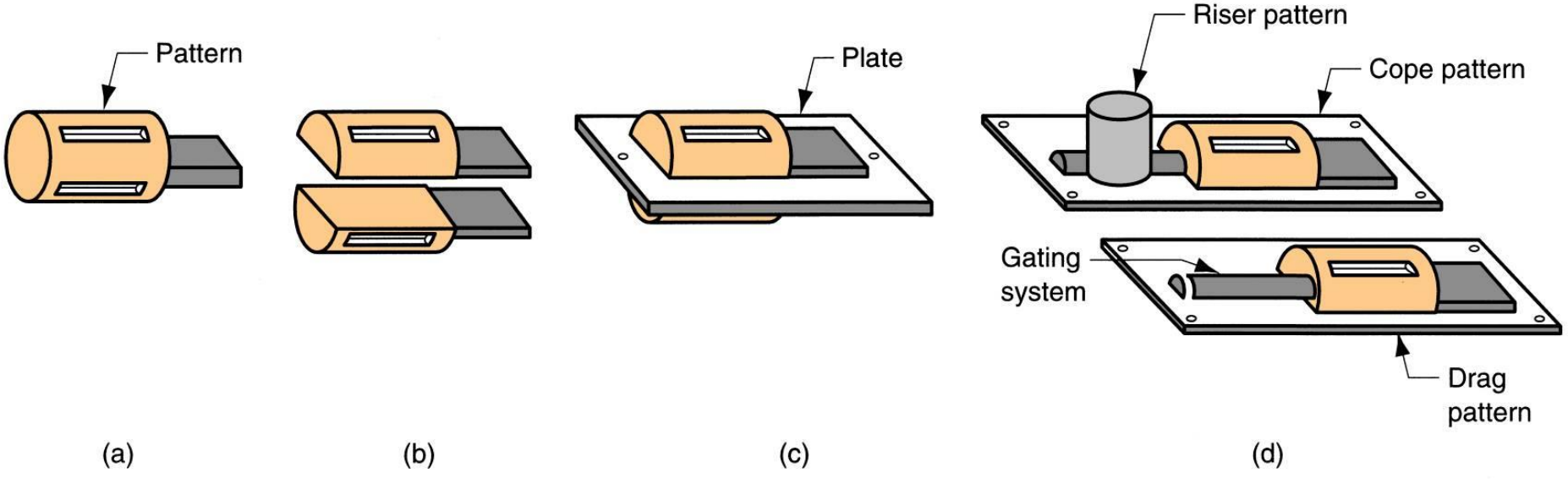
Sand Casting – Patterns required

Pattern – a model of the part, slightly *enlarged to account for shrinkage and machining allowances*

Types of patterns used in sand casting:

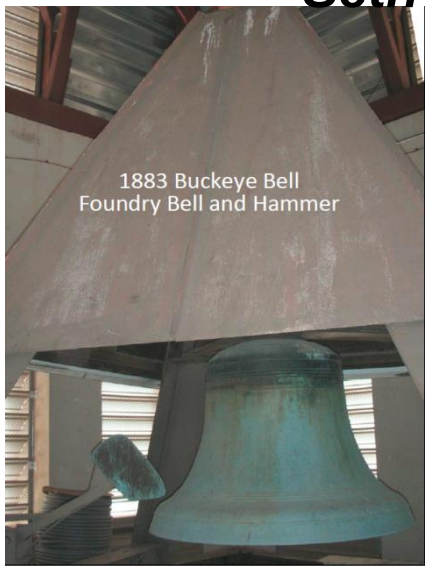
(a) solid pattern, (b) split pattern, (c) match-plate pattern

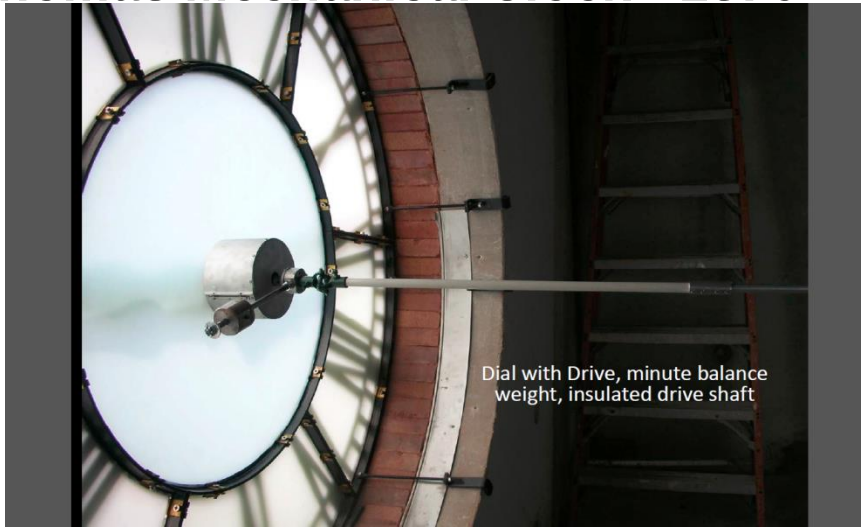
(d) cope and drag pattern

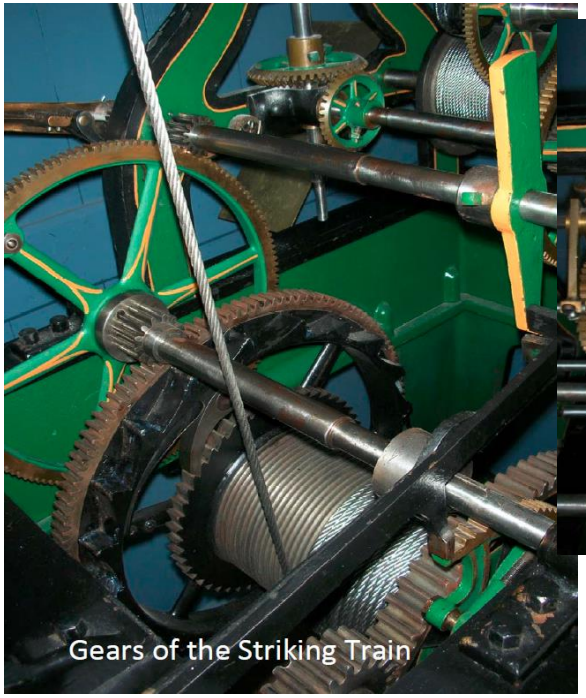


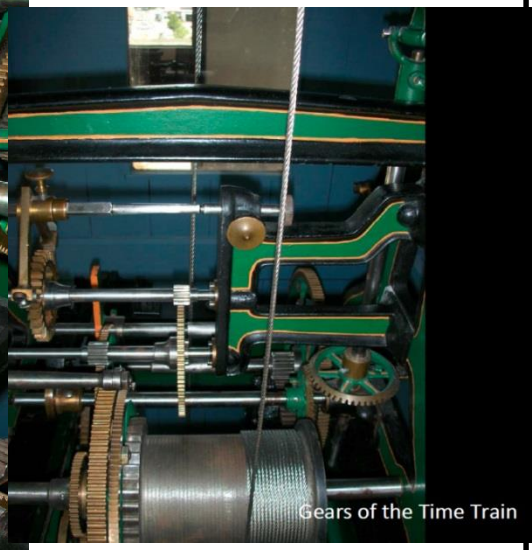
Urbana Courthouse Clock Tower Renovation - 2009

Seth Thomas Mechanical Clock - 1876









Restoration: 2002 - 2009

Horizontal Automatic Sand Casting

- **Vertical or Horizontal Mold Making Machines**
  - **200 to 600 parts/hr**
  - **Patterns and cores placed in by robotic device**

Horizontal Molding Machine video

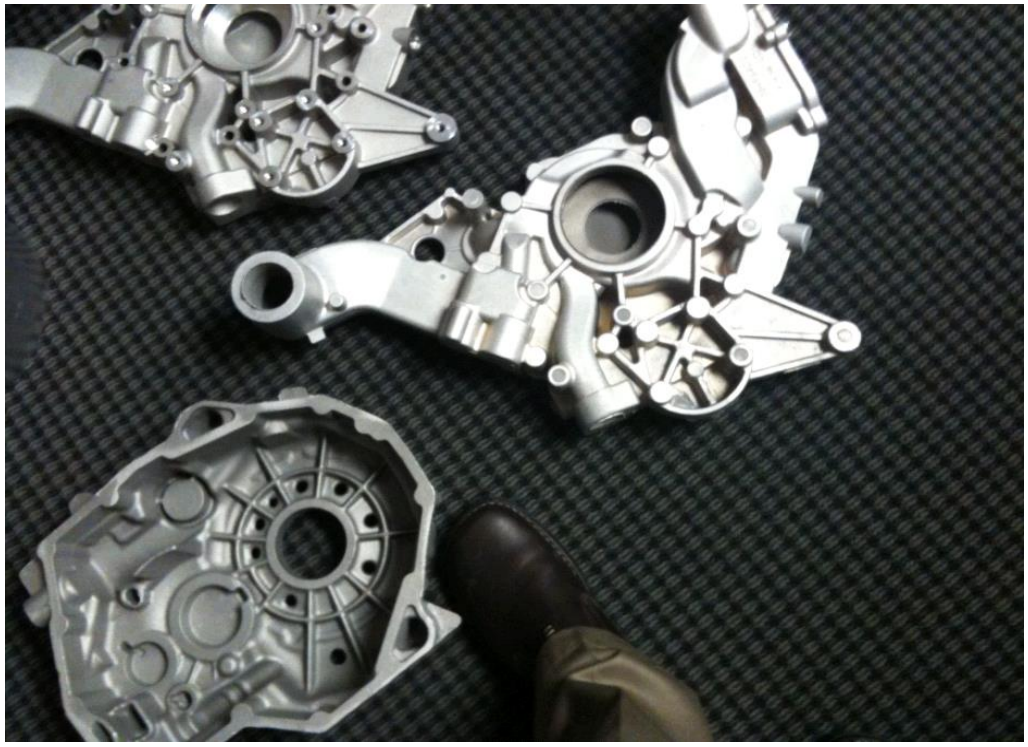
Investment Casting (Lost Wax Process)

A pattern made of wax is coated with a refractory material to make mold, after which wax is melted away prior to pouring molten metal

- **"Investment" comes from a less familiar definition of "invest" - "to cover completely," which refers to coating of refractory material around wax pattern**
- **It is a precision casting process - capable of producing castings of high accuracy and intricate detail**

Lost Wax Video

Permanent Mold Casting

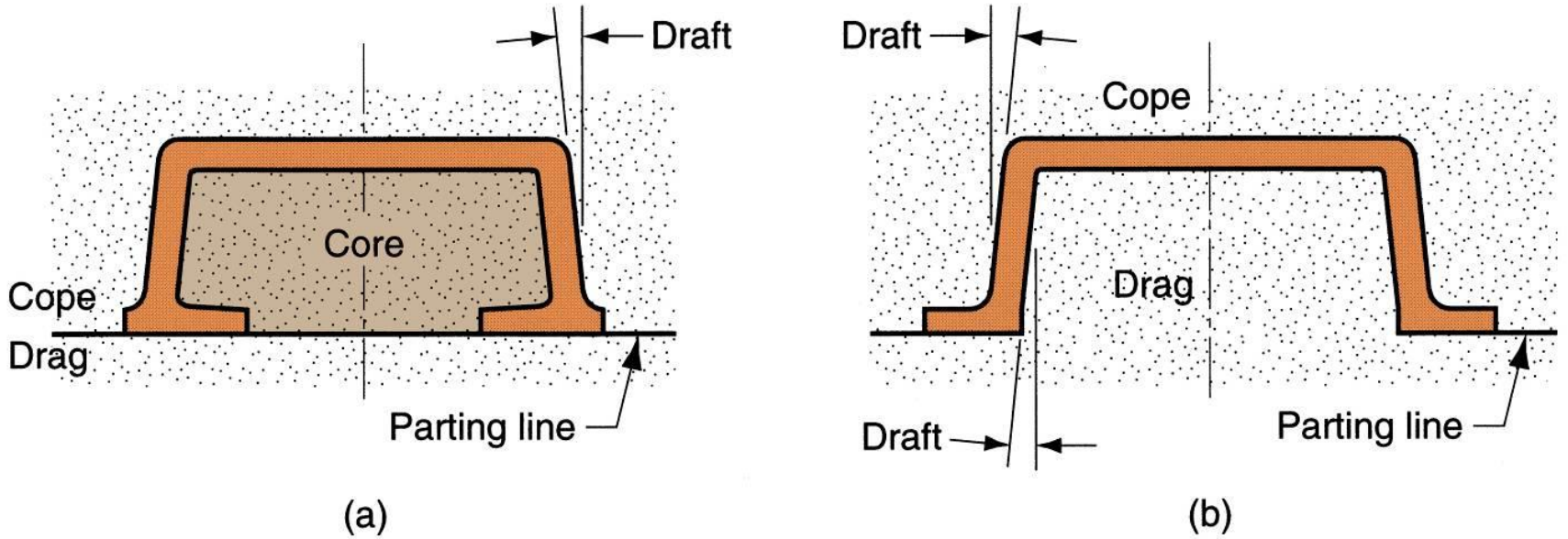


Product Design Considerations

1. **Geometric simplicity that allows for shrinkage and reduces the need for cores.**
2. **Reduce sharp angles by rounding corners and reducing stress concentrations areas that may cause hot tearing and cracks.**
3. **Increase draft angles (interior and exterior). Minimums:**
   - **Draft = 1° for sand casting**
   - **Draft = 2° to 3° for permanent mold processes**

Draft

- **Minor changes in part design can reduce need for coring**



Design change to eliminate the need for using a core: (a) original design, and (b) redesign.

Product Design Considerations - Cont

4. Dimensional Tolerances and Surface Finish:

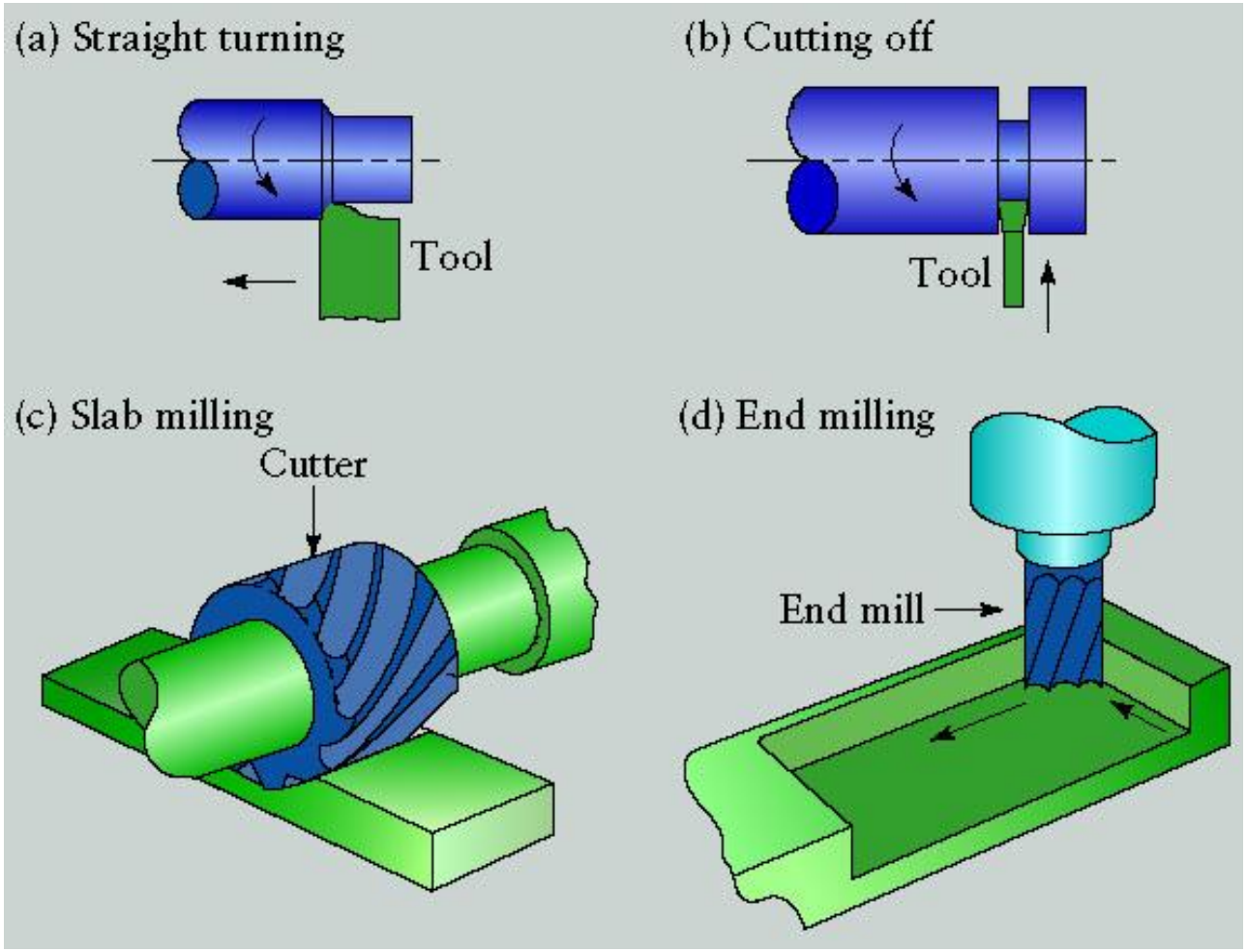
- Sand casting: poor dimensional accuracies and finish
- Die casting and investment casting: better dimensional accuracies and finish

5. Machining Allowances:

- Additional material, called the *machining allowance*, is left on the casting in those surfaces where machining is necessary

Introduction to Machining

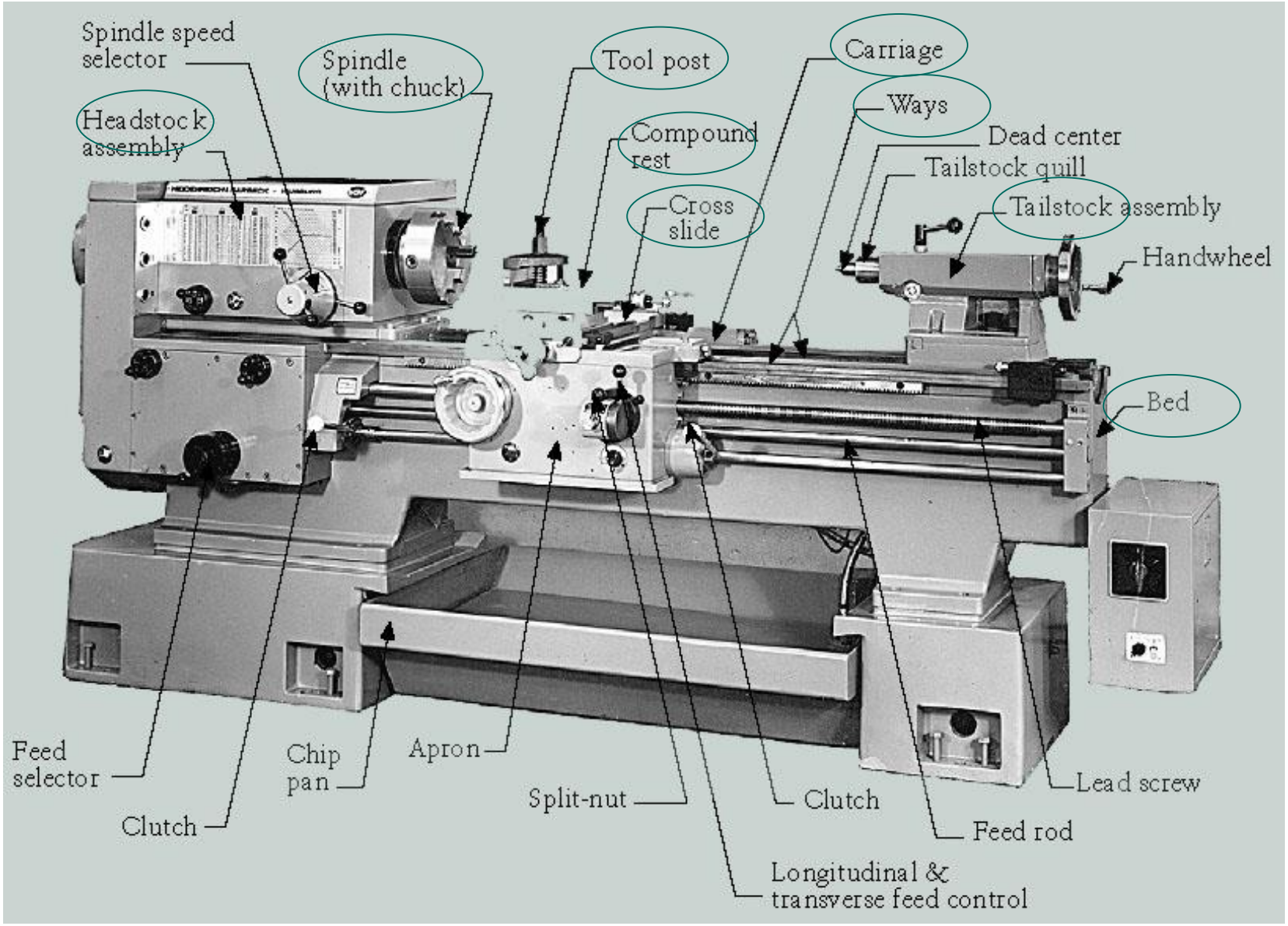
Common Machining Operations



Aka: Material Removal Processes

Kalpakjian

Parts of an "Engine" Lathe



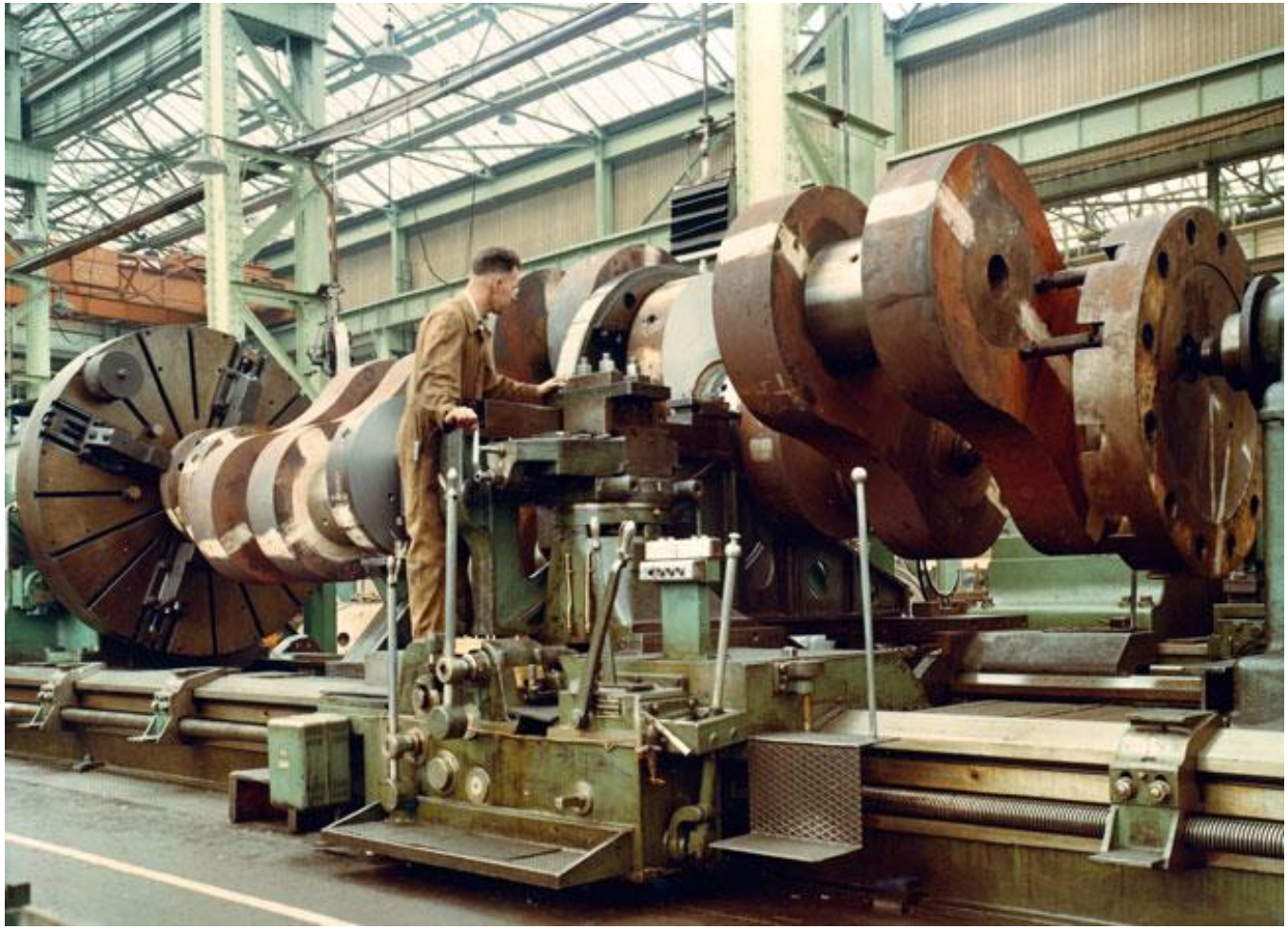
Watchmaker's lathe

Typical "Engine" Lathe

Turret Lathe

Big "Engine" Lathe

Really Big "Engine" Lathes



www.practicalmachinist.com

CNC Lathe: aka "Turning Center"

(carriage is mounted toward back, "upside down")

www.machineryvalues.com

CNC = Computer Numerical Control (features are machined to size and location by a computer)

CNC MILL or "Machining Center"

Links:

CNC machining engine block from solid

Milling an Impeller