SURFACE:MATERIAL –

CAAD, Milling Course SS04

Course Website: www.caad.arch.ethz.ch

http://edu.caad.hbt.arch.ethz.ch/milling03/10

This week: Lecture 2: Digital to Physical

MAYA – Review and Assignment 1a-Surfaces

Workshop – Introduction to SurfCAM

Within the last few the advances in computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies have started to have an impact on building design and construction practices.

CAD/CAM has opened up new opportunities in design, by allowing production and construction of very complex forms that were until recently very difficult and/or expensive to design, produce, and assemble.

The historic relationship between architecture and its means of production is increasingly being challenged by new digitally driven processes of design, fabrication and construction. The consequences of this has been profound, and will only continue to revolutionize the way we design, build and conceive of the built world around us.

"Architecture is recasting itself, becoming in part an experimental investigation of topological geometries, partly a computational orchestration of robotic material production, and partly a generative, kinematic sculpting of space"

Peter Zellner - Hybrid Space: New Forms in Digital Architecture

Lecture 2: Digital to Physical

There are several large issues facing the contemporary „digital“ designer. The form and architecture of a digitally conceived building may be much more complex and irregular than one designed and conceived of using traditional means.

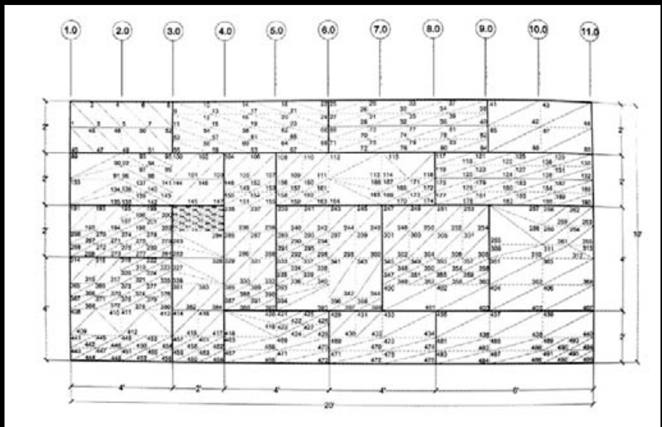
Curvalinear and irregular shapes need to be rationalized for efficient fabrication and assembly. It is only through the use of computer aided desing and fabrication programs that these new forms can be implemented within the difficult economic and technical constraints of current building practices.

1. Design and Form
2. Structure
3. Coordination
4. Assembly
5. Systems integration

1. Design and Form

New digital technologies (both in terms of CAD/modeling, and in terms of forms generated from parametric scripts and programming) allow for very fast and very intricate levels of complexity in design. The development of form is now as often a product of a set of data, as it is an aesthetic sculptural reaction to the architectural program.

The integration of „real digital design“ (scripting or programming), as a method for mass customization, creates greater demands on the output mechnism. The output mechanism for architecture includes the entire building and construction process.

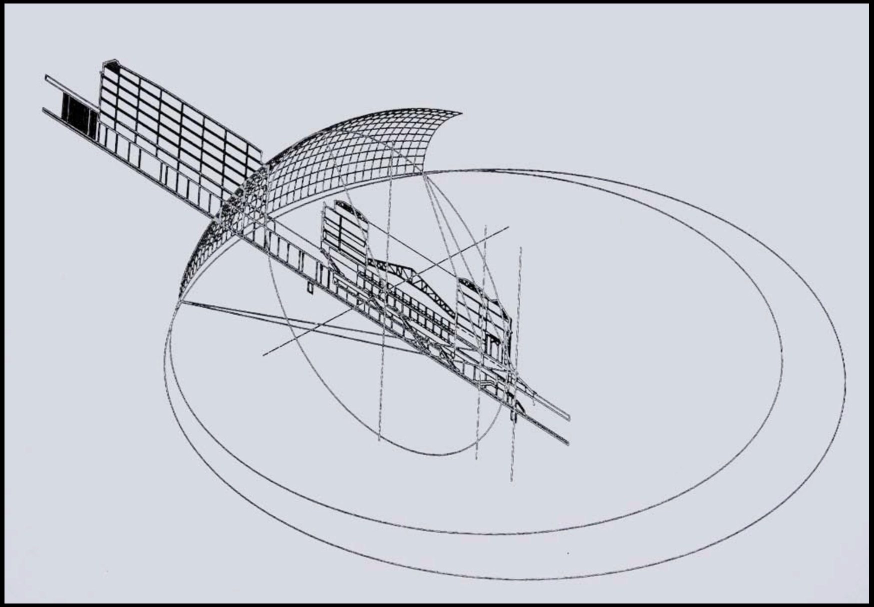


Architects have been creating „parametric design“ for decades, they just havn‘t known about it.

2. Structure

Surface data from a „form“ can also used to directly generate a wireframe abstraction of the building’s structural framework. The wireframe generated by most CAD/modeling programs is a logical, mathmatical, geometric analysis of the surface form. This wireframe can also be directly processed by the structural analysis software to generate the precise definition of all structural members.

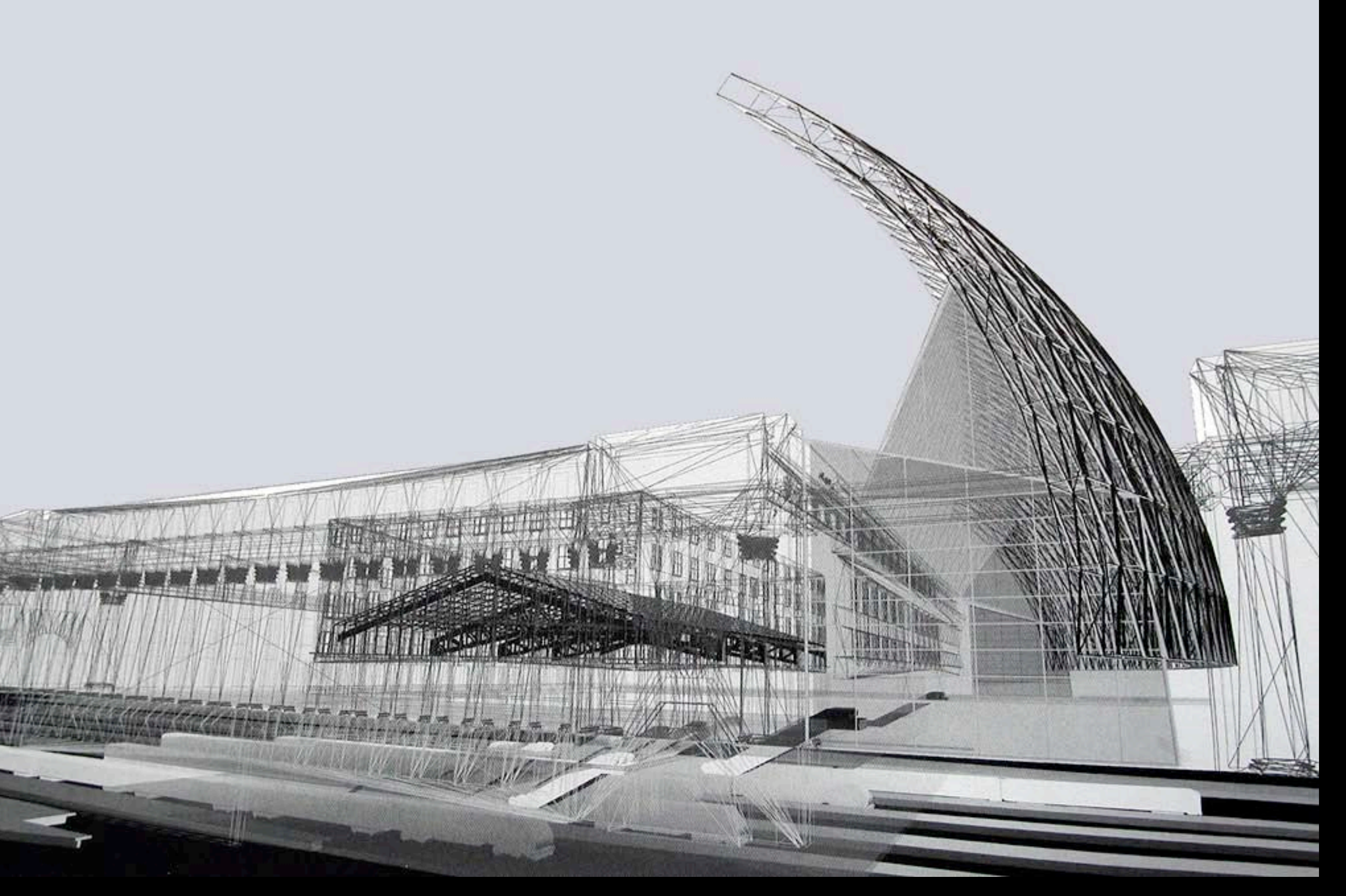
By understanding that a wireframe drawing of a surface is a logical rational explanation of a form, we can rationalize the entire formative system.



Penn-Station Wireframe, Skidmore Owings and Merrill

2. Structure

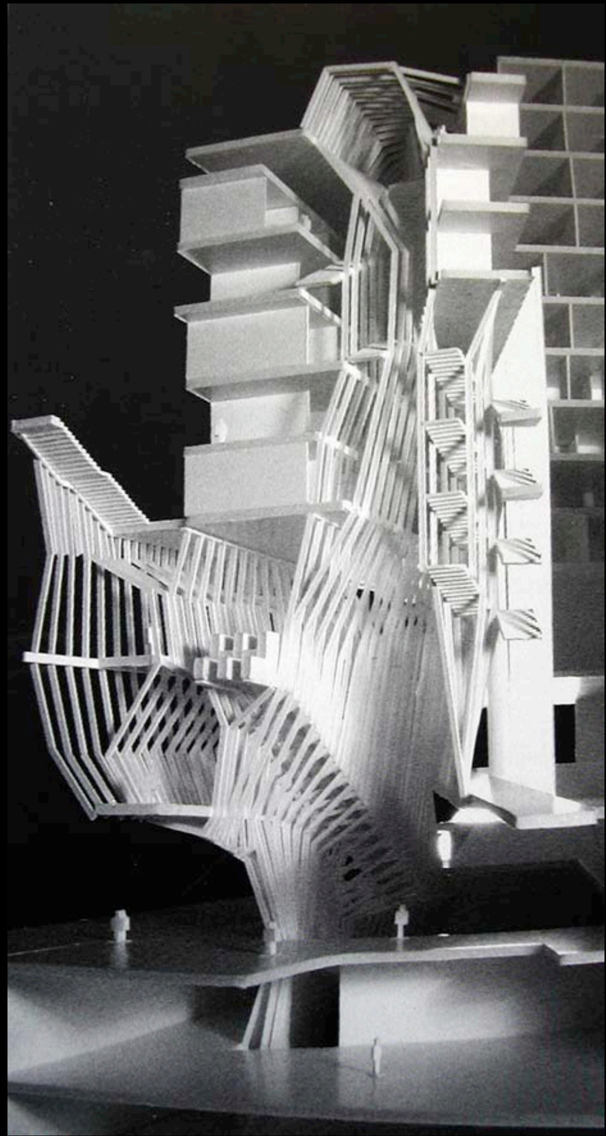
More importantly, the same data used to engineer the form can also produce the fabrication drawings or CNC data to precisely cut and pre-assemble the various components.



Penn-Station Wireframe,
Skidmore Owings and Merrill

3. Coordination

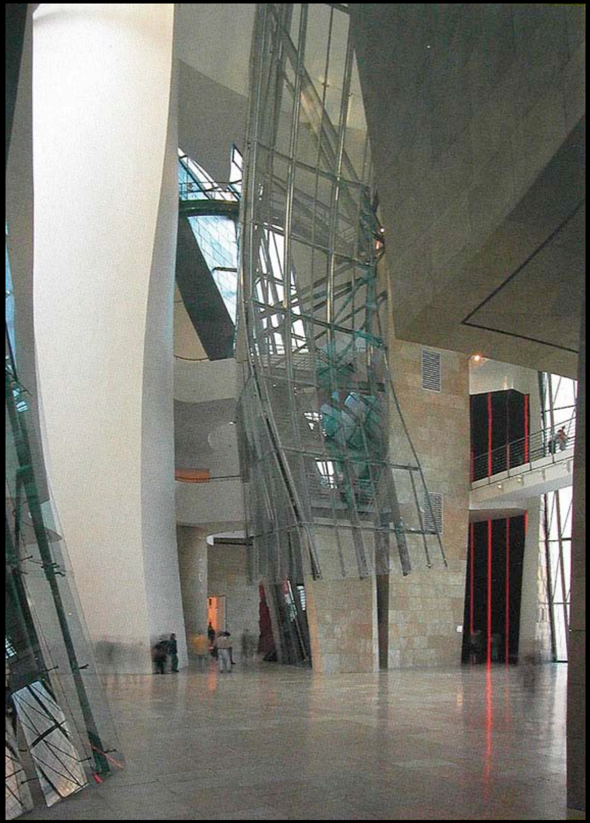
After the components are digitally fabricated, their on site coordination can be augmented with digital technology. Digital three-dimensional models can be used to determine and visualize the location of each component, to localize & move each component to its location, and finally, to assist with the fixation of each component in its proper place.



4. Assembly

New digitally-driven technologies, such as electronic surveying, GPS positioning, construction part databases, and laser positioning, are increasingly being used on construction sites around the world to precisely determine the location of building components.

For example, The Guggenheim Museum in Bilbao was built using GPS and barcode scanners. During fabrication, each structural component was bar coded and marked with the nodes of intersection with adjacent layers of structure. On site bar codes were swiped to reveal the coordinates of each piece in the CATIA model. Laser surveying equipment linked to CATIA enabled each piece to be precisely placed in its position as defined by the computer model. This processes are common practice in the aerospace industry, but relatively new to building.

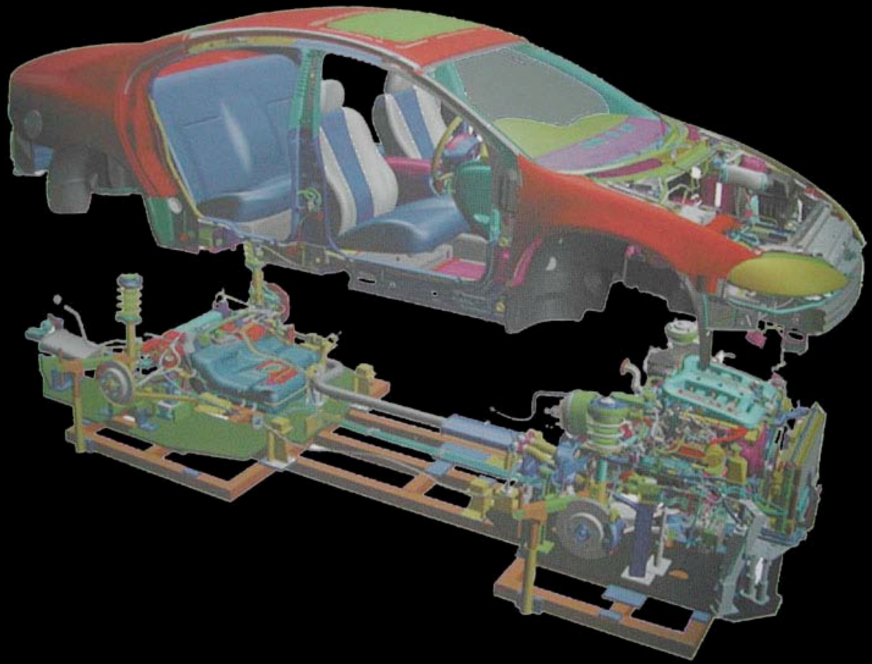


5. Systems integration

The increased ability to visualize and simulate a design while it is still in its digital form, has increased the ability to properly integrate the sub-systems of a building more efficiently into the overall design.

This factor however often also increases the overall complexity of the parts and thier assembly.

The „clean“ integration of systems into architecture is becoming a greater desire for clients, building managers, and inhabitants. This process of integration is new to architecture, however it has a longstanding tradition in the automotive and aerospace industries, and architecture continues to follow thier lead in this field.



Processes of fabrication from digital output:

There are many different digital output manufacturing techniques.

Processes of fabrication from digital output:

The chosen method for fabrication of an object or surface from digital output is dependant on the final desired qualities for the product. The desired qualities could include stress testing, volumetric testing, integration testing, aesthetics testing,… The method of fabrication for a prototype or “mock-up” will be dependant on how closely the model is expected to represent the final manufactured pieces.

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Types of CAM:

In additon to the typical 2D cutting and forming technologies, there are two basic catagories for all 3D CAD/CAM production systems.

Both are used by the large scale design and production industries and are increasingly being used in architecture as well.

- Additive Fabrication – building up
- Subtractive Fabrication – carving out

There is a third type of CAM, however it is considered a secondary process, but it is also now begining to use CNC controlled tools.

- Formative Fabrication – a secondary process

Processes of fabrication from digital output:

i. 2D Fabrication – cutting and forming

ii. 3D Fabrication – Subtractive Fabrication

iii. 3D Fabrication – Additive Fabrication

iv. Formative Fabrication

2D Fabrication

CNC (computer numerically controlled) cutting, or 2D fabrication, is the most commonly used fabrication technique. Cutting technologies involve two axis motion of the cutting head relative to a flat sheet of material.

- Plasma-arc cutting uses electricity to charge gas into a high intensity plasma cutting stream.

- Water-jet cutting, uses a jet of highly pressurized water to cut the material.

- Laser-cutters use a high intensity focused beam of infrared light to melt or burn the material.

2D Fabrication

Plasma-arc cutting

In plasma-arc cutting an electric arc is passed through a compressed gas jet in the cutting nozzle, heating the gas into plasma with a very high temperature (25,000F), which converts back into gas as it passes the heat to the cutting zone.

Plasma-arc CNC cutting of steel supports for FOG+Assoc „Zollhoff Towers“ in Dusseldorf

2D Fabrication

Water-jet cutting

A jet of highly pressurized water is mixed with solid abrasive particles and is forced through a tiny nozzle in a highly focused stream. The cutting stream causes the rapid erosion of the material in its path, thereby producing very clean and accurate cuts.

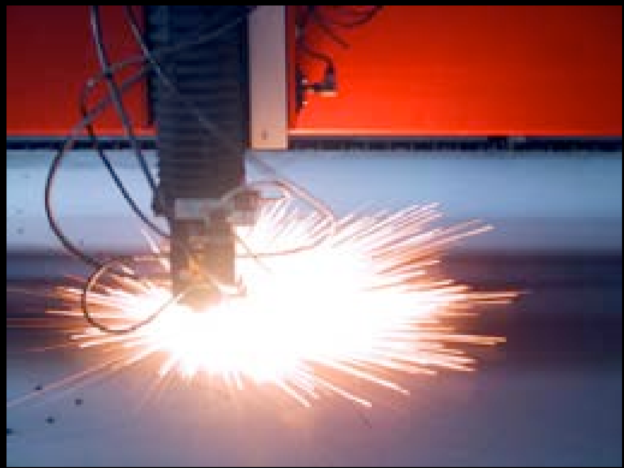
Aluminum space frame for ABB Architects' BMW Pavilion is cut directly from digital data using CNC water-jet technology.

2D Fabrication

Laser-cutting

Laser-cutters use a high intensity focused beam of infrared light in combination with a jet of highly pressurized gas (nitrogen, oxygen, or carbon dioxide) to melt or burn the material that is being cut.

There are, however, large differences between these technologies in the kinds of materials or maximum thicknesses that can be cut. Laser-cutters can cut only materials that can absorb light energy. Laser-cutters can cost-effectively cut material up to 5/8”, while water-jets can cut much thicker materials, for example, up to 15” thick titanium.

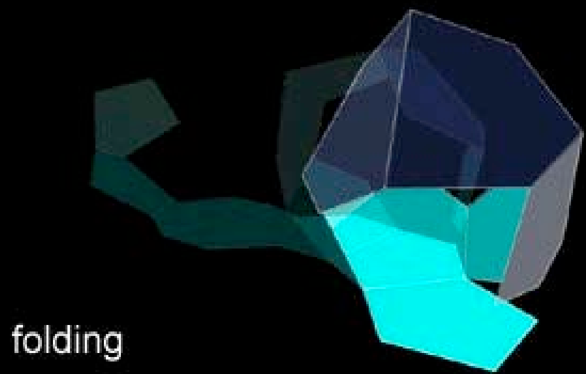


ETH laser cutter, located at Technopark, cutting out steel patterns for the WS02 Seminarwoche 7day Pavillion.

2D Fabrication

The production strategies used in 2D fabrication often include basic 2d line contouring, triangulation (or polygonal tessellation), use of ruled surfaces, and unfolding. They all involve extraction of two-dimensional, planar components from the geometrically complex surfaces or solids that make up the structure‘s form.

Which of these strategies is used depends on what is being defined topologically and tectonically: structure, envelope, combination of the two,... solid, surface, or assembly.



Additive Fabrication

Additive fabrication involved incremental forming by adding material in a layer-by-layer fashion, the opposite to milling. It is often referred to as layered manufacturing, solid freeform fabrication, rapid prototyping, or desktop manufacturing.

All additive fabrication technologies share the same principle in that the digital (solid) model is sliced into two-dimensional layers. The information of each layer is then transferred to the processing head of the manufacturing machine and the physical product is incrementally generated in a layer-by-layer fashion.

A number of competing technologies now exist on the market, utilizing a variety of materials and a range of curing processes based on light, heat, or chemicals:

Additive Fabrication

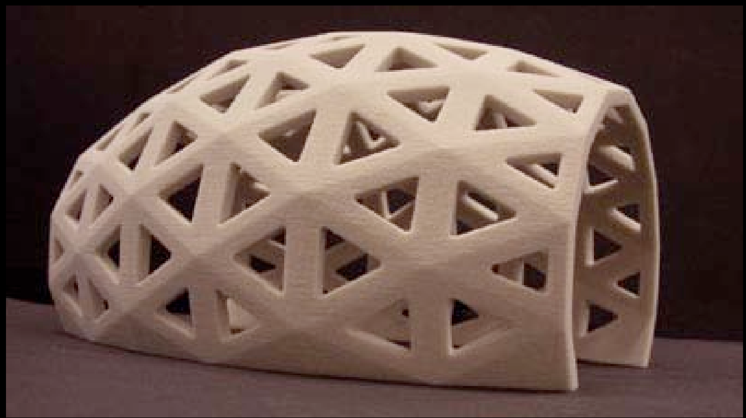
Stereolithography (SLA) is based on liquid polymers which solidify when exposed to laser light.

Additive Fabrication

Selective Laser Sintering (SLS) laser beam melts the layer of metal powder to create solid objects.

Additive Fabrication

In 3D Printing (3DP) layers of ceramic or cellulose powder are glued together using a bubblejet printhead technology to form objects. The objects are then soaked in a resin which hardens them and reduces thier delicacy.



Additive Fabrication

Sheets of material (paper, plastic), either precut or on a roll, are glued (laminated) together and laser cut in the Laminated Object Manufacture (LOM) process.

Multi-jet manufacturing (MJM) uses a modified printing head to deposit melted thermoplastic/wax material in very thin layers, one layer at a time, to create three-dimensional solids.

Additive Fabrication

In Fused Deposition Modeling (FDM) each cross section is produced by melting a plastic filament that solidifies upon cooling.

Additive Fabrication

Sprayed concrete systems have been introduced to manufacture large-scale building components directly from digital data. They either rely on a base form, or are flat on once side.

They are very similar to the 3d printer systems, however at a much larger scale.

Recently there has been reseach and development of free-form concrete sculpting CNC production methods. This technology is experimental at the moment but shows interesting promis for the future.

Lecture 2: Digital to Physical

Subtractive (or Reductive) Fabrication

CNC Milling
CNC Lathes
CNC Wire-cutting
CNC Water-Jet sculpting

Subtractive Fabrication

Subtractive fabrication involves removal of specified volume of material from solids. There are a few subtractive fabrication processes, but all are similar to MILLING. In CNC milling, a dedicated computer system performs the basic controlling functions over the movement of a machine tool, the tool rapidly removes material from a large monolithic block using a set of coded instructions for the static geography of the surface.

The CNC milling has recently been applied in new ways in building industry:

-to produce the formwork (molds) for the off-site and on-site casting of concrete elements with double-curved geometry

-in the production of the laminated glass panels with complex curvilinear surfaces

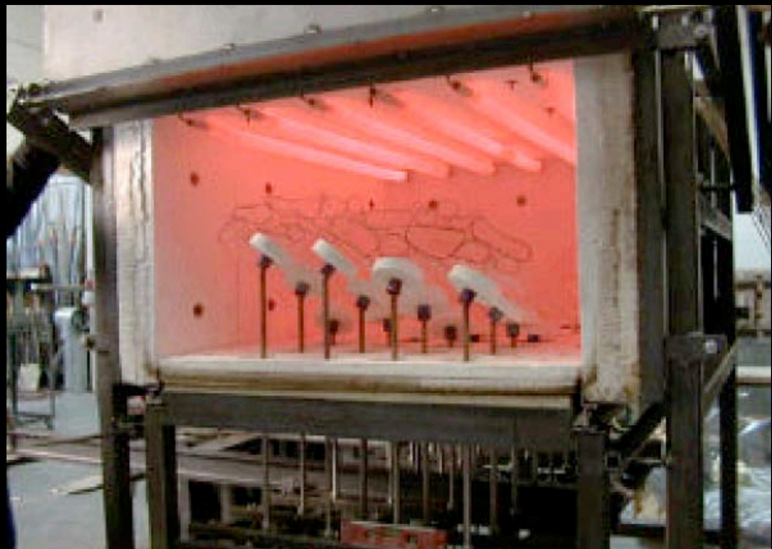
-and to produce parts and componants for customized curtain wall assembly systems.

Formative Fabrication

In formative fabrication mechanical forces, restricting forms, heat, or steam are applied on a material so as to form it into the desired shape through reshaping or deformation, which can be axially or surface constrained.

Formative Fabrication

The reshaped material may be deformed permanently by heat curing and stressing material past the elastic limit, bending it while it is in a softened state, or chemically softening material and stressing it. Double-curved, compound surfaces can be approximated by arrays of height-adjustable, numerically-controlled pins, such as those used for the production of molded glass and plastic sheets.



In all of these processes the manufacturing system has been controlled by a Comuter Numerically Controlled (CNC) device. The controlling computers in all cases are using straight forward numerical code to control the aparatus that is actually doing the manufacturing.

For the CNC mill this code is called G-code, and it looks like this:

```
%
S9000
G90 G17 G40
M3
G0 X-0.059 Y33.169 F99
G0 Z0.984
G0 Z0.039
G1 X-0.059 Y33.169 Z-0.059 F9
Y-0.059 F18
X46.87
Y33.169
X-0.059
G0 Z0.984
M5
M30
M2
%
```

This is a basic rectangle cut with a spindle rotational speed of speed 9000 rpm.

To create the required numeric controlling files, for any of these machine, often CAM generating software is required to create and control just how the machine will interpret the job.

Issues and parameters:

- type of cut
- size of tool
- efficiency of the cut
- degree of roughness, and tolerance
- surface texturing
- speed of the machine
- ......etc.

For this course we will use the software SurfCAM.

Welcome to the SurfCAM WORKSHOP.

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