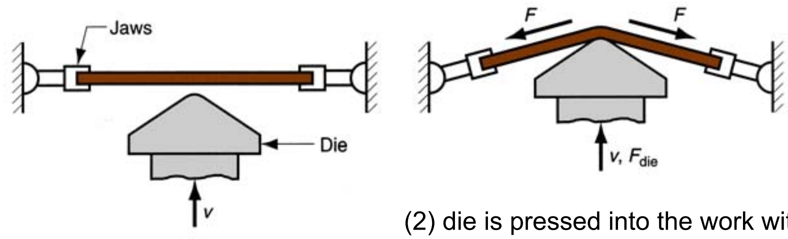
Outline

- Stretch forming
- Automotive stamping processes
- Stretch forming vs. stamping
- Spinning
- HERF
- Superplasticity
- Superplastic forming
- Superplastic forming with diffusion bonding

Stretch Forming

Sheet metal is stretched and simultaneously bent to achieve shape change

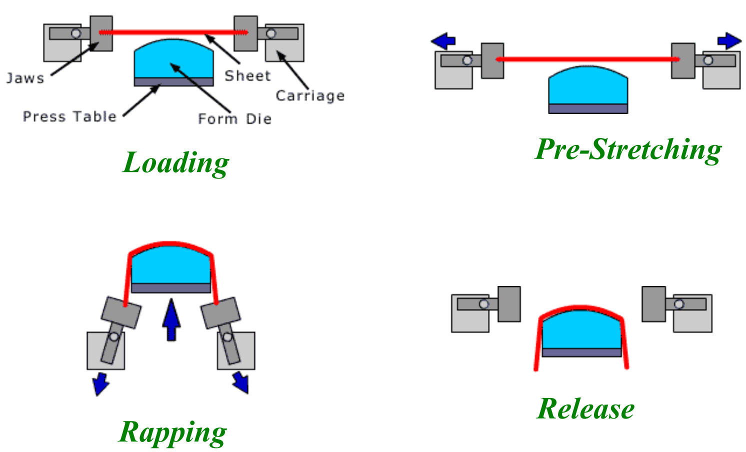


(1) start of process

(2) die is pressed into the work with force F_{die}, causing it to be stretched and bent. F = stretching force

- *The shape is produced entirely by tensile stretching so the limiting strain is that at necking.*
- *It can be thought of as a uniaxial tensile stress condition.*
- *And the forming limit is reached when the local strain equals …………*

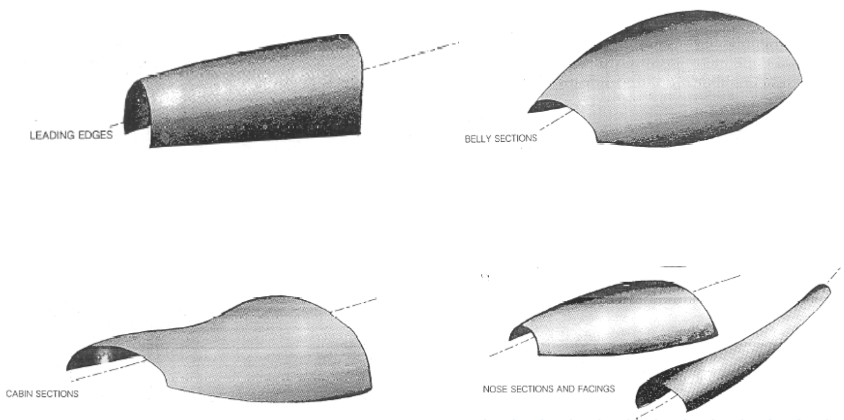
Stretch Forming: *steps*



Stretch Forming: *equipment*

Stretch Forming with ……………. Tool

Stretch Forming: *Products*



Force Required in Stretch Forming

$$F = LtY_f$$

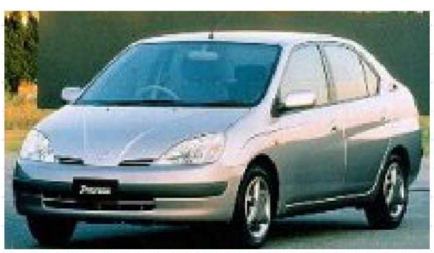
where
F = stretching force
L = length of sheet in direction perpendicular to stretching
t = instantaneous stock thickness
Y_f = flow stress of work metal

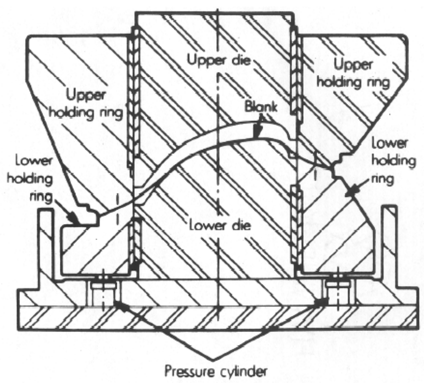
Die force F_{die} can be determined by balancing vertical force components

Example

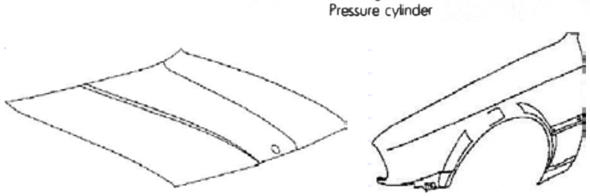
Calculate the force required to stretch form a wing span from a sheet of 2219 aluminum having a cross-sectional area of 13x305 mm, a yield strength of 250 MPa and a UTS of 360 Mpa.

Automotive Stamping

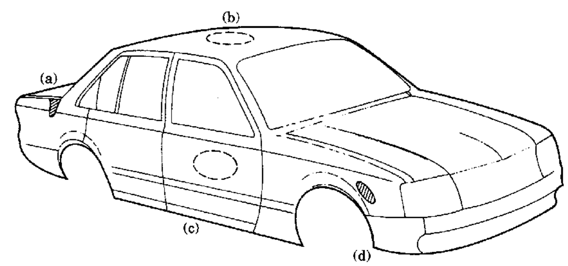


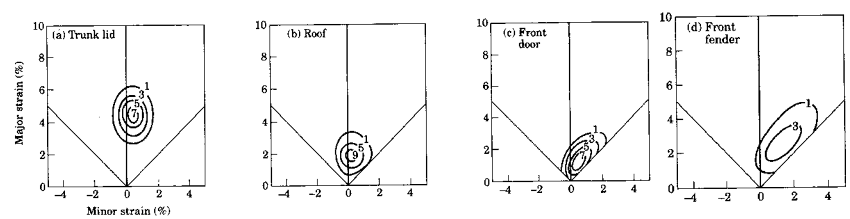


- 10 -11 panels
- 3 to 5 dies each
- ~$0.5M each
- ~$20M investment



Automotive Stamping





Major and minor strains in various regions of an automobile body. The number in the strain paths indicate the frequency of occurrence.

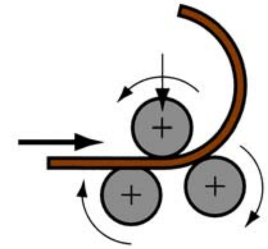
Stretch Forming vs. Stamping processes

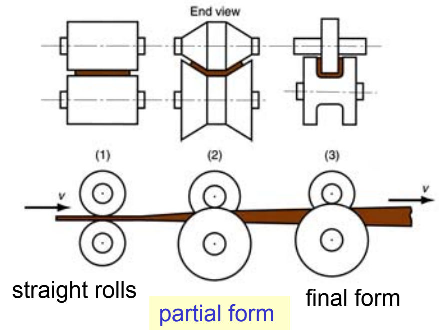
- Stretch Forming Advantages over stamping:
  - Tighter tolerances are possible: as tight as 0.0005 inches on large aircraft parts
  - ……….. problem with either **wrinkling** or **spring back**
  - Large and gently contoured parts from thin sheets
- Stretch forming Disadvantages over Stamping
  - Complex or sharply cornered shapes are ………… or …………… to form
  - Material removal (blanking, punching, or trimming) requires secondary operations
  - Requires special preparation of the free edges prior to forming

Other Sheet metal Forming Processes

Roll Bending:

Large metal sheets and plates are formed into curved sections using rolls



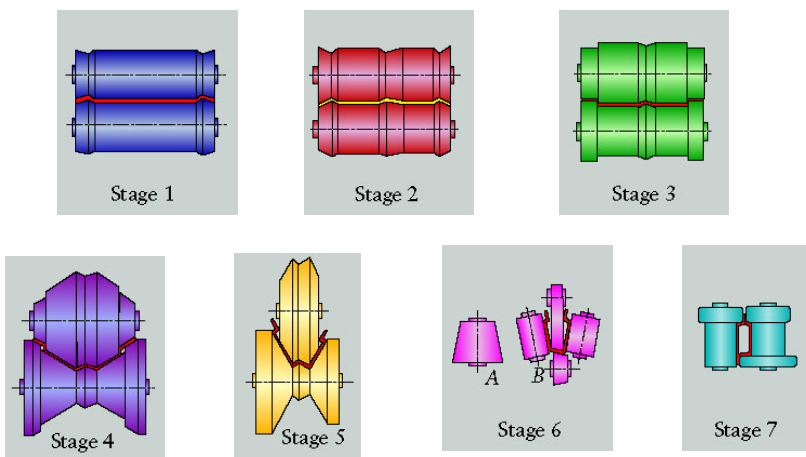


Roll Forming:

Continuous bending process in which opposing rolls produce long sections of formed shapes from coil or strip stock

Roll Forming: *Example*

Stages in roll forming of a sheet-metal door frame:



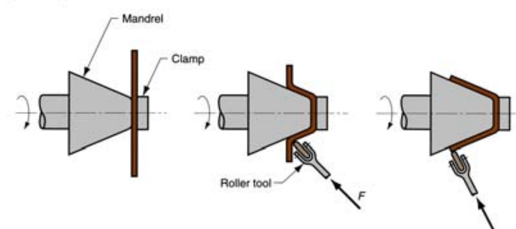
the rolls may be shaped as in *A* or *B*

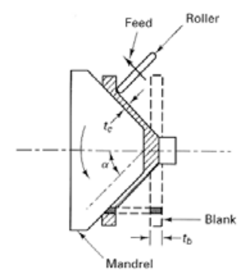
continuous tube

Spinning

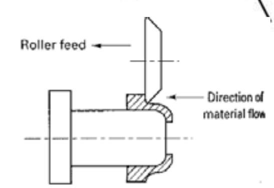
Metal forming process in which an axially symmetric part is gradually shaped over a mandrel rotating at high speed using a rounded tool or roller

Conventional Spinning





Shear Spinning



External Tube Spinning

High-Energy-Rate Forming (HERF)

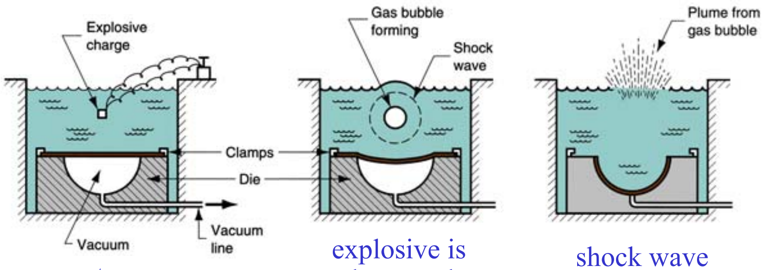
Processes to form metals using …….. amounts of energy over a very ……… time

Explosive Forming

Use of explosive charge to form sheet (or plate) metal into a die cavity

• Explosive charge causes a shock wave whose energy is transmitted to force part into cavity

• Applications: large parts, typical of aerospace industry



setup — explosive is detonated — shock wave forms part

High-Energy-Rate Forming (HERF)

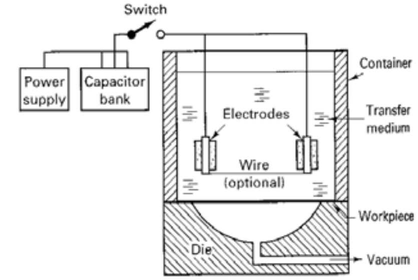
Electro Hydraulic Forming:

• Electrical energy is accumulated in large capacitors and then released to the electrodes.

• Similar to explosive forming except:

- for the smaller amount of released energy

- so, it is good for small parts.



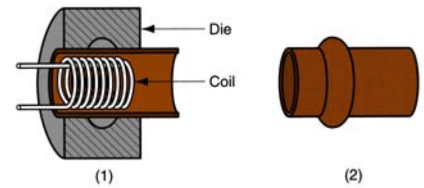
Electro Hydraulic Forming
"Electric Discharge forming"

Electromagnetic Forming:

Sheet metal is deformed by mechanical force of an electromagnetic field induced in workpart by an energized coil

- Presently the …………… used HERF process

- Applications: tubular parts



Electromagnetic Forming
"Magnetic Pulse forming"

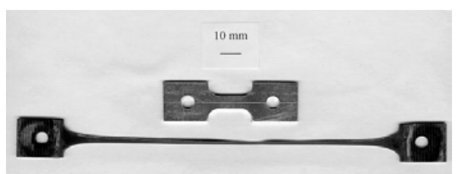
Superplasticity

Superplasticity is the ability of a material to withstand very large amounts of elongation without the occurrence of necking

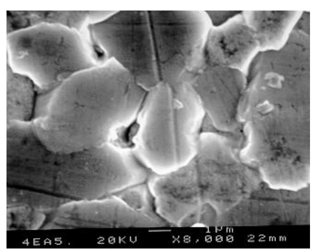
• This property is related to a predominant mechanism of deformation : ………………… ***sliding***

• Consequently, it is promoted by a fine microstructure (*typically a mean grain size less than about twenty microns is required in the case of metallic alloys*).

• This property has been used for a long time as a forming technique for components with a particularly …………… shape



Superplastic deformation of an aluminum alloy



Movement of grains during superplastic deformation of a Pb-Sn alloy

Superplasticity

Important elements in superplastic properties:

• Low strain rate (*so it is not practical*)
• High temperature
• Small grain size
• Grain shape

$$\sigma = C\dot{\varepsilon}^{m}$$

where
C = strength constant
m = strain-rate sensitivity exponent

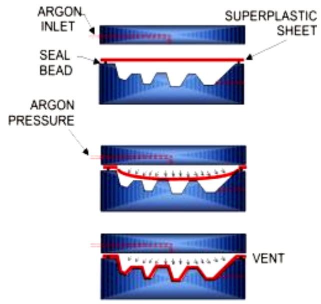
Common **titanium alloys** and several specially processed **aluminum alloys** are superplastic. **Inconel**, specialty stainless steels and several other alloys can also be made superplastic.

• Until recently, superplastic forming has only been available at relatively low strain rates, typically about 1% per min. At this strain rate, about …. is needed to form an advanced structural component; …….. to be economically effective.

• Superplasticity at higher strain rates, however, can be expected to stimulate broad commercial interest in superplastic forming.

• A strain rate higher than …... per minute is considered economically practical. Such a strain rate would allow the forming of relatively complex structures in **less than three minutes**, including set-up time.

Superplastic Forming Process

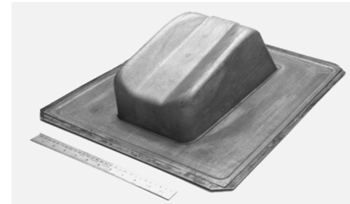


- The SPF process uses superplastic materials to form very complex sheet metal parts.
- Dies are heated in a press (900°C for titanium alloys) and inert gas pressure is applied at a controlled rate.
- SPF can produce parts that are **impossible to form using conventional methods**

Benefits...

- Lower Tooling Cost
  - *- As much as …….. lower than stamping dies*
- Reduced Part Count and Weight
  - *- Replace built up structures with integrally stiffened structures*
- Greater Design Flexibility
  - *- Incorporate compound curvatures*
  - *- Produce deep draws*
  - *- Fabricate very tight bend radii*

Superplastic Forming Process

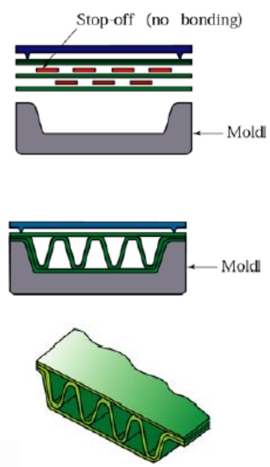


A superplastically formed Al-Li alloy component

- Elimination of unnecessary joints and rivets
- Reduction of subsequent machining
- Minimization of materials waste

An integrated aluminum structure, for example, traditionally manufactured by welding four pieces of metal, can be manufactured in a single operation through superplastic forming

Superplastic Forming with Diffusion Bonding



- Superplastic Forming can be combined with Diffusion Bonding to produce a number of complex SPF/DB structures.
- SPF/DB parts are produced by joining several sheets in a specific pattern and then superplastically expanding the sheets to produce an integrally-stiffened structure.

Next time:

Review for sheet metal working