

## The Principle of Shaping-Forming Process



- ▷ **the type of Shaping-Forming Processes**
- ▷ **Slip Casting**
- ▷ **Sintering**
- ▷ **Pressing**
- ▷ **Injection Molding**

## the type of Shaping-Forming Processes

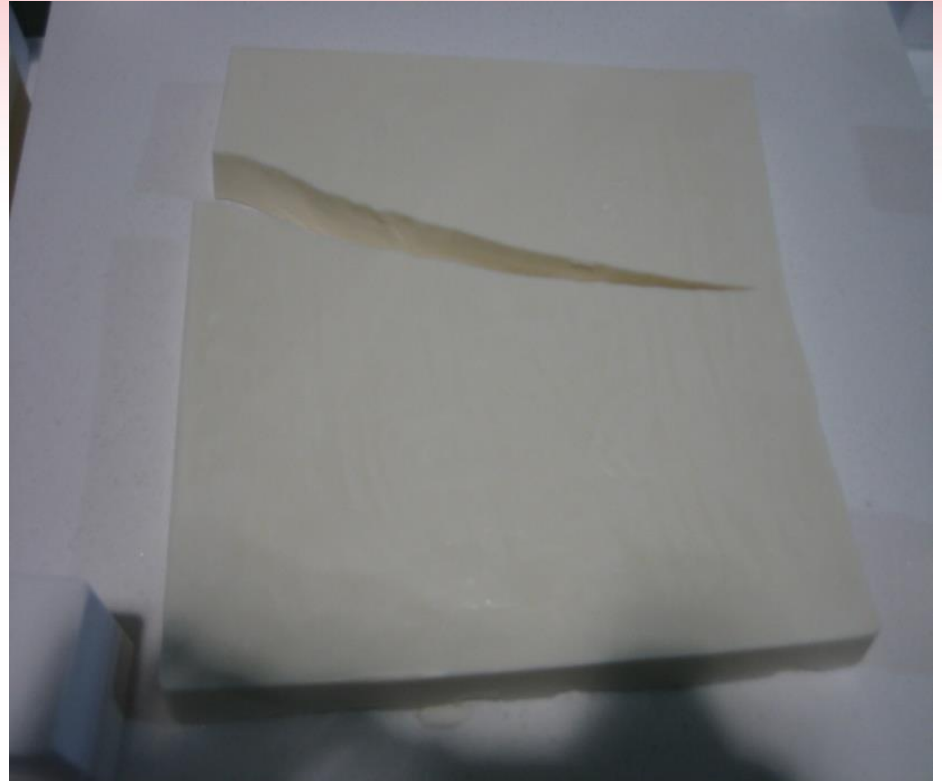
- ▷ **Casting** : Slip casting, Solid casting
- ▷ **Pressing** : uniaxial , isostatic pressing
- ▷ **Plastic forming**
  - Injection Molding , Compression Molding
- ▷ **Forging**

# Slip Casting

A.



B.



# Slip Casting

A.

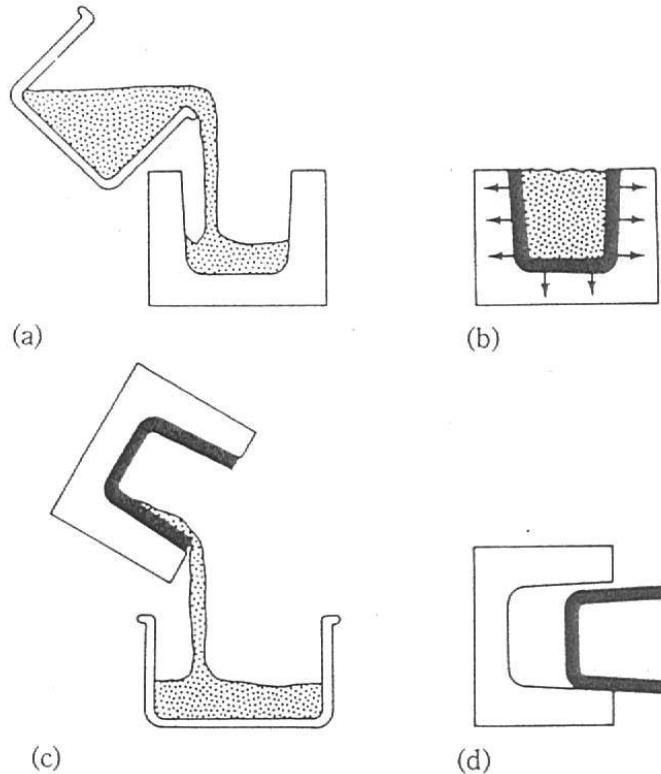


그림 1. drain casting

(a) permeable is filled with slip.

(b) liquid is extracted from the mold while forming compacts along mold walls

(c) excess slip is drained ,

(d) casting is removed after partial drying.

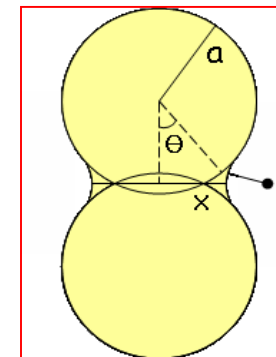
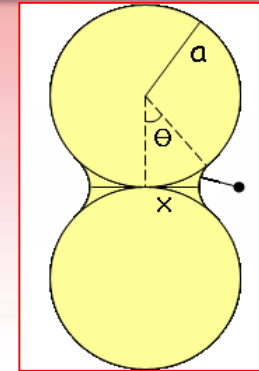
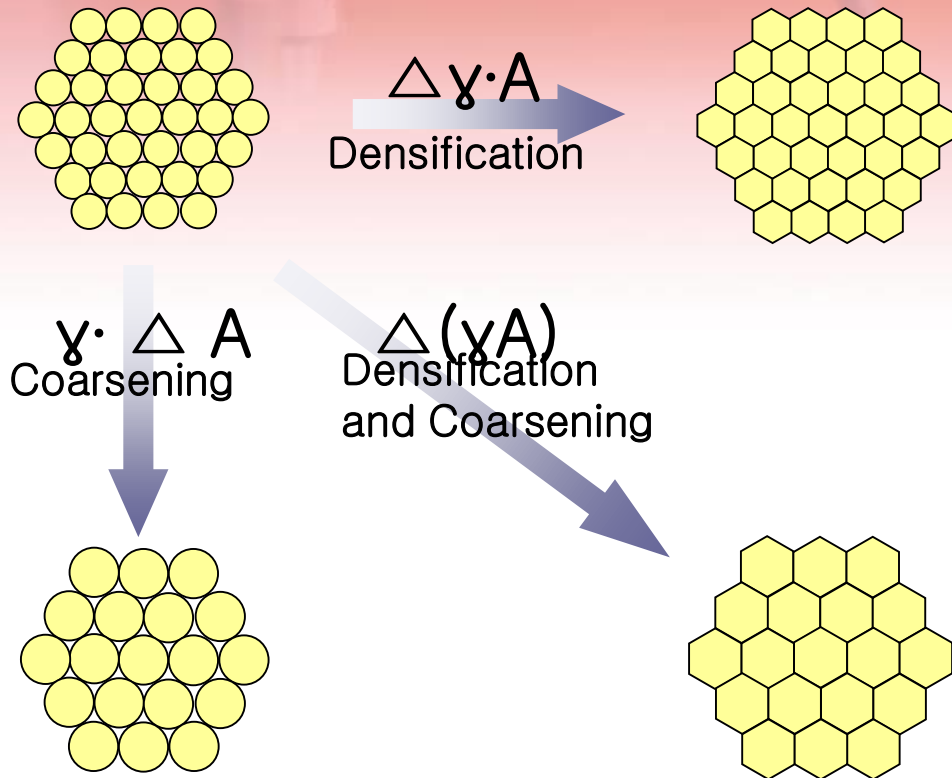
B. Solid casting: No excess slip is drained.(No (c) step)

# Sintering

Sintering :mean particle of coarse by high temperature

$$F_c = 5Dr$$

# Sintering

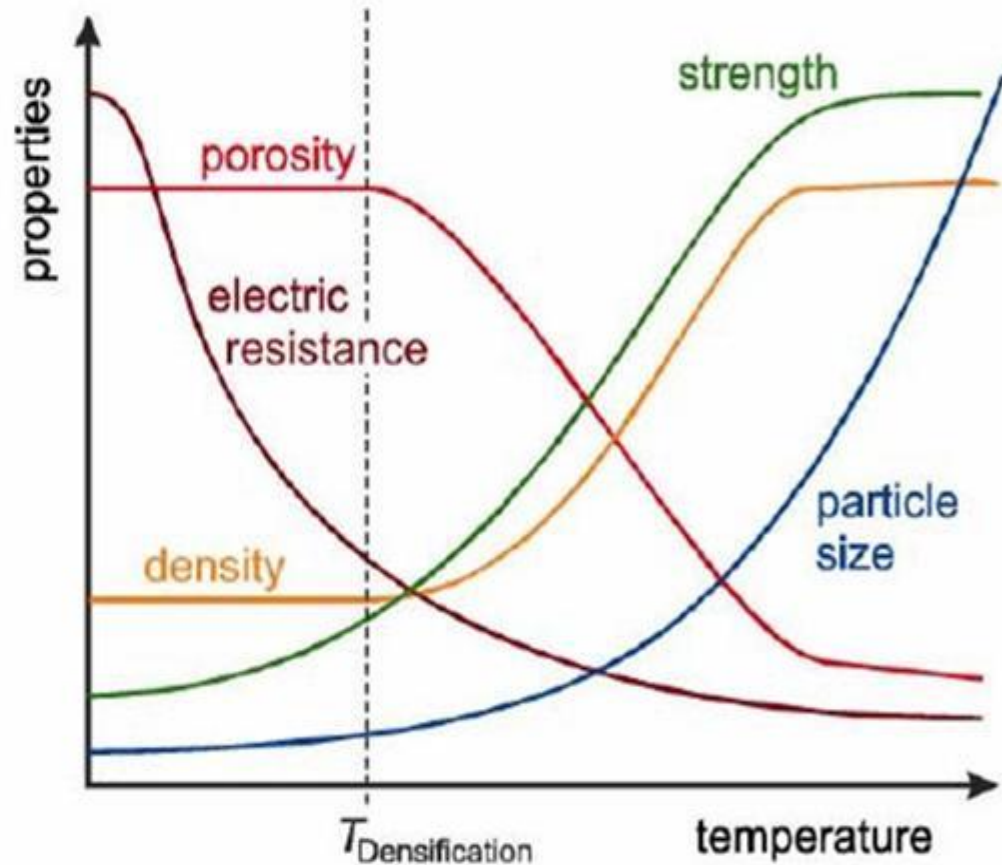


$$\Delta(\gamma A) = \Delta \gamma \cdot A + \gamma \cdot \Delta A$$

Driving force is the decrease free energy by reduction of the particle surface

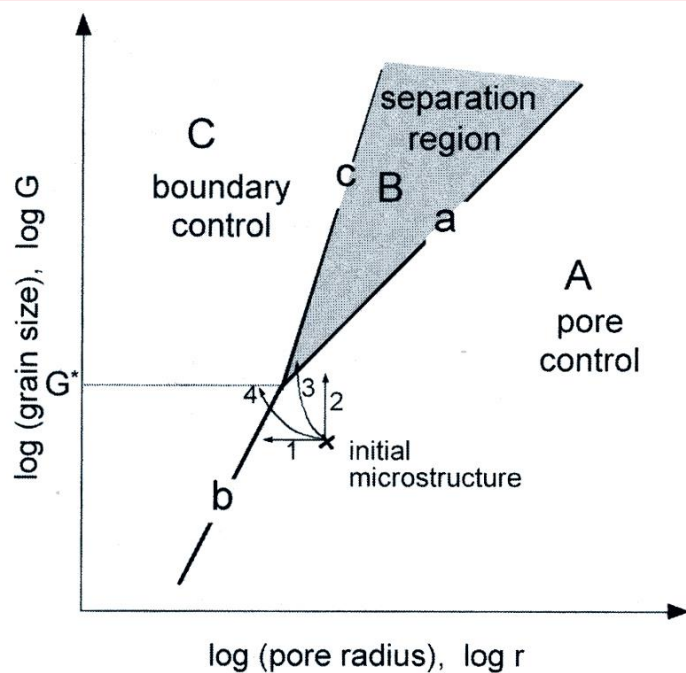
# Sintering

It is the sintering operation where the compact acquires the strength or other properties needed to fulfill the intended role as an engineering component





# Sintering

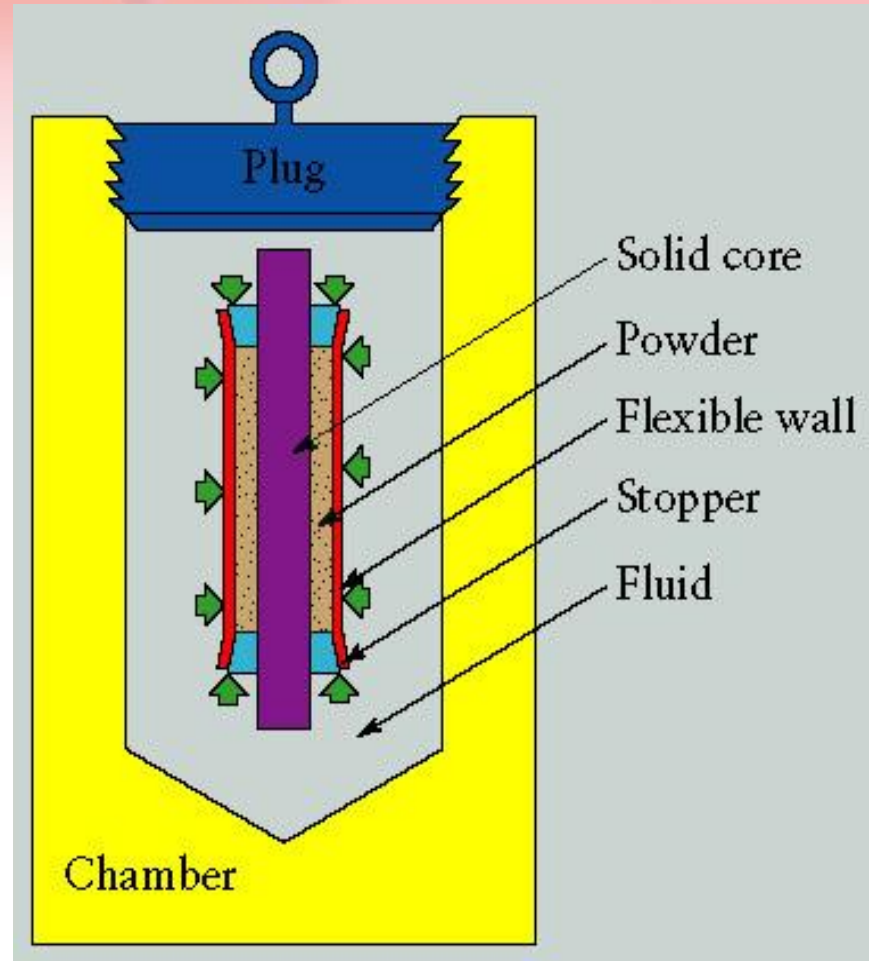
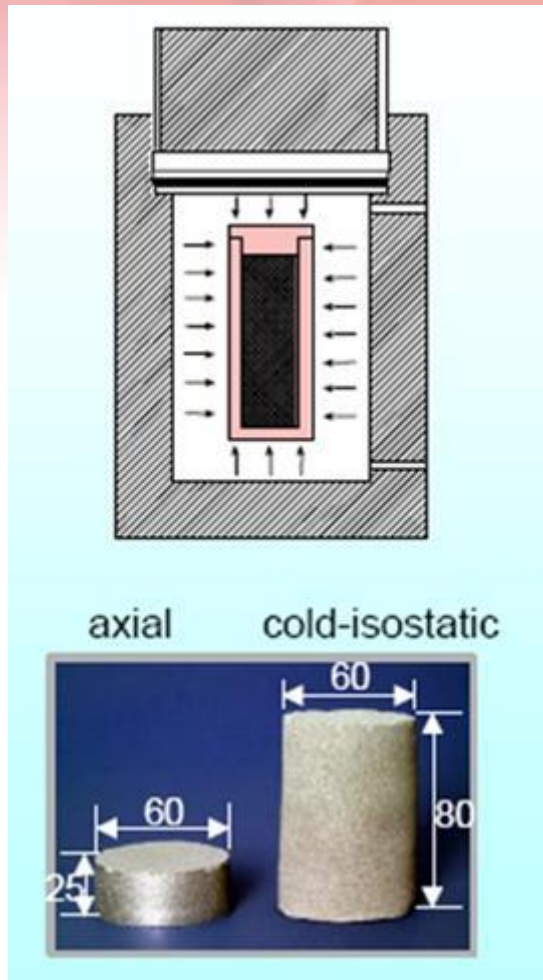


영역A : 기공의 크기가 커서 기공이 입계의 이동을 효과적으로 억제. (기공제어)

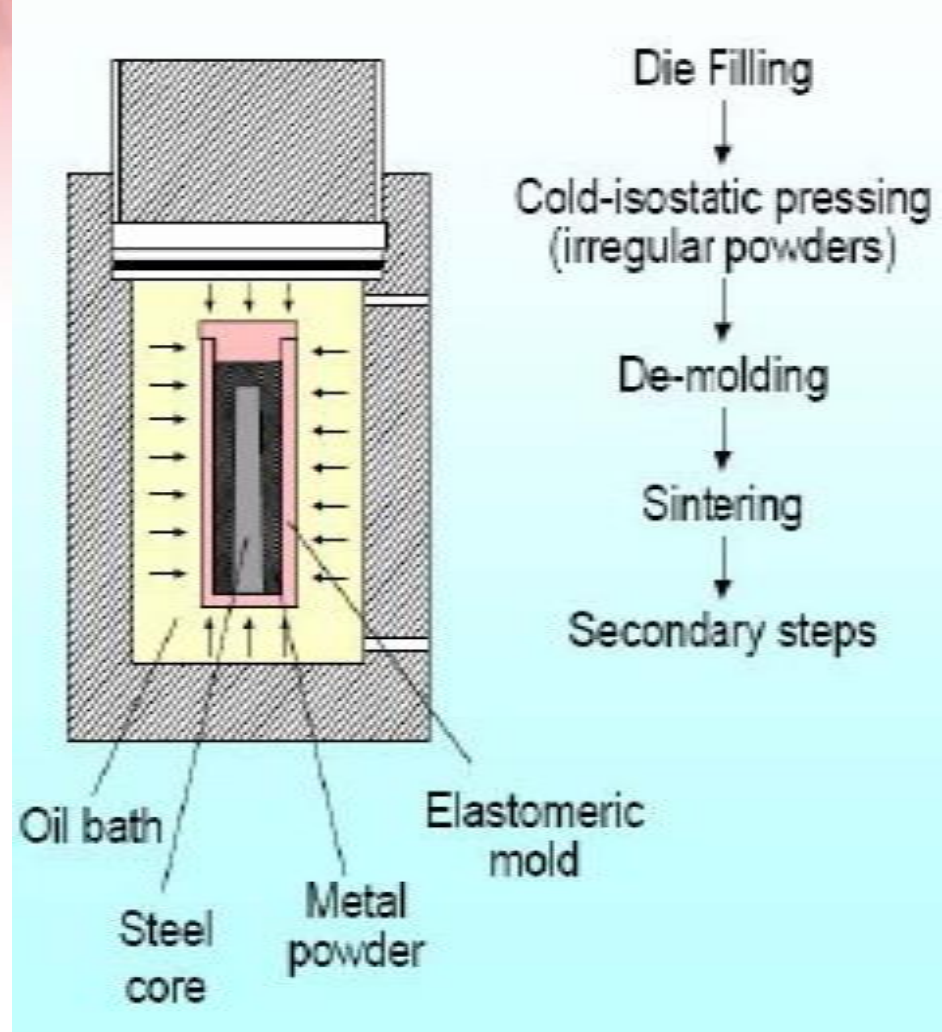
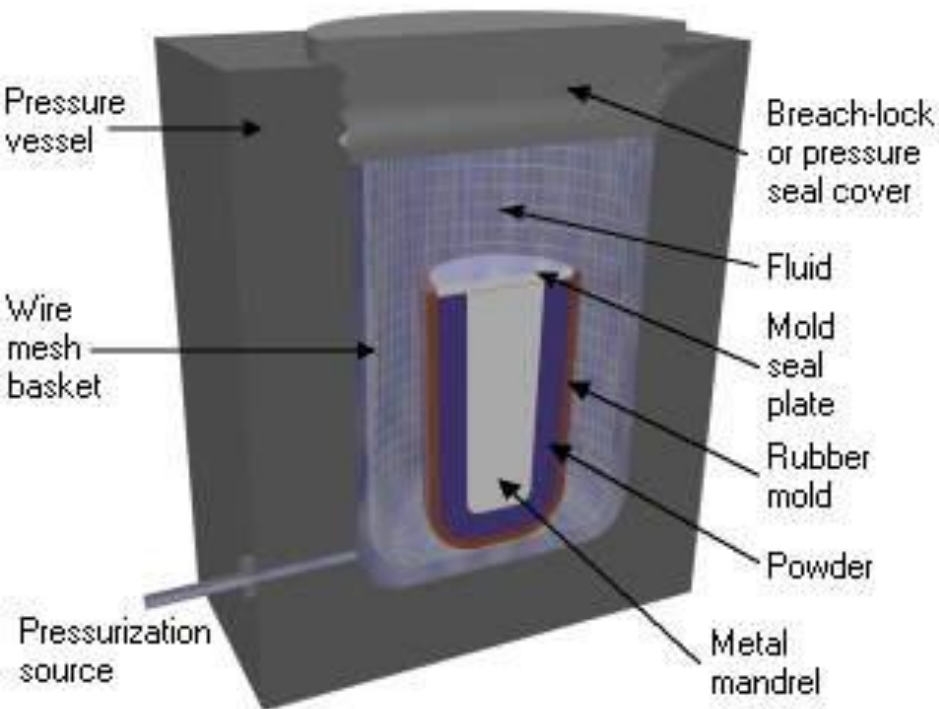
영역B : 입계 이동 속도가 기공 이동속도보다 커서 입계와 기공이 분리되는 영역

영역C : 기공의 크기가 작고 기공의 이동도가 커서 입계 이동시 기공이 따라 이동 가능 (입계제어)

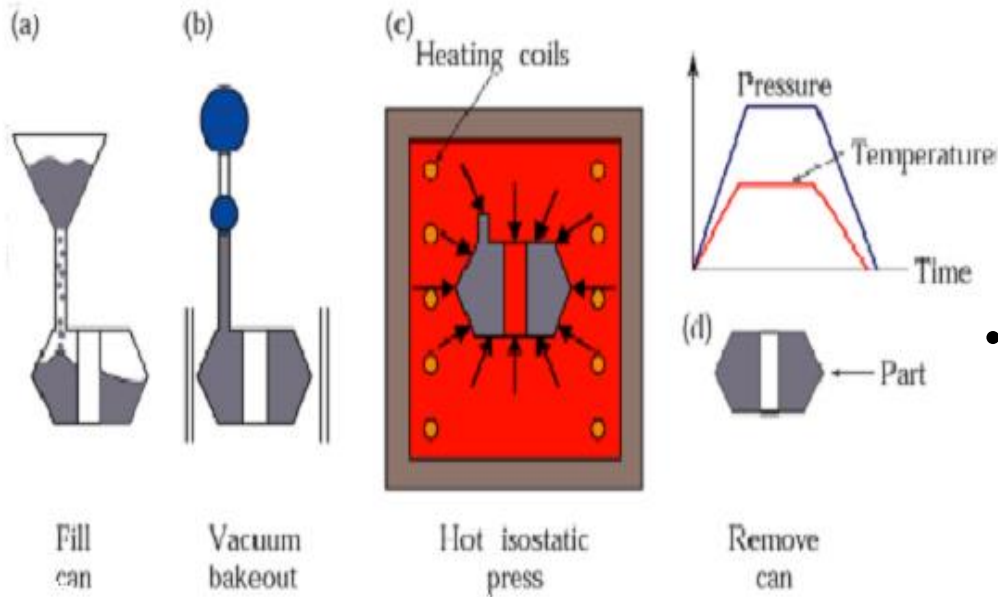
# Cold Isostatic Pressing



# Cold Isostatic Pressing



# Hot Isostatic Pressing



- Hot Isostatic pressing
  - Container is made of high-melting-point sheet metal
  - Uses an inert gas as the pressurizing medium
  - Common conditions for HIP are 15KSI at 2000F
  - Mainly used for super alloy casting

# Injection Molding – Powder Injection Molding

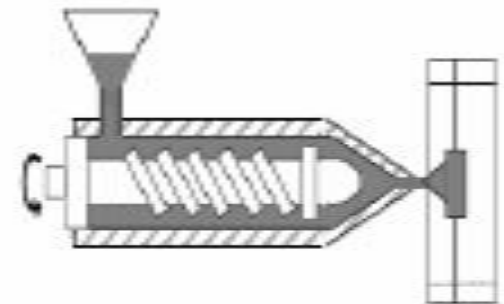


Selection

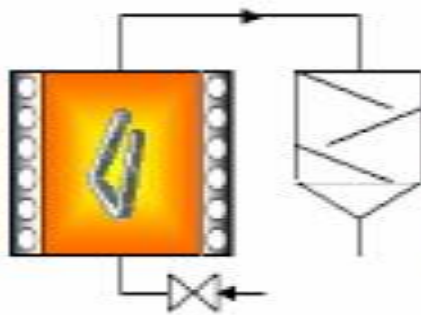


Feedstock

Mixing and  
Pelletizing



Injection Molding



Debinding



„Brown part“



Sintering



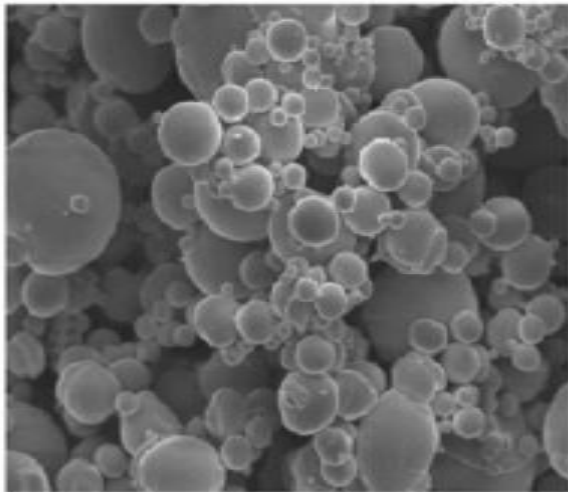
Sintered part



# Injection Molding- Particle shape

Particle shape

spherical shape:



nickel titanium

10  $\mu$ m

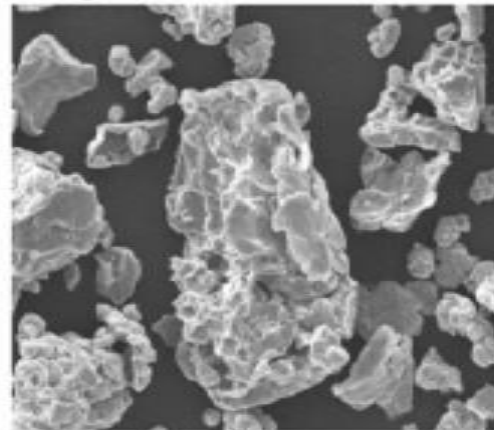
hollow particles:



silicon carbide

100  $\mu$ m

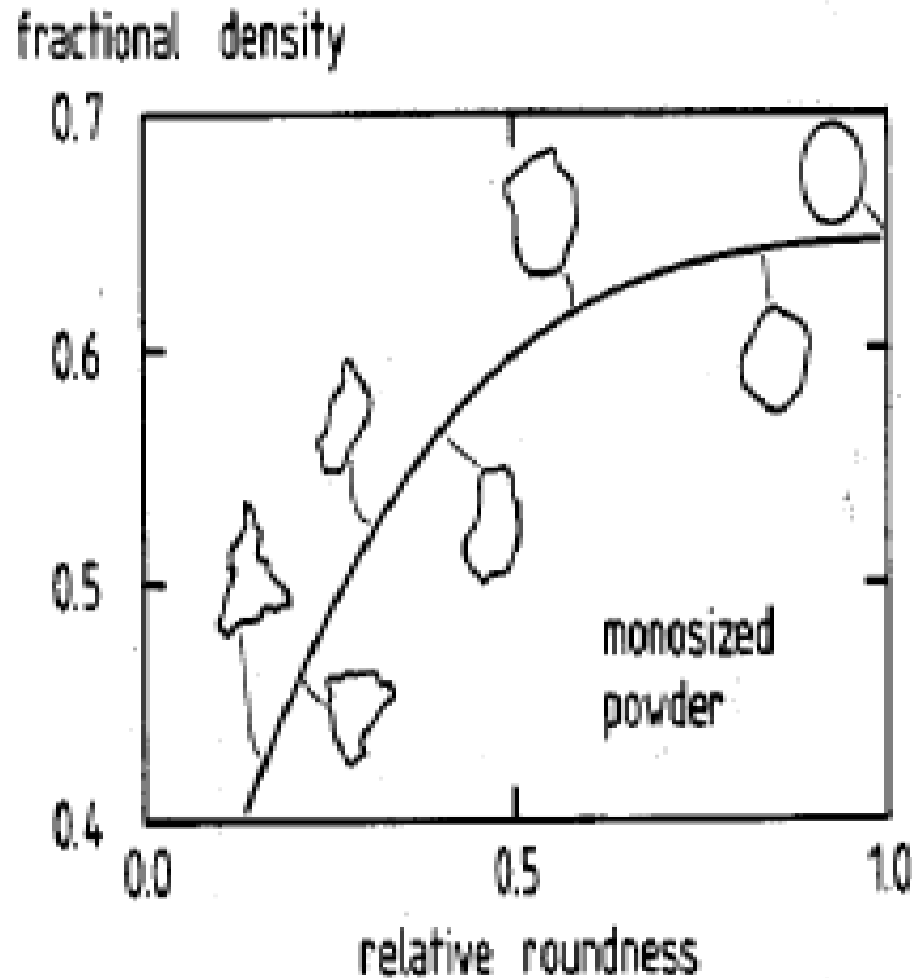
angular:



nickel, agglomerates

30  $\mu$ m

# Injection Molding – Deviation from spherical shape



The lower the relative roundness of particles, the lower the packing density.

# Injection Mold ing – Metal Injection Molding

Starting material:

- powder
- binder
- feedstock

Injection molding:

- mixing
- pelletizing
- injection molding
- debinding
- sintering

Design



# Injection Molding – Metal Injection Molding



Form Physics – Guitar parts



Parmaco



FormPhysics – T-pieces



Ortho Organizers Inc. – Brackets



Parmaco



Central Corporation

# Injection Molding – Metal Injection Molding

## Advantage of MIM

- intensive utilization of raw materials
- reduction of energy consumption
- complex geometries
- high accuracy in manufacturing
- near net shape
- high volume production
- particular material properties
- compound materials
- controlled density (homogeneous)
- controlled porosity
- controlled microstructure

# Injection Molding – Ceramic Injection Molding



Form Physics – medical technology



Honeywell



Sinter-Metal – medical technology



Form Physics



BASF - watchcase



Wundermold

# Injection Molding – Binder

Selection of binders essential for the quality of the products  
→ composition often know-how of companies  
(many patents in the field of PIM concern binders)

## Function:

temporary vehicle for homogeneously packing a powder into the desired shape and holding the particles in that shape until the beginning of sintering



- providing the rheological properties for molding
- ensuring a stable green part for handling
- elimination before or during sintering without leaving residues aiming at pure materials

# Injection Molding –Example for thermoplastic binder system

69 % paraffin wax  
20 % polypropylene  
10 % carnauba wax  
1 % stearic acid

Even very different properties of binders with the same composition are possible (e.g. chain length of the polymers are essential)



Selection of binder system very complex

Know-how of companies



# Injection Molding – Mixing

homogeneous feedstock is prerequisite for error-free component

**Aim:** Wetting of particles with binder, breakup of agglomerates, homogeneous distribution of binder and particles

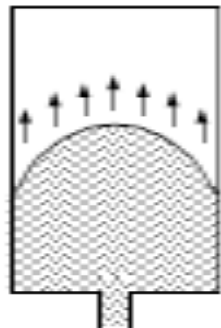
- homogeneous mixture down to molecular level: each interspace of particles filled by binder
- risk of decomposition due to particles with different shape, size, density
- two types of inhomogeneity: segregation powder – binder; particles with different size



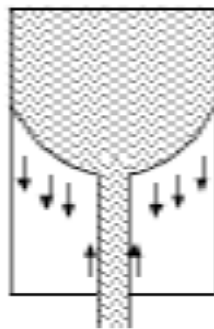
control of mixing process is essential:  
temperature, rotational speed, order of mixing steps,  
precise measurement of weight of feedstock specimens,  
usage of mixer with high shear rate

# Injection Molding –Molding defects

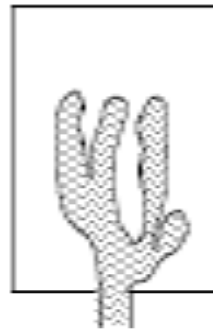
- to high velocities and pressures: segregation, jetting, swirling, cracks, trapped air
- to low velocities: insufficient filling
- to low mold temperature: freezing at the mold wall



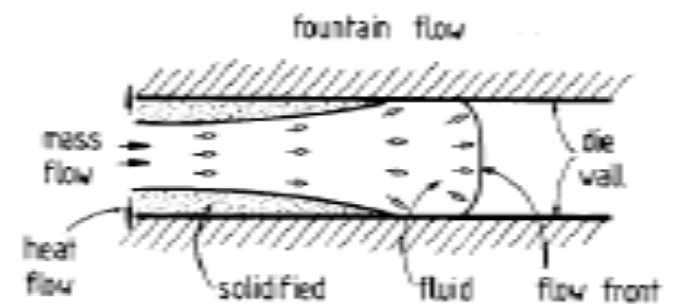
optimal filling:  
progressive fill



jetting



swirling



freezing at the mold