Ceramic Materials Manufacturing

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Ceramic Powder Compaction

Pressure compaction:

These techniques involve application of external Low pressure to compact the loose powder particles;

Powder Extrusion

Powder Extrusion Moulding (PEM) is a development of conventional polymer extrusion processes.

This technology consists of four stages:

Mixing, extrusion, binder removal and sintering.

In the first stage a metallic or ceramic powder is mixed with a binder system usually formed by a thermoplastic polymer and lubricants.

This mixture, named "feedstock", is fed into an extrusion machine where is melted and passed through a nozzle that shapes the profile.

The cross-sectional area of this profile is constant.

$$D_c = D_T - \Delta D^{-(\beta E^{\gamma})}$$

Where

Dc : is the compacted density

DT :is the full density of the material(powder)

ΔD : is the difference between full and compacted density

β : constants of powder

γ : constants of design

E: is the net energy absorbed by the powder.

Next,

binder removal stage:

The organic component that served as a vehicle during extrusion stage is decomposed. Commonly, the elimination takes place by means of thermal degradation.

Finally,

sintering stage,

the part is subjected to a high temperature thermal cycle to densifie and get final dimension.

- Previous to mixing, an important issue is powder selection (ceramic or metallic) in accordance to final application.
- Powder characteristics, such as size and particle size distribution are crucial for “feedstock” formulation and determine the results obtained at the different stages of the process.
- Binder system selection should be based on rheological behaviour, powder-binder interaction, processing temperature and decomposition range, etc.

It can be said that binder should be tailored to the powder in accordance to the final application.

During mixing stage a suitable powder-binder ratio should be determined.

This ratio is a commitment between obtaining the suitable rheological behaviour for the extrusion step and simultaneously to obtain final parts with the required density.

- For example:

If final pieces with high porosity are required it will not be a problem to reduce powder loading in "feedstock" which in addition will improve the flow properties during the extrusion stage.

Nevertheless, in this case special attention should be paid to the dimensional stability of the profile after the following stages of the process.

In the extrusion stage parameters such as temperature profile, rotor speed and *wire drawing,* etc should be carefully controlled.

In the removal stage a thermal cycle should be designed in accordance to the binder system used.

Binder removal should be carried out gradually to avoid defects in the final part.

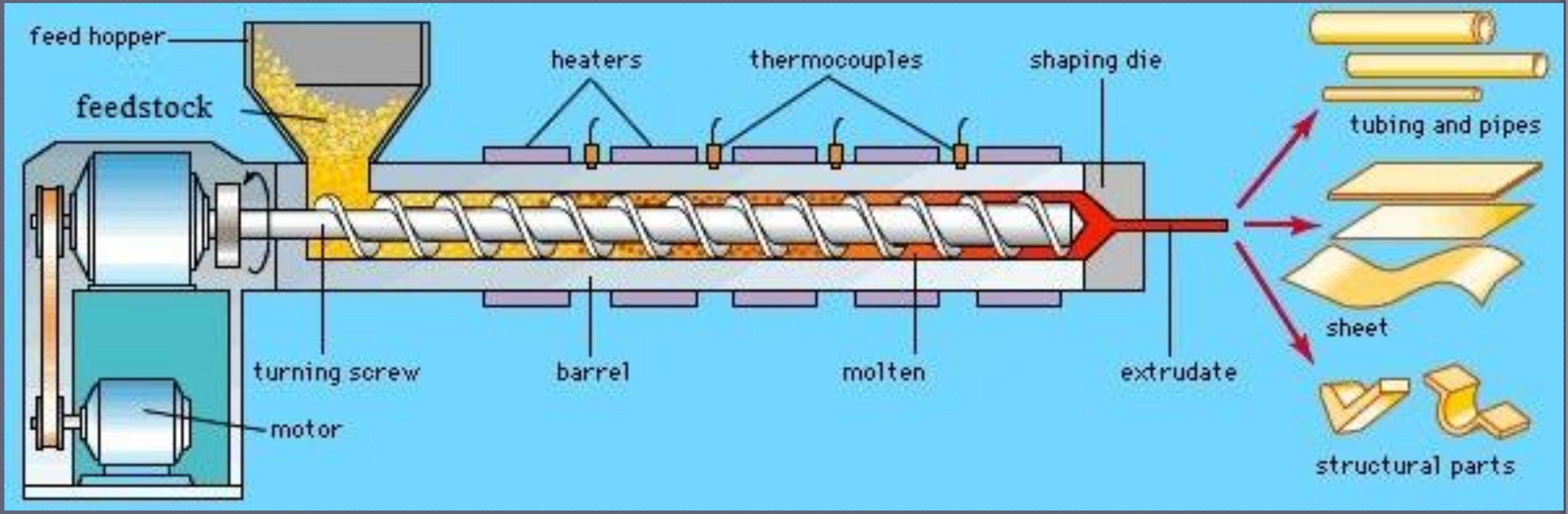
Finally, in the sintering stage the thermal cycle is designed to obtain the required properties according to the final application

Innovative Aspects:

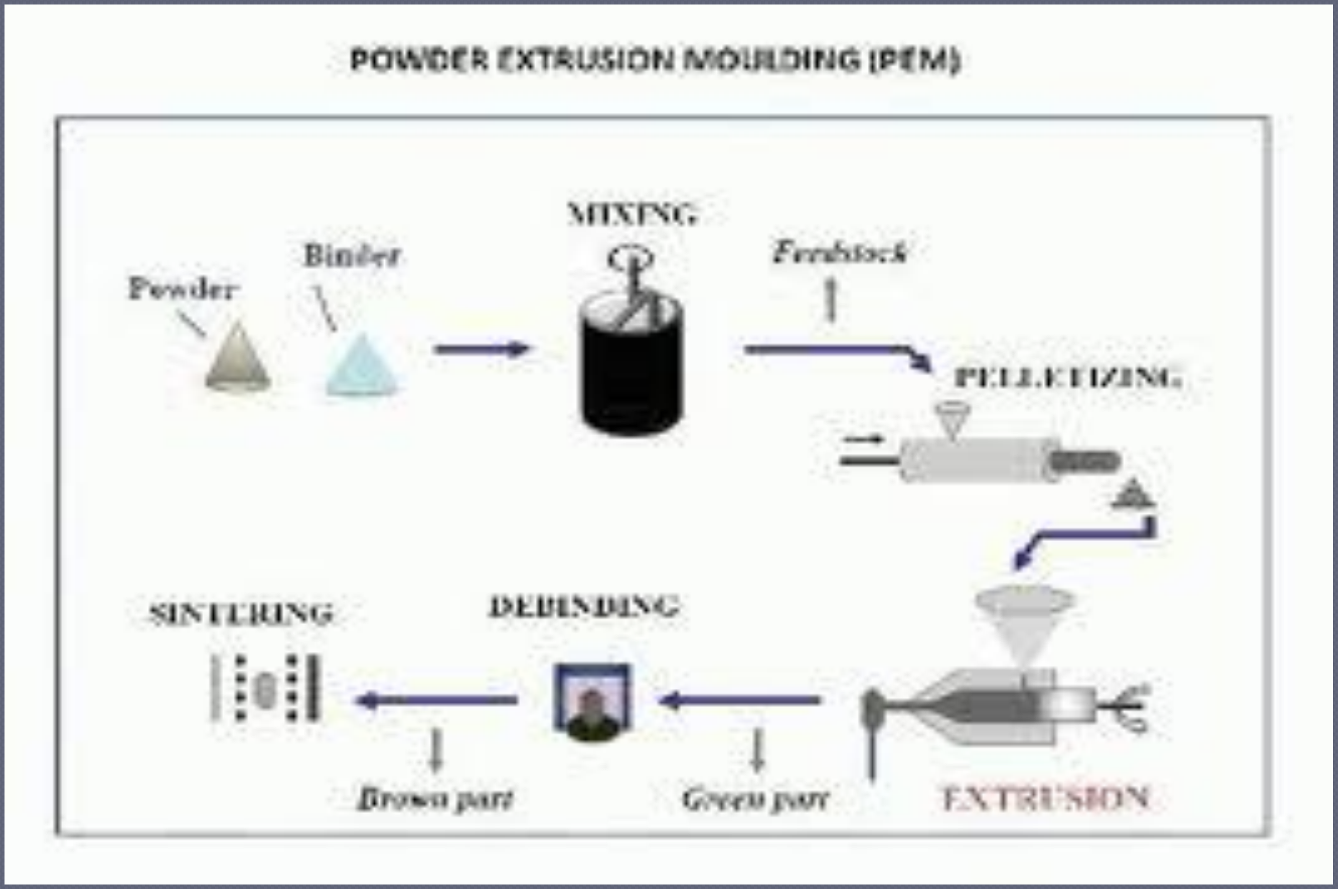
This technology allows to produce metallic or ceramic profiles with high accuracy.

Since starting material are powders and an organic vehicle, usually constituted by thermoplastic polymers and some lubricants, the materials can be processed at polymer processing temperature avoiding high processing temperatures commonly used for metallic or ceramic processing.

On the other hand final parts have high dimensional accuracy and the porosity of the profile can be controlled by establishing a suitable powder-binder ratio or by carefully designing thermal cycle during sintering stage. The research group has managed to produce pieces with the required porosity according to the final application.


feed hopper
feedstock
heaters
thermocouples
shaping die
tubing and pipes
sheet
turning screw
barrel
molten
extrudate
motor
structural parts

3-D printing


POWDER EXTRUSION MOULDING (PEM)
MIXING
Binder
Powder
Feedstock
PELLETIZING
SINTERING
DEBINDING
Brown part
Green part
EXTRUSION

One of the advantages of this technology:

1- possibility of obtaining metallic and ceramic profiles with high dimensional accuracy.

2-Very thin thicknesses of wall can be obtained (in the order of microns), the diameters can be very small.

3-The porosity of the profile can be controlled. high densities can be produced.

4- A cost reduction coming from a smaller energy demand since processing temperature of ceramics and metallics materials is diminished substantially

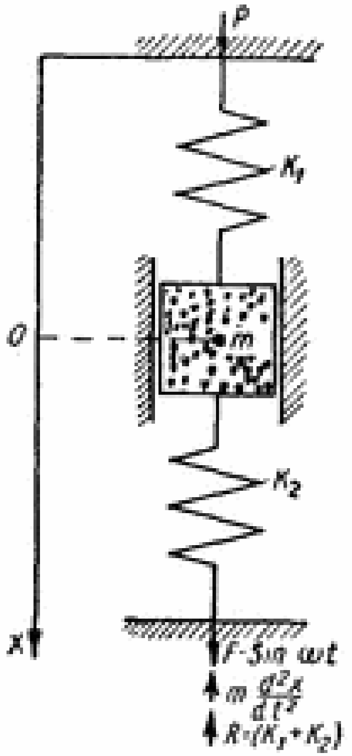
Vibratory Compacting

Vibration can be very effective in obtaining higher packed densities in powders.

The relative densities of powders vibrated under carefully controlled conditions are much higher than those obtained by simply pouring the powder into the container. Therefore, much lower compaction pressures are required to reach a given density for a vibrated powder than for a poured powder. This is illustrated in Fig. 8 for a carbonyl iron powder.

The density of 5.53 g/cm3 (71% relative density), reached by compacting under a pressure of 245 MPa (35 ksi), is due to the plastic deformation of the iron powder particles, while the 5.37 g/cm3 (69% relative density) obtained by vibrating at 167 MPa oscillations per second is due mainly to vibratory packing. Plastic deformation during the simultaneous compacting at 2.4 MPa (0.36 ksi) is minimal.

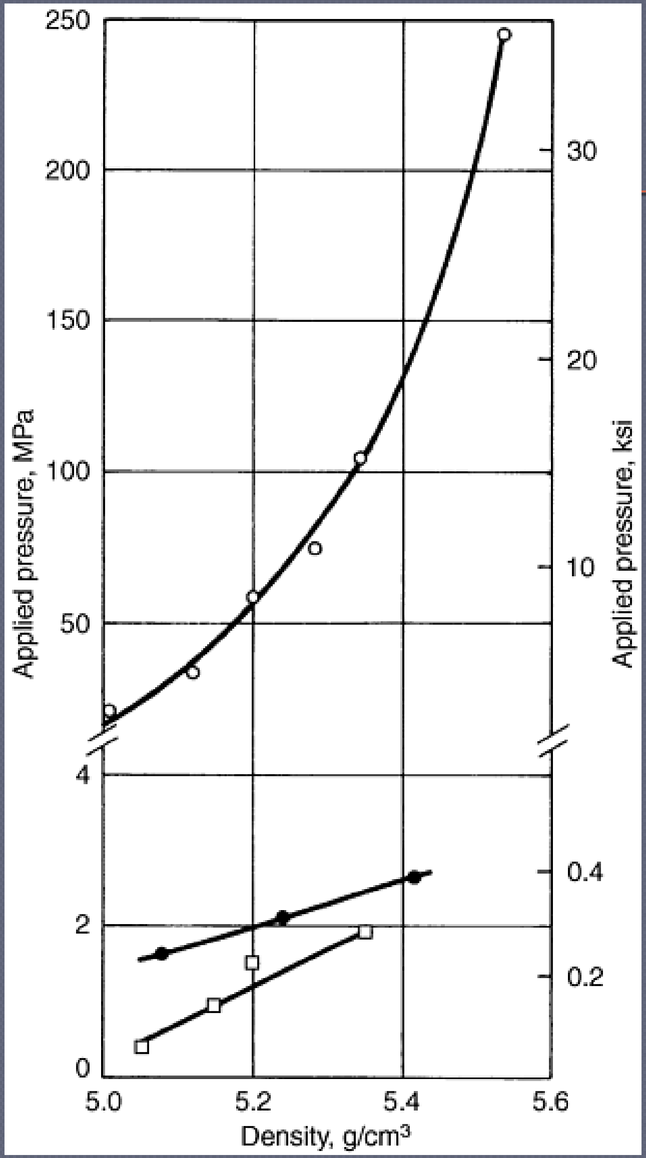
The method of consolidating powders by vibrating and simultaneous compacting is, therefore, primarily applicable to hard powders, such as refractory metal and cemented carbide powders, which can be densified relatively little by pressure application alone.



Theoretical model of vibration pressing.

$$K_2 = \frac{C\sigma d}{2},$$

where C is a coefficient which takes into account the effect of the static force P and the dynamic force F, σ is the shear modulus of the material, and d is the diameter of the part to be compacted.



Vibratory compacting at a frequency

of 233 oscillations per second.

Vibratory compacting at a frequency

of 167 oscillations per second

Effect of powder vibration on densities of FeO2 compacts.

Obtained in static pressing.