Table of contents

1. Designing structural parts
2. Capabilities of PM technology
3. The compacting process
4. Design tips for PM structural parts:
   - Ejectability
   - Robust tooling
   - Powder filling
   - Compact integrity
5. Design tips for Gears
6. Dimensional tolerances
7. PM self-lubricating bearings: shapes and tolerances
PM structural components
PM soft magnetic components
Designing components

Geometry
- Size
- Shape
- Dimensional tolerances

Material
- Mechanical, physical and/or chemical characteristics
- Chemical composition
- Manufacturing process

Function to be fulfilled inside a Mechanism

CONDITIONANTS:
- Process reliability
- COST

CHosen MANUFACTURING TECHNOLOGY
Let’s suppose that....

- **The component size fits with PM capabilities:**
  - Press size 1,200 Tm max.
  - Compacting surface 180 cm\(^2\) max.
  - Outer diameter 200 mm max.
  - Length 80 mm max.

- **Characteristics are reachable:**
  - Yield strength
  - Fatigue strength
  - Hardness
  - Toughness
  - Wear resistance
  - Friction coefficient
  - Corrosion resistance
  - Magnetic properties
The PM manufacturing process

Powders
- Graphite
- Copper
- Iron
- Lubricant
- Alloying elements or additives
- Other base powders

Mixing

Compacting

Sintering

Tooling

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The compacting process

Die filling                          Compacting                           Ejection

Powder filling

Robust tooling

Ejectability
Compact integrity

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**Design tips: EJECTABILITY**

- Avoid external grooves, orifices perpendicular to the direction of compaction, threads and knurls/indents.

- Obtainable by additional machining, or replaceable by axial indents, longitudinal grooves or faceting.

- Both inner and outer flanges must have a minimum thickness and radius (higher **COMPACT INTEGRITY**).

- Recommended 2 - 3 mm (lower values are possible in certain cases).

- Other options achievable by additional machining.
Design tips: EJECTABILITY

- Introduce draft angles and limit relative lengths between levels
- Recommended $\alpha > 10^\circ$ $\beta > 12^\circ$ $L_2 < 0.2 \cdot L_1$ $L_3 < 0.15 \cdot L_1$ (improvable values)
- Higher COMPACT INTEGRITY

- STEPPED PARTS: Select the inner diameter dimensions to match the outer diameters
- Wall thickness > 2 mm
- Higher COMPACT INTEGRITY
- Other options available by additional machining
Design tips: ROBUST TOOLING

- Ratio between depth and diameter in blind holes:
  - Upper side: $L/D < 2$
  - Lower side: $L/D < 5$

- Other options available by additional machining

- Holes diameter $> 1.5$ mm
- Diameter/length ratio for cores rods: $D > 0.15 \cdot L$
- Wall thickness $> 1.5$ mm (lower for specific cases): good POWDER FILLING
- Other options available by additional machining
Design tips: ROBUST TOOLING

- Chamfers strengthen punches (sharp tip punches) and reduce the risk of material loss of green parts: COMPACT INTEGRITY

- Chamfer angles: $\alpha = 30^\circ-45^\circ$
  $\beta = 45^\circ-60^\circ$ $\gamma > 25^\circ$, ending with a short plane of width 0.1-0.5

- Radii or other chamfers are possible by additional machining

- Inner and outer profiles need a straight cylindrical zone to allow proper fit and guide between punch, core rod and die

- Chamfers and cylindrical zones reduce the unavoidable burrs appearance
Design tips: ROBUST TOOLING

- Cylindrical shapes with axes perpendicular to the pressing direction should be avoided (*sharp tip punches*).
- Design alternative shape or machine the shaft.

- Superimposed shapes must allow the part ejection and must be achievable with tools with a robust section (*avoid sharp tip punches*).
- Maximum cone: 20°
- Greater angles of other superimposed shapes can be obtained by additional machining.
Design tips: ROBUST TOOLING

- Deep and narrow notches make tooling more brittle
- Recommended $a > 2.0\, \text{mm} \quad a/b > 0.2$ (more restrictive in some cases)

- Sharp edges make tooling brittle (sharp tips), make the green part more brittle (COMPACT INTEGRITY) and make powder filling difficult (POWDER FILLING)

- Introduce radii and work with minimum wall thicknesses: $a > 2.0\, \text{mm} \quad a/b > 0.2$ (more restrictive in some cases)

- Arm-to-bushing unions should not be tangential (sharp tip punches)
Design tips: GEARS

- Modulus of spur teeth and splines > 0.5 mm: POWDER FILLING
- Radius > 0.25 mm is required to manufacture the die

- Helical teeth should feature a helical angle < 25° in order to limit side pressure on the punches
- Higher helical angles are possible with special press and tooling architecture
Design tips: GEARS

- The distance between tooth root and central hub diameter must be: $d > 3 \text{ mm}$ (ROBUST TOOLING)

- Introduction of a draft angle $\alpha > 5^\circ$ in the upper diameter reduce the tooling cost

- A chamfer along the profile or a circular relief densify the tooth tip (COMPACT INTEGRITY) and strengthen punches (ROBUST TOOLING)
Typical tolerances applicable to dimensions of a part in mass production (Cpk = 1,33)
Typical tolerances applicable to teeth of a gear in mass production (Cpk = 1.33)

Table of basic ISO tolerances in microns

| Dimensions in mm | Quality
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than</td>
<td>Up to</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
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<tr>
<td>3</td>
<td>6</td>
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<td>80</td>
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<td>80</td>
<td>120</td>
</tr>
<tr>
<td>120</td>
<td>180</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Sinter-hardened or heat treated</th>
<th>Sized</th>
<th>Added machining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance over pins (a)</td>
<td>11</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Dimension between “k” teeth (b)</td>
<td>10</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Fₚ: Total cumulative pitch error</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Fₗ: Total profile deviation</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Fᵦ: Total helix deviation</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Fᵦ: Total radial composite deviation</td>
<td>10</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Fᵦ: Tooth-to-tooth radial deviation</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Fᵦ: Radial runout</td>
<td>10</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

Quality according to ISO 286 standard

Class according to ISO 1328-1:2013 or DIN 3962 standards
PM self-lubricating bearings

PM Self-lubricating bearings vs PM structural parts

- Simpler geometry
- Lower density (15-25% porosity)

Relaxed criteria for tooling robustness
- Lower draft and chamfer angles
- Lower powder filling criticality

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Typical geometries and tolerances

### Cylindrical
- **Ø d (inner diameter)**: IT-5 / IT-7, IT-6 / IT-8, IT-5 / IT-7
- **Ø D (outer diameter)**: IT-5 / IT-7, IT-6 / IT-8
- **Ø D’ (flange diameter)**: IT-6 / IT-11
- **Ø E (sphere diameter)**: IT-6 / IT-11
- **L (length)**: IT-12
- **e (flange thickness)**: IT-12

### Flanged cylindrical
- **Ø d (inner diameter)**: IT-6 / IT-8
- **Ø D (outer diameter)**: IT-6 / IT-8
- **Ø D’ (flange diameter)**: IT-6 / IT-11
- **Ø E (sphere diameter)**: IT-10 / IT-11
- **L (length)**: IT-12
- **e (flange thickness)**: IT-12

### Spherical
- **Dimensions in mm**
  - **Quality**: IT-3, IT-4, IT-5, IT-6, IT-7, IT-8, IT-9, IT-10, IT-11, IT-12, IT-13, IT-14
  - **Dimensions greater than**: 1, 3, 6, 10, 18, 18, 30, 30, 50, 80, 120, 180
  - **Dimensions to**: 3, 6, 10, 18, 30, 30, 50, 80, 120, 180

### Bearing type
- **Cylindrical**: IT-5 / IT-7, IT-6 / IT-8, IT-5 / IT-7
- **Cylindrical with flange**: IT-6 / IT-8
- **Spherical**: IT-10 / IT-11

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- Improved function
- Improved assembly

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