MFS
SINTERING

SINTERED PARTS
TECHNICAL GUIDE

WHAT IS **POWDER METALLURGY**?

The POWDER METALLURGY is a process which begins with the mixings and blending of metal powders to a material specification, together with lubricant, until a homogeneous mix is obtained. This powder mix is then compacted in a press to the required component shape. This shape is obtained from a specific tool evolved by MFS.

Once the compacting process is completed, the component parts are heated with a protective atmosphere in a special sintering furnace at temperatures of up to 1200ºC (below the melting point of the main constituent). During this operation a bond is created between the material grains producing the component's final properties.

In many cases, the parts are then sized in special presses providing more accurate tolerances. Parts can then be subject to additional processes –machining, deburring, heat treatment, steam treatment, impregnation, etc. To achieve better tolerances and other specific properties for particular applications.

POWDER METALLURGY is developing at a growth rate higher than most competitive technologies. This is mainly because it is capable of offering solutions which are more competitive in terms of both of performance and costs. Technical advantages are summarized below.

FAVOURABLE FACTORS

- ✓ Mechanically defined shapes and good tolerances: Part ready for assembly
- ✓ Homogeneous and good level mechanical properties
- ✓ High productivity
- ✓ Self-lubricating properties
- ✓ Metallurgical combinations and composites not available from traditional technology
- ✓ Possibility to conceive parts whose shape would not be available from other processes without sacrificing tolerances, etc.

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MATERIALS

POWDER METALLURGY offers the designer an exceptionally wide choice of materials. This is mainly because the raw materials are in the form of powder particles whose composition and structure may be chosen at will.

In the design of mechanical components, iron based materials have an equal importance in PM as with wrought steels, etc. To achieve their requirements design engineers have an extremely wide choice by combining compositions and structural conditions.

In selecting PM materials the designer has to take in account one important aspect.

The dimensions of the component can change during the production cycle mainly due to the sintering process. This dimension change is controlled by a number of factors. Some are created by the supplier, e.g., nature of the powders, sintering temperature and atmosphere, etc. The other are by the customer in his drawing specification, like alloy composition, density and heat treatments, case hardening, etc.

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STANDART MATERIALS – **COMPARISON CHART**

DIN	ISO	(AFNOR)	MPIF	B.S
C00	P1024	FC 1064	F0000-10	A.201
D00	P1025	FC 1068	F0000-15	A.203
E00	P1026	FC 1072	F0000-20	
C01	P1034	FC 5064	F0005-20	
D01	P1035	FC 5068	F0005-25	
B10	P2023		FC0200-18	
C10	P2024	F10U364	FC0200-18	A.301
D10	P2026	F10U370	FC0200-24	
D11	P2045	F50U368	FC0205-40	
B11	P2053		FC0208-40	
C11	P2054	F80U366	FC0208-50	
C35	P1064	F 10 P64		

DIN	ISO	(AFNOR)	MPIF	B.S.
D35	P1065	F 10 968		
C36	P2094	F 10U3P66		
D39	P3086	F50N2U2D70		
C39	P3104			
D39	P3106	F50N5U2D70		
D30	P3076	F10-N2U2D-70		
E30		F10-N2U2D-72		
B50	P4013Z			
C50	P4033	FU-E10-76	CT1000-13	
C02		FC 05-64		
D02		FC05-68		
E02		FC05-72		

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STANDART SINTERED MATERIALS - **SPECIFICATION CHARTS**

Application: Structural parts

- IRON

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C00	<0.3	<0.1					Bal	2	6.4-6.8	15±2.5	>35	130
Sint D00									6.8-7.2	10±2.5	>45	190
Sint E00									>7.2	<7.5	>60	260

*representative values
Economic grades with high elongation rate.
Parts requiring a mechanical deformation such as crimping at assembly on.
Oil burner pump parts.

- CARBON STEEL

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C01	0.3-0.6	<0.1					Bal	2	6.4-6.8	15±2.5	>70	260
Sint D01									6.8-7.2	10±2.5	>90	320

*representative values
According to their carbon content may be hardened or case hardened.
Economic steels with average mechanical properties.
Economic gearing, spacer.

STANDART SINTERED MATERIALS - **SPECIFICATION CHARTS**

Application: Structural parts

- COPPER ALLOY STEELS

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C00	<0.3	<0.1					Bal	2	6.4-6.8	15±2.5	>35	130
Sint D00									6.8-7.2	10±2.5	>45	190
Sint E00									>7.2	<7.5	>60	260

*representative values
Susceptible to hardening or case hardening and also steam treatment.
Economic copper steels with average mechanical properties, case-hardening possible.
Passenger cars: Oil pump gears, steering rack rods, shock absorber components.

- COPPER CARBON STEELS

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C11	0.4-1.5	1.5					Bal	2	6.4-6.8	15±2.5	>80	320
Sint D11									6.8-7.2	10±2.5	>95	400
Sint c21		5-10							6.4- 6.8	15±2.5	>105	410

*representative values
Copper steels with a very good cost/mechanical performance ratio. A group of grades widely used in powder metallurgy, which can be heat treated and surface treated.
Passengers cars: Engine timing sprockets, oil pump gears, rotors and stators of oil pumps with vanes, shock absorber components.
Motor bikes: Clutch cam.
Portable electric tools: Standard duty components.
Miscellaneous: Sewing machine components, transmission chain gears.

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STANDART SINTERED MATERIALS - **SPECIFICATION CHARTS**

Application: Structural parts

- NICKEL-COPPER-MOLYBDENUM STEEL

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	∆v/v*100(%)	HB	N/mm2
Sint C30	<0.3	1.5	1-5	0.8			Bal	2	6.4-6.8	15±2.5	>55	310
Sint D30									6.8-7.2	10±2.5	>60	370
Sint E30									>7.2	<7.5	>90	440

*representative values
Steels for heat treatment, excellent wear resistance.
Passenger cars: Heavy duty transmission components, cams of engine camshaft.
Manual tools: Key ratchets, jaws.

Sint C39	0.3-0.6	1.3	1-5	0.8			Bal	2	6.4-6.8	10±2.5	>90	360
Sint D39									6.8-7.2	10±2.5	>120	360

*representative values
Excellent grades to manufacture parts with high to very high mechanical properties, shock and wear resistance. Can be heat treated.
Passengers cars: Synchronising Hubs, baulk rings, transmission inner control levers, safety components, shock absorbing steering wheel cones, starter rings.
Portable electric tools: Electric impact drill assembly, gears and miscellaneous components.
Miscellaneous: Impact pin of air stapler gun, drive pinion of lawn mower.

STANDART SINTERED MATERIALS - **SPECIFICATION CHARTS**

Application: Structural parts

- PHOSPHOROUS ALLOY STEELS/COPPER PHOSPHOROUS ALLOY STEELS

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C35	<0.3	1.5				0.3-0.6		2	6.4-6.8	15±2.5	>70	310
Sint D35									6.8-7.2	10±2.5	>80	330
Sint C36		1-5							6.4-6.8	15±2.5	>80	360
Sint D36									6.8-7.2	10±2.5	>90	390

*representative values

Additions of phosphorus to iron act as a sintering activator conferring good ductility
Applications similar to those of copper steels with a capacity for excellent elongation and good welding in the case of low carbon.
Good dimensional accuracy after sintering.
Passenger cars: Speedometer sensor, crankshaft bearing cap, transmission fork, alternator base; door hinge.
Miscellaneous: Extractor clamp.

- BRONZES

	Chemical composition %								Density	Porosity	Hardness	Radial Strength *
DIN	C	Cu	NI	Mo	Sn	P	Fe	Other elements	(g/cm3)	Δv/v*100(%)	HB	N/mm2
Sint C50		bal			9-11			2	7.2-7.7	15±2.5	>35	150
Sint D50									7.7-8.1	10±2.5	>45	220

*representative values

Mechanical bronze with high properties, very good machining, very good friction characteristics, parts working in corrosion atmosphere. Can be structurally hardened on nickel bronze, which provides wear and impact resistance.
Miscellaneous: Special or heavy duty bearings, current collector rings on cranes; pump connecting rod slider.

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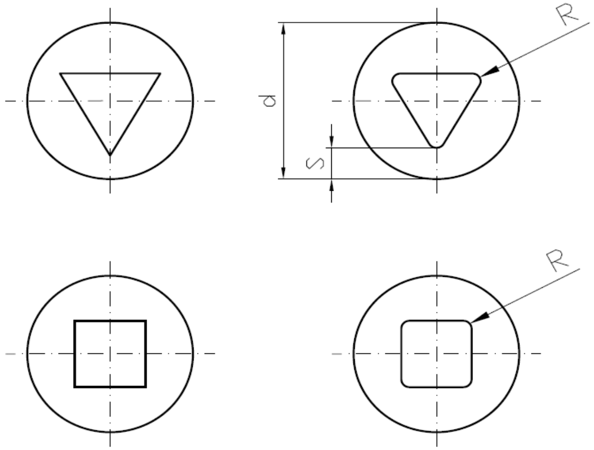
DESIGN

There are a group of basic rules which can help the designer in order to producing sintered parts. Following there are some of the most important.

SHAPES

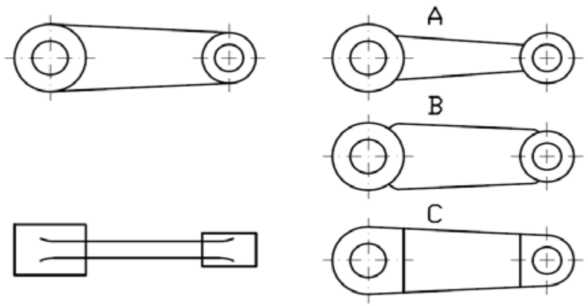
UNSUITABLE SHAPE	PREFFERED SHAPE



Components sections should be as thick as possible: thin walls require thin walled tooling, which increases the possibility of tool failure. This can be avoided in a number of ways such as by increasing the outside diameter modifying the design in the problem area .
(S = 0.1d if it’s possible not <2mm).

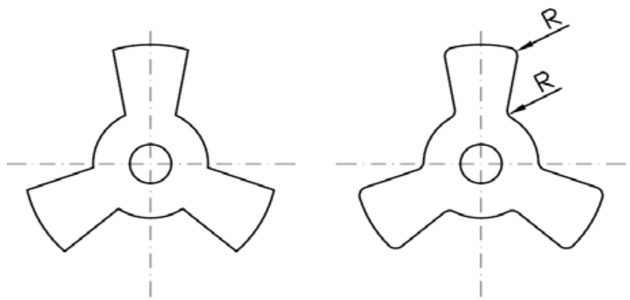
Where **sharp edge** is present, the part will be more susceptible to cracking. Rounded corners allow better powder filling and increase die life.

UNSUITABLE SHAPE	PREFFERED SHAPE



It is not advisable to produce jointed parts by designing **feather edges**. The tooling will be extremely fragile.

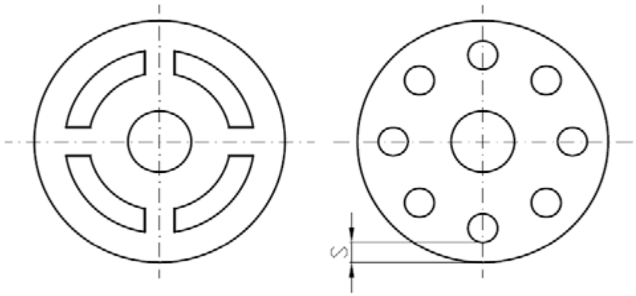
UNSUITABLE SHAPE	PREFFERED SHAPE



Radii are preferred, sharp corners on tooling can also lead to tool failure. This is best avoided by designing in radii where possible.

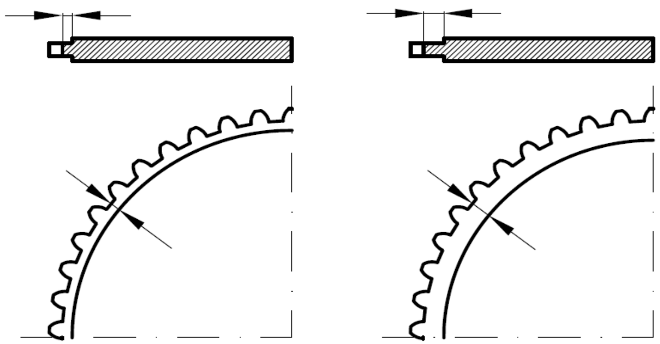
SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE



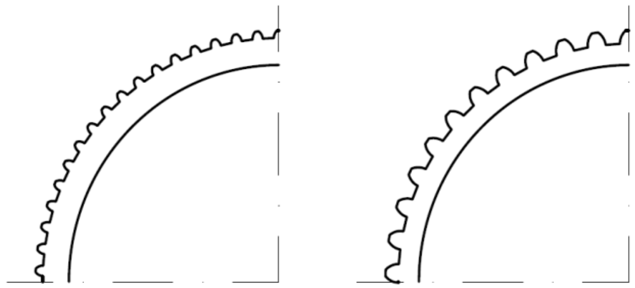
Holes and Wall Thickness. It is possible to produce holes that will help lighten the part and save powder while reducing the pressing surface. It is much more economical to design round hole rather polygonal holes; the reason begins that the tooling is much simple to produce.

UNSUITABLE SHAPE	PREFFERED SHAPE



Gear hub, It is important to remember to leave enough room between the teeth and the hub. This extra space help to insure stronger tooling and produce more resistant part.

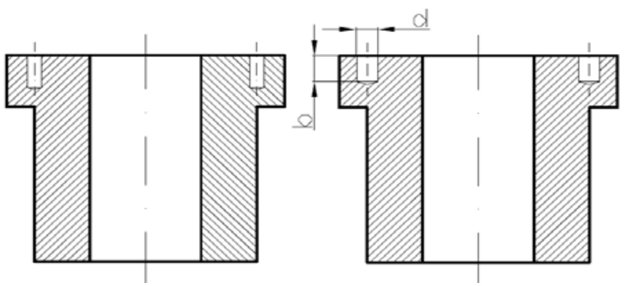
UNSUITABLE SHAPE	PREFFERED SHAPE



Teeth with modulus smaller than 0.5 may not guarantee sufficient mechanical strength; additionally the flow of powder during filling is difficult. In the edge a 0.25 radius is needed to make the tool.

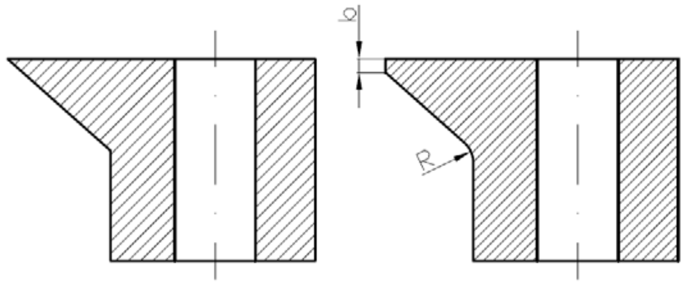
SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE



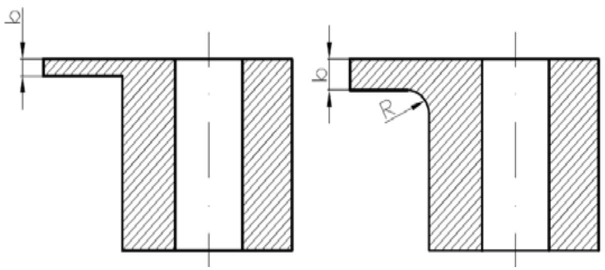
The ratio between diameter and height of blind holes must be: d : b max 1: 2.

UNSUITABLE SHAPE	PREFFERED SHAPE



Conical parts cause damages in the upper punches during the pressing (b=1mm). It is necessary a straight area that let the correct fit between punch and die.

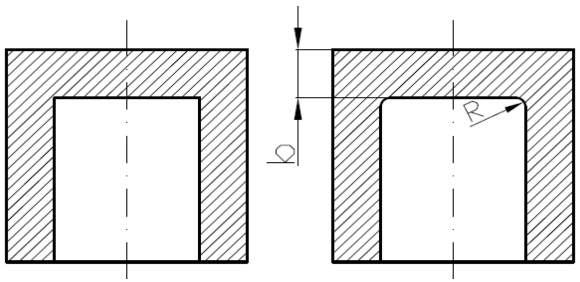
UNSUITABLE SHAPE	PREFFERED SHAPE



Thin components with large surface area are difficult to produce: a large density variation is the problem, but also, a thin part is fragile and tends to crack during production. Projections should be as thick as possible. And all-sharp edges designed out by radioing.

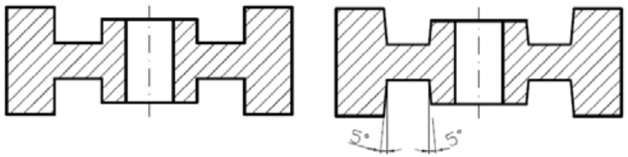
SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE



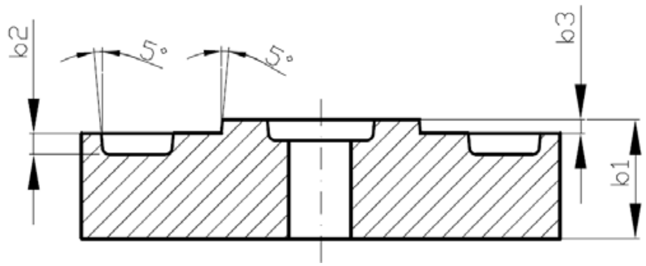
Height b=2mm.
A fillet radius favors filling of the die cavity and increases the robustness of the part.

UNSUITABLE SHAPE	PREFFERED SHAPE



An 5° angle is needed to favor ejecting the green part from the die and simplify the tooling design.

UNSUITABLE SHAPE	PREFFERED SHAPE



Profiled faces, can be produced without subdivided punches if b2 = 0.2. b1 y b3 = 0.1b1.. The angle should be at least 5°.

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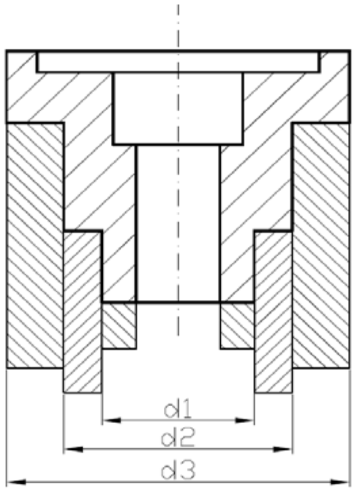
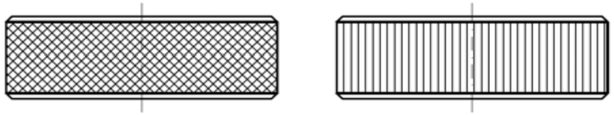
SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE



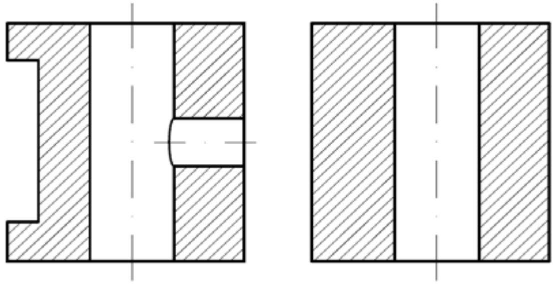
Multiple punches. Where the widths of the steps allow it, several punches should be used. Atypical minimum width is 2mm. However, during the design stage, the tooling strength must be kept in mind in order to avoid buckling of punches during compression. A design with as few punches as It is possible is preferred.
If the press do not permit more than one lower punch, one must examine the possibility of using a shelf die.

UNSUITABLE SHAPE	PREFFERED SHAPE



Diamond knurls, can not be obtained by pressing. There are some alternatives such as machining the knurls after sintering, generate straight knurls (possible with a minimum depth of 0.3mm and it's pattern rounded of by a radius of at least 0.1mm). Instead of knurls it would be possible to produce a profiled periphery.

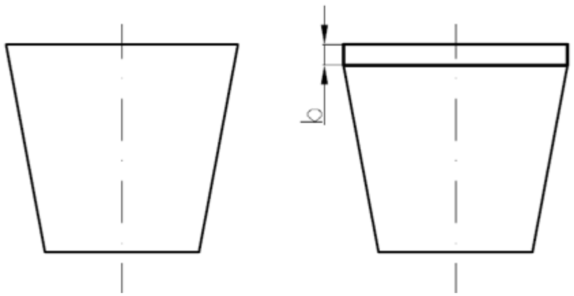
UNSUITABLE SHAPE	PREFFERED SHAPE



Grooves, undercuts and cross-holes can not be produced directly in the pressing operation, must be machined after sintering.

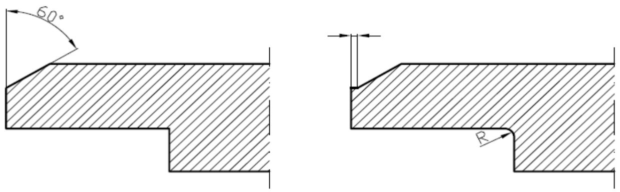
SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE



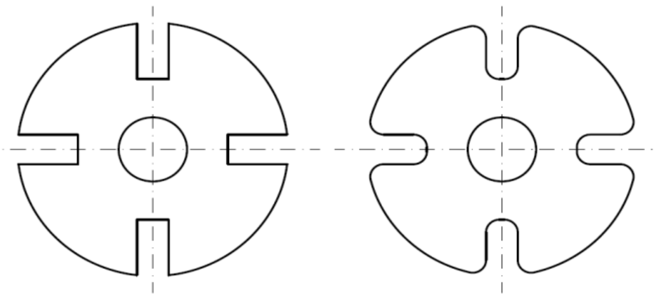
Completely conical parts may cause the upper punch to jam in the die during pressing

UNSUITABLE SHAPE	PREFFERED SHAPE



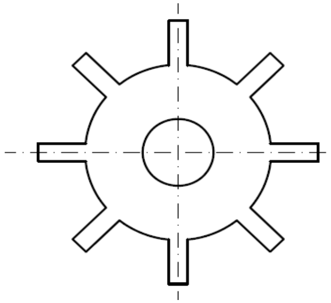
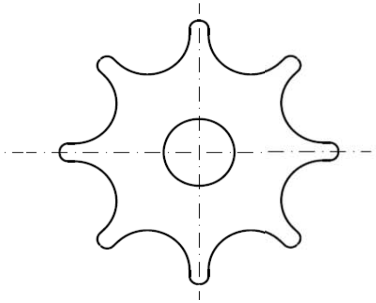
Chamfers with angles over than 45° should be avoided.
A small flat area should be designed eliminating the feather edge on the punch witch will give it longer life.

UNSUITABLE SHAPE	PREFFERED SHAPE



Avoid specifying narrow and deep splines, requiring the construction of dies with reduced and therefore weak sections.

SHAPES

UNSUITABLE SHAPE	PREFFERED SHAPE
	

Long and narrow teeth difficult the flow of the powder mix during the filling of the die cavity and the die becomes fragile.

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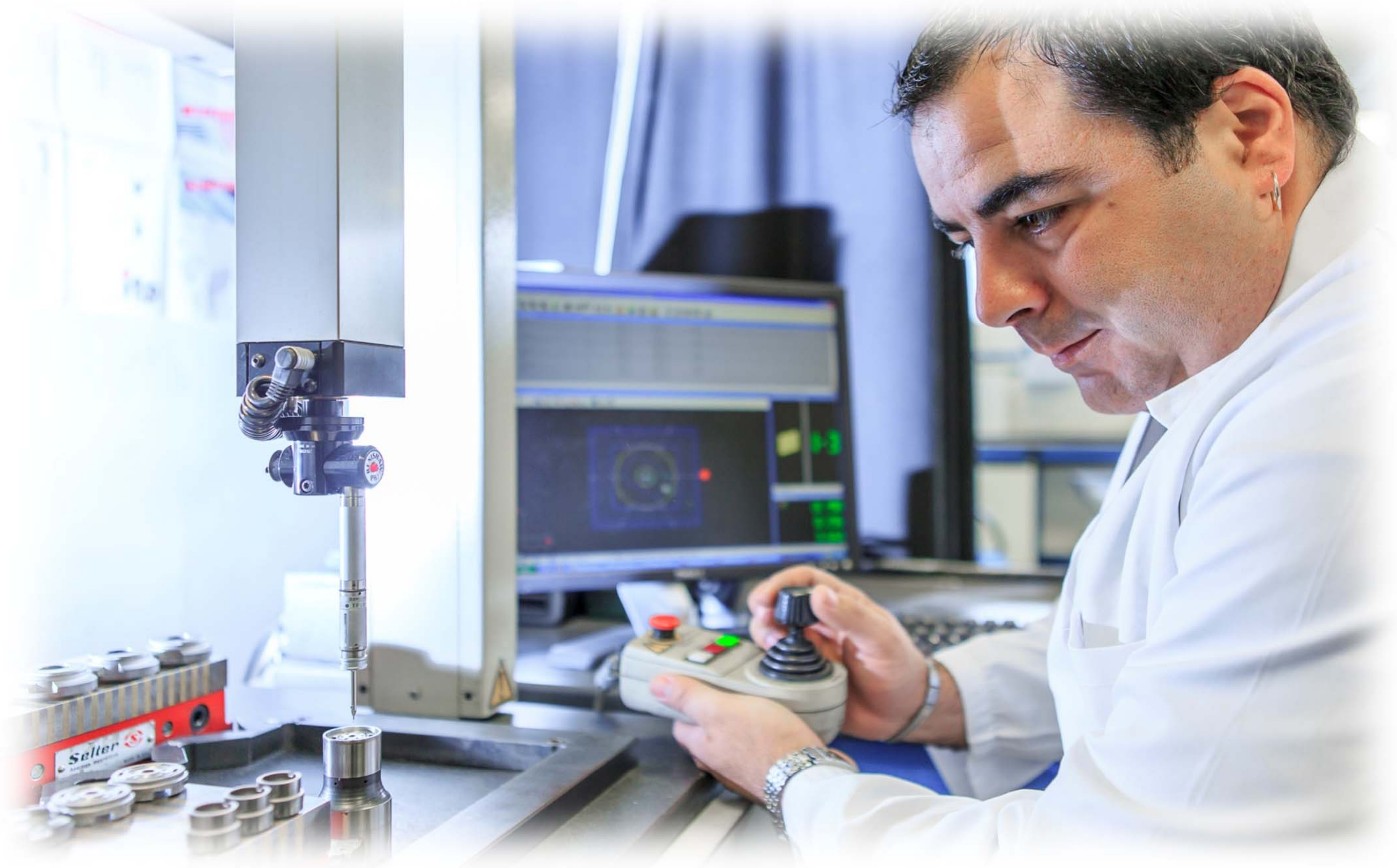
DIMENSIONAL ACCURACY



DIMENSIONAL ACCURACY

PM components are cost competitive, mainly because complex shapes may be produced economically. But as in every other mass production process additional machining can only be avoided if the shaping cycle tolerances meet the requirements of the application.

Although the press tooling may be produced to a high tolerance level, the operation of pressing and subsequent sintering is controlled by quite complicated mechanism. Each stage introduces changes that alter dimensions and restrict the tolerances of the final component.

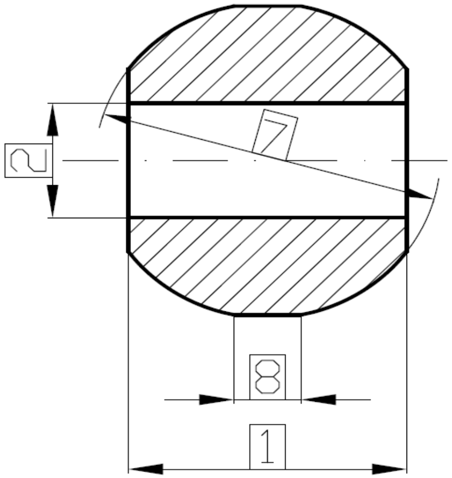
Dimension created by pressing in a transverse direction will not be as accurate as dimensions created by the press direction. Better tolerances can be achieve by introducing sizing, coining etc.

Below are some of the factors, common to all material, which contribute to the precision of a part produced by POWDER METALLURGY:

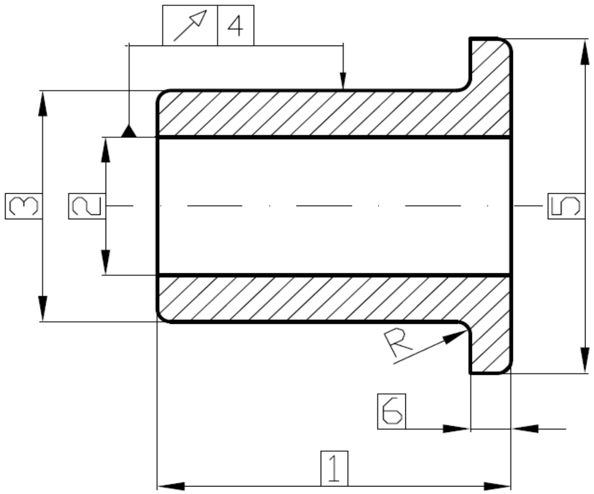
- Clearance between tool members.
- Elastic deformation of the press and the tool members.
- Uniformity of powder filling in the die cavity.
- Segregation of alloying elements.
- Friction of the powder against the tool walls during compaction.
- Green density.
- Chemical composition.
- Sintering conditions.

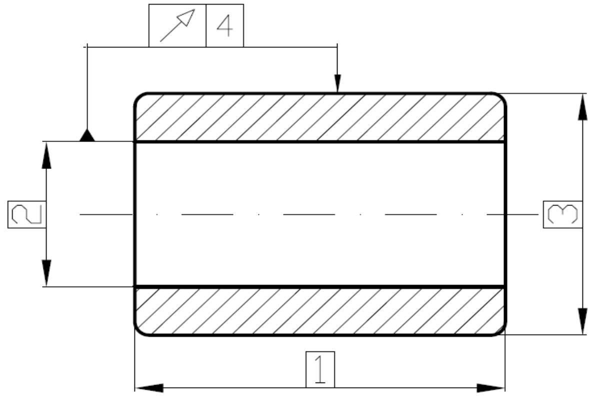
Heat treatment also introduces additional dimensional change and scatter, resorting in distortion.

BUSH COMMON TOLERANCES

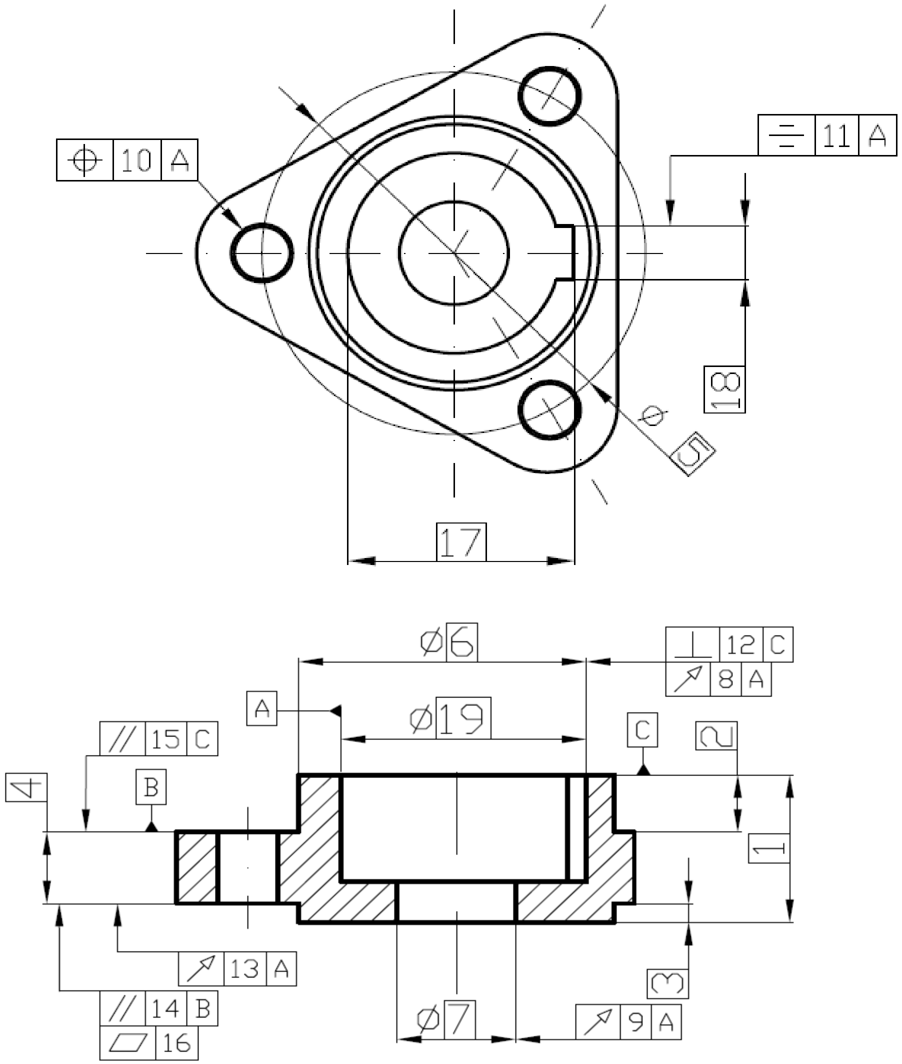


TOLERANCE VALUE	SINTERING	SIZING
1	Js-13	Js-13
2	IT-9	IT-7
3	IT-9	IT-6
4	IT-8	IT-8
5	IT-9	IT-6
6	Js-13	Js-13
7	IT-13	IT-11
8	Js-13	Js-13





STRUCTURAL PART COMMON TOLERANCES



TOLERANCE VALUE	SINTERING	SIZING
1	IT-13	IT-13
2	IT-12	IT-12
3	IT-11	IT-10
4	IT-13	IT-13
5	IT-10	IT-9
6	IT-9	IT-8
7	IT-8	IT-7
8	IT-10	IT-10
9	IT-8	IT-8
10	IT-11	IT-11
11	IT-10	IT-10
12	0.0015*h(2)	0.0010*h(2)
13	0.0020*Ø(6)	0.0015*Ø(6)
14	0.0025*Ø(6)	0.0020*Ø(6)
15	0.0020*Ø(6)	0.0015*Ø(6)
16	0.0015*Ø(6)	0.0010*Ø(6)
17	IT-11	IT-10
18	IT-9	
19	IT-9	IT-8

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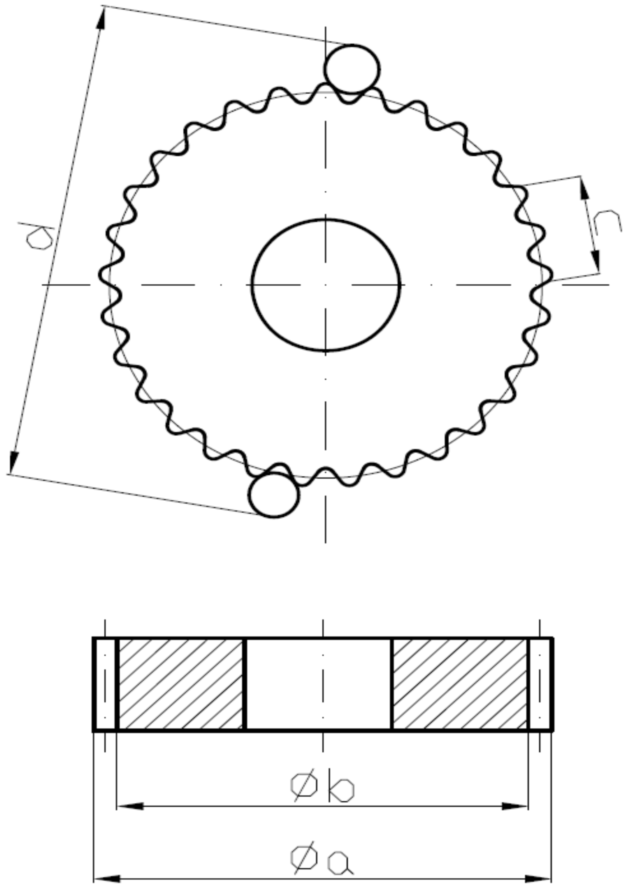
GEARS COMMON TOLERANCES



CHARACTERISTICS	SINTERING	SIZING	
Head diameter (a)	IT-10	IT-9	Tolerance quality ISO-286-2
Foot diameter (b)	IT-10	IT-9	
Measure between "k" foot (c)	IT-10	IT-9	
Measure between rollers (d)	IT-11	IT-10	
Division total mistake (Fp)	7-8	6-8	Accuracy class ISO-1328
Profile total mistake (ff)	8-9	7-8	
Scatter total mistake (fß)	7-10	7-10	
Compound total mistake (F"i)	8	7	
Foot to foot	7	6-7	

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