The most important prerequisite of a successful mass production of high-quality sintered parts is a high and consistent quality of the powder from which the parts are to be made. The characteristics of the powder decide about its compacting and sintering behavior and, eventually, about the properties of the finished product.
3. CHARACTERISTICS OF IRON AND STEEL POWDERS

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3.1 General aspects

Iron and steel powders - as well as other metal powders - used in the production of sintered parts can be characterized by three categories of properties:

1. Metallurgical properties
   - chemical composition and impurities
   - microstructure
   - microhardness

2. Geometrical properties
   - particle size distribution
   - external particle shape
   - internal particle structure (particle porosity)

3. Mechanical properties
   - flow rate
   - bulk density
   - compressibility, green strength and spring-back

All these powder properties are inherited from and specific to the process by which the powder was produced. Some of them are interrelated with each other. For instance:

- microstructure and microhardness are depending on chemical composition;
- compressibility decreases with increasing microhardness, increasing particle porosity and decreasing particle size;
- coarser powders and powders of regular particle shape flow better than fine powders and powders of irregular particle shape;
- powders of irregular particle shape have better green strength after compacting than powders of regular particle shape.

In the following, we present a brief definition of the aforementioned powder properties and their relevance to processing steps in the production of sintered parts.

**Metallurgical properties**

are determined by chemical analysis and metallographic procedures. The chemical composition of a ferrous powder has a great influence upon the final strength properties of the sintered parts. Non-metallic impurities may have an adverse effect upon compressibility and upon the life of compacting tools.
3. CHARACTERISTICS OF IRON AND STEEL POWDERS

Geometrical properties, viz. particle size distribution, particle shape and particle porosity, determine the powder’s specific surface which is the driving force of the sintering process (Chapter 6).

Particle size distribution is determined by sieve analysis if particle sizes are above 45 μm (minimum screen aperture). Finer powders are suspended in water and analyzed by means of laser diffraction methods.

External particle shape is analyzed by means of scanning electron microscopy (SEM). (See Fig. 3.1 left).

Internal particle structure is analyzed by means of metallographic techniques. (See Fig. 3.1 right).

Figure 3.1. External particle shape (SEM) and internal particle structure (cross-section) of sponge iron powder (NC100.24) and water-atomized iron powder (ASC100.29).
3.1 GENERAL ASPECTS

Flow rate, or rather its reciprocal value, is the time in seconds which an amount of 50 g dry powder needs to pass the aperture of a standardized funnel. Flow rate is influenced by type and amount of lubricant admixed to the powder. The flow rate decides about how fast a compacting tool can be filled with powder, and thus is a limiting factor in the compacting cycle of the powder press.

**Bulk density (Apparent density)**
is determined by filling the powder through a standardized funnel into a small cup, leveling-off the surplus powder on top of the cup, and dividing the weight of powder contained in the cup by the cup volume (25 cm$^3$). Apparent density is influenced by type and amount of lubricant admixed to the powder. The apparent density of the powder decides about the required filling depth of the compacting tool.

**Compressibility**
is the name of a curve obtained by plotting the compact densities of a series of small cylindrical powder compacts (Ø 25 mm), over the applied pressures. Compact density is the weight of a powder compact divided by its bulk volume. Compact density is influenced by type and amount of lubricant admixed to the powder. Green density is the compact density of a small cylindrical powder compact (Ø 25 mm) pressed with a standardized pressure (either 4,2 tons/cm$^2$ or 600 N/mm$^2$).

The compressibility of the powder decides about how high a compacting pressure is needed to achieve a desired compact density.

**Green strength**
is the bending strength of a green (i.e. compacted but not sintered) rectangular test bar. Green strength increases with increasing compact density and is influenced by type and amount of lubricant admixed to the powder. Sufficient green strength is required to prevent compacts from cracking during ejection from the compacting tool and prevent them from getting damaged during handling and transport between press and sintering furnace. The more complex and delicate the shape of a compact, the higher its green strength should be. If the green strength of compacts is high enough, they may even be machined prior to sintering (e.g. undercuts, traverse slots and holes).

**Spring-back**
is the elastic expansion of a cylindrical powder compact (Ø 25 mm) after ejection from the compacting die. Its value is expressed as the difference between the OD of the compact and the ID of the (empty) die divided by the ID of the die. Spring-back increases with increasing compacting pressure and is influenced by type and amount of lubricant admixed to the powder, and by the elasticity coefficient of the die material in which the powder is compacted.

The spring-back value is important for calculating the exact dimensions of the compacting tool in relation to the required dimensions of the compact.
3.2 Properties of Höganäs Iron Powders

As has been mentioned in the preceding chapter, Höganäs AB produces two different kinds of ferrous powders:
- sponge-iron powders, and
- water-atomized (unalloyed and low-alloyed) iron powders.

Typical structural differences between these two kinds of powders appear on SEM-photographs and cross-sections of representative powder particles shown at Fig. 3.1. The external shapes of both particles are irregular and fairly similar to one another. But the sponge iron particle has, as its name suggests, a spongy internal structure, while the water-atomized particle is internally compact.

Both kinds of powder are specially treated to yield various standard grades having different properties to fit different applications. These standard grades are also used in various press-ready powder mixes, i.e. blended with lubricants and alloying additives like graphite, copper, nickel, molybdenum, phosphorous and others.

Properties of three sponge-iron grades – NC100.24, SC100.26, MH80.23, and of two water-atomized iron powder grades – ASC100.29, ABC100.30, are presented in the diagrams at Figs. 3.2 and 3.3 and in Table 3.1.

Table 3.1 Properties of some Höganäs Iron Powders

<table>
<thead>
<tr>
<th>Powder grade</th>
<th>Approx. particle size range μm</th>
<th>Apparent density g/cm³</th>
<th>Flow s/50g</th>
<th>H₂-loss %</th>
<th>C %</th>
<th>Green density 1) g/cm³</th>
<th>Green strength 1) N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC100.24</td>
<td>20 – 180</td>
<td>2.44</td>
<td>30</td>
<td>0.20</td>
<td>&lt;0.01</td>
<td>7.02</td>
<td>47</td>
</tr>
<tr>
<td>SC100.26</td>
<td>20 – 180</td>
<td>2.66</td>
<td>28</td>
<td>0.12</td>
<td>&lt;0.01</td>
<td>7.12</td>
<td>40</td>
</tr>
<tr>
<td>MH80.23</td>
<td>40 – 200</td>
<td>2.30</td>
<td>33</td>
<td>0.32</td>
<td>0.08</td>
<td>6.29²)</td>
<td>24³)</td>
</tr>
<tr>
<td>ASC100.29</td>
<td>20 – 180</td>
<td>2.96</td>
<td>24</td>
<td>0.08</td>
<td>0.002</td>
<td>7.21</td>
<td>38</td>
</tr>
<tr>
<td>ABC100.30</td>
<td>30 – 200</td>
<td>3.02</td>
<td>24</td>
<td>0.06</td>
<td>0.001</td>
<td>7.27</td>
<td>39</td>
</tr>
</tbody>
</table>

1) compacted at 600 N/mm² in a lubricated die.
2) compacted at 4.2 t/cm² in a lubricated die.
3) measured at a green density of 6.0 g/cm³
Figure 3.2. Compressibility, Green Strength and Spring-back of five different iron powder grades.

3.2 Properties of Höganäs iron powders
3. CHARACTERISTICS OF IRON AND STEEL POWDERS

Figure 3.3. Particle Size Distribution, Flow and Apparent Density of five different iron powder grades.
3.2 PROPERTIES OF HÖGANÄS IRON POWDERS

NC 100.24
is one of the most widely used grades in the manufacturing of sintered parts. Due to the irregular surface and the spongy structure of its particles, it has high green strength; and due to its low contents of oxygen and carbon, it has good compressibility.

SC 100.26
has the best compressibility of all Höganäs sponge-iron powder grades. Its green strength is slightly lower and its apparent density slightly higher than for NC 100.24. It is very useful in cases where parts with high density are to be achieved in one single pressing operation.

MH 80.23
is especially designed to match the requirements for self-lubricating bearings. Its particle size range is chosen to give a pore structure optimal for this application. MH 80.23 can also be added to powder mixes in small quantities to dramatically improve green strength.

ASC 100.29
is a water-atomized iron powder which due to its high purity and its compact particle structure has very high compressibility. ASC 100.29 can be compacted in one single pressing operation at moderate pressures to densities of up to 7.2 g/cm$^3$. It is also suitable as basic material for soft-magnetic applications.

ABC 100.30
is a water-atomized iron powder of outstanding compressibility and chemical purity. It is especially well suited for the production of high-density structural components. Densities of up to 7.4 g/cm$^3$ are achievable in one single pressing operation. ABC 100.30 is also used in applications where very good soft-magnetic properties are required.

An interesting feature of practical importance must be mentioned here: The apparent density of iron powders increases with increasing mixing time. This phenomenon can be utilized in some cases to match a slightly under-dimensioned filling depth in the compacting tool. See diagrams at Fig. 3.4.
Apart from unalloyed iron powder grades, Höganäs AB produces also water-atomized low-alloyed steel powders – trade-name Astaloy, and a variety of non-segregable press-ready powder mixes – trade-name Distaloy. (The Distaloy-process has been described in some detail in the preceding chapter).
3.2 PROPERTIES OF HÖGANÄS IRON POWDERS

Properties of some Astaloy- and Distaloy-powders are presented in Table 3.2.

Table 3.2 Properties of some Astaloy- and Distaloy- Powders

<table>
<thead>
<tr>
<th>Powder grade</th>
<th>Approx. particle size range (\mu m)</th>
<th>Apparent density g/cm(^3)</th>
<th>Flow s/50g</th>
<th>(H_2)-loss %</th>
<th>C %</th>
<th>Green density (^1) g/cm(^3)</th>
<th>Green strength (^1) N/mm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astaloy A</td>
<td>20 - 180</td>
<td>3.30</td>
<td>23</td>
<td>0.10</td>
<td>0.01</td>
<td>7.01</td>
<td>17</td>
</tr>
<tr>
<td>Astaloy Mo</td>
<td>20 - 180</td>
<td>3.28</td>
<td>23</td>
<td>0.07</td>
<td>0.01</td>
<td>7.14</td>
<td>22</td>
</tr>
<tr>
<td>Distaloy SA</td>
<td>20 - 150</td>
<td>2.83</td>
<td>27</td>
<td>0.13</td>
<td>&lt;0.01</td>
<td>7.09 (^2)</td>
<td>41</td>
</tr>
<tr>
<td>Distaloy SE</td>
<td>20 - 150</td>
<td>2.82</td>
<td>28</td>
<td>0.12</td>
<td>&lt;0.01</td>
<td>7.11</td>
<td>39</td>
</tr>
<tr>
<td>Distaloy DC-1</td>
<td>20 - 180</td>
<td>3.28 (^2)</td>
<td>24 (^2)</td>
<td>0.10</td>
<td>&lt;0.01</td>
<td>7.16</td>
<td>22</td>
</tr>
<tr>
<td>Distaloy DH-1</td>
<td>20 - 180</td>
<td>3.41 (^2)</td>
<td>22 (^2)</td>
<td>0.10</td>
<td>0.01</td>
<td>7.13</td>
<td>29</td>
</tr>
<tr>
<td>Distaloy HP-1</td>
<td>20 - 180</td>
<td>3.37 (^2)</td>
<td>22 (^2)</td>
<td>0.10</td>
<td>0.01</td>
<td>7.07</td>
<td>25</td>
</tr>
</tbody>
</table>

\(^1\) compacted at 600 N/mm\(^2\) in a lubricated die.
\(^2\) rust inhibitor admixed.

Astaloy A
is a water-atomized steel powder alloyed with 1.90% Ni, 0.5% Mo and 0.25% Mn. Astaloy A is primarily intended for powder forging, but is also used for pressed and sintered structural components. It has very good hardenability and can be used for case-hardened as well as through-harden parts with non-critical tolerances.

Astaloy Mo
is a water-atomized steel powder alloyed with 1.50% Mo. Astaloy Mo has high compressibility, exhibits an homogeneous microstructure after sintering, and has optimal hardenability. These properties make it an excellent choice for surface-hardened components requiring high surface hardness in combination with good core toughness.

Distaloy SA
is based on the sponge-iron grade SC100.26, to which 1.75% Ni, 1.5% Cu, and 0.5% Mo in form of very finely dispersed powders have been diffusion-bonded. Distaloy SA is recommended for densities up to 6.9 g/cm\(^3\) after single pressing. With additions of graphite, a tensile strength of 600 N/mm\(^2\) can be achieved in one pressing and sintering operation, and so produced parts respond well to heat-treatment.
Distaloy SE
is also based on the sponge-iron grade SC100.26, but contains 4% Ni, 1.5% Cu, and 0.5% Mo. Due to its higher nickel content, it has better hardenability than Distaloy SA and is especially well suited for large sintered parts requiring heat-treatment.

Distaloy DC-1 (DC = Dimensional Control)
is based on Astaloy Mo to which 2% finely dispersed nickel powder has been diffusion-bonded. It thus contains 2% Ni + 1.5% Mo. Parts compacted from Distaloy DC-1 admixed with graphite exhibit high strength and very small scattering of dimensions after sintering, independent of compact density; and the sintered parts respond very well to subsequent heat-treatment.

Distaloy DH-1 (DH = Direct Hardening)
is based on Astaloy Mo to which 2% finely dispersed copper powder has been diffusion-bonded. It thus contains 2% Cu + 1.5% Mo. Parts compacted from Distaloy DH-1 admixed with graphite can be hardened directly from sintering heat (in belt furnaces equipped with a rapid cooling system) and exhibits small scattering of dimensions after sintering and hardening.

Distaloy HP-1 (HP = High Performance)
is based on Astaloy Mo to which 4% finely dispersed nickel powder and 2% finely dispersed copper powder have been diffusion-bonded. It thus contains 4% Ni + 2% Cu + 1.5% Mo. Parts compacted from Distaloy HP-1 admixed with graphite exhibit dimensional changes close to zero during sintering and adopt very high strength values.

More detailed information about all powder grades described above, as well as about many other interesting powder grades and powder mixes can be obtained from Höganäs AB in form of special brochures and electronic data.