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OTTAWA   September 8, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1931.

Metallurgical Examination of Iron Powder.

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(Copy No. 9.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Origin of Material and Object of Investigation:

In June, 1945, a 1-pound sample of iron powder was received from Sorel Industries Limited, Sorel, Quebec. This sample had been prepared by hydrogen reduction.

It was requested that this iron powder be examined to determine its suitability for the powder metallurgy process.

Physical Characteristics of the Powder:

Chemical Analysis -

Chemical analyses are shown in Table I. The hydrogen loss is considered as an indication of the oxide content and was determined by heating approximately eight grams of the powder in an alundum boat at 1800° F. for one hour in a hydrogen atmosphere, cooling in a furnace to room temperature, and then re-weighing the sample.

All other determinations were carried out by standard methods of iron and steel analysis.

TABLE I. - Chemical Analysis.

		Per Cent
Total iron	-	95.34
Carbon	-	0.04
Manganese	-	0.05
Silica	-	1.09
Phosphorus	-	0.005
Sulphur	-	0.015
Hydrogen loss	-	0.77

Screen Analysis -

A screen analysis was made with standard Tyler 8-inch screens and a Ro-Tap machine. The screening time was 10 minutes. A 500-gram sample was used.

TABLE II. - Screen Analysis.

	+100	+150	+200	+270	+325	-325
			- P e r	C e n t -		
Iron Powder -	0	0	0	0	0.01	99.99

Flow Rate -

The flow rate of a powder is determined as the length of time required for 50 grams to fall freely through the orifice of a standard flowmeter. The flowmeter consists of a funnel the sides of which form a 60° angle and at the base of which is an orifice 0.10 inch in diameter.

This sample was too fine to flow.

(Physical Characteristics of the Powder, cont'd) -

Apparent Density -

This is measured by allowing powder to fall down a baffle tower, called a Scott volumeter, into a 1-cubic-inch container. The weight of this volume was determined.

TABLE III.

	Flow Rate	App. Density
Iron Powder -	No flow.	2.26 gm./c.c.

Mechanical Properties of Compacts:

To investigate the pressing characteristics, the iron powder was mixed with 1 per cent of its weight of stearate lubricant and pressed in a die the walls of which were lubricated with a thin film of stearate lubricant. This die was designed to give a compact of 1 square inch cross-section. The well depth of the die was 2 inches and the height of compacts was kept as close to 1/2 inch as possible; thus, the resultant volume was approximately 1/2 cubic inch. Forming pressures of 40,000 and 100,000 p.s.i. were used and were applied to one side of the compact only.

Compressibility and Ultimate Strength -

The compressibility of powders is expressed as

(a) the compressibility density, i.e., the density as grams per cu. in., of a compact formed at 40,000 p.s.i.,

or

(b) the compressibility ratio, which is $\frac{\text{volume before pressing}}{\text{volume after pressing}}$,

for any given pressure.

Both were measured and are recorded in Table IV.

The green compacts were sintered in a dry, purified hydrogen atmosphere at 1000° C. for one hour and cooled in the furnace. Tensile test specimens, 0.188 inch in diameter and of ¾-inch gauge length, were machined from the sintered

(Mechanical Properties of Compacts, cont'd) -

compacts. The ultimate strengths of the samples, after pressing at 100,000 and 40,000 pounds per square inch respectively, are also shown in Table IV.

TABLE IV.

Sintered Compact	Compressibility Density, gm./cu.in.	Compressibility Ratio	Tensile Strength p.s.i.
At 40,000 p.s.i. =	85.7	2.25	8,900
At 100,000 " =		2.72	22,600

Density and Porosity of Compact -

The density was calculated from the volume and weight of sintered compacts formed at pressures of 40,000 and 100,000 pounds per square inch.

The porosity (per cent) was calculated from these densities by dividing these by the theoretical density for iron of 7.87 grams per c.c. Results are given in Table V.

Shrinkage of Sintered Compacts -

Measurement before and after sintering gave the percentage shrinkage. This is expressed in per cent and is listed in Table V.

TABLE V.

Sintered Compact	Density, gm./c.c.	Porosity (Per Cent)	Shrinkage (Per Cent)
At 40,000 p.s.i. =	5.09	35.2	0.5
At 100,000 " =	6.26	20.6	0.5

Microscopic Examination:

Examined under a binocular microscope, the powder particles appeared to be dendritic in shape and not very porous. Substantiating sieve analysis results, they were of small and uniform size. Occasional particles of silica and iron oxide were also observed.

To investigate the microstructure of the powder, (Microscopic Examination, cont'd) -

samples were mounted in lucite and polished. As shown in Figure 1, this microstructure consists largely of ferrite, indicating that the carbon content is low and that any other impurities are in solid solution.

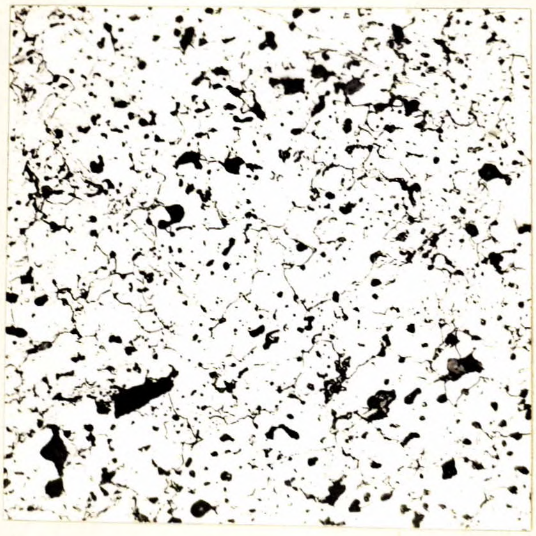
The microstructure of a compact that was pressed at 100,000 pounds per square inch and subsequently sintered is shown in Figure 2, a photomicrograph at X250 magnification.

Figure 1.

X500, etched in
2 per cent nital.

POWDER PARTICLE.

Figure 2.



X250, etched in
2 per cent nital.

COMPACT PRESSED AT 100,000 P.S.I. AND SINTERED.

Dark areas are voids.

Discussion:

The value of an iron powder cannot be judged solely on its chemical composition, since specifications vary according to the applications of the powder. This powder has a total iron content slightly below the 96% Fe + range.

There are limitations to the amount and type of chemical impurities permissible in such a powder. These impurities have a bearing on the properties of the sintered product. For instance, the silica in this sample is more than double the allowable maximum. The carbon, phosphorus, sulphur and manganese are close to the general values.

Screen analysis has shown that 99.99 per cent of this powder will pass through 325 mesh. This is not in agreement with usual specifications for iron powder. Generally, only about 30 per cent through 325 mesh is required.

Although there is considerable variation in these specifications, the following is a typical one:

			Per Cent
On 60	mesh	-	6 max.
+100	"	-	17-20
+150	"	-	12-16
+200	"	-	15-20
+250	"	-	5-8
+325	"	-	10-14
-325	"	-	25-32

The flow rate shown in Table III is, of course, not acceptable in a powder. The apparent density shown is comparable with that of presently marketed powders. However, it is notable that the flow rate and the apparent density are functions of the particle shape and size distribution. If the particle size of this powder were increased, the flow rate would approach the desired value but the apparent density would be expected to be even higher.

The tensile strength of the sintered product, as

(Discussion, cont'd) -

tested at these Laboratories, is up to average for this type of powder.

The compressibility density and ratio are about the usual values for this type of powder. The porosity and shrinkage percentages are considered satisfactory.

In general, the chemical composition of this powder is similar to that of currently marketed powders, with the exception of the slightly low total iron content and the high silica content. It is not considered advisable to make the same comparison for the mechanical and pressing properties, inasmuch as the mesh size is small and so unlike that usually specified for powders of this class. It is recommended that an examination be made of another sample of this powder made by the same process but of a more conventional particle size distribution.

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