SOME PHYSICAL PROPERTIES OF POWDERED IRON COMPACTS

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Powder metallurgy may provide a quick, economical means of fabricating parts which are difficult and costly to produce by ordinary methods. By compacting the powdered metal under pressure and annealing at a temperature well below the melting point to give the compact added strength, it is possible to produce a finished machine part within fairly close tolerances without once resorting to machining. These parts may be subjected then to "coining" where close tolerances are required. This operation consists of repressing in a die. It gives added strength due to cold work, and improves the surface finish. This powder method is, therefore, particularly advantageous in producing small parts which are difficult and expensive to machine.

The purpose of this experiment is to determine how some of the properties of a hydrogen reduced iron powder will vary with varying conditions of briquetting and annealing, and to determine, if possible, why these changes in properties occur.

The powder used was produced by Metals Disintegrating Company, Inc., and is made from artificially produced iron oxide which is reduced with pure hydrogen. Chemically, it will run about 0.35 per cent manganese, 0.06 per cent carbon, 1.25 per cent oxygen, the balance being substantially iron. This powder was furnished in four particle sizes. The sizes ranged from minus 325-mesh to a minus 100 plus 150-mesh.

One quarter of one per cent of stearic acid was mixed in the powder as a lubricant, and samples weighing approximately 0.85 grams were pressed in a simple two-way compression die at pressures of 26,000, 53,000, and 80,000 pounds per square inch. The compacts thus produced were 0.314 inches in diameter and approximately one-eighth of an inch in length.

In this experiment, the quantity of metal used was measured by weighing; but in industrial applications, the powder is measured by volume. Therefore, it is necessary to know the flow density of the material. The flow density was determined, and was found to increase with increasing particle size. This is due to the greater irregularity of the shape of the fine particles, and to the larger amount of rough surface of the fine powder for a given weight of metal, thus reducing the close contact.

After pressing, the compacts were measured, weighed, and annealed in an electric furnace using a commercial hydrogen atmosphere. This was done at 2000 and 2200 degrees Fahrenheit, time at temperature being one minute, 15 minutes, 45 minutes, and 180 minutes. After cooling in hydrogen, the compacts were measured again, and a Rockwell H hardness was determined for each compact.

For each treatment given the compacts, three samples were used. One from each group of three was selected, mounted, polished, and examined microscopically.

The compressibility of the powders was determined by weighting, measuring the length of the compacts, and computing their lengths to a base weight of 0.8500 grams. Compressibility was found to increase: (1) With increased briquetting pressure; (2) with increased particle size.

After pressing, the compacts have some strength due to cold welding of the particles. This strength is increased with increased briquetting pressure. This increase is due, essentially, to increased area of contact between particles. London states that increased contact is effected by:

(1) The breakdown of "bridging" and the movement of particles into voids of packed masses to reduce porosity thereof;

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(2) the deformation of particles to conform with the internal irregularities of packed configurations of particle boundaries, so that particles may key one into the other; (3) the reduction of interparticle voids by ironing out of surface roughnesses of particles.

Oxide, which is believed to be Fe_3O_4, is present in the powder before annealing due to incomplete reduction of the oxide during the manufacture of the powder. Since large particles require more time for reduction than do small particles, more oxide is contained in the coarse powder. This oxide is distributed randomly throughout the structure, and is not broken up by briquetting at high pressure. Annealing caused the Fe_3O_4 to be reduced with hydrogen, forming water vapor. A new oxide, believed to be FeO, was formed in the voids by reoxidation. This change is hastened by increased temperature. The FeO is then gradually removed at a rate that increases with increase in temperature. Removal of the FeO is also faster in a more dense compact. This is believed to be due to the decreased surface offered for reoxidation.

Annealing of the compacts causes them to shrink. This is accomplished by closing up of the voids due to surface tension, while the metal is in a plastic condition. Generally speaking, shrinkage is increased by the following: (1) Increased time at temperature; (2) increased temperature of annealing; (3) decreased briquetting pressure. Axial shrinkage is consistently greater than radial shrinkage.

A fine grain structure exists in the metal after one minute at annealing temperature. Longer time at temperature caused coalescence of the grains until a limiting grain size was reached. The grain size is reached in less time at the higher temperature, and is essentially the same at 2000 and 2200 degrees Fahrenheit. Decreased particle size of the powder and decreased briquetting pressure tend to decrease the limiting grain size.

The hardness after annealing was generally increased by the following: (1) Increased time at annealing temperature; (2) increased briquetting pressure; (3) increased annealing temperature, except at short times at temperature; (4) increased particle size of the powder. This last was true except for the finest powder, minus 325 mesh, where the effect of shrinkage was enough to increase the density sufficiently to cause it to have the highest hardness of the powders tested. Generally, the hardness values correspond to density values such that increased density was accompanied by a higher hardness.

In industrial applications, mixes of powders are generally used, and are cheaper in price than powders of one particle size, because the manufacturer cannot afford to sell one powder and have no market for the other.

It was desired to run tests using mixes of powders in an effort to find a mix which would give the least possible shrinkage in combination with maximum hardness. This would be accomplished by mixing a coarse powder and a fine one, so that the fine powder would fill the voids between the coarse particles. However, enough time was not available to do this work.

The most desirable properties, low shrinkage and high hardness, are obtainable using high briquetting pressure, but ordinarily, die wear will limit industrial applications to about 600,000 pounds per square inch. Low shrinkage is desired, because more variation is inherent where shrinkage is high, and tolerances would be more difficult to meet. Allowable shrinkage is limited by the design of the part to be made, the tolerances to be met, and whether the part is to be "coined" after sintering.

It is necessary, then, in commercial practice to select the briquetting pressure, and annealing time and temperature, which would give the best balance between desirable and undesirable properties for those particular parts which are to be manufactured.