<技術講演>

Finishing Powder Metallurgy Products[*]

F. V. Lenel[**]

Surface finishing procedures for products produced by power metallurgy differ from those produced conventionally: castings and wrought products, i. e. products which are forged, rolled, drawn or extruded from cast ingots. In order to give you an appreciation for this difference I should like to review briefly how products are manufactured by powder metallurgy. The raw materials are metal powders which may be produced by many methods. I am mentioning the most important ones:

Reduction of oxide is the method used for making sponge iron powder from a pure grade of iron ore by reduction with carbon. It is also the method for producing tungsten and molybdenum powder from their oxides by reduction with hydrogen.

A second important method of powder production is by a process called "atomizing", in which a stream of molten metal is broken up by a stream of fluid, a liquid such as water or a gas such as air, into fine droplets which solidify and form a powder. Certain grades of iron and steel powders, of copper alloy powders, as well as powders of metals with lower melting points, such as aluminum, tin and lead are produced by atomizing.

Electrolytic deposition is the method used for certain grades of copper powder. If a smooth adherent deposit of copper is to be produced by copper plating, the cathodic current density of the bath and its concentration must be controlled. Using low copper sulfate concentrations and high current densities copper powder can be deposited as a spongy dendritic deposit which serves as raw material for copper powder metallurgy.

The next step in powder metallurgy is compacting in which the powder is pressed in a die under relatively high pressure, 2 to 8 tons per square centimeter, into a compact. The shape of the compact is determined by the shape of the die in which it is pressed. For this reason, rather complex shapes, such as cams, gears or levers, can be pressed to the desired shape from metal powder. The powders as pressed are called "green compacts". They are somewhat fragile, the more fragile, the harder the metal powder from which they are pressed, but in general, they are strong enough to be handled, put on the belt of a continuous belt furnace and sintered.

Sintering is the last of the fundamental steps in powder metallurgy. Sintering means heating to an elevated temperature, not so high that the compacts melt and lose their shape, but high enough so that they become much stronger, tougher and more ductile than in the "green"condition. In certain powder metallurgy applications the compacts also shrink, i. e. their dimensions become smaller, but they preserve their shape. Most sintering cannot be done in air, because the metals would form oxides at the elevated temperatures, but must be done under a protective gas atmosphere.

In my presentation today, I will be primarily concerned with structural parts. These are powder metallurgy products which do not shrink or shrink only a small amount during sintering. They are fabricated by powder metallurgy because this method is more economical than conventional methods such as casting or machining from bar stock. If a product produced from a casting has to have closely controlled dimensions, it must, in general be machined all over, unless a precision casting method, such as diecasting or investment casting is used. Machining operations, such as turning, drilling, milling or planing are needed to produce a finished product from bar stock or from a rough forging. On the other hand, parts can be compacted from metal powder into complex shapes with quite closely controlled dimensional tolerances. If the dimensional

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[**] R. P. I. 공대 명예교수, 한국과학원초청교수

changes in these compacts during sintering can also be closely controlled, it is possible to produce structural parts by powde metallurgy, which do not need any or very little machining before they are assembled in a finished assembly. It is easiest to control the dimensional changes during sintering when these changes are small on the order of 1/2 percent or less.

On the other hand, parts which do not shrink or shrink very little during sintering will be porous as sintered and have densities less than those which cast or wrought parts of the same composition have. Most structural parts from base metals, such as iron, steel, stainless steel, copper, brass, bronze, nickel silver or aluminum have as sintered densities in the range of 80 to 90 percent of theoretical. Higher densities are desirable because the higher the density, the better are the mechanical properties, tensile strength, ductility and toughness. There are several methods for increasing the density of as sintered metal powder structural parts. All of these methods increase the cost of fabrication. Whether they are used or not is often a matter of economics. Structural parts may be repressed after sintering and then resintered, which may increase their density up to 95 percent of theoretical. Iron and steel structural parts may also be infiltrated with copper or a copper alloy which will fill most of the pores and make the parts nearly dense. Certain methods for increasing the density of structural parts, i. e. precision hot forging of sintered preforms and cold forming of sintered preforms result in parts of theoretical density. The technical and economic problems in hot forging and cold forming of preforms have, however, not yet been completely solved and the methods are not yet widely used.

The porosity of the structural parts is both a problem and an opportunity as far as the finishing of these parts is concerned. Parts from iron, plain carbon steel and low alloy steel have, of course, quite limited corrosion resistance. Making the parts from stainless steel powder will improve the corrosion resistance considerably. Powders having the compositions of 304 and 316 austenitic stainless steels (18% Cr, 8% Ni and 17% Cr, 12% Ni and 21/2% Mo) and powders having a straight iron chromium composition very low in carbon with 12 percent chromium are available for compacting and sintering. Stainless steel structural parts have, however, not so good corrosion resistance as wrought materials of the same composition, because the porosity of the parts promotes a tendency towards crevice corrosion. In order to have equivalent corrosion resistance for powder materials as for wrought materials the material made from powder should be considerably higher in alloy content.

One method for improving the corrosion resistance of iron, straight carbon or low alloy steel parts from powder is to impregnate them with oil. This method has, however, limited applicability, because the degree of corrosion resistance which oil impregnation imparts is not very great, also this method can only be used when the small amount of oil which may ooze out of the part will not intefere with its operation.

Structural parts from metal powder can be electroplated, but certain precautions are necessary because of their porosity. It is desirable to fill the pores of the parts before they are plated to inhibit impregnation of the part with plating solution. Thorough washing after plating may remove most of the plating solution, but complete removal is often difficult. If the electrolyte comes out of the pores during use of the part, it may form an undesirable deposit. For this reason, plating of porous parts in a cyanide electrolyte is not recommended because of the obvious health hazards.

Recently polymer compounds have been developed with which the pores of the porous compacts may be filled and which overcome the usual plating troubles. The parts are impregnated with a monomeric or partially polymerized liquid impregnant and then rinsed. A low temperature polymerization process transforms the liquid impregnant into a solid.

The porosity of structural iron and steel parts must also be considered when they are to be casehardened by gas carburizing. Highly porous parts will not form the usual high carbon case and low carbon core during carburizing, which upon heattreatment forms a wear resistant case and a tough core. Instead the carburizing gas will penetrate to the interior of the part and produce a rather brittle high carbon composition throughout the cross-section. This difficulty is much diminished, if the parts have densities of 90 percent or more of theoretical, in which case a satisfactory case-core structure can be readilly produced.

Finally, porosity is a disadvantage if several structural parts are to be joined into an assembly by brazing. The liquid copper, copper alloy or silver alloy which serves as a brazing material will penetrate into the pores of the part to be brazed instead of being available as a material for the joint between the parts to be assembled. It is possible to combine copper infiltration of iron and steel parts with joining them by brazing into an assembly, but the exact dosage of infiltrating and brazing material may be somewhat tricky. There is an alternative method of joining metal powder parts into an assembly which involves using somewhat different compositions for the parts to be joined, one which slightly grows or expands during sintering, the other which slightly shrinks. The composition which grows is used for the inner portion of the assembly, the one which shirnks for the outer portion. The parts are assembled in the as compacted composition. During sintering an excellent joint is formed.

Porosity in powder metallurgy structural parts is, however, not always a drawback, but also provides certain opportunities. When porous parts are protected by certain finishes, the pores near the surface of the parts may provide better anchoring between metal substrate and finish. This is the case in phosphate and chromate treatments as well as in organic finishes.

There is one finishing operation in which the porosity of powder metallurgy structural parts from iron and steel is diretly used. This operation has been called "steam treating". The parts are treated in dry steam at a temperature of approximately 550°C. Thest eam reacts with the surface of the part forming magnetic iron oxide, Fe_3O_4. Since the pars are porous, they have not only an outersurface, but also a large amount of inner surface along all those pores which are connected with the outside and can therefore react with the steam penetrating into the pores. The magnetic iron oxide therefore forms not only a layer on the outside but also a skeleton throughout the interior of the part. The oxide is, therefore, quite adherent and provides considerable resistance to corrosion. For this reason, steam treatment is not just a surface treatment, but actually changes the mechanical properties of the part, increases its hardness, its wear resistance and its compressive strength. This improvement in mechanical properties is the principal reason for steam treating, for instance such parts as shock absorber pistons produced from powder.

My principal emphasis in this discussion on finishing powder metallurgy products has been on the so-called structural parts. Certain quite specialized surface finishes have, however, been developed for other powder metallurgy products. The one I should like to discuss briefly is surface finishing of cemented carbides. Cemented carbides are used primarily as cutting tools and have, in this area, replaced high speed steel for many applications. Cemented carbides for cutting non-metallic materials, non-ferrous alloy and cast iron and those used for cutting rock in the mining industry consist of 80 to 97 percent tunsgten carbide and 3 to 20 percent cobalt as a binder. Cemented carbides for cutting steel must contain additions of titanium, niobium and tantalum carbide to the tungsten carbide base in order to keep the tools from cratering and welding to the material to be cut. Titanium carbide containing grades have also somewhat better wear resistance than grades without titanium carbide, but this improved wear resistance goes hand in hand with lowered toughness. Grades in which the carbide phase is entirely titanium carbide are available, but they are used only for specialized applications, where outstanding wear resistance is required and lower toughness can be tolerated. Recently, a way has been found to combine the extreme wear resistance of titanium carbide with the toughness of cemented carbide. The surface of the cemented carbide tool is coated with a very thin layer, approximately 5 microns thick of titanium carbide. One of the methods of coating cemented carbide with a layer of titanium carbide is chemical vapor deposition, a method which has been of interest in other metal finishing applications.

Powder metallurgy is, of course, a specialized method for producing metal products, where fabrication by powder metallurgy either lowers costs or provides properties which cannot be obtained by conventional methods of fabrication. The uses of powder metallurgy are still increasing and with the expanding uses goes the search for improved methods for finishing these products.