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[54] POWDER METALLURGY ALUMINUM PARTS

[75] Inventor: **Sherwood W. McGee**, Lisle, Ill.

[73] Assignee: **Amsted Industries, Inc.**, Chicago, Ill.

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[58] **Field of Search** 75/206, 211, 212, 224, 221; 29/182.5

[56] **References Cited**

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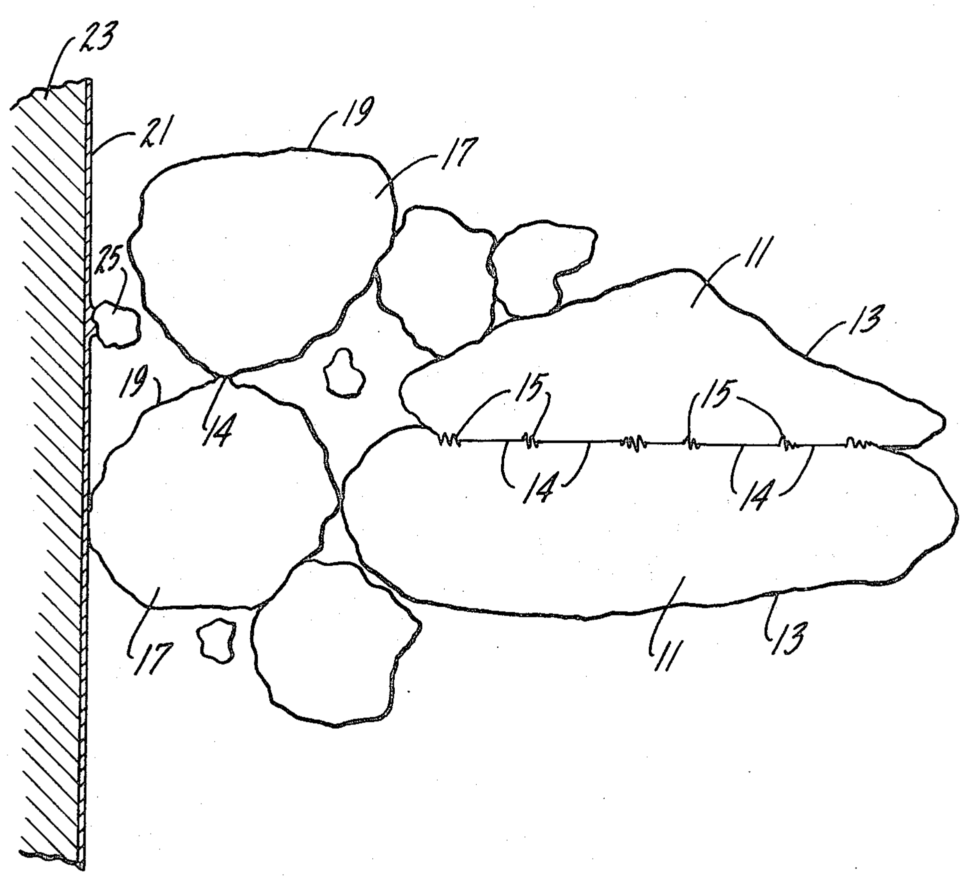
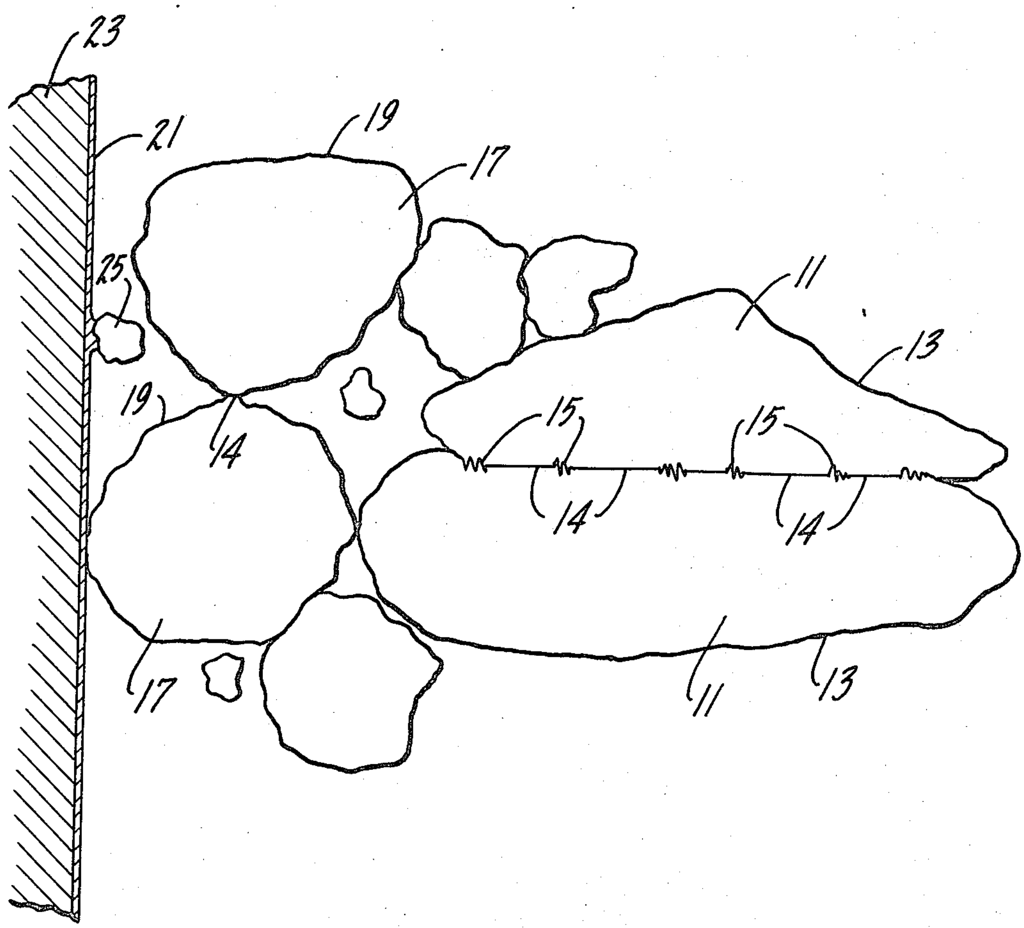
Primary Examiner—Benjamin R. Padgett
Attorney, Agent, or Firm—Alexander, Speckman & Staples

[57] **ABSTRACT**

A powder metallurgy aluminum article and a method of producing it in which a lubricant is mixed with an aluminum powder of selected particle shape and size and the mixture is cold compacted to a desired density. The compacted mixture is then sintered in air or a protective atmosphere. The sintered article may then be coined or sized.

6 Claims, 1 Drawing Figure





INVENTOR.
Sherwood W. McGee
BY Parker, Carter & Markey
Attorneys.

POWDER METALLURGY

SUMMARY OF THE INVENTION

This invention is directed to a powder metallurgy aluminum article and to a method of producing it.

An object of this invention is a powder metallurgy aluminum article of suitable tensile strength and ductility which may be produced by cold compaction and sintering.

Another object is a powdered aluminum article which does not adhere to punches and dies during compaction thereof.

Another object is a powdered aluminum article which is not subject to seizing and galling during compaction thereof.

Another object is a powdered aluminum article containing a lubricant, which article may be sintered after compaction.

Other objects may be found in the following specification, claims and drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a somewhat diagrammatical representation, greatly enlarged, of a partial cross-section of the aluminum powder and the die wall after compaction of the powder.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Previous attempts to form useful aluminum articles by compacting and sintering aluminum powders have not been completely successful either physically or economically. These attempts failed because aluminum powders are reactive and highly weldable when their oxide films are abraded, which occurs during compaction. Although an oxide film forms almost instantaneously on the exposure of pure aluminum to air, it will not form quickly enough to prevent the particles of aluminum powder from welding to punches and dies when the oxide film is removed from the particles by the punches and dies. The welding of the aluminum particles builds up deposits of metallic aluminum on the punches and dies, resulting in heavy scoring, galling and die seizure. It is known that lubricants such as waxes and metallic soaps can be added to aluminum powder to prevent the build up of aluminum on punches and dies but the addition of such substances has prevented the sintering of the particles comprising the aluminum powder. Sintering is necessary at a later stage of the process.

It has been determined that by selection of aluminum powders of particular particle shapes and sizes and selection of particular types of waxes, the problems of seizing and galling previously connected with the build up of aluminum on compaction tools can be overcome without interfering with the sintering of the aluminum particles to one another. The aluminum powders used may be entirely aluminum or they may be blended with up to 5% copper or tin powder.

The sintering of particles of aluminum is facilitated by the mechanical abrasion of the oxide films from the particles during compaction. Mechanical abrasion is enhanced through the use of aluminum particles of geometrical shapes which provide cutting edges to break through the oxide films on the particles and thereby provide nucleation sites or aluminum to aluminum contacts for subsequent sintering between the particles.

Atomized aluminum powder formed of particles of various irregular shapes is available, including such shapes as irregular teardrop, rice grain, cylinder and plate. Almost any particle shape except spherical is desirable for use in connection with the process of this invention. A mixture of irregular shaped particles and spherical particles may be used but because it is desirable to provide as many sharp edges as possible to cut the oxide film on the particles, better results are obtained as the percentage of spherical particles in a mixture is reduced.

In addition to using aluminum particles having irregular shapes, it is also advantageous to control the size of the aluminum particles. It has been found that aluminum powders containing particles of a size finer than 200 mesh U.S. standard screen scale series do not function as satisfactorily as powders containing particles of larger sizes. Particles smaller than 200 mesh tend to fit in the clearances between the die and punch and remain to cause galling. Particles smaller than 200 mesh also contain a higher proportion of oxide film to unoxidized aluminum than do larger particles and therefore do not sinter as readily as the larger particles. The smaller particles also fill the interstices between larger particles of aluminum and tend to spring back to their original shape after compaction. This action of the particles tends to laminate the pressed body after compaction.

The following tables indicate typical cumulative Screen Analysis of atomized aluminum powder:

TYPICAL CUMULATIVE SCREEN ANALYSIS ATOMIZED ALUMINUM POWDER OF REYNOLDS METAL COMPANY

Grade LS - 929		Grade LSA - 29	
+100 MESH	0%	+14 MESH	0%
+200 MESH	35%	+20 MESH	5%
+230 MESH	43%	+30 MESH	15%
+270 MESH	52%	+40 MESH	99%
+325 MESH	65%	+50 MESH	100%
−325 MESH	35%		

Grade 1 - 842		Grade 1 - 511	
+ 30 MESH	0%	+200 MESH	0%
+ 40 MESH	2%	+230 MESH	0.2%
+ 70 MESH	39%	+325 MESH	4.6%
+100 MESH	68%	−325 MESH	95.4%
+140 MESH	96%		
+200 MESH	100%		

The number following a plus mesh size indicates the percent of the particles retained on that screen and preceeding screens. The number following a minus mesh size indicates the percent of particles passing through the screen.

It has been found desirable in certain instances to add aluminum oxide or other refractory grained powders to the aluminum powders. The aluminum oxide has a scourifying effect on the oxide films of the aluminum particles and is especially desirable in powders where particles of smaller than 200 mesh size are used. The addition of aluminum oxide or other refractory grain powders also reduces galling because the oxide acts on the tool surfaces to remove aluminum that has been welded to these surfaces.

The purpose of the lubricant is to coat the tool surfaces and protect them during compaction. The lubricants should not coat the aluminum particles to any substantial extent. Also, the lubricant should not chemically oxidize the aluminum particles when the compacted particles are heated during the burn-off period of the heating cycle before sintering takes place. Satisfactory lubricants include both ordinary and chlorinated hydrocarbon waxes. The lubricant used in the examples listed is a synthetic wax sold under the trademark "ACRAWAX C" by Glyco Chemicals, Inc., New York, New York. Other suitable lubricants include "CYNDAL" sold by E.F. Houghton Company and butyl stearate, common technical grade.

After the aluminum powder is mixed with the lubricant, it is compacted to densities of about 2.5 gm/cc or higher and the lubricant is burned off in a box, forced air convection type furnace for twenty minutes at 700°F. the aluminum powder mixture is then sintered for sixty minutes at 1,200°F. In the following examples, the atmosphere used was air. However, other atmospheres such as dry hydrogen, dissociated ammonia or carburizing compound may be used. Air atmosphere is preferred for the burn off portion of the heating cycle. The ductility of air sintered aluminum appears to be adequate giving approximately 5 percent or more tensile elongation. Sintering in a dry hydrogen atmosphere appears to provide improved ductility. Thus, for the sintering portion of the heating cycle either air or reducing atmosphere might be chosen, depending upon economics and properties required.

The drawing is a more or less diagrammatical representation of a portion of the aluminum particles and the die wall after compaction. The larger aluminum particles **11** are shown flattened against one another by the compressive forces of compaction. During compaction, the cutting edges of the irregular shaped particles have broken and sheared away the oxide films **13** on the aluminum particles thereby forming nucleation sites or aluminum to aluminum contacts **14** between the particles. The broken oxide film gathers in clusters **15** between the nucleation sites.

The large number of nucleation sites between the irregularly shaped particles of aluminum should be compared with the small number of such sites or aluminum to aluminum contacts **14** between the spherical particles **17**. The smaller number of such sites is due to a lack of cutting edges on the spherical particles to shear and break the oxide films **19** formed on the spherical particles.

The wax particles **21** form a film on the surface **23** of the die to protect the surface against the adherence of particles of pure aluminum, such as particles **25** shown in the drawing.

In the following examples, in which different mixtures of aluminum powder were used, the lubricant was mixed with the powder and blended for approximately 10 minutes. The resulting mixtures were compacted under various pressures ranging from 5 to 17.5 t.s.i. (tons per square inch) to densities ranging from 2.4 to 2.47 gm/cc. The compacted product thus formed was heated for twenty minutes at 700°F. in a box, forced air convection type furnace to burn off the lubricant. The product was then sintered for sixty minutes at 1,200°F. by raising the temperature in the same furnace. Some of the products made were then dipped in a lubricant of butyl stearate fluid, technical grade, and coined to a density of 2.62/2.67 gm/cc under 30 t.s.i. pressure. After coining, some of the products were resintered.

Although many examples may be furnished, there are set out below typical examples in which aluminum powders of different compositions were used. Obviously, other examples may be cited and the invention is not limited to the particular examples set out below nor to the precise proportions, temperatures and sintering cycles. The specific values given for portions, compaction pressures, densities, temperatures and heating cycles have all been carried out and verified in practice and the values given are satisfactory and in some cases preferred. Variations are contemplated and the invention is therefore not limited to the precise values given.

EXAMPLE I

Composition and Blending Procedure: 100 percent Reynolds Metal Company, grade LS–929 aluminum powder and 1.0 percent "Acrawax C" lubricant.

Blending time: ten minutes: Hall flow: 12.6 seconds.

Apparent density: 1.22 gm/cc

Compaction Recommendations

Maximum green density: 2.47 gm/cc, obtained at 10 t.s.i. compaction.

Typical stripping pressure: 0.35 t.s.i. of sidewall.

Recommended tool clearance: 0.002 inch maximum punch/die.

Coining

Lubricant: butyl stearate fluid, technical grade, dip parts.

Maximum coined density: 2.62/2.67 gm/cc under 30 t.s.i. pressure.

Mechanical properties (Typical)

Part Type	Condition	Density	Tensile Strength	Hardness	Elong.	Crush
Tensile Bar	As Sintered	2.45gm/cc	5,770psi	—	0.79%	—
Tensile Bar	As Coined	2.58gm/cc	8,000psi	H60	1.2%	—
Tensile Bar	Coined Resinter	2.58gm/cc	6,500psi	H30	3.5%	—
Gear Bushing+	Sintered and Coined	2.55gm/cc	K=9,500	—	—	232lb.
Bushing+	Sintered, Coined Resintered	2.55gm/cc	K=9,400	—	—	234lb.

+Bushing dimensions; 0.688"OD, 0.432"ID, 0.833" Long

Stripping pressure from coining tools: 0.75 t.s.i. of sidewall.

EXAMPLE II

Composition and Blending Procedure: 66.6 percent Reynolds Metal Company, grade LSA–29 aluminum

Mechanical properties (Typical) Part Type	Condition	Density	Tensile Strength	Hardness	Elong.	Crush
Tensile Bar	As Sintered	—	—	—	—	—
Tensile Bar	As coined	2.62	1000psi	10RH	2.0%	—
Tensile Bar	Coined Resinter	2.62	1500psi	8RH	1.5%	—
Gear	—	—	—	—	—	—
Bushing+	As Sintered and coined	2.36	K=4,900	—	—	116lb.
Bushing+	Sintered, Coined Resintered	2.36	K=6,200			146lb.

+Bushing Dimensions; 0.688"OD, 0.432"ID, 0.833" Long

powder and 33.3% grade 1-842 aluminum powder plus one-half percent "Acrawax C" lubricant.

Blending time: 10 minutes. Hall flow: oversized (6 minutes with assist)

Typical Stripping Pressure: 0.35 t.s.i. of sidewall.

Recommended Tool clearance 0.002 inch maximum punch/die

Coining

Mechanical properties (Typical) Part Type	Condition	Density	Tensile Strength	Hardness	Elong.	Crush
Tensile Bar	As Sintered	2.44gm/cc	1,187psi	<20RH	<0.5%	—
Tensile Bar	As Coined	2.62gm/cc	1,974psi	<20RH	<0.5%	—
Tensile Bar	Coined Resinter	2.63gm/cc	2,407psi	<20RH	—	—
Gear+	As Sintered	2.49gm/cc	—	<20RH	—	291lb.
Bushing++	As Sintered	2.33gm/cc	K=2,900	<20RH	—	58lb.

+Gear dimensions; 11 tooth spur, 1.125" root circle, 0.600"ID, 0.575"thick.
++Bushing dimensions; 0.548"OD, 0.298"ID, 0.515" long.

Apparent density 1.16gm/cc.

Compaction Recommendations

Maximum Green Density: 2.4 gm/cc obtained at 5 to 10 t.s.i. compaction

Typical stripping pressure: 0.40 t.s.i. of sidewall (30 t.s.i. compaction)

Recommended Tool Clearance: 0.002 inches maximum punch/die.

Coining

Lubricant: butyl stearate fluid, technical grade, dip parts.

Maximum Coined Density: 2.62/2.67 gm/cc under 30 t.s.i. pressure

Stripping pressure from coining tools: 0.60 t.s.i. of sidewall

EXAMPLE III

Composition and Blending Procedure: 100 percent Reynolds Metal Company grade 1-842 aluminum powder plus 1.0 percent "Acrawax C" lubricant.

Blending time: 10 minutes. Hall flow: 11.0 seconds,

Apparent density 1.17 gm/cc.

Compaction Recommendations

Maximum Green Density: 2.45 gm/cc obtained at 10 t.s.i., compaction.

Lubricant: butyl stearate fluid, technical grade, dip parts.

Maximum Coined density: 2.62/2.67 gm/cc under 30 t.s.i. pressure

Stripping Pressure from Coining tools: 0.53 t.s.i. of sidewall

EXAMPLE IV

Composition and Blending Procedure: Composition 98.0 Reynolds Metal Company grade 1-511 aluminum powder and 2.0% Al_2O_3 (240 Grit) and 2.0 percent "Acrawax C" lubricant.

Blending time: 10 minutes. Hall flow: 10 minutes (with assist). Use 60 cps feed shoe vibration with "Syntron" unit.

Apparent density 1.03gm/cc Compaction Recommendations:

Maximum Green Density: 2.45 gm/cc obtained at 17.5 t.s.i. compaction

Typical Stripping Pressure: 0.80 t.s.i. of sidewall (30 t.s.i. compaction)

Recommended Tool Clearance: 0.002 inch maximum punch/die

Coining

Lubricant: butyl stearate fluid, technical grade, dip parts.

Maximum Coined Density: 2.62/2.67 gm/cc under 30 t.s.i. pressure

Mechanical properties (Typical) Part Type	Condition	Density	Tensile Strength	Hardness	Elong.	Crush
Tensile Bar	As Sintered	2.45gm/cc	9,742psi	—	0.57%	—
Tensile Bar	As Coined	2.64gm/cc	13,659psi	—	0.27%	—
Tensile Bar	Coined Resinter	2.63gm/cc	12,619psi	—	0.99%	—
Gear+	As Sintered	2.20gm/cc	—	—	—	409lb.
Gear+	As Sintered	2.45gm/cc	—	—	—	713lb.

+ Gear dimensions; 11 tooth spur, 1.150" P.D. (approx.), 0.600"ID, 0.575" thick.

I claim:

1. In a method of making a powder aluminum part having excellent aluminum to aluminum bond between contacting particles from commercial aluminum powder, the steps of

providing, as a starting material, powder from the group consisting essentially of (1) commercial aluminum powder containing the usual impurities, (2) a mixture of said commercial aluminum powder with up to 5 percent commercial copper powder or 5 percent commercial tin powder, and (3) said commercial aluminum powder with either commercial aluminum oxide powder or other commercial refractory grained powders,

at least the aluminum powder portion of said starting material being further composed of irregular shapes or a mixture of irregular and spherical shaped particles, whereby sharp edges are provided for cutting oxide films on the aluminum powders,

adding to the above described powder a lubricant capable of coating compaction tool surfaces and incapable of chemically oxidizing the aluminum particles during subsequent heating and sintering,

compacting the powder-lubricant mixture to a density of about 2.5 gm/cc,

heating the compacted powder-lubricant mixture at a first temperature to remove the lubricant, and

heating the compacted powder mixture at a second temperature which is higher than said first temperature to sinter said compacted powder mixture.

2. The method of claim **1** further characterized in that

at least a portion of the heating step is performed in an atmosphere selected from the group consisting essentially of air, dry hydrogen, disassociated ammonia, and a carburizing compound.

3. The method of claim **1** further characterized in that

the aluminum powder consists of particles no finer than 200 mesh U.S. Standard screen scale series.

4. The method of claim **1** further characterized in that

the powder-lubricant mixture is subjected to a temperature of about 700°F, and, thereafter,

the resultant compacted powder mixture is subjected to an elevated temperature treatment of about 1,200°F for about one hour to thereby sinter the compacted powder.

5. The method of claim **1** further including the steps of

lubricating the sintered compacted powder mixture, coining, and, optionally, re-sintering.

6. An aluminum powder metallurgy article having excellent aluminum to aluminum bond between contacting aluminum particles made by the following method:

providing, as a starting material, powder from the group consisting essentially of (1) commercial aluminum powder containing the usual impurities, (2) a mixture of said commercial aluminum powder with up to 5 percent commercial copper powder or 5 percent commercial tin powder, and (3) said commercial aluminum powder with either commercial aluminum oxide powder or other commercial refractory grained powders,

at least the aluminum powder portion of said starting material being further composed of irregular shapes or a mixture of irregular and spherical shaped particles, whereby sharp edges are provided for cutting oxide films on the aluminum powders,

adding to the above described powder a lubricant capable of coating compaction tool surfaces and incapable of chemically oxidizing the aluminum particles during subsequent heating and sintering,

compacting the powder-lubricant mixture to a density of about 2.5 gm/cc,

heating the compacted powder-lubricant mixture at a first temperature to remove the lubricant, and

heating the compacted powder mixture at a second temperature which is higher than said first temperature to sinter said compacted powder mixture,

said article having a tensile strength of from about 1,200 to 10,000 psi in the as-sintered condition.

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