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DISPERSION HARDENING OF LEAD

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This application is a continuation-in-part of my patent application Serial No. 71,410 filed November 25, 1960, and now U.S. Patent 3,098,293.

This invention is concerned with the manufacture of lead sheeting, and extruded lead sections, and is particularly concerned with a method of producing a sheet material consisting of lead or lead alloy which has been specially strengthened for certain industrial purposes.

The rather low tensile strength and softness of unalloyed lead often present major difficulties in the use of lead for constructional purposes, e.g. in the construction of accumulators. Some method of strengthening the metal is therefore desirable, and a method based on the technique called dispersion-hardening has been found to give the desired result.

In a dispersion-hardened metal, particles of hard material which are inert to the matrix are well dispersed throughout the body of the metal. Dispersion-hardened metal objects are therefore commonly made by powder metallurgy techniques according to which a uniform mixture of the powdered metal and hardening component in appropriate proportions are compacted to the required shape and then sintered. The hardening component may be in the form of the oxide of the same or another metal and is very finely divided, the size range being typically from 0.1 to 10 microns. However conventional powder metallurgy methods are not suitable for dispersion-hardening of lead, principally because the natural oxide film with which lead particles are normally covered is not broken down during the normal compacting process, and there is therefore no metal-to-metal contact to permit the particles to be sintered. Sintering in a reducing atmosphere will not effectively remove the oxide coating from the surfaces of the particles.

As a result of experiments in the cold working of lead, it has been found that by cold extrusion of lead oxide coated lead particles through a die of circular or other cross-section and followed by rolling the extruded lead along and across the direction of extrusion, a polycrustalline piece of lead can be obtained with the lead oxide distributed uniformly throughout it—the lead being thus dispersion-hardened .

The process of extrusion breaks up the oxide film on some of the particles into fragments which become embedded in the lead particles. The lead particles then bond to each other and recrystallise as a result of the deformation to which they are subjected. If a cross-section through a piece of lead extruded in the manner described above is examined under a microscope, it will be seen that the oxide films on the original particles have been most effectively broken up near the surface of the extruded piece, i.e. in the region subjected to the greatest deformation whilst the lead was being forced through the die. Towards the centre of the extruded piece the break up of the oxide films into discrete fragments becomes progressively less pronounced until finally no break up can be seen.

When the extruded piece is rolled down to a thin sheet the oxide films and fragments are further broken up and dispersed throughout the metal and further recrystallisation of the metal occurs with the fragments of oxide located within and between the metal crystals. The fact that recrystallisation has occurred is evidenced by the

ductility of the rolled sheet. The oxide fragments, being situated inside the lead crystals and in the grain boundaries, inhibit slip thus increasing the tensile strength, creep strength and hardness of the metal, and its resistance to grain growth. The rigidity of the dispersion-hardened lead is increased and an increase of tensile strength up to two-to-three times that of normal lead can be obtained.

Grain growth can be described in general terms as follows:

A body of metal may be regarded as being composed of "grains" (i.e. crystals) very strongly bonded together, and it is generally accepted that the grain boundary regions are stronger than the grains themselves. Neglecting the influence of other factors such as work hardening etc., the hardness and strength of a metal will depend upon the grain size. The larger the grain size the softer and weaker the metal and conversely. Thus, when the temperature of a piece of metal is raised sufficiently high it commonly happens that the metal grains coalesce (i.e. grain growth occurs) so that, after cooling, the said piece of metal is composed of a smaller number of larger grains and is accordingly softer and weaker than it was before. Most metals have to be heated to well above room temperature to cause grain growth; 250° C. for copper for example and 400–450° C. for iron. In the case of ordinary lead, however, grain growth occurs at room temperature.

Cold, plastic deformation (i.e. deformation without cracking) of a piece of metal, distorts and work hardens the crystals so that the piece of metal as a whole is work-hardened. Heating a work-hardened piece of metal to a sufficiently high temperature results in recrystallisation (i.e. the growth of new small crystals) and further heating to higher temperatures results in grain growth as described above. It is a peculiarity of ordinary lead that such recrystallisation and grain growth will occur at temperatures not much above room temperature.

In dispersion-strengthened lead the dispersed particles and, in particular, those particles located at or near the grain boundaries, prevent grain boundary movement and thus inhibit grain growth.

The preferred size range of the initial lead particles is determined by such considerations as thickness of oxide, packing density of the particles and the final grain size required, but the range would normally be from 1 to 100 microns.

The method is not necessarily limited to pure lead particles, but may be applied to lead alloy particles. Particles of lead containing, for instance, 1% tin to improve the corrosion resistance of the finished product, might be used.

To demonstrate the remarkable improvement in the strength of lead treated in accordance with the invention the following examples are given.

Example I

Lead powder with a maximum particle size of about 104 microns was taken "as received," with its natural lead oxide coating, and compacted into a 2 inches diameter billet. This was extruded to a cross-section of 1½ inches x 0.375 inch at room temperature (about 20° C.) and the resultant strip was then rolled firstly in the direction of the extrusion to reduce the 0.375 inch dimension to 0.175 inch, and then crosswise to reduce this dimension to 0.075 inch. The tensile strength of pieces of lead so prepared was found to be between 3220 and 3360 pounds per square inch, namely approaching twice that of ordinary lead (1800–2000 pounds per square inch).

Example II

Lead powder with a maximum particle size of about

53 microns, again taken "as received" with its natural lead oxide coating, was compacted and extruded as in Example I and then rolled lengthwise and crosswise to reduce the 0.375 inch dimension to 0.005 inch. The tensile strength of pieces of lead so prepared from this finer powder was found to be in the region of 5700 pounds per square inch. This is about three times the strength of ordinary lead.

The reduction of grain size and improved resistance to grain growth is demonstrated by the following example:

Example III

A specimen of ordinary cast pure lead was extruded and found to have a coarse grain size of less than 1 grain per square inch at 500 diameters magnification. A sample of lead made by extruding and rolling lead powder as in Example I was found to have a grain size of about 200 grains per square inch at 500 diameters magnification in the well crystallised skin. Moreover a specimen of the latter material when heated to 200° C. for half an hour was found still to have a grain size of about 200 grains per square inch at 500 diameters magnification, that is the grain growth was negligible.

What I claim is:

1. A method of producing strengthened lead which comprises extruding lead oxide coated lead particles through a die and then rolling the extruded lead along and across the direction of extrusion.

2. The production of strengthened lead by cold extrusion of lead oxide coated lead particles followed by rolling of the extruded lead.

3. A method of producing strengthened lead which comprises compacting lead oxide coated lead particles into a billet, extruding this billet into a thin sheet, then rolling the sheet lengthwise and crosswise relative to the direction of extrusion.

References Cited by the Examiner

Powder Metallurgy, 1962 No. 10, "Preparation and Selection Properties of Certain Dispersion-Strengthened Lead-Base Alloys," Lenel, pp. 120–121.

"Dispersion-Strengthened Lead and Its Applications," Roberts et al., pp. 132–157.

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