New Power Rolling Process

Dispersion strengthening principles may need revision when applied to larger powders—high strength and workability are features of product.

by S. Storchheim

A NEW, proprietary, high-energy powder consolidation technique has been developed which seems to shed new light on dispersion strengthening principles, and in addition yields materials which possess substantially higher strength properties, both at room and elevated temperatures. Powders are rolled in a conventional or vertical powder rolling mill in such a way that after passing between the rolls, the resultant strip is reguline in almost all respects. This means that the strip is not in the green compacted state as conventionally obtained, but rather has almost 100 pct of theoretical density.

Lead powders have been rolled with strengths as high as 8600 psi, compared to a maximum value of 2960 psi stated in the literature. Also, commercially pure aluminum powders have been rolled to strengths as high as 32,000 psi, and this has been increased to over 40,000 psi by additional cold rolling. Conventionally-produced, commercially-pure aluminum sheet has a maximum tensile strength of only 24,000 psi.

One of the major advantages of the new technique is that it can consolidate almost any size particle of almost any shape. It is here, working with powders from -325 mesh up to substantial sizes, that discrepancies with accepted dispersion strengthening principles have been noted.

It has been established that with SAP (sintered aluminum powder) products the maximum cold reduction that can be attained is approximately 30 pct. Further reduction causes micro-cracking with a loss of strength and ductility, and no appreciable increase in strength is obtained. However, this has not been found to be the case with powder-rolled materials using coarse starting powders. When -325 mesh material is used (17.5 μ diam), response to further cold reduction is almost identical to that of SAP-type materials. However, when coarse needle-like particles were utilized—even spheres of a large particle size, for that matter—cold reductions as high as 95 pct were attained with a continued increase in strength and no evidence of micro-cracking.

It is believed that the spacing theory of distance between refractory particles is no longer valid, at least not for larger sized powder rolled to strip by this new technique. Rather, the following is believed to occur: there are discontinuities on the surfaces of powder particles. The finer the particle, the more discontinuities there are per unit area. During high energy consolidation, coherency stresses are set up when particles are brought together, and the discontinuities are bonded. The more surface area available on the particles, the greater the actual number of discontinuities that are available for mismatch bonding.

Where extremely fine particles are used, such as SAP-type flakes and fine -325 mesh powder, there

is a minimum amount of volume available in the particles to be cold worked, i.e., most of the dislocations are pinned down and the three dimensional dislocation continuity is not extensive. As such, the response to cold reduction is not particularly great. In the case of coarse particles, there is a considerable volume of *unworked* metal withing the original particles. As such, dislocations can be moved and reductions made well past the 30 pct limit of the fine materials. So long as there is sufficient volume available, cold working can continue to the higher percent reductions attained in this work without any deterioration of the properties.

Ansell¹ brought out the possibility that with lower extrusion ratios fewer of the dislocations would be pinned down, and the material should have the ability to be worked further. As such, the data in this work appear to coincide with his thoughts, only instead of using a lesser bonding energy, larger volumed particles were used to accomplish the same objective. This greater volume in the particles allowed for the availability of unpinned dislocation sites, dislocation sources, and a continuous three dimensional dislocation network capable of accepting a very considerable degree of cold work. Of course, the oxide films can not be disregarded altogether, but their function seems to stem from a more macro viewpoint. It is believed that room-temperature properties are primarily a function of this ratio of surface area to volume and not so much that of percentage oxide content.

It was felt that powders which do not oxidize, such as gold or platinum, could be worked so that the surface area to volume hypothesis could be validated. As such, a few cursory experiments were conducted utilizing gold powders of -100 mesh and -325 mesh. These materials were consolidated into strip form, given a full anneal at 850°C for 1 hr, and then cold reduced 60 pct. The -100 mesh material attained a UTS of 41,300 psi. Compare this to 32,000 for cast-wrought gold 60 pct cold reduced. Not only did the powder-rolled gold evidence strengths greater than that of the normal cast-wrought material, but in addition, the strip made from the finer sized powder in itself attained a considerably higher value than the strip made from the coarser powder.

As a corollary to the theoretical considerations discussed above, hot explosive compacting experiments were run on the same lead powders; the results, which gave further evidence in support of the theory, have been reported elsewhere.²

It is apparent that further work on dispersion hardening is required for a true understanding of the principles involved. Also, techniques, other than hot pressing followed by hot extrusion, should be considered.

S. STORCHHEIM is President, Storchheim Research and Development Corp., Woodside, N. Y.

¹ G. S. Ansell: A Proposed Mechanism for the Strengthening of SAP-Type Alloys, *AIME Trans.*, vol. 215, no. 2, pp. 294-295.

² A. Cross: *The Iron Age*, Dec. 24, 1959, pp. 48-50.