

The effect of particle shape on the sintering of aluminium

1. Introduction

The sintering of aluminium is problematical because of the presence of the thermodynamically stable oxide shell on the particle surfaces. It has been suggested that an important prerequisite for sintering of aluminium is self-gettering, an autogenous process by which the powder in the outer layer of the compact serves as a getter for the powder in the interior. Ultimately, the partial pressure of oxygen deep within the compact becomes low enough for sintering to occur, while the outer layer is un-sintered. Here we show that particle shape may also be important for liquid phase sintering of uncompacted aluminium powders.

2. Experimental

The aluminium powders were mixed with 4 wt% Sn in a Turbula mixer. For sintering, approximately 1.5g of loose powder was loaded into alumina crucibles, tapped and then separately sealed using aluminium foil. Sintering was conducted at 620°C for 2 hours in argon.

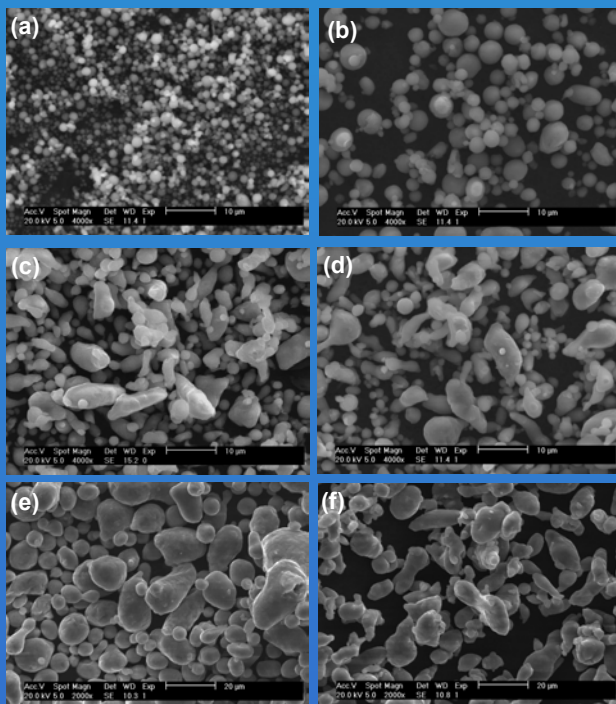


Fig. 1 SEM micrographs of the aluminium powders. (a) ALPOCO 3µm spherical; (b) ALPOCO 5µm spherical; (c) ALPOCO 6µm irregular; (d) AEE 7µm irregular; (e) ALPOCO 15µm spherical; (f) ALPOCO 15µm irregular

3. Results

Table 1 compiles particle size and selected characteristics of the as-received aluminium powders and the sintered density. The irregular powders have a consistently higher sintered density (88-91%) than the spherical powders (65-73%) do. There appears to be no causal relationship between the sintered density and any of the other powder characteristics examined.

Source	Titular		Particle Size			Tap Density (%)	O ₂ Content (wt%)	Surface Area (m ² /g)	Oxide Thickness ² (Å)	Sintered Density ³ (%)
	Size (µm)	Shape ¹	D ₁₀ (µm)	D ₅₀ (µm)	D ₉₀ (µm)					
ALPOCO	3	sph	1.60	3.23	6.28	24.7	0.6995	2.1158	17.96	65.7 ± 5.4
	5	sph	2.72	5.38	11.51	43.2	0.26	0.3695	17.68	72.9 ± 3.2
	15	sph	7.34	14.77	29.25	52.4	0.37	0.3733	24.90	88.3 ± 1.4
	6	irr	2.80	5.70	11.40	44.0	0.57	0.773	18.53	89.5 ± 0.3
	15	irr	7.73	14.69	28.02	44.0	0.57	0.773	18.53	89.5 ± 0.3
AEE	7	irr	3.17	6.97	14.64	37.0	0.57	0.773	18.53	89.5 ± 0.3

Due to the thermal expansion mismatch between aluminium and its oxide, a dynamic oxide breakage and repair process will occur during heating. Any stress concentration which occurs on the surface of irregular particles will cause its oxide shell to crack and heal more frequently than that on the smooth, spherical shaped ones. The irregular particles will therefore scavenge more oxygen than spherical particles will.

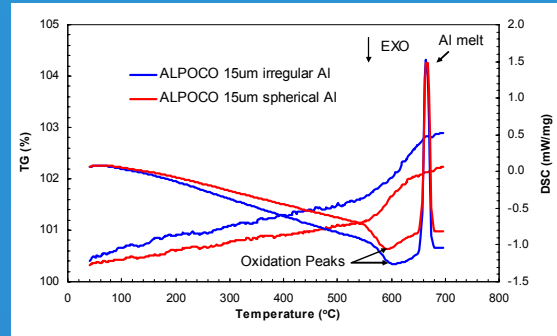


Fig. 2 Typical TG and DSC curves for ALPOCO 15µm irregular and 15µm spherical Al powders. The irregular powders have a greater weight gain than the spherical powders do.

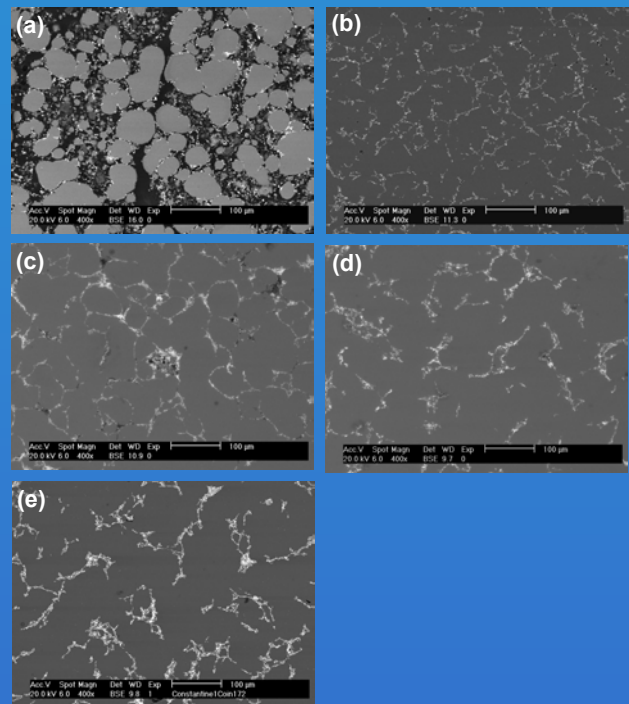


Fig.3 Backscattered electron microstructures of the centre portion of Al-4Sn sintered parts made with powders of different size and shape. The part from the ALPOCO 5µm spherical powders (a) remains very porous, although some of the particles have bonded together. In contrast, the ALPOCO 6µm irregular powders (b) sintered extensively. The ALPOCO 15µm spherical (c), ALPOCO 15µm irregular (d) and AEE 7µm irregular (e) are well sintered.

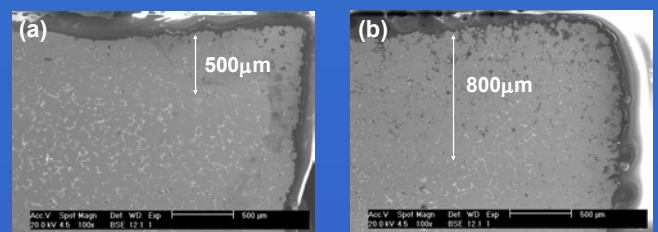


Fig.4 The microstructure of the top corner of parts showing the non-sintered, self gettingting zone is thinner in parts from (a) ALPOCO 15µm irregular powder than (b) ALPOCO 15µm spherical powders. Irregular powders provide a more effective autogenous gettingting zone than the outer layers made up of spherical particles.

4. Summary

Using aluminium powders of irregular shape, a density of ~90% was attained in Al-4Sn sintered at 620°C for 2 hours under argon. In contrast, a density of ~70% was reached when spherical powders were used. The enhanced sintering may be a consequence of a greater tendency for fracture of the oxide in the irregular powders and thus more effective oxygen scavenging.