

Composite Particle Powders – Manufacture and Applications

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Introduction

Westaim composite powders consist of metallic or non-metallic core particles which are uniformly coated with a layer of metal. Due to their good heat and corrosion resistance high purity nickel or nickel alloys are preferred coating metals to produce a variety of composite powders for functional applications in the aerospace and electronics industries. This paper describes the unique hydrometallurgical method of manufacture of composite powders, typical core materials and shapes used, the coatings applied and industrial applications of the resulting products.

Manufacture of Composite Powders by Hydrometallurgy

A hydrometallurgy method is used to produce composite particle powders described in this paper. According to this method nickel is reduced onto core particles in a batch operation in reduction autoclaves following the reaction equation:



The autoclave is agitated to keep the core particles in suspension. Nickel is reduced from the solution to uniformly coat the core surface. The powder is then screened, analyzed and packaged. Alloying elements such as Cr, Al and Mo can also be introduced into the cladding to produce alloyed powder coatings which provide increased oxidation and corrosion resistance. Figure 1 gives an example of a graphite core coated with nickel.

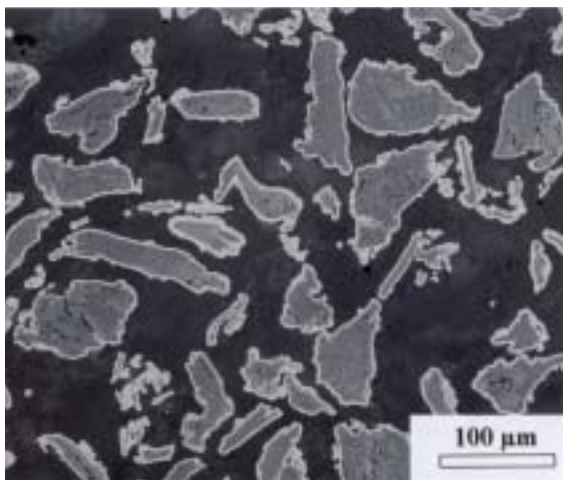


Fig. 1: Cross section of a nickel coated graphite composite powder (75 wt% Ni / 25 wt% C)

Process Capabilities

Cores: A variety of core materials can be clad by this process with the only limitation for the core material being that it should be stable in the Ni solution under the given pressure and temperature conditions. Table 1 gives some examples of powder cores which have been successfully coated with Ni according to the aforementioned process.

Elemental (non metallic)	Pure Metals and Alloys	Oxide / Nitride Ceramics and Ceramic Compounds	Carbides	Inorganic Compounds	Organic Compounds
C	Al	Bentonite	Cr₃C₂	cBN	Polyester
P	Cr	Cr ₂ O ₃	SiC	MoS ₂	Teflon
	Cu	ZrO ₂	WC	TiB ₂	Diamond
	Ti	Si ₃ N ₄	WTiC₂	CaF ₂	Wood
	W	Others	TiC	Glass	
	Mo			Sand	
	Mn			PMF	
	Bi				
	Brazing Alloys				
	Stainless Steel				

Table 1: Examples of core powders successfully used to produce Ni clad composite powders.

The hydrometallurgical process can accommodate various core shapes such as flakes, solid and hollow spheres and short fibres, as depicted in figure 2.

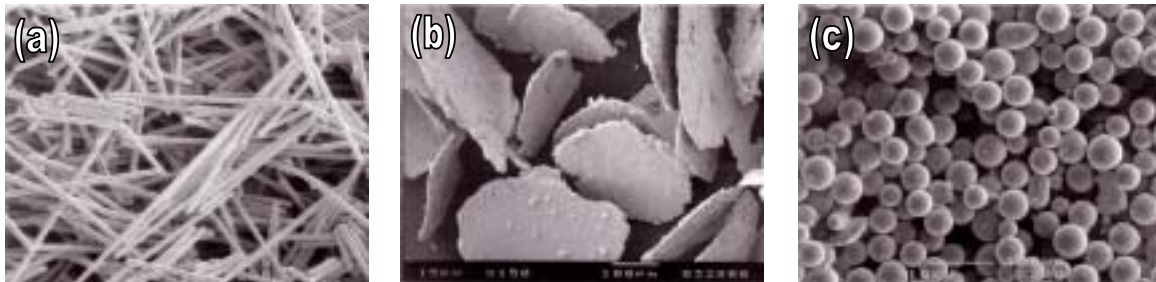
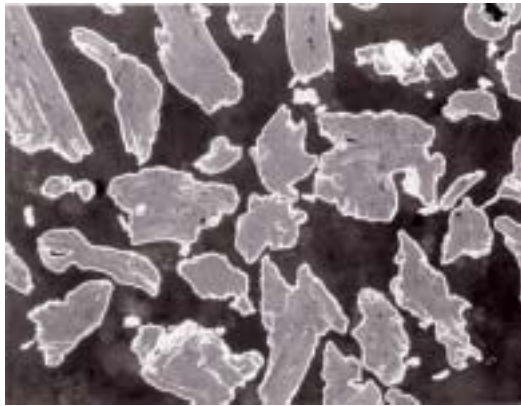
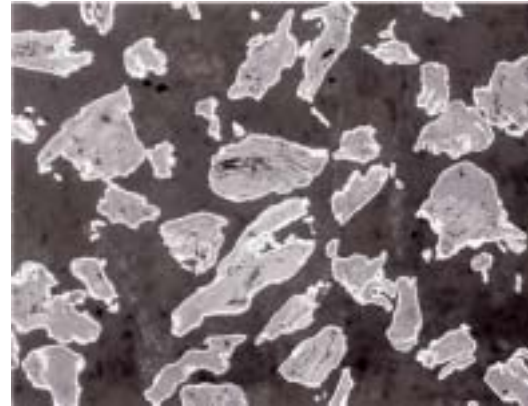


Fig. 2: Ni coated cores; (a): Ni coated glass fibres; (b): Ni coated Mica flakes and (c): Ni coated glass spheres

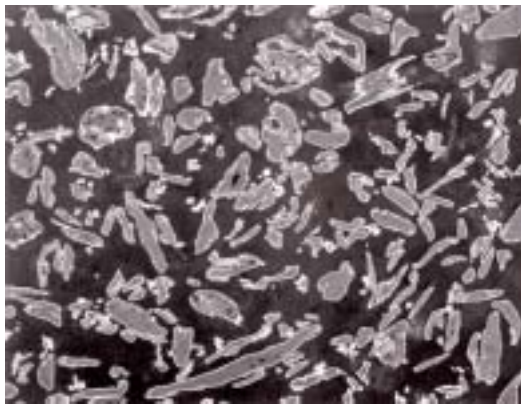
The process can also be used to coat a broad range of particle sizes. In designing new products a consistent coating method across a broad particle size range has the advantage that material quality and characteristics will be maintained even though the particle size has significantly changed. Figure 3 gives an example of Ni / C composite powders with core powder particle size varying from 11 to 112 μm .



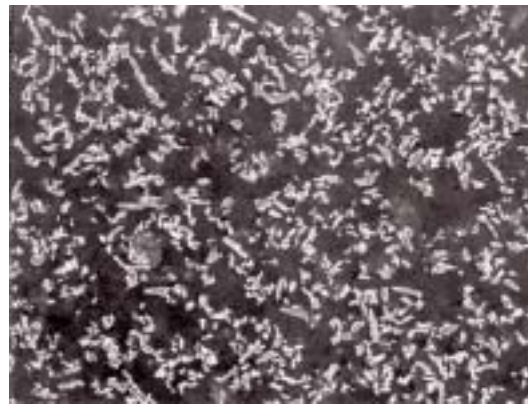
(a) 65 % Ni / 35 % C; D50 = 112 μm



(b) 60 % Ni / 40 % C; D50 = 85 μm



(c) 75 % Ni / 25 % C; D50 = 54 μm



(d) 86 % Ni / 14 % C; D50 = 11 μm

Fig. 3: An illustration of different particle size ranges of graphite cores which have been coated with nickel; (d) at double the magnification of (a) to (c)

Core coatings: The coating thickness on the core can be varied from approx. 0.2 μm to a thickness of several μm . The nickel or nickel alloy to core weight and volume ratios can therefore be adjusted accordingly. For example Ni / C composite powders are manufactured with a nickel content ranging from 60 to 90 wt %.

While simple nickel claddings are used in a number of cases, some applications call for alloyed Ni claddings, especially when improved oxidation and corrosion resistance are required. Various methods can be employed to produce alloyed coatings or multiple layer coatings. Due to their superior oxidation resistance NiCrAl claddings are preferred alloy coatings. Besides this composition NiAl, NiCr, NiMo and NiCrMo alloy coatings, the latter three providing optimum hot corrosion resistance, have all been successfully applied. Other special applications may require duplex coatings such as Ni – Au, Ni – Pd, Ni – Ag or Ni – Pt. Figure 4 gives an example.

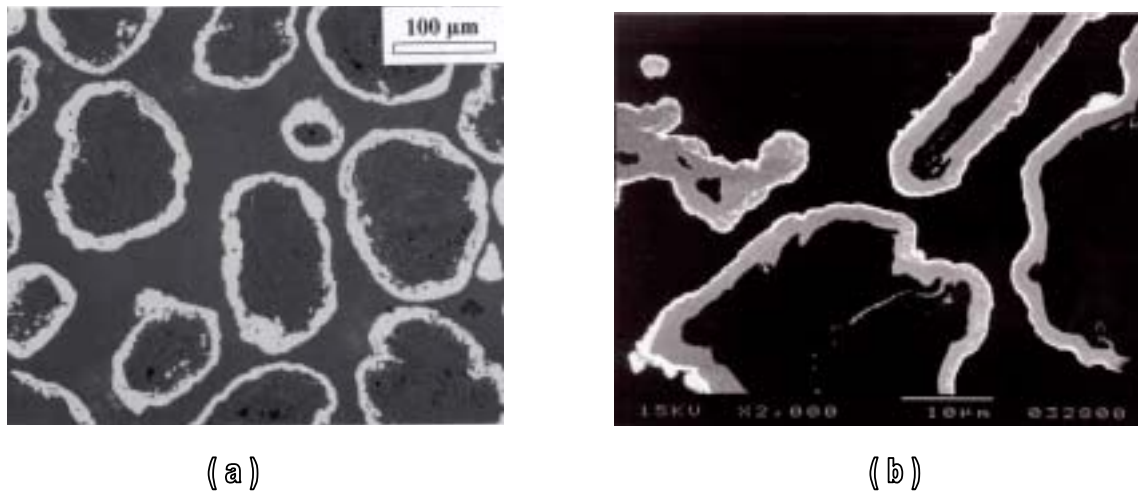


Fig. 4: Alloy coatings and duplex claddings; (a) Ni – Cr – Al alloy cladding on a non-metallic (ceramic) core; (b) duplex coating; 5 wt% Au on a 75 wt% Ni / 25 wt% C composite powder.

Aerospace Applications

One of the major markets for hydrometallurgically produced composite powders is for turbine engine abrasible seals. Abrasible seals are used in turbomachinery to reduce the clearance between rotating components such as blades and labyrinth seal knife edges and the engine case. Reducing the clearance improves the turbine engines' efficiency and reduces fuel consumption. While such sealing is achieved with honeycombs brazed to backing structures in the case of combustion gas sealing at the turbine end of the engine, the compressor seal is in many cases achieved by applying a porous coating to the compressor case or rotating component as shown in figure 5.

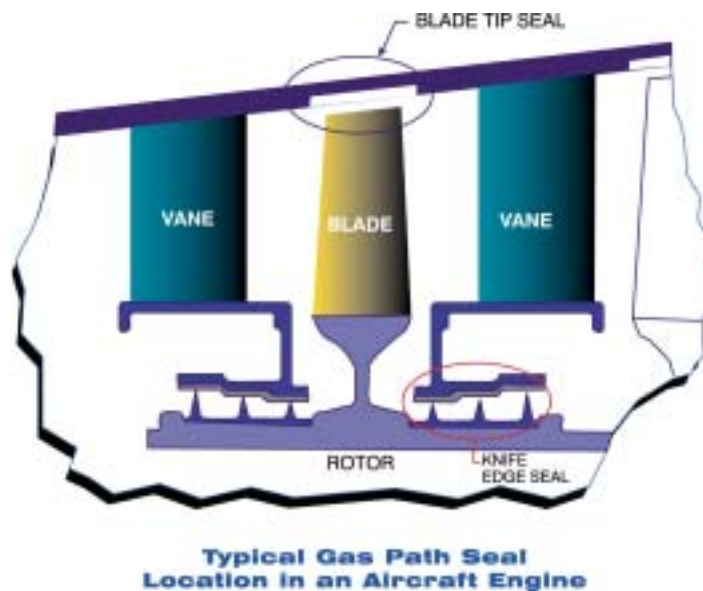


Fig. 5: Typical locations of abrasible blade tip and shaft knife edge seals in the compressor section of a jet engine gas turbine.

Levinstein and Betts (1) listed no less than the following nine requirements for a turbine engine abradable seal material: (1) Machine away smoothly with negligible wear to blades, vanes or seal teeth as the case may be; (2) generate little heat in the rubbed component; (3) not adhere to the rubbing component since such build-up may result in additional clearance and subsequent loss of performance; (4) generate a very fine debris which will not affect downstream components either mechanically or chemically; (5) have adequate corrosion resistance and must not cause or permit electrolytic corrosion with the substrate; (6) have adequate resistance to erosion from ingested fine particulate matter; (7) be applied at reasonable cost with high level of reliability and repeatability; (8) be amenable to reliable quality control procedures and (9) be readily repaired or easily removed and replaced at overhaul.

The above combination of varied and often conflicting combination of properties required for high temperature abradable seals is met very satisfactorily by the use of thermally sprayed composite particle powders. The composite particle powders used in this application are:

- ⦿ Durabrade™ 2200 Series Coatings (Ni / C) in the following compositions: 85 % Ni / 15 % C; 75 % Ni / 25 % C, and 60 % Ni / 40 % C.
- ⦿ Durabrade™ 2300 Series Coatings Nickel Chromium Aluminium / Ceramic Core,
- ⦿ Ni / Al; composition: 80 % Ni / 20 % Al

Ni / C - Durabrade™ 2200 Series abradable coatings are applied by Flame Spraying with the spray parameters adjusted to produce a highly porous coating as shown in figure 6. The structure of the sprayed coating consists of three phases: The metallic nickel phase which provides structural strength, erosion resistance and bonding between particles and to the substrate. The graphite acts as a solid lubricant. The amount of porosity has a strong influence on the hardness and other mechanical properties of the sprayed coating. The latter two phases provide the structural weakness or abradability of the coating.

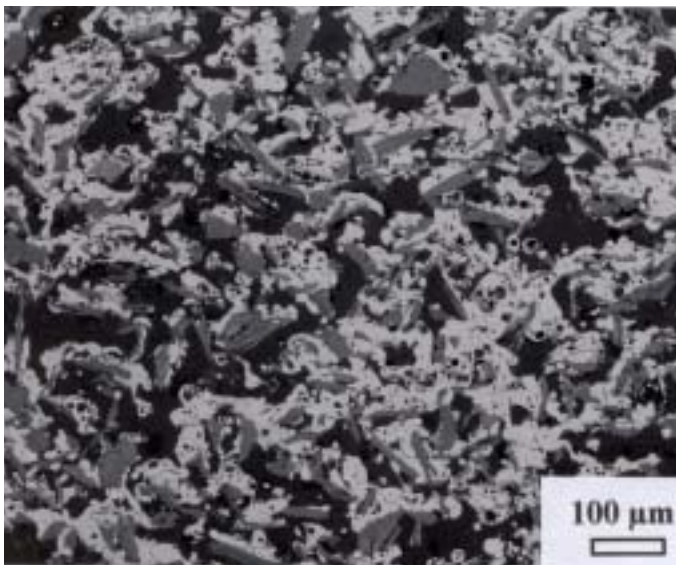


Fig. 6: Flame sprayed Durabrade™ 2200 Series (Ni / C) abradable coating. Black phase: porosity; grey phase: solid lubricant (Graphite) and bright phase: Ni.

NiCrAl / Ceramic Core (Durabrade™ 2300 Series Coatings): Nickel graphite has limited temperature capability because the graphite phase rapidly oxidizes above 450 °C. For seals operating at higher temperatures, not only must the nickel coating be alloyed but also the graphite core must be replaced by a more oxidation resistant material. The choice of the core material must not decrease the required abrasability. Durabrade™ 2300 Series Coatings (see figure 4) were developed to provide gas turbine compressor designers with a thermal spray coating that can function as an abradable seal at temperatures up to 815 °C. It is widely used in the high pressure compressor of commercial and military jet engines. Figure 7 shows a sprayed NiCrAl / Ceramic Core coating for use as an abradable compressor seal.

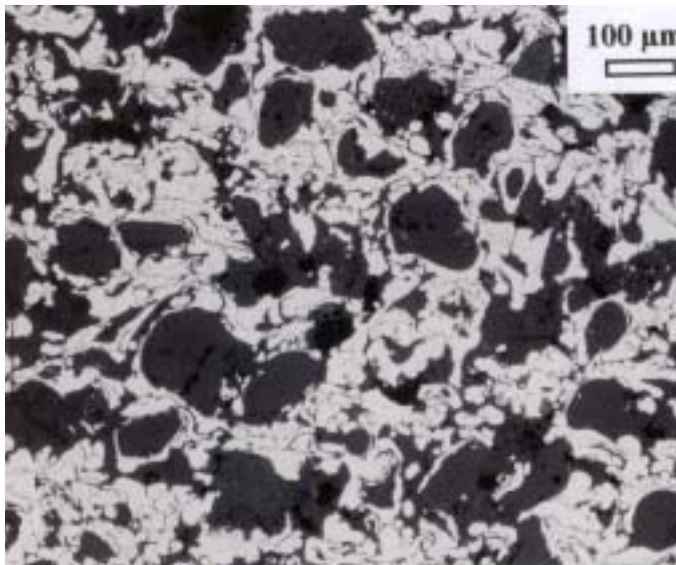


Fig. 7: A flame sprayed Durabrade™ 2300 Series abradable coating.

Ni / Al composite powder is used as a sintered abradable seal material and also as a bond coat material to improve the adherence of thermally sprayed coatings to various substrates. When filled into honeycomb cells and sintered, the aluminium core of the composite diffuses into the nickel cladding. At the same time a reaction occurs to form an intermetallic compound, nickel aluminide. Nickel aluminide is very oxidation resistant and can be used at temperatures up to 1000 °C in engine hot gas environments. Sintered Ni / Al has some interesting attributes for use as an abradable seal: during sintering it expands by approximately 20 % while metal powders normally shrink during sintering. The volume expansion that occurs helps to anchor the sintered powder in the honeycomb cells. The sintered product consists of a network of hollow nickel aluminide spheres bonded to each other and to the honeycomb foil.

Industrial and Aerospace Applications for Wear Resistant Coatings: NiCr / Cr₃C₂ coatings are used in applications where both resistance to wear and oxidation are required, e.g. in the temperature regime 500 – 800 °C. As compared to a blended powder consisting of chrome carbide powder mixed with an atomized NiCr alloy, nichrome clad Cr₃C₂ as produced by the hydrometallurgical technology discussed here has significant advantages during spray deposition: The blended powders show the tendency for Cr carbide particles to bounce off the substrate and the coating

consequently exhibits less than optimum wear resistance. Cladding the chromium carbide helps the spray process to retain a higher level of carbide in the final coating. This enhances wear resistance. Composite NiCr / Cr₃C₂ can be applied by either HVOF or Plasma Spray processes. Applications in aerospace focus on hot running components where particulate erosion, fretting or cavitation may occur. Industrial applications include piston ring coatings for heavy duty diesel engines and boiler tubing coatings in coal fired power plants to limit erosion and oxidation. NiCr / Cr₃C₂ thermal spray coatings are also a candidate in applications where hard chromium plating is being eliminated for environmental reasons.

Electromagnetic Shielding (EMI) Applications for Composite Powders

As the magnetic spectrum becomes more congested due to the ever increasing use of portable electronic devices, and the complexity of electronic devices increases, the need for electromagnetic shielding for electrical and electronic equipment becomes more important.

Applied solutions usually entail having some or all of the component parts enclosed in a conductive envelope. This conductive envelope contains the emissions radiated from within the device to a confined area while protecting the device from emissions that radiate from external devices. Furthermore, sensitive components within a single device can operate free from cross contamination from other electronic components within the device. This conductive envelope is often achieved through the use of coatings and electromagnetic interference (EMI) gaskets. EMI gaskets and adhesives are used to fill or join apertures in order to provide a continuous low impedance joint with the chassis. Metal particles or metal-coated particles, mixed in a high volume fraction with a polymeric binder or adhesive, have become one of the accepted techniques to meet this need. The additional advantage of this approach is that the conductive gasket also acts as an environmental seal for the device.

In the past the military and aerospace industries were the largest consumers of conductive gaskets. Due to the high standards of these traditional users, silver was the most widely used conductive filler. However, with shrinking budgets and rising demand in consumer applications, other materials such as silver plated aluminium, copper, nickel and glass, pure nickel, and nickel graphite composite powders have gained wider acceptance.

Combining low density graphite with a layer of conductive nickel results in a lightweight filler that is ideally suited for conductive gaskets and sealants. Shielding using nickel brings the corrosion resistance to the plastic product that nickel is famously noted for in many alloy compositions. The result is better environmental stability of the conductive shield.

Besides graphite other cores can be coated as well with the hydrometallurgical method discussed in this paper to produce composite particle powders for use as conductive fillers. Figure 8 gives some examples.

As mentioned, the hydrometallurgical production technique can accommodate a wide range of core particle sizes which is a significant advantage over other methods of producing composite conductive fillers. It also has the advantage that the surface roughness can be tailored to specific requirements.



Fig. 8: A few examples of nickel coated cores for use as conductive filler materials. Nickel coated graphite (a); nickel coated copper (b) and nickel clad aluminium (c).

References

- (1) M. A. Levinstein and R. K. Betts: 6th Int. Metal Spraying Conference, Institut de Soudre, Paris (1970).