Prealloyed PM Steels

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Abstract

The diversity of alloys available to the Powder Metallurgy (PM) industry provides a sizable range in properties, where increased alloy content generally equates to better properties, particularly in the as-sintered state. PM alloys are commonly employed in either the as-sintered condition or heat treated, where sinter-hardening is considered a heat-treated condition. The most cost effective alloy system for as-sintered properties is Fe-Cu-C, followed by Fe-Ni-C. Admixed copper aids in the sintering process and strengthens both ferrite and pearlite microstructures and admixed Ni is known to increase toughness as well as strength. Traditionally, 2 w/o (weight percent) Cu or 2 -4 w/o Ni alloys are used in parts for heat-treating too; however, it is not always clear how much alloy is required to achieve desired properties for a given application. Prior to 2003, the consistently low alloy prices for Ni and Cu made heavily alloyed PM steels an excellent choice for many components, including heat-treated applications. Market pricing fluctuations, though, in combination with ever increasing dimensional tolerance demands, have forced a re-assessment of alloy selection for many applications.

In response to price fluctuations and environmental concerns, both powder and part manufacturers have been striving to reduce the dependence on these elements. One method to alleviate the impact of price volatility is to reduce the alloy content to the minimum necessary to meet the property requirement of the parts. For conventional quench and temper heat treatment that utilizes more rapid cooling rates than sinter-hardening, less alloy is required to produce a hardened, martensitic component. Though this processing approach can lead to challenges in dealing with greater variation in dimensional behavior with the potential inability to size due to higher hardness. Additionally, environmental concerns with using quenching oil, elemental Ni additions, and the difficulty in recycling Cu-containing steels remain issues. Removal of alloy content and the corresponding reduction in mechanical properties, however, may not be allowed based on the mechanical property requirements of the part. In this case, alternative alloying elements or advanced compaction techniques to reach higher density become necessary to achieve desired properties. This has resulted in the use of non-traditional PM alloying elements, such as Mn and Cr, as well as a move towards prealloyed sinter-hardening PM steels instead and the development of leaner alloy systems based on molybdenum (Mo).

Molybdenum contents of 0.85 w/o and 1.5 w/o have historically been used to ensure robust properties and, as one of the key alloying elements in iron, it serves to improve the hardenability in PM steels when prealloyed. Leaner versions of these prealloys use 0.3 w/o or 0.5 w/o Mo and are promising alloy alternatives in terms of meeting demands in optimizing performance with part design and cost. Fe-Mo prealloys have many beneficial properties and uses. The addition of Mo has little effect on base iron compressibility, it is robust in various sintering atmospheres, and has a profound effect on hardenability (the ability to form martensite), which makes steels containing Mo ideal candidates for heat-treating applications. It can be seen in Figure 1(a) how Mo additions impact hardenability in Fe-C alloys as the depth of hardening increases in a Jominy end-quench test. All sinter-hardening grades available in the ferrous PM market, be it conventional Fe-Mo-Cu alloys (FLD-49DH) and Fe-Mo-Ni-Cu alloys (FLC-4608, FLNC-4408 and FLC-4808), contain some level of Mo for these reasons. Figure 1 (b) demonstrates the Jominy hardness for a small variety of sinter-hardening alloys available to the industry. Higher Mo levels along with prealloyed Ni can be used to harden parts with larger cross-sections and achieve robust processing with challenging dimensional tolerances.

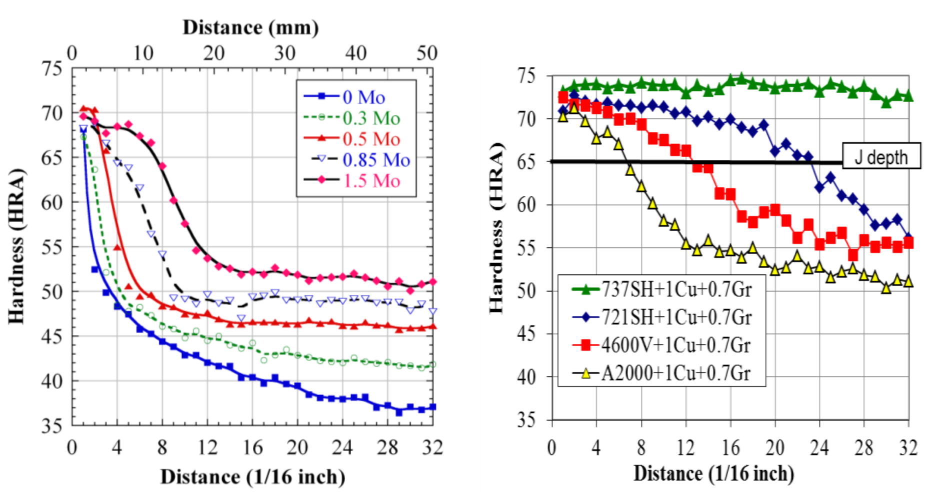

Figure 1: Jominy end-quench hardness profiles of PM steels at 7.0 g/cm^3 with (a) different levels of Mo content and 0.6 w/o graphite; and (b) typical sinter-hardening alloy compositions readily available to the market.