Looking for lean-alloy PM steels with performance and economy

Joe Capus, *MPR* contributing editor, continues his ongoing reporting of the technical papers presented at PowderMet 2013 in Chicago this past June. In this piece, he puts the focus on attributes of lean-alloy PM steels.

There were, as usual, a large number of separate ferrous PM topics presented during the recent PowderMet 2013 APMI/MPIF conference in Chicago (see *Metal Powder Report*, July/August 2013 edition). One of the more interesting sessions held on the first day dealt with developments in lean-alloy PM steel compositions.

As Ian Donaldson (GKN Sinter Metals) pointed out in a joint presentation with Bruce Lindsley (Hoeganaes Corp.), the continuing demands of the automotive manufacturers are [still] driving innovation in the PM industry. Furthermore, in recent years the need for higher strength components has been compounded by the extreme volatility in prices of the alloy elements that traditionally have been used to boost the strength of pressed and sintered parts. Result: the risk that PM will lose out on new engine and transmission developments, and consequently cede market share to manufacturers using less-costly, wrought-based materials.

Hence, there has been an ongoing battle to find leaner or alternative alloy compositions, as well as other means of reaching desired properties. A consequence of the many studies and developments that have been made on this in the recent past is that there is now a multiplicity of options to explore.

In the work presented by Donaldson, this was illustrated by results from several related investigations giving sets of comparison test data. The first set of lab tests involved warm-die compaction of ferrous-based mixes to a green density of 7.1 g/cm³, followed by high-temperature sintering at 1250°C in a roller-hearth furnace using a lean 95/5 nitrogen/hydrogen atmosphere and then accelerated cooling to provide sinter-hardening — and, finally, tempering at 205°C for one hour. Six different lean alloy compositions with molybdenum contents ranging from 0.3% to 0.8% and various additional alloy combinations selected from chromium, manganese, silicon and nickel were compared with a "base-line" FD 0405 (4% Ni, 1.5% Cu) diffusion-alloyed PM steel that is successfully used in synchronizer hubs and other auto components. The lean-alloy compositions contained only 10-30% of the expensive alloying ingredients (Mo, Ni, and Cu) that are employed in the FD-0405 mix. With a constant combined carbon level of 0.5%, variations in properties resulted from changes in microstructure brought about by the different alloy contents. The lean alloys showed apparent hardness and tensile strength values mostly surpassing that of the FD-0405 steel base-line. However, the nickel steel showed a higher elongation, at 2%. All of the sinter-hardened materials showed complex but fairly similar microstructures, with various combinations of tempered martensite, bainite, pearlite, and nickel-rich regions (where nickel was added to the mix). In other tests, the influence of atmosphere and sintering temperature were investigated. For the atmosphere study, sintering of lean-alloy (1.3% Mn, 0.5% Mo, 0.3% Si) mixes was made in a mesh-belt furnace at 1140°C for 20 minutes. Endothermic atmosphere diluted with nitrogen was used, to compare with sintering with a 90/10 N_2/H_2 atmosphere. Diluting the atmosphere to either 68% or 51vol.% Endo caused a significant rise in the sintered oxygen content (0.40/0.45% vs. 0.16%) and substantially lower strength and % elongation.

In further experiments with the same manganese and molybdenum-containing composition — as well as one with a higher molybdenum content (0.8%) and a chromium-containing mix (0.8% Mo, 1.0% Cr, 1.0% Ni and 0.6% Si) — the effect of sintering atmosphere was confirmed. In this investigation, using a roller-hearth furnace with accelerated cooling, the atmosphere was either 95/5 N_2/H_2 or diluted Endo (90/10 N_2/Endo). The tests were run at three sintering temperatures: 1120°C, 1200°C, and 1250°C. The use of diluted Endo reduced the UTS more-or-less significantly, but the hardness was little affected for all three compositions (see Figure 1). The conclusion was that using Endo, even when diluted with nitrogen/hydrogen, was not a good idea.

Looking at specific application examples, such as an automotive gear currently using a 4% nickel material, the authors demonstrated how targeted properties like YS, UTS and impact energy could be met by the right selection of a lean alloy composition to replace the more expensive material. Compared were mechanical properties of the base-line FD-0405 (4% Ni) and the lean 1.0%Cr, 1.0%Ni, 0.6% Si, 0.3% Mo alloy steel, both sintered in a mesh-belt furnace at 1180°C with accelerated cooling.

The authors concluded by referring to successful applications for new lean Cr-Mo-Ni PM steels when suitable compaction and sintering conditions were employed. These included torque-vectoring systems for premium all-wheel-drive vehicles (see Figure 2) and synchronizer hubs for manual and double-clutch transmissions.

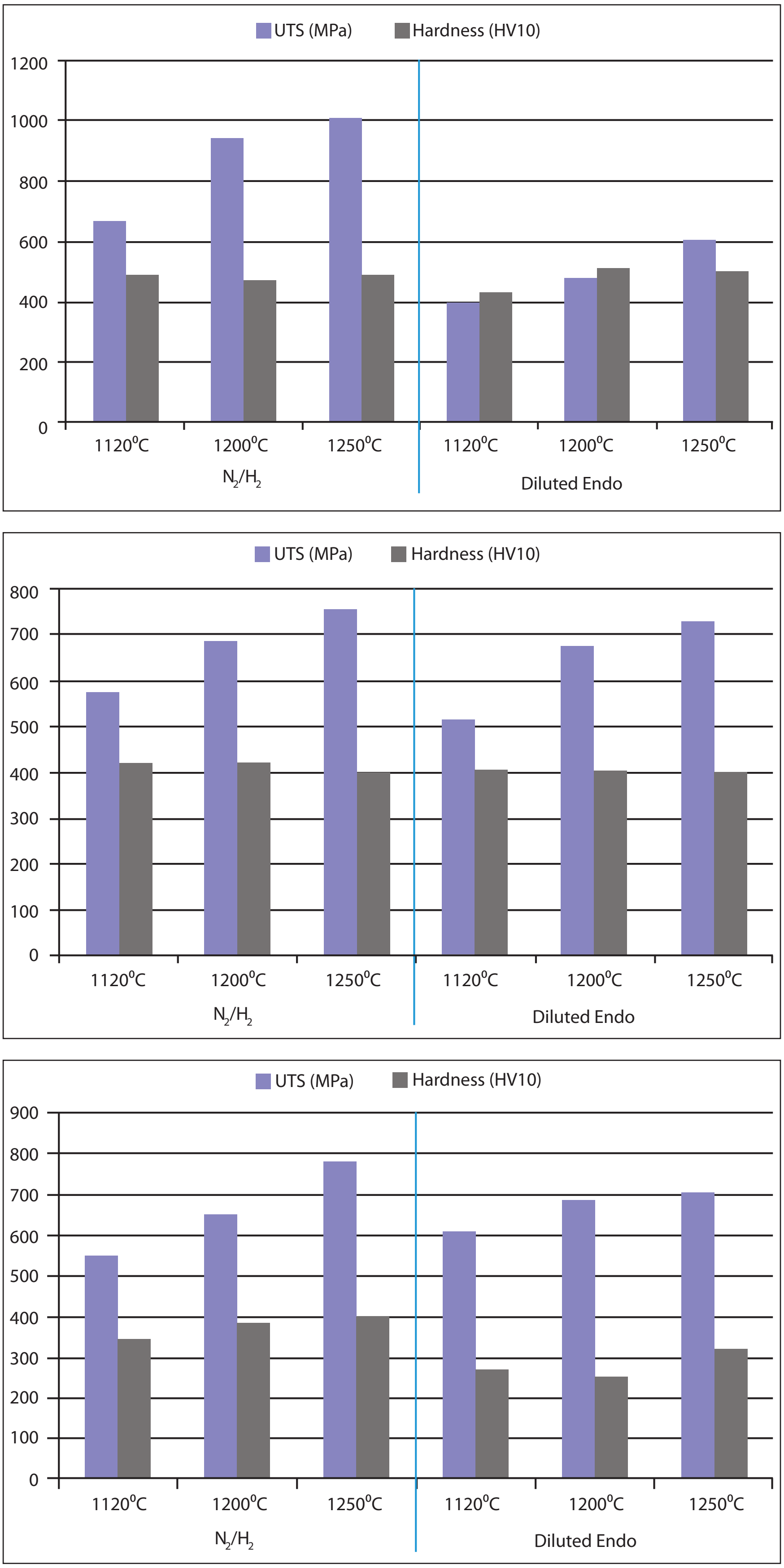

Figure 1. UTS and apparent hardness for different sintering temperatures and atmospheres (95/5 N_2/H_2 or 90/10 N_2/Endo) with accelerated cooling in a roller hearth furnace. (After Donaldson and Lindsley) (Mix 1: 0.8% Mo, 1.0% Cr, 0.6% Si, 1.0% Ni, Mix 4: 0.5% Mo, 1.3% Mn, 0.3% Si, Mix 8: 0.8% Mo, 1.3% Mn, 0.3% Si) (Ancorbond®FLM), (All mixes contained 0.65% graphite)

Nickel-free Lean Alloy PM Steels

A novel approach to nickel-free lean alloy PM steels was presented by François Chagnon in a paper co-authored by Lydia Aguirre, both with Rio Tinto Metal Powders. In this work, Mn-Cr-Mo steels were synthesized by mixing together pre-alloyed Mo-containing steel powder with ferro-alloys containing Mn or Cr, plus a new carbon master-alloy. The carbon master-alloy was designed to replace the conventional graphite admixture. The carbon master-alloy (M.A.1) was produced in house by atomising a 2% carbon, 1% silicon iron melt and subsequently malleablising the powder by heat treatment. (Details of this malleable powder product were given at last year's MPIF conference, PowderMet 2012, in