Enhanced Properties of Extra-fine Nickel Steels for PM Gears

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Abstract

Highly compressible Ni-Mo steels are attractive materials for PM due to high sinter density and ease of processing. Extra-fine Ni admixed PM steels have demonstrated improved mechanical properties and rolling contact fatigue resistance due to a more uniform microstructure and increased Ni diffusion during sintering. Sinter densities of single press single sinter XF Ni-Mo steels can approach 7.5 g/cm³ at moderate compaction pressures. Leaner alloys based on extra-fine Ni powder are possible depending on the performance requirements of the PM steel part. Extra-fine Ni steels are particularly attractive for the growing market of high performance PM gears and sprockets.

Keywords : Nickel, Gears, Hardenability, high density

1. Introduction

The main advantage powder metallurgy has over other metal forming technologies is the ability to produce near net shape complex geometry parts to tight tolerances. Complex geometry however requires highly compressible powders in order to achieve high green density. With high raw materials prices, more effective use of admixed Ni powder offers the potential to both increase performance of PM steels or lower both Ni and Mo alloy content, while achieving similar properties to standard grade admixed Ni-Mo steels.

2. Experimental and Results

The steel blends were based on prealloyed Fe-Mo powders - Ancorsteel® 85 HP and 50 HP[1]. Nickel powders (2 and 4 wt.%) were: "Standard" (Inco ® T123 PM) and "Extra-fine" (Inco ® T110 D) referred to as STD-Ni and XF-Ni respectively [1]. Other additives included: 0.5-0.8% graphite (Asbury SW1650); 0.6% lubricant (Lonza Acrawax C). Samples of Ni-Mo P/M steels were fabricated and tested using standard methods [2]. Powders were mixed in a V-cone blender then compacted at 410 to 690 MPa (30 to 50 tsi). Green compacts were sintered for 30 min at 1120 to 1280 °C, with accelerated cooling performed for sinter hardenable grade steels. Heat-treated samples were held at 850°C for 30 min followed by oil or argon gas quenching (~1°C /s).

XF-Ni increased compressibility and sinter density of Ni-Mo steels. Mechanical properties of sintered XF Ni-Mo steels improved compare to STDNi steels (Table 1). Elongation varied from 1.5 to 3% and increased with increasing Ni content and XF Ni vs. STD Ni powder.

Table 1. Properties of 0.85% Mo – Ni Steels

Comp. Pressure (MPa)	Sinter Density (g/cm^3)		TRS (MPa)		Apparent Hardness (HRA)		UTS (MPa)	
	wt.% Ni		wt.% Ni		wt.% Ni		wt.% Ni	
	2	4	2	4	2	4	2	4
STD Ni								
410	7.02	7.01	900	1100	50	55	520	620
550	7.16	7.15	1290	1400	55	60	610	730
690	7.28	7.25	1430	1500	57	61	690	820
XF Ni								
410	7.16	7.12	970	1230	60	61	640	680
550	7.22	7.27	1400	1550	61	62	670	750
690	7.36	7.41	1540	1730	62	63	860	910

Properties of heat-treated 0.5% Mo-2% XF Ni steels were also enhanced in comparison with STD Ni steels. Microstructures of heat-treated Fe-Ni-Mo steels with XF Ni consisted mostly of martensite with small amount of bainite (Fig. 1). Apparent hardness reached 42-44HRC, compared with 39-41HRC for STD Ni steels, and micro-indentation hardness was 750-820 HV_{100}.

[1] Ancorsteel® 85 HP and 50 HP are registered trademarks of Hoeganaes Corporation

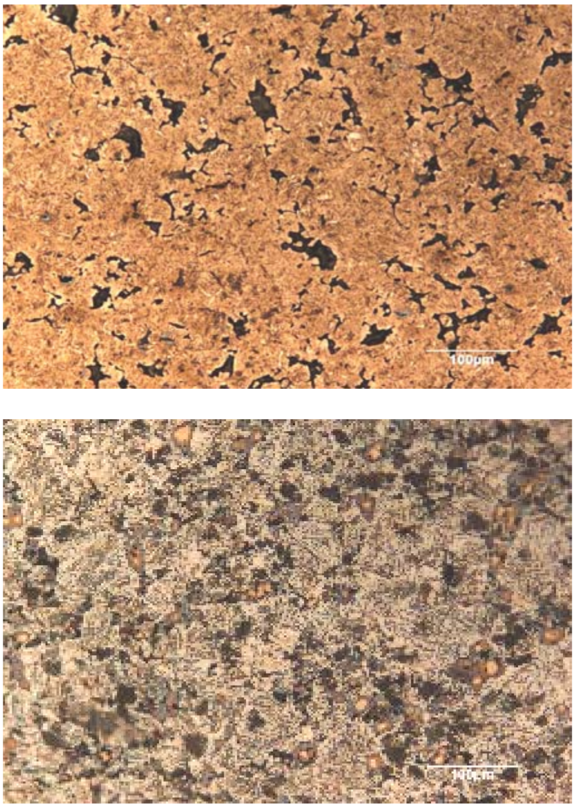

Fig. 1. Heat-treated 2% Ni-0.5% Mo steels. XF Ni steel is homogeneous martensite (top) vs. STD Ni steel showing light Ni-rich austenite areas (bottom)

Uniform microstructures with high apparent hardness and mechanical properties can therefore be obtained in 0.5%Mo-2%XF Ni steels. Mechanical properties approach those of 0.85%Mo-2%STD Ni steels, particularly in the heat-treated condition. Lower Mo content XF Ni steels are potential replacement materials for thinner heat-treated PM steel parts, or parts not requiring through-hardened fully martensitic microstructures.

Hardenability of sintered 2%Ni-0.85%Mo steels was determined using the standard Jominy water quench end test [3]. In Figure 2, XF Ni increased the hardenability depth of 2%Ni-0.85% Mo PM steel by 50%. 4% XF Ni-0.85% Mo steels doubled hardenability depth to over 56 Jominy units (88 mm or 3.5") compared to STD Ni steel [4].

High temperature (1250 °C) sintered carburised PM steels admixed with extra-fine Ni have demonstrated improved rolling contact fatigue resistance due to the absence of soft Ni-rich phases resulting in a more uniform microstructure. 2% XF-Ni-0.85% Mo steel performed better than the baseline 5120 wrought steel at a contact stress of 2000 MPa and lasted twice as many cycles to failure at 2500 MPa as the next best PM steel tested under similar conditions [5].

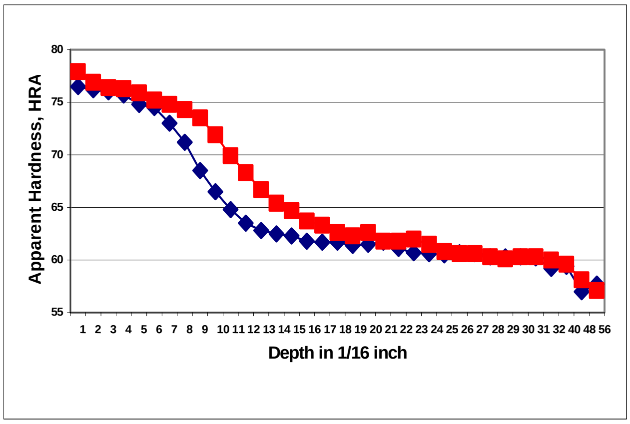

Fig. 2. Jominy hardenabilty of 2%Ni-0.85% Mo steels (sinter density = 7.35 g/cm^3). XF Ni = red; STD Ni = blue.

3. Summary

Admixed XF Ni steels achieve higher mechanical properties than prealloyed Ni-Mo and Cr-Mo steels at equivalent compaction pressure. Microstructures of XF-Ni steels sintered at 1120 °C contain Ni-rich martensite as compared to Ni-rich austenite in STD-Ni steels. Increased diffusion of XF-Ni improves hardenability of Ni-Mo steels by up to 200% depending on the alloy composition. XF Ni-Mo steels are very promising materials to improve rolling contact fatigue performance of PM gears.

4. References

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