# Capabilities of Two Chromium Powder Metallurgy Steels for High Performance Applications at Conventional Sintering Temperatures

Patrick King[a] and Bruce Lindsley[b]

Hoeganaes Corporation 1001 Taylors Lane
Cinnaminson, NJ 08077 USA
[a]patrick.king@hoeganaes.com, [b]bruce.Lindsley@hoeganaes.com

**Abstract**

*Ancorsteel 4300, a high performance Cr-Si-Ni-Mo steel, was unveiled two years ago as the first in a series of powder metallurgy alloys that will simulate wrought steel compositions. Advantages of this alloy include good compressibility, high hardenability, and excellent dimensional stability. More important, however, is that this alloy has the ability to be effectively sintered at 1120 °C and maintain oxygen contents below 500 ppm. This unique blend of performance and processing capabilities provides static and dynamic properties that exceed those of conventional powder metallurgy alloys and approach wrought gearing materials. A second Cr-Si-Ni-Mo alloy has now been developed that offers complimentary performance levels at a lower Mo content. This manuscript reviews properties of the two chromium steels with comparisons to traditional sinter-hardened and heat-treated powder metallurgy alloys.*

**Keywords : chromium steels, hardenability, fatigue, high performance applications**

## 1. Introduction

Parts manufacturers have often used wrought materials containing chromium, nickel, and silicon in high performance components because of improvements in hardenability and mechanical properties obtained at a modest cost. These alloying elements have been used independently in a range of commercially available powder metallurgy (PM) materials, and have been found to dramatically enhance performance [1-2]. Chromium and silicon, however, tend to form stable oxides. As a result, alloys containing either element are traditionally sintered at temperatures above 1200 °C to avoid the adverse effects of oxygen on mechanical properties [3-4].

A recently commercialized Cr-Si-Ni-Mo PM steel, Ancorsteel (Ancorsteel is a registered trademark of Hoeganaes Corporation) 4300, was specifically engineered to simulate wrought steel compositions and counteract the oxygen-related problems that are associated with chromium and silicon. Under a typical reducing furnace atmosphere it provides sintered oxygen contents below 500 ppm at 1120 °C, which helps maximize the performance of the alloy by enabling full use of alloying elements [5]. A second Cr-Si-Ni-Mo alloy has now been developed to offer complimentary performance levels at a lower Mo content. Advantages of both alloys include good compressibility, high hardenability, and exceptional dimensional stability.

## 2. Experimental and Results

Table 1 summarizes the compositions evaluated. All mixes contained 0.75 wt.% Lonza Acrawax C as a lubricant.

Mechanical property specimens were compacted to a green density of 7.1 g/cm$^3$. Sintering was conducted for 30 min at 1120 °C in a belt furnace in $90N_2$-$10H_2$ (vol.%). Three average cooling rates over the range of 650 to 315 °C were obtained: 0.7, 1.6, and 2.2 °C/sec. FLN2-4405 was oil quenched and tempered (Q&T) by austenitizing at 900 °C for 30 min in $25N_2$-$75H_2$ (vol.%) and quenching in agitated oil at 65 °C. All samples were tempered at 205 °C for 1 hour. Axial fatigue testing was conducted in load control, R = 1, at 40 Hz and a runout of 2 x 10$^6$ cycles.

**Table 1. Nominal compositions (in wt.%)**

| Designation | Chemistry |
|---|---|
| Cr-Si-Ni-Mo-1 | Fe-1.0Cr-0.6Si-1.0Ni-0.8Mo-0.6C |
| Cr-Si-Ni-Mo-2 | Fe-1.0Cr-0.6Si-1.0Ni-0.3Mo-0.8C |
| FLNC-4408 | Fe-2.0Ni-0.8Mo-0.8C |
| FD-0408 | Fe-4.0Ni-0.5Mo-1.5Cu-0.8C |
| FLN2-4405 | Fe-2.0Ni-0.8Mo-0.6C |

Figure 1 shows a plot of yield strength as a function of cooling rate for the four sinter-hardening alloys. The chromium alloys both had higher strength than the two conventional alloys. Axial fatigue results are shown in Figure 2 for Cr-Si-Ni-Mo-1 and FD-0408. The chromium steel has significantly higher fatigue life, a result of a more martensitic microstructure (Figure 3). The sinter-hardened properties of this alloy also match that of Q&T FLN2-4405 without the necessity of a secondary quench (Table 2).

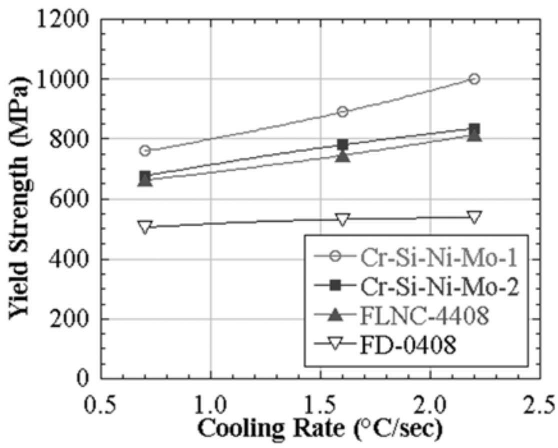


**Fig. 1. Yield strength vs. cooling rate.**

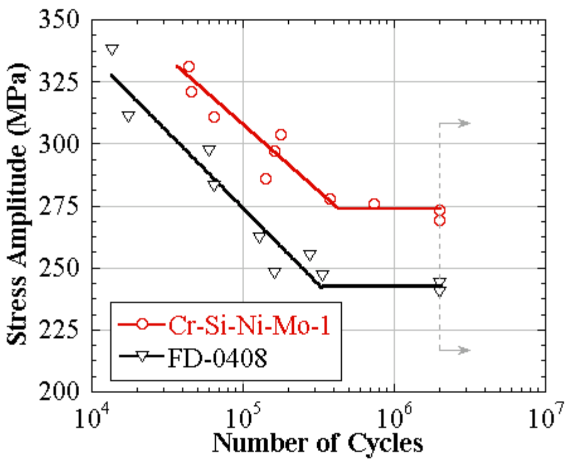


**Fig. 2. Axial fatigue performance for Cr-Si-Ni-Mo-1 and FD-0408 at 2.2 °C/sec.**

**Table 2. Property comparison of sinter-hardened Cr-Si-Ni-Mo-1 and Q&T FLN2-4405.**

| Alloy | Processing | YS [MPa] | Hard [HRC] |
|---|---|---|---|
| Cr-Si-Ni-Mo-1 | Sinter-hardened | 1001 | 39 |
| FLN2-4405 | Q&T | 1038 | 39 |

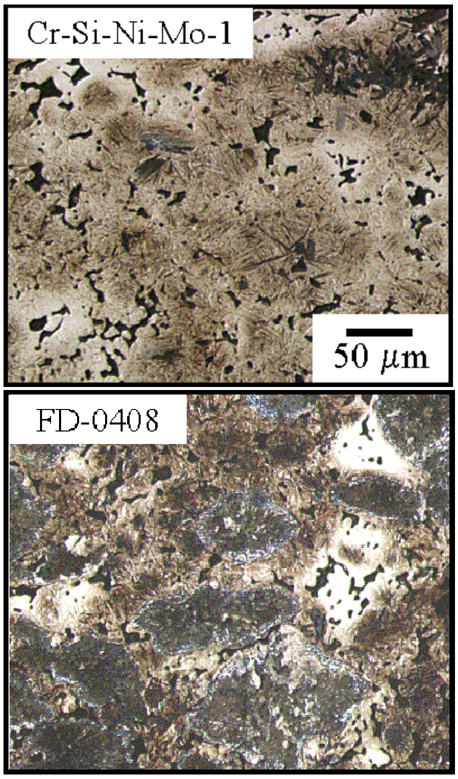


**Fig. 3. Microstructures at 2.2 °C/sec.**

## 3. Summary

Data were presented for two Cr-Si-Ni-Mo steels with different Mo levels. The higher Mo content alloy provided superior properties compared to conventional sinter-hardening alloys and equivalent properties to a Ni-Mo steel processed by Q&T. The chromium steel containing a lower Mo content demonstrated performance levels comparable to the conventional sinter-hardening alloys. Based on the recent instability of Mo prices, this alloy will enable a more economic production of sinter-hardening components without sacrifice of performance.

## 4. References


[1] Causton, R. et al., "High Density Processing of Cr-Mn P/M Steels," *Advances in Powder Metallurgy & Particulate Materials*, MPIF, Princeton, NJ, vol. 5, p. 89, 1994.

[2] Baran, M. et al., "New High Performance P/M Alloys for Replacing Ductile Cast Irons," *Adv. in Powder Met. & Part. Materials*, MPIF, Princeton, NJ, vol. 6, p. 163, 2000.

[3] Salak, A., *Ferrous Powder Metallurgy*, Cambridge Int'l Science Publishing, Cambridge, England, p. 235, 1995.

[4] Motooka, N. et al., "Strength and ductility of Mn-Cr sintered steel," *Metal Powder Review*, Nov. 1983, p. 629.

[5] King, P., "Cr Containing Materials for High Strength Applications," *PM World Congress*, vol. 3, p. 115, 2004.