

Material Cost Savings in Powder Metal Transfer Case Sprockets and Sun Gears

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ABSTRACT

For years powder metal (P/M) nickel steel sprockets have been in use in the SUV Transfer Case market. The heat-treated, nickel steel powder metal provides a high strength and high wear resistant material for this very demanding application. Recently the cost of nickel has increased from \$5 / lb Oct'05 to \$24 / lb May'07. Because of this almost 5 fold increase in the commodity price a replacement material for the powder metal nickel steel was sought that would have comparable properties, comparable processing steps at a raw material cost that would be equal to the nickel steel powder metal prices of 2005. A replacement material was found that has comparable properties at a competitive price. Material composition, testing data and microscopic analysis will be presented.

INTRODUCTION

P/M Sprockets were first designed into automotive transfer cases in 1994. These initial components were large chain system sprockets. Why use Powder Metal to make automotive transfer case parts? "Consumers want to get what they pay for but they don't want to pay for more than they need. This forced design engineers to find the least expensive manufacturing processes to get the job done." [1]

The original design requirements for ultimate strength were matched to the MPIF Standard 35 designations and the FN-0205-105HT material was chosen. "P/M nickel steels are used typically for heat-treatable structural parts requiring the combination of strength, wear resistance and impact properties." [2] This material would allow the manufacture of a single pressed - single sintered, heat treated part that would meet the engineering requirements yet offer a significant cost savings over a machined wrought steel sprocket.

At that time, elemental nickel used as a premix additive to iron based powder cost about \$2.50 /lb.; thus making P/M the preferred production methodology over a machined part.



Graph 1. Nickel and Molybdenum Prices vs. Time [3]

The Sun Gears used in the SUV Transfer Case market have an even more demanding level of design requirements than sprockets. In 2001, a P/M replacement to the machined gear was sought that would duplicate the toughness, impact resistance and wear resistance of the wrought machined gear. As MPIF FLN2-4400 + 0.2C alloy, at a typical tooth density

of 7.3g/cm³, was selected. This double pressed, double sintered, heat treated material would have high impact resistance resulting from the combination of 2.0% elemental nickel and 0.2% core carbon. The pre-alloyed 0.85% molybdenum base iron provided additional toughness and hardenability to this material system. This material and processing almost bested the performance of wrought machined gears. Increasing the tooth density to 7.4g/cm³ minimum (7.45 typical) improved overall gear performance enabling the sun gear to pass all testing requirements. As with the sprockets, potential cost savings for the sun gears facilitated the conversion of these two parts to P/M. A key component to the reduced cost of P/M was the relatively insignificant cost contribution of the nickel and molybdenum alloy additions to the P/M raw material. As the raw material cost of nickel and molybdenum increased dramatically during 2005 and 2006, the cost of the P/M sprockets and sun gears also increased dramatically and alternative materials were sought. This paper discusses the path to a new material.

CASE STUDIES

SPROCKETS - In an attempt to develop a material that would perform, equal to or better than the current material, several iterations were tested. Using production tools, samples were manufactured and tested. The manufacturing process followed the production intent process including compaction, sintering and heat-treating. The two main criteria a transfer case sprocket must pass are: wear from the chain impacting the sprocket teeth during continuous use, and ultimate strength testing. Dynamometer testing serves two purposes, one is to induce cyclic fatigue at various loads and speeds, and the other is to create impact loads and contact fatigue. Contact stresses can create a “Piano Key” effect on sprocket teeth from the chain loading. This causes partial densification as well as tooth wear. The wear can cause fine metal particles to contaminate the oil, which can lead to increase wear of other components. Ultimate strength testing consists of mounting the transfer case on a fatigue stand, holding the front output stationary and applying a load until failure.

	Original	New
Iron (Fe)	Balance	Balance
Carbon (C)	0.55	0.55
Nickel (Ni)	2.00	0
Molybdenum (Mo)	0	0.30

Table 1. Chemical Analysis of Standard and Proposed Materials for Sprockets

The current production design utilized MPIF: FN-0205 at 6.9 g/cc minimum density in the teeth. This design was able to withstand ultimate strength testing of the transfer case. The current design also completed the required high speed and low range dynamometer testing, without incident.

The first iteration tested was MPIF: FL-4405 modified 0.3% molybdenum and 0.7% Carbon at 6.9 g/cc in the sprocket teeth and the same heat treat specification as the current production parts. These samples passed dynamometer testing with reduced tooth wear as compared to the current parts. Compared to the original material, ultimate strength testing resulted in a 7% reduction in strength. This was not acceptable so, a slightly modified heat treat process was attempted. The ultimate strength did improve slightly but did not meet the current production parts. The next attempt was to increase the density slightly while still retaining the single press single sinter processing. The density was increased to 7.1 g/cc in the teeth on the one sprocket that failed during testing. The parts made to this change performed as well as the current production parts. Dynamometer testing proved to be successful while improved sprocket wear at the sprocket tooth to chain interface was observed.

In previous testing the reduction in Molybdenum required an increase in carbon to improve the hardenability of the material. The improved hardenability allows the same heat treat cycle to be used, which reduces the in-plant complexity of having to run separate cycles for each family of parts.



Figure 1. Photograph of sprocket evaluated in this study