Surface Densification Coupled with Higher Density Processes Targeting High-performance Gearing

Francis Hanejko, Arthur Rawlings, Patrick King, and George Poszmik

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

Abstract

This paper will describe a powder and processing method that facilitates single press-single sintered densities approaching 7.5 g/cm³. At this sintered density, mechanical properties of the powder metal (P/M) component are significantly improved over current P/M technologies and begin to approach the performance of wrought steels. High performance gears have the added requirement of rolling contact fatigue durability that is dependent upon localized density and thermal processing. Combining high density processing of engineered P/M materials with selective surface densification enables powder metal components to achieve rolling contact fatigue durability and mechanical property performance that satisfy the performance requirements of many high strength automotive transmission gears. Data will be presented that document P/M part performance in comparison to conventional wrought steel grades.

Keywords: High-density compaction, mechanical properties, rolling contact fatigue, heat-treatment, selective densification

1. Introduction

Warm compaction techniques are two-fold; one is heated die combined with heated powder and the second is simply heated tooling. DP/DS techniques require the use of two distinct compaction and sintering operations. Limitations of DP/DS include additional processing steps in the manufacture of parts and an inability to effectively produce complex shapes such as helical gearing.

Warm compaction techniques are limited to producing a green part that is a maximum of 98% of the pore free density (PFD) of the starting premix material. [1] Low-density premix additives such as graphite and lubricant dramatically reduce PFD thus lowering attainable green and sintered densities. To achieve high single press / single sinter densities without having excessive shrinkage during sintering, it is necessary to limit both the amount of lubricant and graphite present in the starting premix. Limiting internal lubrication will potentially result in problems ejecting parts from the die while limiting graphite additions may negatively affect mechanical properties of the final component.

2. Experimental and Results

A recent development in powder lubrication technology facilitated the use of 0.40% total internal lubricant. This reduced lubricant level coupled with compaction die temperatures of ~85 °C and compaction pressures up to 760 MPa produced green densities $\geq$ 7.4 g/cm³ enabling part lengths up to 30 mm with excellent surface finish.

Presented in Table 1 are mechanical properties of an FLN2-4405 material (with 0.35% graphite). As sintered density increases, yield and tensile strengths approach the strength values established for AISI 8620 wrought steel. Elongation and impact toughness of P/M steels are less than wrought steel. The Q&T values listed in Table 1 were determined following austenitizing at 925 °C for 1 hour, oil quenching, and tempering at 205 °C for 1 hour.

Presented in Table 2 is a summary of recently developed rolling contact fatigue data. This data presents a comparison of rolling contact fatigue life of high core density FLN2-4405 (0.30% sintered carbon) along with FLN2-4405 (at 0.50% core carbon) and two wrought steel materials. The data presented lists the material, type of carburizing employed, B50 life during rolling contact fatigue testing at two Hertzian stress levels, and a measure of the scatter defined as the ratio of B10 life to B90 (statistical determined as cycles to 10% failure and cycles to 90% failure). For all materials, the Hertzian stress was adjusted so as to achieve approximately the same B50 life. For the low carbon FLN2-4405 and the AISI 8620 steel, the B50 life was determined at 2100 MPa and 2000 MPa respectively. Testing these materials at 1900 MPa produced run-outs (defined at >50 million cycles) for both materials. The significance of this testing was that both FLN2-4405 with low core carbon and AISI 8620 wrought steel would have superior B50 life compared to either AISI 5120 or FLN2-4405 (with 0.50% core carbon) if all testing was done at 1900 MPa.

Table 1. Mechanical Property of FLN2-4405 (0.35% Graphite)Sintered at 1120 °C for 20 minutes (90 v/o nitrogen and 10 v/o hydrogen)

Mtl	Den., g/cm³	0.2% Offset YS, MPa	UTS, MPa	El, %	H RA	Impact Joules
FLN2-4405 As-sinter	7.36	392	578	4.0	49	31
	7.41	397	602	4.2	51	35
	7.46	423	626	4.6	52	48
FLN2-4405 Q&T	7.33	828	951	1.4	59	16
	7.37	896	1027	1.5	62	18
	7.43	917	1075	1.8	62	21
AISI 8620, Q&T	7.86	1075	1355	8.0	71	312

Table 2. Rolling Contact Fatigue Data of High Density P/M Materials

Mtl	Processing Condition	**Contact Stress, MPa**	**B50 Life, 10^6 cycles**	**Ratio B10/ B90**
AISI 5120**	Vac. Carb,	1900	16.7	1.8
		2500	6.1	2.7
FLN2-4405*	7.35 g/cm³ 0.6mm densified	1900	19.0	3.0
		2500	2.6	2.5
FLN2-4405** (0.3%C)	7.4 g/cm³ 0.6mm densifed	2100	19.0	3.8
		2500	5.1	3.4
AISI 8620*	Vac. Carb	2000	20.0	1.8
		2500	4.2	2.7

* Carburized via single boost / single diffuse cycle
** Carburized via multiple boost / multiple diffuse

3. Conclusions

Green densities of ≥7.4 g/cm³ are possible utilizing a new lubricant system enabling the use of 0.40% admixed lube. Compacted parts up to 30 mm in length are possible.
At sintered densities ~7.45 g/cm³, tensile and yield strengths are similar to wrought AISI 8620 material. Elongation and impact toughness of the P/M material are lower.
Rolling contact fatigue is critical in gearing. It is dependent upon the density of the P/M part in the critical sub-surface stress region. Surface densified P/M parts with 7.4 g/cm³ core density and 0.30% core carbon give rolling contact fatigue life equal to wrought steel..
With this high density processing combined with surface densification, P/M is now able to give static properties that are approximaately equal to wrought with equivalent rolling contact fatigue properties.

4. References

1. H. Rutz, F. Hanejko:*High Density Processing of High Performance Ferrous Materials,* ed. C. Lall & A.J. Newpaver, Advances in Powder Metallurgy and Particulate Materials-1994, MPIF, vol. 5, pp117-133.