The Application of P/M Advanced Techniques to Sintered Gears

Bao Chongxi[1, a], Shen Zhouqiang[1, b], Shu Zhengping[1, c]

[1]Ningbo Tongmuo New Materials Co, Ltd, Ningbo 315041, China
[a]cxbao@pm-china.com, [b]shenzq@pm-china.com, [c]shuzp@pm-china.com

Abstract

The processes of P/M affect the properties of sintered gears. The different techniques of P/M lead to the different properties of sintered gears. This paper summarizes new progress in powder metallurgy for sintered gears. These progresses include warm compaction, high velocity compaction, sinter hardening, high temperature sintering, infiltration, CNC powder press and surface densification etc.

Keywords : warm compaction, high velocity compaction, sinter hardening, compaction by CNC powder press and surface densification

1. Introduction

Gears are key and important structural components in modern driving technology. Gears are commonly machined. This manufacturing route generates a significant amount of waste material and machining operations. Powder metallurgy is a proven technology to produce high strength gears and complex gear shapes. Raw materials, energy and time can be saved. It is suitable for volume-produce too [1].

Performance of sintered gears is tied to their density and hardness etc. By advanced P/M techniques, green density of gears is enhanced and performance is improved. At the same time, parts have higher precision and more complex shapes [2-3]. Discussed here are seven new techniques that expand the potential for P/M use in competitive environments. These new techniques include warm compaction, high velocity compaction, sinter hardening, high temperature sintering, infiltration, CNC (Computer Numerical Control) powder press and surface densification.

2. Warm Compaction

The warm compaction process has been shown to provide increased density in ferrous powder metallurgy parts[3-4].

Warm compacted gears have been manufactured in Ningbo Tongmuo (NBTM). The material is FD-0205. The green density is 7.35g/cm^3 and sintered density reach to 7.3g/cm^3. The hardness is over HRA 70 after quenching and tempering.

A second-generation warm compaction method intended to achieve this goal is the so-called warm die lubrication technology. [5-6]

3. High Velocity Compaction

High Velocity Compaction (HVC) is a compaction method that enables high density Densification in HVC is achieved by intensive shock waves. Radial spring-back is generally lower for HVC than for conventional compaction [7].

HVC is a developing technique. Components with single or two levels are only compacted at present. Other multi-level parts are not compacted by HVC [8-9].

4. Sinter Hardening

Sinter-hardening refers to a process where the cooling rate experienced in the cooling zone of the sintering furnace is fast enough that a significant portion of the steel matrix is transformed into martensite.

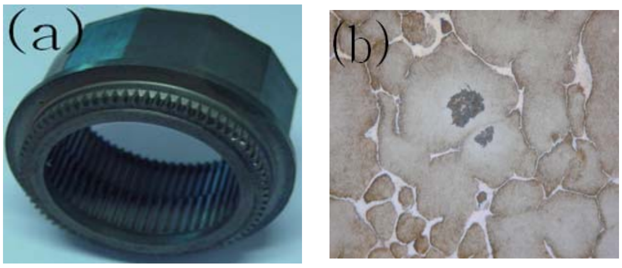
Gears of sinter-hardening have been produced in NBTM. Table 1 shows the properties of this material. After sintering at 1200℃ for half hour, the hardness is over HRC 40, ultimate strength is 1250MPa and impact energy is 17J. The cost cuts down on 10%.

5. High Temperature Sintering

By fully exploiting these materials, high apparent hardnesses coupled with exceptional impact energies and tensile properties were possible [10]. For FLNC-4405, one effect of the increase in sintering temperature is reduction of the nickel-rich austenite areas. This is due to the better diffusion of nickel at the higher temperature.

6. Copper Infiltration

As copper infiltrant offers improved tensile strength, elongation, hardness and impact properties of iron or iron based P/M parts, it allows the fabricator to compete with other markets.



(a) Copper infiltrated gear　　b) Photomicrograph of copper infiltrated gear

Fig. 1. Copper infiltrated gear and its photomicrograph in NBTM

Fig. 1(a) is a copper infiltrated gear in NBTM. This gear is compacted by CNC powder press. Its mass is over 2700g and its height is 70mm. After sintering and infiltrating, its hardness (HRB) is 85. The density is 7.3g/cm^3. At the teeth of gear, liquid copper infiltrates through the pore (see Fig. 1b).

7. Compaction by CNC Press

The development of the CNC powder compacting press has increased the freedom of shape and facilitated near-net shape and net-shape production. With a CNC press, the operating speed and timing of the punch to press the powder are accurately controlled by a computer controlled hydraulic system, and the powder being pressed is moved with high accuracy [11-14].

Gears are compacted by CNC powder press in NBTM. The hardness is HRB90 and the density is over 7.0g/cm^3 and the ultimate tensile strength are over 650MPa after sintering. The hardness is over HV700 after heart treatment. The cost of parts is low for without machining.

8. Surface densification of gear

Rolling contact fatigue resistance of P/M gear has typically been inferior to that of wrought steel. Surface densification is used to achieve the required pore free layer in the contact area [2, 11, 13-14].

In China, rolling machine and grinding machine of roller dies have been installed in NBTM. Surface densified gears are been developing.

This processing offers the mechanical properties of a high-density part, the surface fatigue resistance of a wrought part, and potentially the low cost inherent to P/M processing. Surface densification gives the following advantages: pore-free tooth surface, excellent (mirror) surface finish, increased wear resistance, reduced noise, improved corrosion resistance, minimal tooth-to-tooth and total composite error, redirects helix angle to improve gear tooth lead while incorporating a tooth crown, customized tooth profile, improved fatigue endurance[2.11].

9. Summary

The density of sintered gears produced by traditional P/M routes is low and the mechanical performance is poor. Low density and low precision and poor performance of sintered gears are solved by application of P/M advanced techniques. At present, sintered gears with full density can be manufactured by press with high pressure and/or powder forged and/or high temperature sintering. The precision of gear can meet the requirement of design. However production cost is another important factor to select sintered gears. The real difficulties to produce sintered gears are to get high density and high precision and low cost components at the same time.

10. References

[1] PM Association of China Machine General Parts Industry Society. Powder metallurgy parts handbook---automotive and motorcycle parts [M]. Beijing: Ordnance industry press, 1996: 1-17.
[2] Richard H. Slattery. Gear Solutions, 2005, 7:32-43.
[3] Bocchini G.F. Powder Metallurgy, 1999, 42(2):171-180.
[4] Fordén Linnéa, Bengtsson Sven, Bergström Magnus. Powder Metallurgy. 2005, 4(1): 10-12.
[5] Unami Shigeru, Zaki Yukiko, Enosono Stoshi. JFE technical report, 2004, 4:81-88.
[6] Makoto Iwakiri, Tsuyoshi Kagaya.Editorial Office of Metal Powder Report. PM Asia 2005 conference proceedings, NJ: MPIF, 2005:240-248.
[7] Paul Skoglund, Mikael Kejzelman, Ingrid Hauer. Metal Powder Report, 2002,57(9):26-31.
[8] Allroth Sven, Johansson Bjorn, Skoglund Paul. US Patent: 6537489, 2003, Mar.25.
[9] Gerd Hinzmann, Dirk Sterkenburg. Metal Powder Report, 2005, 60(5):32-33.
[10] Kalathur Naraimhan. Editorial Office of Metal Powder Report. PM Asia 2005 conference proceedings, NJ: MPIF, 2005:43-71.
[11] Lorenz Sigl. Editorial Office of Metal Powder Report. PM Asia 2005 conference proceedings, NJ: MPIF, 2005:265-279.
[12] Sven bengtsson. Editorial Office of Metal Powder Report. PM Asia 2005 conference proceedings, NJ: MPIF, 2005: 161-174.
[13] Teruie Takemasu, Toshinaka Shinbutsu. Gear Solutions, 2004,2:32-39.
[14] Yang Yu, Linnea Forden. Powder metallurgy technology, 2005, 23(1):62-74. (In Chinese)