Sinter-hardening Process of P/M Steels and its Recent Developments

Yi Jianhong[1,a], Ye Tuming[1,b], Peng Yuandong[1,c], Xia Qinglin[1,d], Wang Hongzhong[1,e]

[1]State Key Laboratory for Powder Metallurgy, Central South University, Changsha, Hunan 410083, China
[a]yijianhong2004@yahoo.com.cn, [b]sailingytm@163.com, [c]pengyuandong@163.com, [d]qlxiacsu@126.com, [e]csuwhc@126.com

Abstract

The mechanical properties of ferrous powder metallurgy (P/M) materials are directly related to their microstructure. Ferrous P/M materials with sufficient hardenability will develop microstructures containing significant percentages of martensite in the as-sintered condition. Recently, sinter-hardening has developed into a highly cost effective production method through hardened P/M parts without the need for additional heat-treatments. This paper reviews the advances of sinter-hardening as well as some key processing parameters such as sintering temperature, cooling rate, tempering required to produce high quality sinter-hardened components. Specific topics including effect of alloying elements, alloying methods, and the Characterization and observation of microstructure are discussed.

Keywords : P/M steels, sinter-hardening, hardenability, tempering, hybrid alloys

1. Introduction

Sinter-hardening is a process in which martensitic transformation occurs when the P/M parts are cooled from the sintering temperature. Sinter-hardening combines sintering and heat treatment in a single step to confer high strength and wear resistance while minimizing the number of processing steps. Sinter-hardening offers an alternative method to through hardening powder metal components without the use of a traditional austenization, oil quench, and tempering cycle. Over the last several years, interest in sinter-hardening has grown because it offers good manufacturing economy by providing a one step process and a unique combination of strength, toughness, and hardness. There are a number of benefits of the sinter-hardening process compared with conventional P/M process.

Sinter-hardening can be achieved in a variety of ways including the use of standard sintering furnaces with modified ferrous P/M admixed alloy systems and the use of specialized P/M alloys in conjunction with sintering furnaces equipped with accelerated cooling zones. The standard sinter-hardening process consists of compaction of P/M component, sintering, and a tempering cycle, the comparison of the sinter-hardening and quench and temper process. Each of these steps has to be optimized to ensure the consistent production of sinter-hardened parts.

2. Influence of Alloying Elements

Alloying elements are used in P/M steels to promote hardenability and to increase strength. At a given density level, alloying elements that aid hardenability of an alloy system generally improve the mechanical performance of the system. Such alloying elements can be added to the melt prior to atomization, thereby creating a prealloyed material. However, increasing prealloy content generally decreases a powder's compressibility and makes it more difficult to reach higher density levels. Efficient sinter-hardening alloys require significant chromium and manganese contents.

3. Influence of Sintering Process

3.1 Effect of sintering temperature

The higher sintering temperature aides diffusion of the admixed alloy elements and helps to produce a more homogenous microstructure in P/M steels, which can improve the hardenability of sintered parts and hence increase the ability to form a martensitic microstructure. Higher sintering temperature also produces higher impact properties. Sinter-hardening materials processing via warm compaction techniques have improved mechanical properties when compared to conventional pressing process. The sintering temperature of P/M steels are usually 1120°C -1250°C.

3.2 Effect of cooling rate

The properties of steels are dependent on their microstructures and it is important to understand how the microstructure develops in a P/M part during heat treatment. Different microstructures can be obtained by varying the cooling rate. Cooling rate is the most important processing parameter of sinter-hardening, and hardness is primarily dependent on the cooling rate.

3.3 Effect of tempering

Tempering is also an important part of the sinter-hardening process. Tempering is employed as a stress relief that slightly soften the martensitic microstructure. Generally, tempering is used to restore the mechanical properties of sinter hardened materials. However, tempering reduces apparent hardness, particularly for materials sinter hardened above 30HRC because tempered martensite shows lower hardness than un-tempered martensite.

4. Summary

• Sinter-hardening alloys should be chosen with the final properties. The alloy should optimize hardenability for mechanical properties and compressibility for higher density while keeping the total alloy content as lean as possible to minimize cost.
• Molybdenum, Nickel and copper are usually recommended as alloying elements in sinter-hardening.
• In order to obtain higher percentages of martensite which resulting in better mechanical properties of sintered parts, higher cooling rates are required.
• Tempering should be employed which increasing the tensile strength and yield strength during sinter-hardening.

5. References

[1] W B James. *Advances in Powder Metallurgy and Particulate Materials-1998*, MPIF, Priceton, NJ(1998).
[2] M Gagne and Y Trudel. *Advances in Powder Metallurgy-1991*, MPIF, Priceton, NJ, 4, p.115(1991).
[3] F Chagnon and Y Trudel. *Advances in Powder Metallurgy and Particulate Materials-2003*, MPIF, Priceton, NJ, 5, p. 77(2003).
[4] A Molinari, V Stoyanova. *Euro PM 2004 Proceedings*, EPMA, Shrewsburg, UK, 2, p. 291(2004).
[5] F Chagnon, D Barrow. *Advances in Structural PM Components Production*, EPMA, Shrewsburgy, UK, 1997, p. 273.
[6] F Chagnon. *Proceedings of 2000 Powder Metallurgy World Congress*, Japan Society of Powder and Powder Metallurgy, p. 927(2000).