Rolling Contact Fatigue Property of Sintered and Carburized Compacts Made of Molybdenum Hybrid-alloyed Steel Powder

Shigeru Unami[a], Yukiko Ozaki[b] and Satoshi Uenosono[c]

JFE Steel Corporation, Steel Research Laboratory
1 Kawasaki-cho, Chuo-ku, Chiba, JAPAN
[a]s-unami@jfe-steel.co.jp, [b]y-ozaki@jfe-steel.co.jp, [c]s-uenosono@jfe-steel.co.jp

Abstract

A developed molybdenum hybrid-alloyed steel powder is based on a molybdenum prealloyed steel powder to which molybdenum powder particles are diffusion bonded. The sintered compact made of this powder has a finer pore structure than that of the conventional molybdenum prealloyed steel powder, because the ferritic iron phase (α-phase) with a high diffusion coefficient is formed in the sintering necks where molybdenum is concentrated resulting in enhanced sintering. The rolling contact fatigue strength of the sintered and carburized compacts made of this powder improved by a factor of 3.6 compared with that of the conventional powder due to the fine pore structures.

Keywords : rolling contact fatigue property, hybrid-alloyed steel powder, α-phase, carburizing

1. Introduction

High contact fatigue strength is required for some automotive sintered parts, because they will be used under a high contact pressure. Increase in a density of sintered steels is the most effective way for improving a rolling contact fatigue strength because it makes the pores small and decrease the amount of them which act as stress concentration points. Densification methods such as double-pressing and double-sintering [1], or high temperature sintering at over 1200 °C [2] by a tray pusher furnace have been adopted for productions of special type of heavy duty automotive sintered parts. However, the high production cost of these methods due to their low productivities inhibits their widespread use.

Therefore, the appropriate structures and chemical compositions of alloyed steel powders have been investigated for attaining sintered compacts with high rolling contact fatigue strength, produced by a conventional belt furnace at the temperatures less than 1200 °C without using above-mentioned special densification methods. Consequently, it was found that the molybdenum hybrid-alloyed steel powder based on 0.6 mass% molybdenum prealloyed steel powder to which 0.2 mass% molybdenum powder particles were diffusion-bonded showed a remarkable improvement in a rolling contact fatigue property compared to molybdenum prealloyed steel powders.

This report describes the rolling contact fatigue strength of the sintered and carburized compacts made of the molybdenum hybrid-alloyed steel powder.

2. Experimental Procedure

Hybrid-alloyed or prealloyed steel powders as shown in Table 1 were used as base materials. A natural graphite powder (Nippon Graphite J-CPB, average diameter: 4 μm) and the internal lubricant developed for warm compaction by JFE Steel [3] were added in the base powders.

The mixed powders which contain the base powders, 0.3 mass% of graphite or 0.6 mass% of the internal lubricant were compacted under 686 MPa at 130 °C. The green compacts were sintered at 1130 °C for 20 min in endothermic gas, and then carburized at 870 °C for 60 min under a carbon potential of 0.8 %, subsequently quenched into oil at 60 °C and then tempered at 200 °C for 60 min.

The rolling contact fatigue properties were measured by the test machine, where 6 steel balls (SUJ-2, diameter: 9.525 mm) were rolling on the surface of the specimen at the frequency of 1000 rpm. The size of the specimen for the test was 60 mm in diameter and 6 mm in thickness. As a lubricant, the motor oil was used. The rolling cycles to pitting were measured at Hertzian stress of 3.5 GPa using 10 specimens. Hertzian stress was calculated by the equations suggested by Ogura [1].

TABLE 1. Chemical composition of powders used.

[mass%]

Symbol	Prealloy	Partially alloy
	Mo	Mo
Hybrid	0.6	0.2
Prealloy	0.6	-

© Korean Powder Metallurgy Institute

3. Results and Discussions

The relationships between loading cycles to failure and Weibull cumulative failure probabilities in the rolling contact fatigue test for the sintered and carburized compacts are shown in Fig. 1. The cycles at cumulative failure probability of 50% of the hybrid material is 7.07×10^{6} cycles, which is improved by a factor of 3.6 compared to that of the prealloy material (1.95×10^{6} cycles).

The cross-sectional microstructures of the sintered and carburized compacts are shown in Fig. 2. The prealloy material has a homogeneous martensite structure. The hybrid material has dark and light martensite structures which should be caused by the Mo concentration distribution in the sintered compacts. The hybrid material has fewer amounts of coarse pores of over 20μm in diameter compared to the prealloy material.

It is known that a ferritic iron phase (α-phase) is stable in Mo-rich composition in Fe-Mo binary-alloyed system at a high temperature such as a sintering temperature. There are Mo-rich regions near the surface of the hybrid powder particle, which are caused by the diffusion-bonded Mo particles. The self-diffusion coefficient of the α-phase at 900 °C ($4.2\times10^{-15}[m^2/s]$) is about 100 times larger than that of the γ-phase ($1.7\times10^{-17}[m^2/s]$) [4]. Therefore, the hybrid material should have a finer pore structure than the prealloy material, because the α-phase with a high diffusion coefficient is formed in the sintering necks during the early sintering stage resulting in enhanced sintering.

The reduction of coarse pores, acting as stress concentration points, should affect suppressing a fatigue crack generation. Consequently, the fine pore structure of the hybrid material should result in the improvement of the rolling contact fatigue strength.

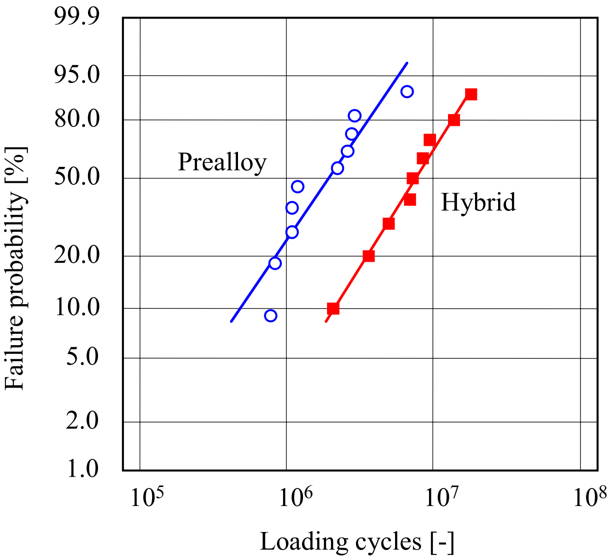

Fig.1. Relationship between loading cycles to failure and Weibull cumulative failure probability in the rolling contact fatigue test.

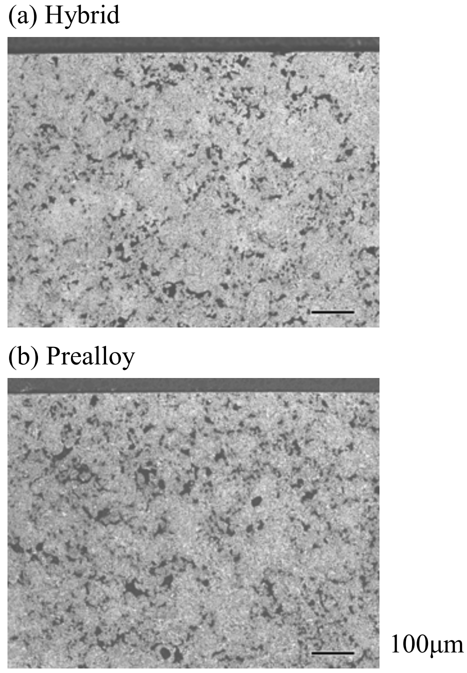

Fig.2. Cross-sectional microstructures of the sintered and carburized compacts made of the hybrid-alloyed steel powder (a) and the prealloyed one (b).

4. Summary

The rolling contact fatigue property of the sintered and carburized compacts made of the molybdenum hybrid-alloyed steel powder has been investigated compared to the molybdenum prealloyed steel powder. The major results are summarized as follows.

1) Cycles equivalent to cumulative failure probability of 50% of the hybrid material (7.07×10^{6} cycles) improves by a factor of 3.6 compared with that of the prealloy material (1.95×10^{6} cycles).
2) Improvement in the rolling contact fatigue strength of the hybrid material should result from suppression of fatigue crack generation due to the fine pore structure.

5. References

1. K. Ogura, S. Takajo, Y. Maeda, J. Katsuki and K. Sakurada, KAWASAKI STEEL GIHO (in Japanese), Vol.21, No.3, p. 250 (1989).
2. S. Unami and S. Uenosono: Advances in Powder Metallurgy &Particulate Materials, MPIF, Part 10, p. 254(2004).
3. Y. Ozaki, S. Unami and S. Uenosono: KAWASAKI STEEL TECHNICAL REPORT, No.47, December, p. 48(2002).
4. F. S. Buffington, K. Hirano and M. Cohen: Acta Metall, Vol.9, p. 434(1961).

© Korean Powder Metallurgy Institute